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RESEARCH ARTICLE

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON YIELD AND PASSIVE POOLS OF SOIL ORGANIC CARBON IN LONG TERM FERTILIZER EXPERIMENT

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Abstract

Soil organic carbon (SOC) plays a vital role order to improve soil properties and sustainable production. The different fractions of SOM are more effective in indicating changes in soil use than total soil organic matter content. The present study was conducted to investigate the effect of integrated nutrient management (INM) on yields and passive pools of soil organic carbon (SOC) under groundnut-wheat cropping sequence of a Haplustepts soil. Such studies were for the first time initiated in long term field experiments initiated during kharif 1999 at Junagadh, Gujarat. Effect on varying doses of N, NP, NPK, NPK with FYM, Zn, S and Rhizobium on yields and passive pools of SOC viz., Humic acid, Fulvic acid and Humin was conducted after 16 year of groundnut-wheat crop sequence was studied. The result of the two was compared and conclusion deduced. The result revealed that application of 50% NPK + FYM @ 10 t ha^{-1} to groundnut and 100% NPK to wheat significantly increased the groundnut pod and haulm yield, wheat grain and straw yield. The highest and significant increase passive pools of soil organic carbon viz., Humic acid, Fulvic acid and Humin was also observed under combine application of 50% NPK + FYM @ 10 t ha^{-1} to groundnut and 100% NPK to wheat. These results indicate that long-term integrated use of FYM with chemical fertilizers or use of FYM alone exerted significant effect on the passive pools of soil organic carbon.

Introduction:-

The amount of SOM in soil of India is relatively low (0.1 to 1.0%) and typically less than 0.5%. Maintenance of organic carbon in tropical soils up to a desirable level of 0.5-1.0 per cent is extremely important for sustainable crop production (Swarup and Wanjari, 2000). In the tropics especially when these are highly weathered, with small or no reserves of nutrients and are managed without any external inputs of organic or inorganic fertilizer (Feller and Beare, 1997). The status of soil organic matter has important implications for agricultural productivity, global climate due to its role as a source and sink of carbon. In order to make sound decision about soil and crop management, it is important to understand the process of accumulation or loss of soil organic matter. The primary source of soil organic matter formation is vegetal detritus. The SOM dynamics should be related to its fractions or pools that have biological significance as they relate to the potential of soils to provide nutrients to plants (Collins et

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al., 1992). Vegetal detritus is the primary source of SOM formation. The SOM is composed of series of fractions from very active and passive pools. The subsequent decomposition/synthesis products of humification process are passive fraction of SOM consisting of stable materials remaining in soil for hundreds or even thousands of years. It includes humus physically protected in clay- humus complexes viz., humin and humic acids. The passive fraction accounts for 60 to 80 per cent of the organic matter in most soils and its quality is increased or diminished only slowly. The passive fractions contribute to the colloidal properties of soil, CEC and WHC (Smith and Paul 1990).

Vegetation (Bhudhilal and Rao, 1977), climate (Gupta et al., 1982), soil reaction (Ghosh and Schnitzer, 1980) and biological conditions influence the quantity and quality of organic matter representative of humic and non-humic substances. The decreasing organic matter is the cause of the concern, keeping in view the above facts, it was thought pertinent to conduct such studies. Organic matter fractions from the soil of long-term field experiment and its comparison with earlier studies will provide a platform for predicting the organic matter status of these soils.

Materials And Methods:-

Study Site description:

The experiment was conducted in Saurashtra region, Gujarat. It is a peninsular region situated between 20.39^o to 21.8^{o}N latitude and 69.0^o to 72.3^{o}E longitude with altitude of 60 meters above the mean sea level on the Western side at the foothills of mountain Girnar in South Saurashtra agro-climatic zone of Gujarat state. In Junagadh the climatic condition is tropical. When compared with winter, the summers have much more rainfall. The average annual temperature is 25.7 °C in Junagadh. Average annual rainfall is about 903 mm with 45 rainy days. During southwest monsoon season (June-September) about 91% of the annual rainfall is received.

Soil Description:

Saurastra region has medium black soil which is calcareous in nature, alkaline in reaction and clayey in texture derived from trap basalt, lime stone and sand stone under semi arid climate. Taxonomically, the soil is classified as Haplustepts. The soil is dominated by smectite group of clay minerals, which give rise to mild cracking in dry season, due to which it is further classified as TypicHaplustepts at sub group level. From fertility point of views, the soil has medium in available nitrogen, low in available phosphorus but high in available potassium. The organic matter content is also low in this soil.

