

Original Research Article

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Impact of Organic, Inorganic and Integrated Nutrient Management Practices On Carbon Pool and Nutrient Availability of Perennial, Annual and Seasonal Crops Grown Innagpur District, India

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ABSTRACT

The present study on impact of organic, inorganic and integrated nutrient management practices on carbon pool and nutrient availability of perennial, annual and seasonal crops was studied during 2019-20. The total four villages were selected for study. The surface (0-15 cm) and sub-surface (15-30 cm) soil samples from each field were collected after harvest of Nagpur mandarin, Pigeonpea and Paddy. The total of 72 (surface and subsurface) samples were collected. The results revealed that, Addition of organic matter lowered the soil pH, increased residual organic C and available N, INM increased available S, inorganic fertilizer increased available P and K compare to organic and INM farming practices. INM resulted in the improvement of most soil physico-chemical properties and nutrient balances that lead to increased and sustained production. Under conventional management, the agronomic relevance of SOM with regard to nutrient supply is much lower than under organic. The highest very labile carbon, labile carbon and less labile carbon was observed under the regular addition of organic fertilizers like FYM in case of Nagpur mandarin and non-labile carbon under the use of inorganic fertilizers. The lower values of C_{VL} , C_L and C_{LL} were registered where the use of inorganic sources takes. It was observed that the non-labile carbon was lowest under integrated nutrient management practices. Active pools are highest in organic and INM practices and passive pool is found abundant where inorganic sources were used.

Keywords

Carbon pool, Nutrient availability, Management practices, Perennial, Annual and Seasonal crops

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Introduction

Soils are the largest carbon reservoirs of the terrestrial carbon cycle. Soil, if managed properly, can serve as a sink for atmospheric carbon dioxide (Jha *et al.*, 2012). The global soil carbon (C) pool of 2500 gigatons (Gt) includes about 1550 Gt of soil organic carbon

(SOC) and 950 Gt of soil inorganic carbon (SIC). The soil C pool is 3.3 times the size of the atmospheric pool (760 Gt) and 4.5 times the size of the biotic pool (560 Gt). The SOC pool represents a dynamic equilibrium of gains and losses. Conversion of natural to agricultural ecosystems cause depletion of the SOC pool by as much as 60% in soils of

temperate regions and 75% or more in cultivated (Lal, 2004). Globally, one third of the arable land is in agriculture. Agricultural soil has dual nature as it also serves as a potential sink for atmospheric carbon as soil organic carbon (SOC), which contributes to improve productivity and quality (Brar *et al.*, 2013). Therefore, agricultural soils are the largest reservoirs of carbon. Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decay roots, litter and crop residues. Integrated nutrient management (INM) aims at achieving efficient use of chemical fertilizers in conjunction with organic manures. Combined application of chemical fertilizers and organic manures contributed to the improvement of physical, chemical and biological properties of soil. Integrated use of organic manure and chemical fertilizers improved soil carbon pools viz. organic carbon, total carbon, inorganic carbon, water soluble carbon, light fraction carbon, particulate organic carbon, labile and non-labile carbon pools and maintain soil health and fertility.

SOC is the main component of soil organic matter (SOM) and is an indicator of soil health. It is important for its contributions to food production, mitigation and adaptation to climate change, and the achievement of sustainable development goals (SDGs). A high SOM content in soil provides nutrients to plants and improves water holding capacity, both of which enhance soil fertility and ultimately improve food productivity. Moreover, SOC improves structural stability by promoting aggregate formation which, together with porosity, ensure sufficient aeration and water infiltration to support plant growth. Optimum levels of soil organic matter can be maintained through crop rotation, fertility maintenance organic manures, tillage

methods, and other cropping system components (Purakayastha *et al.*, 2008). Each 1% increase in average soil organic carbon levels could in principle reduce atmospheric CO₂ by up to 2% (Dutta *et al.*, 2018). Previous studies have indicated that soil tillage and crop residue management affected microbial population, activity, and biomass, soil moisture content, bulk density, porosity, nutrient distribution, and structure stability. At the same time, changes in vegetation lead to modifications of the physico-chemical characteristics of the soils, which can also induce changes in the soil organic reserves. Changes in soil and vegetation management can impact strongly on the rates of carbon accumulation and loss in soil, even over short periods of time. Lal (2004), reported that considerable part of the depleted SOC pool can be restored through conversion of marginal lands into restorative land uses, adoption of conservation tillage with cover crops and crop residue mulch, nutrient cycling including the use of compost and manure, and other systems of sustainable management of soil and water resources (Jha *et al.*, 2012). Conversion from conventional till to no-till farming reduces emission by 30 to 35 kg C ha⁻¹ per season. Similarly, a judicious use of C-based inputs is essential to enhancing use efficiency and minimizing losses (Lal, 2004).

Materials and Methods

The present investigation was undertaken to identify the different organic, inorganic and integrated nutrient management farms (farmer's field) from Chichbhavan, Gangner, Savner and Selu of Nagpur district growing Nagpur mandarin, Pigeonpea and Paddy crop. Total 72 samples were collected from surface (0-15 cm) and sub-surface (15-30 cm) soil from each field. The soil samples were further used for studying soil properties and carbon pool fractions i.e., Pools I, Pools II, pools III and Pools IV.

