Effect of Integrated Nutrient Management on Yield and Active Pools of Soil Organic Carbon under Groundnut-Wheat System of Typic Haplustept in Long term Fertilizer Experiment

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The effect of integrated nutrient management (INM) on active pools of soil organic carbon (SOC) under groundnut-wheat cropping sequence of a Haplustepts soil, was studied in a long-term field experiment initiated during kharif1999 at Junagadh, Gujarat. Effect of varying doses of N, NP, NPK with FYM, Zn, S and *Rhizobium* on active pools of SOC *viz.*, soil microbial biomass carbon, soil microbial biomass nitrogen,soil microbial biomass phosphorus; water soluble carbon; water soluble carbohydrates and dehydrogenase activity after 12th year of groundnut-wheat crop sequence was studied. Application of 50% NPK + FYM @ 10 t ha^{-1}to groundnut and 100% NPK to wheat significantly increased the microbial biomass carbon (SMB-C), soil microbial biomass nitrogen (SMB-N), soil microbial biomass phosphorus (SMB-P) water soluble carbon (WS-OC) water soluble carbohydrates (WS-CHO) and dehydrogenase activity (DHA). Integrated use of FYM with chemical fertilizers or use of FYM alone exerted significant effect on the active pools of soil organic carbon.

Keywords: Integrated Nutrient Management, active pools, soil organic carbon and soil organic matter..

A key factor in maintaining sustainable production in the tropical soils is improvement in the soil organic matter (SOM) content. In the tropics, SOM determines the fertility and productivity of soils, especially when these are highly weathered, with small or no reserves of nutrients and are managed without any external inputs of organic or inorganic fertilizers (Feller and Beare, 1997).

Sustainable agriculture involves successful management of resources for increase agricultural production to satisfy changing human needs, while maintaining or enhancing the environment and natural resources (FAO, 1989). Integrated nutrient management (INM) or integrated nutrient supply (INS) system aims at achieving efficient use of chemical fertilizers in conjunction with organic manures. Long term fertilizer experiments involving intensive cereal based cropping systems reveal a declining trend in productivity even with the application of recommended levels of N, P and K fertilizers (Mahajan *et al*., 2002; Mahajan and Sharma, 2005). The crop productivity increases from the combined application of chemical fertilizers and organic manures. Such combination contributed to the improvement of physical, chemical and biological properties and soil organic matter and nutrient status. In sustainable agriculture the organic matter is a single property which influences soil fertility, soil formation, soil biology, physical and chemical properties, organo-chemical, biotic and hydrothermal characteristics of a soil (Katyal, 2000). The nature, content, composition and behaviour

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of organic matter in soil are fundamentally important for growth of crop under diverse climatic conditions.Crop production; nutrient uptake and physico-chemical, chemical and microbiological properties of soil an be potentially improved by continuous application of chemical fertilizers alone or in combination with FYM. Manure addition affects enzyme activities, microbial biomass and carbon mineralization as compared to inorganic fertilization or unamended control. Therefore, present study was carried out to study the effect of INM on active pools of SOM under groundnut-wheat cropping sequence of a *Typic Haplustept*.

MATERIALS AND METHODS

A long term field experiment on integrated nutrient management under groundnut – wheat sequence was initiated in the year 1999-2000 at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. The climate of the experimental site is sub-tropical. The maximum and minimum temperatures are 36.8 and 22.5 ^{0}C. The mean annual rainfall of the region varies from 650 to 750 mm. The soil of the experimental field is clayey in texture and medium black calcareous in nature, having field capacity and permanent wilting point 41 % and 20%, respectively. Organic carbon is 0.65 %, $CaCO_3$ 48 %, Available N, P_2O_5 and K_2O is 106.06, 28.16 and 272.00 kg ha^{-1} respectively. The cation exchange capacity of the soil is 27.30 cmol (P^+) kg^{-1}. The experiment consisted of 12 treatments replicated four times in a randomized block design. These are: T_1 - 50 % NPK of recommended dose to Groundnut-Wheat sequence; T_2- 100% NPK of recommended dose to Groundnut-Wheat sequence; T_3- 150% NPK of recommended dose to Groundnut-Wheat sequence; T_4 - 100% NPK+ $ZnSO_4$ @ 50 kg ha^{-1} once in three year to groundnut only; T_5 - NPK as per soil test; T_6 -100% NP of recommended dose to Groundnut-Wheat sequence; T_7 - 100% N of recommended dose to Groundnut-Wheat sequence; T_8 - 50% NPK + FYM @ 10 t ha^{-1} to Groundnut and 100% NPK to wheat; T_9 - Only FYM @ 25 t ha^{-1} to Groundnut only; T_{10} - 50% NPK + Rhizobium + PSM to groundnut and 100 % NPK to wheat; T_{11} - 100% NPK of recommended dose to Groundnut-Wheat sequence. (P as SSP); T_{12} - Control; The recommended dose of fertilizers for groundnut 12.5 kg/ha N, 25 kg/ha P, and for wheat 120* kg/ha N, 60 kg ha^{-1} P_2O_5 and 60* kg/ha K_2O; (*50% as basal dose and 50% at 21 DAS.). The fertilizers used were Urea, Diammonium phosphate, and muriate of potash, ($T_{11:}$ P source is single super phosphate) and zinc sulphate. Groundnut GG-20 and wheat GW- 496 were raised as test crop in the cropping system. At the harvest of wheat crop of year (2012), soil samples (0-15 cm) were drawn to assess the organic carbon by rapid titration method (Walkley and Black 1936), soil microbial biomass carbon by chloroform-fumigation incubation method (Jenkinson and Powlson, 1976; Jenkinson and Ladd, 1981), soil microbial biomass nitrogen by chloroform-fumigation extraction method (Brookes *et al,* 1985),soil microbial biomass phosphorus bychloro form-fumigation incubation method (Brookes *et al.,* 1982; Srivastava and Singh, 1988b),water soluble carbon by acid extraction method (Meloon and Sommers, 1996), water soluble carbohydrate by hydrolytic extraction with H_2S0_4 (Chebire and Mundie, 1966) and soil dehydrogenase activity by anthrone extraction method (Casida *et al,* 1964)