Treatments:

The long-term experiment included twelve fertilization treatments and each treatment had four replicates; the 48 plots of 10×20 m each were arranged in a randomized block design. All plots were continuously under groundnut - wheat rotation from the beginning of the experiment. The twelve treatments were T_1- 50% NPK of recommended doses in Groundnut-wheat sequence, T_2- 100% N P K of recommended doses in Groundnut -wheat sequence, T_3 - 150% N P K of recommended doses in Groundnut -wheat sequence, T_4 - 100% N P K of recommended doses in Groundnut –wheat sequence + $ZnSO_4$ @ 50 kg ha^{-1} once in three year to Groundnut only (i.e. '99, 02, 05 etc), T_5 - N P K as per soil test, T_6 - 100% N P of recommended doses in Groundnut –wheat sequence, T_7 - 100 % N of recommended doses in Groundnut - wheat sequence, T_8 - 50% N P K of recommended doses + FYM @ 10 t ha^{-1} to Groundnut and 100% N P K to wheat, T_9 - Only FYM @ 25 t ha^{-1} to Groundnut only, T_{10} - 50% N P K of recommended doses + Rhizobium + PSM to Groundnut and 100% N P K to wheat, T_{11} - 100% N P K of recommended doses in Groundnut -wheat sequence (P as SSP) and T_{12} – Control.

Soil sampling and analysis:

In the earlier studies conducted, groundnut crop was grown during kharif 1999-2000 and wheat crop was grown during rabi 1999-2000. The soil samples were collected during two periods (1st and 16th years), Initial year (1999- before Groundnut) and 16th year (2015- after Wheat). For the present study, soil samples were collected with the help of tube auger from the each plot of the above mentioned treatments representing the plough layer (20 cm). The composite representative soil samples were obtained from these samples for each plot and these soil samples were cleaned and air-dried. After air-drying, were ground with wooden mortar and pestle so that they can pass through a 2 mm plastic sieve. The bulk soil samples were stored in polyethylene bags for chemical analysis. Organic carbon was determined by wet oxidation method (Walkley and Black, 1935) and the passive fraction of organic carbon viz. humic acid, fulvic acid and humin are analyze by Stevenson (1965) method.

Depletion per cent:

The nutrients depleted from soil by different cycles were calculated by the formula:

$$\text{Depletion of Nutrient (\%)} = \frac{\text{Nutrient status of index year} - \text{Nutrient status of final year}}{\text{Nutrient status of index year}} \times 100$$

Statistical Analysis:
The analytical data recorded during the course of investigation were subjected to statistical analysis using the SPSS 16.0 software package for Windows. Statistically significant differences were identified using analysis of variance ANOVA. As per the method outlined by Panse and Sukhatme (1985), the value of test at 5 and 1 per cent level of significance was determine and the values of SEm, CV per cent were also calculated.

Result And Discussion:-

Groundnut pod Yield:
In earlier studies the pod yield of groundnut was showed highest values in T_6 treatment followed by T_4 and T_{11} treatment. But after 16th years the maximum values of pod yield (1146.75 kg ha^{-1}) were recorded under application of 50 % NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence & 100% NPK to wheat (T_8) followed by (1046.75 kg ha^{-1}) FYM @ 25 t.ha^{-1} to groundnut only (T_9). The pod yield of groundnut were not influenced significantly by various treatments of experiment, in 1st year but numerically higher pod yield was recorded under T_6 treatment (100 % NP of recommended dose of Groundnut-Wheat sequence) in 1st year(Table-1). This result is in conformity with the result of earlier works likeRedda and Kebede (2017) who observed that increased crop yield with combine application of FYM @ 9 t ha^{-1} and 75 kg ha^{-1} inorganic fertilizer. Vala et al. (2017) reported that the yield of groundnut was significantly increased with combine application of organic and inorganic fertilizers. Similarly Bhattacharyya et al., (2015) also found that the crop yield significantly increased by 74% over the control under the combined application of FYM + NPK.

Table 1:- Influence of different treatment on Groundnut and Wheat yield in 1st year and 16th year of LTFE soils.