The visits to farmers field were done, discussed with them about selection of his field for the study and informed him about the importance of study. Eighteen samples (surface + subsurface) were collected from each village after harvest of Nagpur mandarin, Pigeonpea and Paddy. Sampling was done at surface (0-15 cm) and subsurface (15-30 cm). The samples were processed and analyzed in the laboratories of Soil Science and Agricultural Chemistry section, College of Agriculture, Nagpur during 2019-2020. Available nitrogen was estimated by using alkaline potassium permanganate method as described by Subbiah and Asija (1956). Available phosphorus was determined by using Olsen's reagent as extractant by using spectrophotometer (Jackson, 1973). Available potassium was determined by extracting soil with neutral normal ammonium acetate and the contents of K in solution and was estimated by flame photometry (Jackson, 1973).

The soil samples were analyzed for Soil organic carbon (SOC) determined by Walkley and Black, (1934) using 36 N H₂SO₄ implying the recovery factor of 1.298 represents the total SOC pool. This fraction was sub-fractionated in to four different pools namely very labile (pool I: C_{VL}), labile (pool II: C_L), less labile (pool III: C_{LL}) and non-labile (pool IV: C_{NL}). Pools I and II together represent the active pool [Active pool=∑ pool I + pool II]; while pool III and pool IV together constitute the passive pool [Passive pool=∑(pool III + pool IV)] of organic carbon in soils (Chan *et al.*, 2001) using 5, 10 and 20 ml of concentrated (36.0 N) H₂SO₄ that resulted in three acid-aqueous solution ratios of 0.5:1, 1:1 and 2:1 (corresponding to 12.0, 18.0 and 24.0 N of H₂SO₄, respectively). The amount of C, thus determined allowed the apportioning of total soil organic carbon into the following four different pools

According to their decreasing order of oxidizability

Pool I (C _{VL} very labile)	Organic C oxidizable by 12.0 N H ₂ SO ₄
Pool II (C _L labile)	The difference in C oxidizable by 18.0 N H ₂ SO ₄ and that by 12.0 N H ₂ SO ₄
Pool III (C _{LL} less labile)	The difference in C oxidizable by 24.0 N H ₂ SO ₄ and that by 18.0 N H ₂ SO ₄
Pool IV (C _{NL} non-labile):	The difference between C _{loc} and oxidizable by 24.0 N H ₂ SO ₄ .

Statistical analysis involving the coefficient of correlation between carbon pools and available nutrients of Nagpur mandarin, pigeonpea and paddy was analyzed and interpreted as per the procedure described by Panse and Sukhatme (1985).

Results and Discussion

Physico-chemical properties

Soil pH

The results revealed that the soil pH of an organic, inorganic and INM field has ranged between 6.67-7.32 (surface) and 7.08-7.53 (sub-surface), 7.43-8.50 (surface) and 7.45-8.90 (subsurface) and 7.52-8.13 (surface) and 7.62-8.20 (subsurface), respectively. It indicates that the addition of organic matter lowers the soil pH compare to inorganic and INM farming practices.

Electrical conductivity (dS m⁻¹)

The values of EC of soil ranged between 0.17-0.42 dS m⁻¹ (surface) and 0.22-0.48 dS m⁻¹ (subsurface) with the use of organic, inorganic and both organic + inorganic (INM) fertilizers among the locations. The lowest EC of the soil was recorded 0.17 dS m⁻¹ (surface) and 0.22 dS m⁻¹ (subsurface) with the use of

both organic and inorganic fertilizers (INM) at Chichbhavan location whereas maximum EC of the surface soil was recorded 0.421 dS m⁻¹ with the use of inorganic at Savner location and subsurface soil as 0.483 dS m⁻¹ with the use of inorganic fertilizers at Selu location.

Organic carbon (g kg⁻¹)

In the present study, the soil organic carbon varied from 4.6-9.5g kg⁻¹ (surface) and 4.2-9.2g kg⁻¹ (subsurface) amongst the locations practicing organic, inorganic and INM practices. The lowest soil organic carbon was recorded 4.6 g kg⁻¹ (surface) and 4.2 g kg⁻¹ (subsurface) by the application of inorganic fertilizers at Savner location. The maximum OC was recorded 9.5 g kg⁻¹ (surface) and 9.2 g kg⁻¹ (subsurface) by the application of organic fertilizers at Selu location. The maximum amount of OC recorded under pigeonpea cultivation by using organic fertilizers as source at Selu locations. The OC is moderate, moderately high and high in inorganic, INM and organic practices, respectively.

Calcium carbonate (CaCO₃)

Calcium carbonate status of Chichbhavan, Gangner, Savner and Selu were presented in table-1. The calcium carbonate in surface soil ranged from 2.78-7.57 per cent and 3.01-7.82 per cent in the subsurface soil.

The lowest value of surface (2.78%) and subsurface (3.01%) soil calcium carbonate were observed in Nagpur mandarin at Chichbhavan under the use of organic fertilizers and the maximum value of surface (7.57%) and subsurface (7.82%) calcium carbonate were observed in Nagpur mandarin at Gangner and Savner, respectively under INM practices.

Available nutrient status of soil

Available nitrogen (kg ha⁻¹)

Nitrogen is the most important parameter in substantial agricultural production and soil fertility. The data in respect of available nitrogen content of soil after harvest of crop is presented in table 2. In the present study, the soil available N content was observed between 160.28 - 350.52 kg ha⁻¹ (surface) and 151.35 - 340.26 kg ha⁻¹ (subsurface) under organic, inorganic and INM practices. The observed values of available nitrogen come under the categories of low to medium in range. The maximum available N was recorded 350.52 kg ha⁻¹ (surface) and 340.26kg ha⁻¹ (subsurface) at Selu location under the use of organic sources like FYM, Vermicompost, jivamrut and ghanjivanmurt to pigeonpea. The lowest available N was recorded 160.28 kg ha⁻¹ (surface) 151.35 kg ha⁻¹ (subsurface) at Savner location under the use of inorganic fertilizers applied to paddy. Use of organic sources like FYM, vermicompost, jivamrut and ghanjivanmurt performed better by providing higher available nutrient nitrogen and also good C:N ratio which ultimately helps in increase in availability of nitrogen to the soil over inorganic fertilizers and INM practices. Kumar *et al.*, (2018) expressed that, the continuous application of crop residues along with FYM and green manure significantly increased the available N of soil over 100 per cent NPK alone treatment.

Available phosphorous (kg ha⁻¹)

The available phosphorus content of soil after harvest of crops varied from 14.28 to 30.0 kg ha⁻¹ (surface) and 12.46 to 27.47 kg ha⁻¹ (subsurface) under organic, inorganic and INM practices (Table 2). The higher value of available P in soil 30 kg ha⁻¹ (surface) and 27.47 kg ha⁻¹ (subsurface) was observed under

the application of inorganic fertilizers to Nagpur mandarin at Savner location. The soil available phosphorus value observed under very low to low in category. Further it was observed that, at all locations there was slight increase in the availability of P with the use of chemical fertilizers compared to organic and INM practices. However, decreased in available phosphorus content in soil was observed with the use of organic inputs. The lowest content of available P was recorded 14.28 kg ha⁻¹ (surface) and 12.46 kg ha⁻¹ (subsurface) at Selu under the use of organic inputs to Nagpur mandarin. Balanced inorganic fertilizer and crop residues helps in increasing the phosphorous content in solution and solubilization of native soil phosphorous. Srilatha and Sharma (2015) reported that, continuous use of organic manure coupled with fertilization had build-up of available phosphorous in the treatment where it was applied and slightly depletion those where it was not applied. Maximum accumulation of available P in soil was observed in surface level than subsurface level in all the locations. From the results it was clear that application of inorganic fertilizers resulted in high available P content in soil than organic sources at all locations. The build-up of available P with phosphorus application can be attributed to an increased in available soil phosphorus after satisfying the phosphorus fixation capacity and chemical reaction.

Available potassium (kg ha⁻¹)

The application of organic and inorganic fertilizers and both in combinations to different crops influenced the value of soil available K. The data on available potassium in soil after harvest of crop is presented in table2. The magnitude of available K ranged from 324.82 to 442.07 kg ha⁻¹ in surface and from 318.56 to 431.17 kg ha⁻¹ in subsurface soil. The value of available potassium in soil

was found high to very high in range in the present study. The maximum value of available K was recorded 442.07 kg ha⁻¹ (surface) and 431.17 kg ha⁻¹ (subsurface) and the minimum value of available K was recorded 324.82 kg ha⁻¹ (surface) and 318.56 kg ha⁻¹(subsurface) at Gangner location under the cultivation of Nagpur mandarin (organic) and pigeon pea(inorganic), respectively. Soil available K concentrations were higher in the organic amendment treatments than the control (Hampton *et al.*, 2011). Bhat *et al.*, (2017) concluded that, the soil organic carbon, available nitrogen, available phosphorus and available potassium contents were significantly influenced by the application organic matter. The data further revealed that, the application of organic fertilizers recorded an increased in available K content in soil than inorganic and INM.

Available sulphur (kg ha⁻¹)

Sulphur is considered as fourth major nutrient for plant growth. The data regarding the available sulphur in the soil is presented in table 2. The available sulphur ranged from 10.8 to 16.42 kg ha⁻¹ (surface) and 8.9 to 15.52 kg ha⁻¹ (subsurface) i.e., low to medium category. The variation of available S was observed between the continuous use of organic, inorganic and INM applied. The higher amount of available S was recorded due to application of organic + inorganic (INM) input than the use of organic and inorganic fertilizer alone at Chichbhavan, Gangner, Savner and Selu locations. The data further revealed that application of organic fertilizer alone recorded an increased in available S at all four locations. The data ranged from 11.07 to 14.78 kg ha⁻¹ (surface) and 10.9 to 13.6 kg ha⁻¹ (subsurface). This is because in most of soil, sulphur resides in the organic fraction and hence soil organic matter content has direct bearing on S availability in the soil (Rattan *et al.*, 2015). However, the

maximum available S was recorded 16.42 kg ha⁻¹ (surface) and 15.52 kg ha⁻¹ (subsurface) under integrated nutrient management practice and the minimum available S was recorded 10.8 kg ha⁻¹ (surface) and 8.9 kg ha⁻¹ (subsurface) under the application of inorganic fertilizers. Malavath and Mani (2018) reported that the availability of S was more in surface horizon than the subsurface horizons might be due to soil sulphur is continuously cycled between inorganic and organic forms of sulphur. Similarly, the organic sulphur is also in equilibrium with inorganic counterpart and if there is any decline in inorganic SO₄-S level by means of crop uptake or leaching loss, it will be adequately replenished by the organic fraction.