Treatment	Groundnut Yield (kg ha^{-1})				Wheat Yield (kg ha^{-1})			
	Pod Yield		Haulm Yield		Grain Yield		Straw Yield	
	1st year	16th year	1st year	16th year	1st year	16th Year	1st year	16th year
T_1	962.00	816.25	1790.50	1640.75	1589.00	2093.00	2696.75	2802.50
T_2	984.75	941.50	2018.25	1781.00	1908.50	2758.50	3090.25	3526.75
T_3	916.25	1012.75	1758.00	1960.50	1878.50	2893.00	2847.25	3728.75
T_4	1048.00	951.50	1985.75	1969.75	1806.50	2694.50	2650.25	3419.25
T_5	929.25	928.50	1676.50	1757.50	1856.50	2720.25	2819.50	3434.75
T_6	1101.75	735.50	1969.50	1610.75	1718.75	2426.00	2696.75	2992.50
T_7	927.50	622.00	1693.00	1370.00	1111.00	1562.50	1921.25	2056.75
T_8	916.25	1146.75	1888.00	2037.25	1898.25	3407.00	2766.00	4406.25
T_9	875.75	1046.75	1693.00	1873.50	1289.25	3309.50	2141.25	3966.75
T_{10}	963.50	856.00	2002.00	1709.00	1419.00	2566.50	2581.00	3307.50
T_{11}	1017.25	918.50	1871.50	1735.00	1608.75	2752.50	2963.00	3494.25
T_{12}	968.25	709.75	1725.50	1400.25	1309.25	1678.75	2072.00	2231.25
MEAN	967.54	890.48	1839.29	1737.10	1616.10	2571.83	2603.77	3280.60
S.Em.±	74.12	46.13	131.39	90.22	107.36	132.29	155.89	176.34
C.D. at 5 %	NS	132.73	NS	259.58	309.12	380.62	448.86	507.37
C.V. %	15.32	10.36	14.29	10.39	13.29	10.29	11.97	10.75

Groundnut haulm Yield:
The haulm yields of groundnut were significantly influenced by various treatments in 16th years result and maximum haulm yield (2614.66 and 2037.25 kg ha^{-1}) were recorded under 50% NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence and 100% NPK to wheat (T_8) and this treatment also statistically at par with T_2, T_3,T_4 and T_9 treatment respectively. The haulm yield of groundnut was not influenced significantly by various treatments of experiment, in 1st year, but numerically higher haulm yield was recorded under T_2 treatment. Balaguravaihet al., (2005) reported that influence of long-term use of inorganic and organic manures increased sustainable production of groundnut yield. Similar Das et al., (2011) reported that FYM application @ 15 t ha^{-1} along with 100% NPK

fertilizers and optimal dose of NPK (100%) along with Zn produced maximum yields in comparison to alone application of NPK fertilizers.

Wheat grain Yield:
The grain yields of wheat were significantly affected by various fertilization treatments of LTFE experiment in 1st year as well as in 16 years. Significantly maximum values of grain yield (3407 kg ha^{-1}) were obtained under treatment of 50% NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence & 100% NPK to wheat (T_8) and this treatment was at par (3309.50 kg ha^{-1}) with FYM @ 25 t ha^{-1} to groundnut only (T_9) during 16th year, whereas significantly the higher grain yield of 1908.50 kg ha^{-1} was recorded under T_2 treatment (100% NPK of RDF) and it was at par with T_3, T_4, T_5, T_6, T_8 and T_{11} treatment in first year results (Table-1). Das et al. (2011) application of optimal dose of NPK (100%) along with Zn produced higher grain yields and better grain quality in comparison to alone application of NPK fertilizers. Verma et al., (2012) also reported similar results that the use of FYM along with 100% NPK increased crop productivity. The overall wheat grain yield increased after 16 year of experimentation compared to initial year. Rawal et al., (2015) observed that wheat grain yields were consistently higher in the NPK and FYM treatments than other treatments, where one or more nutrients were lacking. This result was also supported by Singh et al., (2017) who reported that highest productivity of wheat was recorded in the treatment comprising 100% NPK + FYM in long term fertilizers experiment than other fertilizers treatment.

Wheat straw Yield:
The significantly higher straw yields (3911 and 4406 kg ha^{-1}) were registered with T_8 treatment (50% NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence & 100% NPK to wheat) during 16th year, respectively and this treatment was statistically at par with T_9 treatment (FYM @ 25 t.ha^{-1} to groundnut only) during 16th year. Whereas significantly higher straw yield (3090 kg ha^{-1}) was recorded with T_2 treatment which was at par with T_3, T_4, T_5, T_6, T_8 and T_{11} during 1st year (Table-1). The results corroborate the finding of Ravankaret al., (2004) who reported that the highest yield of wheat were recorded by 100% NPK with 10 tonnes FYM ha^{-1} and the lowest under control. Sarawad and sing (2004) was also reported that the straw yield of wheat significantly increased due to all the levels of fertilizer and nutrients over control. The highest yields were obtained with application of 100% NPK + FYM. Similar result was also found by Brar et al., (2015) who reported that continuous cropping and integrated use of organic and inorganic fertilizers increased soil carbon sequestration and crop yields.