Very labile carbon

The highest very labile carbon was recorded in Nagpur mandarin 1.30 g kg⁻¹ (surface) at Chichbhavan and 1.27 g kg⁻¹ (subsurface) at Gangner under the regular addition of organic fertilizers like FYM (Table 3) and the lower value was recorded 0.77 g kg⁻¹ (surface) and 0.74 g kg⁻¹ (subsurface) under inorganic fertilizers sources to pigeonpea at Gangner and Chichbhavan respectively. This highest value may be due to use of organic sources like FYM since last 8-10 years, which has resulted into significant increase in the very labile carbon pool. Das *et al.*, (2016) recorded that FYM treatment encouraged the accumulation of very labile carbon pool and lowest value may be due to long term application of chemical fertilizers since last 8 to 10 years, which has resulted into significant decrease in the very labile carbon pool.

Labile carbon

The data showed the highest labile carbon 1.02 g kg⁻¹ (surface) and 0.98 g kg⁻¹

(subsurface) was recorded under the application of organic fertilizers to Nagpur mandarin at Gangner. This may be due to long term application of FYM since last 8-10 years, which has resulted into significant increase in the labile carbon pool. The lowest value of labile carbon 0.55 g kg⁻¹ (surface) and 0.48 g kg⁻¹ (subsurface) was recorded under the application of inorganic fertilizers to pigeonpea at Savner. The application of inorganic NPK fertilizer fails to sequester SOC, only the application of organic manure alone has showed effective for sequestering soil organic carbon. Hema *et al.*, (2019) reported that, soil C_L increased as a result of the manure application than by the application of inorganic fertilizer alone.

Less-labile carbon

The data in respect of less labile carbon under use of various sources of nutrient have been compiled and depicted in table 3. The highest less labile carbon 0.91 g kg⁻¹ (surface) and 0.89 g kg⁻¹ (subsurface) was recorded under the long-term application of organic sources of fertilizers like FYM in soil to Nagpur mandarin at Chichbhavan. Similar, observation was reported by Moharana *et al.*, (2017) and Das *et al.*, (2016) due to the use of various sources organic fertilizers. The lower value of very labile carbon was registered 0.41 g kg⁻¹ (surface) and 0.37 g kg⁻¹ (subsurface) where the fertilizers were applied through inorganic sources to paddy at Savner. The value of less labile carbon was observed highest in application of organic fertilizers followed by INM and inorganic practices (Table 3).

Non-labile carbon

The lowest non-labile carbon was recorded in surface (3.73 g kg⁻¹) and subsurface (3.52 g kg⁻¹) was recorded under integrated nutrient management practices to pigeonpea at

Chichbhavan. However, highest non-labile carbon was recorded in surface (5.97 g kg^{-1}) and subsurface (5.82 g kg^{-1}) soil due to addition of fertilizers through inorganic sources to Nagpur mandarin at Gangner (Table 3). Bhattacharya *et al.*, (2007) reported that use of FYM with incorporation of crop residue reduces the non-labile pools. The surface soils have higher non labile carbon than the sub surface soils as the soils are clayey in texture the carbon compound may have less migration in subsurface.

Active pool and passive pool

The values of active and passive carbon pools were calculated and data is presented in table 4. The calculation indicates the higher contribution of passive pool recorded in inorganic (80.55%), INM (73.12%) and organic (71.66%) amongst the various application of sources. The highest value of active pool was observed in Nagpur mandarin crop at Chichbhavan (30.77%) due to application of organic fertilizers and its lowest value was observed in pigeonpea crop at Chichbhavan (17.90%) due to the application of inorganic fertilizers. However, the lowest value of passive pool was recorded in Nagpur mandarin at Chichbhavan (69.23 %) and its highest value was recorded in pigeonpea crop at Chichbhavan (82.10 %) where fertilizers applied through inorganic sources. Nath *et al.*, (2015) reported that there was abundance on active pool in surface soil. The abundance of four soil organic carbon fractions was in the order non-labile carbon (65.46%) >very labile carbon (13.76%) > labile carbon (11.14%) > less labile carbon (9.65%). The contribution of very labile pool in active carbon pool was higher than the labile pool, both in surface and sub-surface soil. Similarly, non-labile pool has more contribution than less labile pool in passive carbon pool in surface soils. However,

slightly higher less labile carbon in subsurface soils.

Correlation between carbon pool and available nutrients

The correlation between available nutrients and carbon pool is worked out and presented in table 5. The results revealed that, the very labile carbon had highly significant positive correlation with labile fraction of carbon ($r = 0.896$), less labile fraction ($r= 0.982$), non-labile fraction ($r = 0.952$), active pool ($r=0.995$), passive pool ($r=0.973$), available N ($r= 0.605$), available K ($r = 0.529$) and available S ($r= 0.387$). The labile fraction of carbon pool had highly significant positive correlation with less labile fraction ($r= 0.964$), non-labile fraction of carbon pool ($r = 0.989$), active pool ($r= 0.915$), passive pool ($r= 0.916$), available N ($r= 0.563$), and available K ($r= 0.433$). However, the labile fraction of carbon pool has highly significant negative correlation with available P ($r= -0.438$) was observed. Similarly, the less labile fraction of carbon pool had recorded highly significant positive correlation with non-labile fraction ($r=0.992$), active pool ($r= 0.963$) and available N ($r=0.603$) and highly significant negative with passive pool ($r= -0.974$).The non-labile fraction of carbon also showed highly significant positive correlation with passive pool ($r=0.756$), available N in soil ($r = 0.590$) and had highly significant negative correlation with active pool ($r= -0.949$). The active pool has highly significant positive correlation with passive pool ($r =0.986$), available nitrogen ($r = 0.569$) and had negative significant correlation with available potassium ($r = 0.496$) and available S ($r= -0.491$) in soil. The passive pool showed highly significant positive correlation with Nitrogen ($r= 0.542$) and significant negative correlation with available P ($r= -0.558$) and available S ($r= -0.368$).

Table.1 Physico-chemical properties of the soils

Sr. No	Practice	Crops	pH		EC (dS m ⁻¹)		OC (g kg ⁻¹)		CaCO ₃ (%)			
			1:2.5 Soil: water suspension						S	SS	S	SS
			S	SS	S	SS	S	SS				
1	2	3	4	5	6	7	8	9	10	11		
Chichbhavan												
1	Organic	Paddy	6.67	7.25	0.30	0.31	6.78	6.03	3.25	3.80		
		Pigeonpea	7.32	7.47	0.29	0.33	8.20	7.80	4.00	4.02		
		NM	7.18	7.53	0.31	0.31	7.40	6.80	2.78	3.01		
2	Inorganic	Paddy	7.90	8.12	0.38	0.42	5.40	4.20	3.11	3.93		
		Pigeonpea	8.10	8.23	0.24	0.36	5.60	5.30	3.60	3.72		
		NM	8.40	8.65	0.35	0.41	5.80	5.20	4.16	4.46		
3	INM	Paddy	7.63	7.93	0.35	0.39	6.10	5.60	5.12	5.22		
		Pigeonpea	8.13	8.20	0.24	0.28	5.49	5.20	5.28	5.32		
		NM	7.55	7.65	0.17	0.22	6.20	5.80	7.22	7.32		
Gangner												
1	Organic	Paddy	7.02	7.28	0.27	0.30	5.80	5.15	3.05	3.12		
		Pigeonpea	7.15	7.28	0.29	0.33	8.70	8.60	4.65	4.78		
		NM	7.25	7.48	0.31	0.34	7.56	7.34	3.25	3.40		
2	Inorganic	Paddy	7.65	7.89	0.36	0.42	5.12	4.03	3.10	3.25		
		Pigeonpea	7.43	7.45	0.26	0.32	5.60	5.30	2.95	3.11		
		NM	8.06	8.14	0.32	0.42	6.10	5.80	4.45	4.58		
3	INM	Paddy	7.64	7.84	0.29	0.33	5.78	5.32	5.61	5.71		
		Pigeonpea	8.09	8.10	0.31	0.31	5.45	5.13	6.20	6.29		
		NM	7.80	7.90	0.28	0.32	6.20	5.80	7.57	7.61		
Savner												
1	Organic	Paddy	6.90	7.08	0.33	0.39	6.78	6.50	2.80	3.01		
		Pigeonpea	7.12	7.29	0.25	0.31	7.18	7.12	3.20	3.40		
		NM	7.19	7.32	0.30	0.33	7.20	7.16	3.05	3.40		
2	Inorganic	Paddy	7.52	7.78	0.42	0.47	4.60	4.20	5.10	5.70		
		Pigeonpea	7.82	8.44	0.31	0.42	5.30	4.89	6.20	6.70		
		NM	8.50	8.90	0.32	0.45	5.80	5.20	4.23	5.90		
3	INM	Paddy	7.83	7.93	0.35	0.39	5.90	5.23	5.82	5.91		
		Pigeonpea	8.10	8.20	0.24	0.28	6.50	6.10	6.32	6.48		
		NM	7.70	7.80	0.18	0.23	6.60	6.30	7.50	7.82		
Selu												
1	Organic	Paddy	7.10	7.19	0.29	0.31	6.89	6.70	3.00	3.20		
		Pigeonpea	7.05	7.25	0.24	0.31	9.50	9.20	5.20	5.25		
		NM	7.09	7.19	0.30	0.32	7.30	6.79	3.10	3.15		
2	Inorganic	Paddy	7.52	7.62	0.29	0.31	4.80	4.20	4.23	4.56		
		Pigeonpea	8.11	8.20	0.26	0.34	5.10	4.80	4.56	5.10		
		NM	7.50	7.89	0.33	0.48	6.10	5.80	5.70	5.89		
3	INM	Paddy	7.52	7.62	0.29	0.37	6.20	5.58	5.23	5.42		
		Pigeonpea	8.08	8.18	0.37	0.36	5.80	5.66	6.58	6.71		
		NM	7.77	7.86	0.33	0.33	6.50	6.40	7.40	7.49		