Table 2:- Influence of different treatment on status of organic carbon in 1st and 16th year of LTFE soils.

Treatment	Organic Carbon (%)	
	1st year	16th year
T_1	0.615	0.621
T_2	0.548	0.677
T_3	0.510	0.668
T_4	0.555	0.684
T_5	0.525	0.670
T_6	0.600	0.621
T_7	0.510	0.631
T_8	0.563	0.758
T_9	0.525	0.790
T_{10}	0.563	0.649
T_{11}	0.563	0.667
T_{12}	0.540	0.631
MEAN	0.551	0.672
S.Em.±	0.048	0.015
C.D. at 5 %	NS	0.044
C.V. %	17.240	4.550

Organic Carbon (O. C.):
The organic carbon status of LTEF soils increased after a span of 16 years. These increments were noted more in treatments which received FYM i. e. T_8& T_9. This result is corroborated with the finding of Reddy et al., (2017) who reported that among the various treatment continuous use of farm yard manure with 100% NPK treatment resulted in highest organic carbon content in soil compared to other treatments. There was overall increased in organic carbon

status of LTFE soils after 16th year as compared to initial status (1st year). In 1st year the non-significantly higher value of organic carbon was observed under 50% NPK of RDF in Groundnut-Wheat sequence (T_1) treatment followed by T_6 (150% NPK of RDF in Groundnut-Wheat sequence). Pant et al., (2017) reported that long-term combine application of 100% NPK and FYM increased the organic carbon content in soil after crop harvest. This increase in organic carbon content could be due to enhanced root development of crop resulting in higher residues as a result of intensive farming with continuous fertilizer applications. This increase was attributed to the addition of FYM, because addition of organic manure helps to stimulate the growth and activity of microorganism, thus resulting in the improvement of root and shoot growth, leading to production of higher biomass which increased SOC (Kauret al. 2008). These results indicate that the long term application of FYM improved soil physical condition, ultimately root growth increases and more biomass added to the soil, seems to increases organic carbon status of the particular soil.

Table 3:- Influence of different treatment on status of humic acid, fulvic acid and humin in 1st and 16th year of LTFE soils.

Treatment	Humic acid (mg 100 g^{-1} soil)		Fulvic acid (mg 100 g^{-1} soil)		Humin (mg 100 g^{-1} soil)	
	1st year	16th year	1st year	16th year	1st year	16th year
T_1	143.50	188.75	68.25	81.25	5.02	7.69
T_2	145.00	198.25	71.25	82.50	3.76	9.88
T_3	168.50	211.25	77.25	84.25	4.25	8.86
T_4	177.75	218.25	81.25	86.50	4.75	9.64
T_5	173.75	224.75	79.75	81.25	3.10	9.09
T_6	178.25	200.25	80.25	78.75	3.31	8.88
T_7	174.00	193.75	70.50	83.50	3.18	8.34
T_8	205.50	320.25	90.25	96.00	5.87	13.09
T_9	183.25	308.00	86.50	92.50	5.12	12.41
T_{10}	168.25	257.75	70.50	85.25	3.60	11.19
T_{11}	179.75	235.25	73.50	80.25	4.78	9.71
T_{12}	174.75	220.75	72.50	84.50	2.83	7.25
MEAN	172.69	231.44	76.81	84.71	4.13	9.67
S.Em.±	2.08	2.26	3.40	3.48	0.34	0.47
C.D. at 5 %	6.00	6.50	9.79	NS	0.98	1.35
C.V. %	2.41	1.95	8.86	8.22	16.54	9.72

Humic acid:

Humic acid (HA) is one of the important fractions of SOC whose improvement tells in nutrient restoration and transformation in soil for higher yield production. Humic acid content increased in soil with the application of fertilizer and FYM. The humic acid content in soils o of soils showed significant difference in the years 2000 and 2016 (Table-3) with application of different INM treatment. The manurial treatments produced variations in humic acid (HA) content. During 1st year and 16th years of experiment, treatment T_8 (50% NPK of recommended dose in Groundnut-Wheat sequence + FYM @ 10 t ha^{-1} Groundnut and 100% NPK to Wheat) registered significantly higher amount of humic acid status followed by treatment T_9 (FYM @ 25 t ha^{-1} to groundnut only) which could be due to improved soil physical parameters and a conductive environment for the formation of humic acid (Santhyet al., 2001). The humic acid status of soils under FYM was remarkably high, this was due to higher clay content that contributes in the later stage of humification as it controls the release of the individual functional groups of humic acids in the soil and cultivation was associated with a relative shift of organic matter from the sand and silt fractions towards the fine clay fractions and again decreased humic acid content as a result of long run tillage impact (Lavti and Paliwal, 1981; Zhang et al., 1988). Higher value of humic fraction was observed under application of NPK through fertilizers + 10 t FYM ha^{-1} (Ravankaret al., 2004).

Fulvic acid:

Fulvic acid (FA) is a part of the organic matter which is soluble in alkali and it remains in solution when the humic acid is precipitated with acid. Fulvic constituents bind soil particles into structural units called aggregates, and are involved in the mobilization and transport of sesquioxides in soil. The fulvic acid content in soils of different treatments under the LTFE in the years 2000 and 2016 are presented in table 3, revealed that during the year 2000 treatment T_8 (50% N P K of recommended dose in Groundnut -Wheat sequence + FYM @ 10 t ha^{-1} Groundnut and

100% NPK to Wheat) was increased status of fulvic acid significantly and it was at par with T_4 (100% NPK+ $ZnSO_4$ @ 50 kg ha^{-1} once in three year to groundnut only) and T_9 (FYM @ 25 t ha^{-1} to Groundnut only) treatment. In case of the year 2016, treatment (T_8) was showed higher value of fulvic acid but not a significant level. Overall content of fulvic acid in LTFE soil was increased after 16^{th} year. Similarly, Gathalaet al., (2007) showed that contents of fulvic acid in the soil significantly increased with the application of fertilizer and farm yard manure. This result was also confirmed by Kumariet. al. (2011) who reported that continuous application of organic manure alone or in combination with inorganic fertilizer significantly influenced the fulvic acid fraction in soil.

Humin:

Humin is the most resistant fraction of SOC and its contribution is the largest among other fraction. The humin content increased year wise irrespective of the treatments (Table-3). The results showed that the treatment T_8 (50 % NPK of recommended doses in Groundnut -Wheat sequence + FYM @ 10 t ha^{-1} Groundnut and 100 % NPK to Wheat) registered significantly higher value (5.87 and 13.09 mg 100 g^{-1} soil) of humin during 2000 and 2016 respectively which were at par with treatment T_9 (FYM @ 25 t ha^{-1} to Groundnut only). There was overall increase in humin content status of soil after 16 years as compared to initial status. These finding corroborate the result of Karad (2013) who was found that application of 50 % NPK + FYM @ 10 t ha^{-1} to groundnut and 100 % NPK to wheat (T_8) and FYM @ 25 t ha^{-1} to groundnut only (T_9) significantly increased the humin fraction of organic carbon in comparison to control treatment in LTFE soils of all the span. The continuous addition of organic and inorganic treatments noticed increased content of humin status in soil over control. The reason might be due to better and improved soil physical parameters and conductive environment for its fraction. The humin fraction was increase in the concentration of mineralization owing to the higher temperature of surface soil in tropical regions (Santhyet al., 2001). Meenaet al., (2017) also reported that among the twelve different treatments the highest huminfraction were obtained under the application of FYM 20 t ha^{-1} than other treatment.

Conclusion:-

Long term application of combine mineral fertilizers with FYM balance the soil organic carbon level in soil, crop yield and showed significant higher values when compare to control. However, significant higher values of organic carbon status and crop yields were observed at 50 % NPK + FYM @ 10 t ha^{-1} application. Integrated use of mineral fertilizers along with FYM significantly increased passive pools of soil organic carbon and yield in the crops of groundnut and wheat when compare to non-fertilized (control) and the initial values. The addition of NPK with FYM increased passive fraction of organic carbon viz. Humic acid, Fulvic acid, Humin and yields of both groundnut and wheat under long term fertilization. Thus, NPK + FYM were the best option for increasing organic carbon status in soil and enhance crop yields. Thus the balanced application of NPK fertilizers with FYM was the best option for nutrient management of intensive cropping system in terms of crop yield, improving soil fertility, biological properties of soils both in Groundnut and wheat cropping system.

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