S= surface (0-15cm), SS= surface (15-30cm) NM= Nagpur mandarin

Table.2 Available nutrient status of the soils

Sr.No.	Practice	Crops	N (kg ha ⁻¹)		P (kg ha ⁻¹)		K (kg ha ⁻¹)		S (kg ha ⁻¹)	
			S	SS	S	SS	S	SS	S	SS
1	2	3	4		5		6		7	
Chichbhavan										
1	Organic	Paddy	269.30	256.28	18.29	17.30	439.68	425.83	11.07	10.90
		Pigeonpea	296.66	240.56	17.28	16.98	403.25	400.20	13.29	12.67
		Nagpur mandarin	288.48	257.85	22.35	20.25	398.50	368.78	14.27	13.45
2	Inorganic	Paddy	189.00	176.00	27.43	25.42	382.45	360.28	10.80	8.90
		Pigeonpea	292.50	285.50	20.43	18.13	347.62	336.27	11.20	10.90
		Nagpur mandarin	249.50	239.50	24.36	22.23	409.12	401.10	13.58	11.70
3	INM	Paddy	290.00	281.00	23.02	20.81	415.30	407.25	15.22	14.56
		Pigeonpea	254.10	243.60	18.23	17.11	384.36	369.62	15.20	16.40
		Nagpur mandarin	257.53	243.45	21.01	20.97	390.25	380.54	16.42	15.52
Gangner										
1	Organic	Paddy	278.38	256.3	20.56	18.56	435.56	428.65	11.75	11.00
		Pigeonpea	337.80	330.2	18.34	17.29	422.5	390.45	13.14	12.98
		Nagpur mandarin	288.36	240.26	18.96	16.34	442.07	431.17	14.78	13.60
2	Inorganic	Paddy	196.28	185.54	19.36	18.23	384.42	375.37	12.93	11.45
		Pigeonpea	216.00	206.00	26.34	24.42	324.82	318.56	12.91	11.67
		Nagpur mandarin	229.00	215.28	24.36	23.63	403.50	380.25	11.83	10.46
3	INM	Paddy	286.00	276.35	23.38	21.48	415.30	407.34	14.98	13.56
		Pigeonpea	240.05	232.28	18.40	17.12	383.65	366.56	15.28	14.87
		Nagpur mandarin	283.25	276.38	22.23	21.35	428.83	411.45	15.25	14.98
Savner										
1	Organic	Paddy	269.48	260.26	18.76	18.02	388.6	380.20	12.10	11.05
		Pigeonpea	285.56	240.30	18.66	17.20	347.2	330.40	14.10	12.45
		Nagpur mandarin	280.27	260.28	19.26	18.20	410.32	403.40	11.98	9.09
2	Inorganic	Paddy	160.28	151.35	19.23	17.43	374.21	363.67	11.07	10.99
		Pigeonpea	273.89	268.76	27.74	25.45	421.32	411.67	12.19	11.78
		Nagpur mandarin	260.42	252.00	30.00	27.47	358.57	344.45	12.42	11.87
3	INM	Paddy	278.00	265.72	22.35	20.46	420.20	400.56	14.45	13.53
		Pigeonpea	243.72	238.15	18.22	16.76	391.60	377.50	14.23	13.67
		Nagpur mandarin	235.25	228.75	21.01	20.25	365.12	348.46	14.85	13.78
Selu										
1	Organic	Paddy	263.35	248.40	14.31	13.24	433.26	421.56	12.12	11.78
		Pigeonpea	350.52	340.26	18.22	18.00	395.20	372.48	14.46	12.56
		Nagpur mandarin	287.45	260.40	14.28	12.46	428.56	415.25	13.26	11.12
2	Inorganic	Paddy	168.24	152.32	22.20	21.28	381.45	369.23	12.24	11.56
		Pigeonpea	260.48	249.89	25.28	24.14	349.18	336.12	11.28	10.45
		Nagpur mandarin	260.42	251.52	22.60	20.48	412.28	407.45	13.42	12.54
3	INM	Paddy	286.00	273.49	25.05	23.75	415.50	410.76	14.27	13.45
		Pigeonpea	241.25	233.86	18.91	16.65	385.24	371.98	15.60	14.78
		Nagpur mandarin	258.52	244.81	24.02	22.93	401.36	380.30	15.95	14.56

Table.3 Effect of various organic, inorganic and INM practices on carbon pool fractions at harvest of crops

Sr. No.	Practice	Crops	Carbon pool (g kg ⁻¹)									
			V.L.		L.		L.L.		N.L.		TOC	
			S	SS	S	SS	S	SS	S	SS	S	SS
Chichbhavan												
1	Organic	Paddy	1.28	1.20	0.96	0.94	0.89	0.86	4.48	4.35	7.61	7.35
		Pigeonpea	1.23	1.19	0.87	0.84	0.81	0.79	4.33	4.21	7.24	7.03
		Nagpur mandarin	1.30	1.24	0.98	0.94	0.91	0.89	4.22	4.18	7.41	7.25
2	Inorganic	Paddy	0.86	0.84	0.71	0.69	0.41	0.39	5.21	4.94	7.19	6.86
		Pigeonpea	0.78	0.74	0.62	0.57	0.49	0.45	5.93	5.59	7.82	7.35
		Nagpur mandarin	0.81	0.77	0.65	0.63	0.57	0.55	4.83	4.69	6.86	6.64
3	INM	Paddy	0.95	0.93	0.82	0.79	0.88	0.85	4.27	4.14	6.92	6.71
		Pigeonpea	0.88	0.85	0.83	0.82	0.79	0.75	3.73	3.52	6.23	5.94
		Nagpur mandarin	1.08	0.95	0.80	0.77	0.69	0.65	4.07	4.27	6.64	6.64
Gangner												
1	Organic	Paddy	1.25	1.20	0.91	0.87	0.86	0.83	4.83	4.66	7.85	7.56
		Pigeonpea	1.18	1.11	0.86	0.85	0.83	0.81	4.61	4.54	7.48	7.31
		Nagpur mandarin	1.29	1.27	1.02	0.98	0.90	0.86	4.62	5.57	8.68	7.23
2	Inorganic	Paddy	0.82	0.82	0.69	0.61	0.65	0.51	5.97	5.82	8.13	7.76
		Pigeonpea	0.77	0.75	0.74	0.73	0.71	0.68	5.89	5.62	8.11	7.78
		Nagpur mandarin	0.78	0.77	0.66	0.59	0.54	0.53	5.15	4.89	7.13	6.78
3	INM	Paddy	0.98	0.96	0.88	0.85	0.77	0.68	4.41	4.32	7.04	6.81
		Pigeonpea	0.96	0.89	0.86	0.82	0.79	0.74	4.09	4.05	6.70	6.50
		Nagpur mandarin	1.02	0.95	0.91	0.90	0.69	0.65	4.36	4.27	6.98	6.77
Savner												
1	Organic	Paddy	1.17	1.12	0.93	0.90	0.88	0.85	4.85	4.76	7.83	7.63
		Pigeonpea	1.18	1.15	0.88	0.86	0.82	0.79	4.67	4.51	7.55	7.31
		Nagpur mandarin	1.26	1.24	0.97	0.94	0.89	0.85	4.18	4.08	7.30	7.11
2	Inorganic	Paddy	0.80	0.76	0.68	0.66	0.44	0.37	5.91	5.76	7.83	7.55
		Pigeonpea	0.78	0.77	0.55	0.53	0.52	0.48	5.03	4.99	6.88	6.77
		Nagpur mandarin	0.81	0.79	0.58	0.48	0.45	0.37	5.73	5.36	7.57	7.00
3	INM	Paddy	0.97	0.94	0.81	0.79	0.68	0.63	4.36	4.23	6.82	6.59
		Pigeonpea	0.94	0.90	0.88	0.85	0.61	0.59	4.23	4.05	6.66	6.39
		Nagpur mandarin	1.04	0.95	0.83	0.71	0.69	0.65	4.41	4.27	6.97	6.58
Selu												
1	Organic	Paddy	1.21	1.19	0.96	0.94	0.87	0.81	4.88	4.81	7.92	7.75
		Pigeonpea	1.19	1.15	0.87	0.85	0.83	0.79	4.65	4.62	7.54	7.41
		Nagpur mandarin	1.26	1.21	0.99	0.95	0.91	0.86	5.12	4.88	8.28	7.90
2	Inorganic	Paddy	0.78	0.75	0.72	0.66	0.47	0.45	5.73	5.62	7.70	7.48
		Pigeonpea	0.76	0.74	0.65	0.61	0.54	0.46	5.86	5.59	7.81	7.40
		Nagpur mandarin	0.81	0.78	0.67	0.61	0.47	0.44	5.13	4.93	7.08	6.76
3	INM	Paddy	0.95	0.91	0.82	0.79	0.67	0.52	4.27	4.09	6.71	6.31
		Pigeonpea	0.91	0.87	0.78	0.66	0.71	0.57	4.09	3.91	6.49	6.01
		Nagpur mandarin	1.08	0.96	0.85	0.73	0.69	0.64	4.41	4.32	7.03	6.65

Table.4 Effect of organic, inorganic and INM practices on active and passive pools of soil at harvest of crops

Sr.No.	Practice	Crops	Carbon pool (%)											
			V.L.		L.		A. P		L.L.		N.L.		P. P	
			S	SS	S	SS	S	SS	S	SS	S	SS	S	SS
Chichbhavan														
1	Organic	Paddy	16.82	16.33	12.61	12.79	29.43	29.12	11.70	11.70	58.87	59.18	70.57	70.88
		Pigeonpea	16.99	16.93	12.02	11.95	29.01	28.88	11.19	11.24	59.81	59.89	70.99	71.12
		NM	17.54	17.10	13.23	12.97	30.77	30.07	12.28	12.28	56.95	57.66	69.23	69.93
2	Inorganic	Paddy	11.96	12.24	9.87	10.06	21.84	22.30	5.70	5.69	72.46	72.01	78.16	77.70
		Pigeonpea	9.97	10.07	7.93	7.76	17.90	17.82	6.27	6.12	75.83	76.05	82.10	82.18
		NM	11.81	11.60	9.48	9.49	21.28	21.08	8.31	8.28	70.41	70.63	78.72	78.92
3	INM	Paddy	13.73	13.86	11.85	11.77	25.58	25.63	12.72	12.67	61.71	61.70	74.42	74.37
		Pigeonpea	14.12	14.31	13.31	13.80	27.43	28.11	12.67	12.63	59.90	59.26	72.57	71.89
		NM	16.26	14.31	12.04	11.60	28.30	25.90	10.39	9.79	61.32	64.31	71.70	74.10
Gangner														
1	Organic	Paddy	15.92	15.87	11.59	11.51	27.52	27.38	10.96	10.98	61.53	61.64	72.48	72.62
		Pigeonpea	15.78	15.18	11.50	11.63	27.27	26.81	11.10	11.08	61.63	62.11	72.73	73.19
		NM	16.48	14.63	13.03	11.29	29.50	25.92	11.49	9.91	59.00	64.17	70.50	74.08
2	Inorganic	Paddy	10.09	10.57	8.49	7.86	18.57	18.43	8.00	6.57	73.43	75.00	81.43	81.57
		Pigeonpea	9.49	9.64	9.12	9.38	18.62	19.02	8.75	8.74	72.63	72.24	81.38	80.98
		NM	10.94	11.36	9.26	8.70	20.20	20.06	7.57	7.82	72.23	72.12	79.80	79.94
3	INM	Paddy	13.92	14.10	12.50	12.48	26.42	26.58	10.94	9.99	62.64	63.44	73.58	73.42
		Pigeonpea	14.32	13.69	12.83	12.62	27.14	26.31	11.78	11.38	61.07	62.31	72.86	73.69
		NM	14.60	14.03	13.03	13.29	27.63	27.33	9.88	9.60	62.49	63.07	72.37	72.67
Savner														
1	Organic	Paddy	14.94	14.68	11.88	11.80	26.82	26.47	11.24	11.14	61.94	62.39	73.18	73.53
		Pigeonpea	15.63	15.73	11.66	11.76	27.28	27.50	10.86	10.81	61.85	61.70	72.72	72.50
		NM	17.26	17.44	13.29	13.22	30.55	30.66	12.19	11.95	57.26	57.38	69.45	69.34
2	Inorganic	Paddy	10.22	10.07	8.68	8.74	18.90	18.81	5.62	4.90	75.48	76.29	81.10	81.19
		Pigeonpea	11.34	11.37	7.99	7.83	19.33	19.20	7.56	7.09	73.11	73.71	80.67	80.80
		NM	10.70	11.29	7.66	6.86	18.36	18.14	5.94	5.29	75.69	76.57	81.64	81.86
3	INM	Paddy	14.22	14.26	11.88	11.99	26.10	26.25	9.97	9.56	63.93	64.19	73.90	73.75
		Pigeonpea	14.11	14.08	13.21	13.30	27.33	27.39	9.16	9.23	63.51	63.38	72.67	72.61
		NM	14.92	14.44	11.91	10.79	26.83	25.23	9.90	9.88	63.27	64.89	73.17	74.77
Selu														
1	Organic	Paddy	15.28	15.35	12.12	12.13	27.40	27.48	10.98	10.45	61.62	62.06	72.60	72.52
		Pigeonpea	15.78	15.52	11.54	11.47	27.32	26.99	11.01	10.66	61.67	62.35	72.68	73.01
		NM	15.22	15.32	11.96	12.03	27.17	27.34	10.99	10.89	61.84	61.77	72.83	72.66
2	Inorganic	Paddy	10.13	10.03	9.35	8.82	19.48	18.85	6.10	6.02	74.42	75.13	80.52	81.15
		Pigeonpea	9.73	10.00	8.32	8.24	18.05	18.24	6.91	6.22	75.03	75.54	81.95	81.76
		NM	11.44	11.54	9.46	9.02	20.90	20.56	6.64	6.51	72.46	72.93	79.10	79.44
3	INM	Paddy	14.16	14.42	12.22	12.52	26.38	26.94	9.99	8.24	63.64	64.82	73.62	73.06
		Pigeonpea	14.01	14.48	12.01	10.98	26.02	25.46	10.93	9.48	63.05	65.06	73.98	74.54
		NM	15.36	14.44	12.09	10.98	27.45	25.41	9.82	9.62	62.73	64.96	72.55	74.59

S= surface (0-15cm), SS= surface (15-30cm) NM=Nagpur mandarin

Table.5 Correlation matrix between various carbon pools and nutrients present in soil.

	V.L	L	LL	N.L	A.P	P.P	N	P	K	S
V.L	1									
L	0.896**	1								
LL	0.982**	0.964**	1							
N.L	0.952**	0.989**	0.992**	1						
A.P	0.955**	0.915**	0.963**	-0.949**	1					
P.P	0.973**	0.916**	-0.974**	0.756**	0.986**	1				
N	0.605**	0.563**	0.603**	0.590**	0.569**	0.542**	1			
P	-0.238	-0.438**	-0.310	-0.281	0.269	-0.558*	-0.224	1		
K	0.529**	0.433**	0.202	0.275	-0.496**	-0.320	0.388*	-0.279	1	
S	0.387*	0.255	0.153	0.151	-0.491**	-0.368*	0.277	-0.716**	0.418**	1

**Significance at 1 % is (0.418) and *significance at 5% is (0.325)

The correlation among the available nutrients also worked out and found significant and positive correlation of nitrogen in soil with potassium ($r = 0.388$). Also recorded significant and positive correlation of available K with sulphur ($r = 0.418$). However, available phosphorus in soil had recorded highly significant negative correlation with available sulphur ($r = -0.716$). Chinnadurai *et al.*, (2013) reported that soil acid phosphate and alkaline phosphate activities were higher in manure amended soil and were positively correlated with SOC and MBC, suggesting that SOC and MBC were built upon continuous application of organic amendments. Organic matter acts as nutrients supplement and affords as source for enzyme as well as substrates for hydrolysis.

In conclusion, addition of organic matter lowers the soil pH, increase residual organic C, available N, INM increased available S, inorganic fertilizer increased available P and K compare to organic and INM farming practices. INM resulted in the improvement of most soil physico-chemical properties and nutrient balances that lead to increased and sustained production. The significant and positive relation between carbon fractions (C_{VL} , C_L , C_{LL} , C_{NL}) and available N proves that nitrogen additions significantly increased SOC fractions.

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