RESULTS AND DISCUSSION

Groundnut Yield

The pod and haulm yields of groundnut were significantly influenced by various treatments in 12 yearspan. Significantly the highest pod yield (1001 kg ha^{-1}) was recorded under application of 50 % NPK of RD + FYM @ 10 t ha^{-1} to groundnut and 100 % NPK to wheat (T_8) as compared to rest of the treatments. Significantly higher haulm yield (2614 kg ha^{-1}) was recorded under application of 50 % NPK of RD + FYM @ 10 t ha^{-1} to groundnut and 100 % NPK to wheat (T_8) which was statistically at par with T_9. The pod and haulm yield of groundnut were not influenced significantly by various treatments of experiment in 1st year.The combined application of organic and inorganic fertilizers in continuous manner, might have sustained the crop yield.

Wheat Yield

The grain and straw yields of wheat were significantly affected by various fertilization treatments of LTFE in 12 years span. Significantly the highest grain and straw yield (3137 and 4055 kg ha^{-1}) of wheat were obtained under treatment of 50 % NPK of RD in groundnut-wheat sequence + FYM @ 10 t ha^{-1} in groundnut and 100 % NPK to wheat (T_8) as compared to rest of the treatments. Whereas, significantly the highest grain and straw yield (1898 and 2766 kg ha^{-1}) were recorded under T_2 (100 % N P K of RD) in first year result. The combined application of organic and inorganic fertilizers in continuous manner again sustained the crop yield of wheat.

Table 1. Influence of different treatments on Groundnut and wheat yield in 1st and 12th year of LTFE

Treatment	Groundnut yield (kg ha^{-1})				Wheat yield (kg ha^{-1})			
	Pod yield		Haulm Yield		Grain yield		Straw Yield	
	1st Year	12 Year	1st Year	12 Year	1st Year	12 Year	1st Year	12 Year
T_1	962	836	2104	2233	1589	2079	2696	2675
T_2	984	906	2272	2395	1908	2580	3090	3330
T_3	916	946	2366	2532	1878	2692	2847	3447
T_4	1048	917	2158	2365	1806	2512	2650	3224
T_5	929	894	2088	2282	1856	2560	2819	3253
T_6	1101	787	2343	2382	1718	2448	2696	3067
T_7	927	749	2048	2104	1111	1515	1921	2052
T_8	916	1001	2292	2614	1898	3137	2766	4055
T_9	875	915	2154	2458	1289	2824	2141	3356
T_{10}	963	882	2247	2364	1419	2435	2581	3127
T_{11}	1017	879	2272	2421	1608	2555	2963	3289
T_{12}	968	727	2062	2059	1309	1781	2072	2202
S.Em.±	74	23	83	68.93	107	69	155	86
C.D. at 5 %	NS	65	NS	194	309	191	448	240
C.V. %	15.3	12.1	9.1	12.0	13.2	10.1	11.9	10.8
Mean	968	870	2201	2351	1616	2079	2696	2675

Table 2. Influence of different treatments onstatus of organic carbon in 1st and 12th year of LTFE soils in groundnut-wheat sequence

Treatments	Organic Carbon(g kg^{-1})	
	1st year	12th year
T_1	6.53	7.13
T_2	6.00	7.55
T_3	6.30	7.20
T_4	6.00	7.25
T_5	6.23	7.30
T_6	5.40	7.53
T_7	5.18	6.48
T_8	6.15	8.40
T_9	6.45	8.83
T_{10}	6.08	7.03
T_{11}	5.78	7.33
T_{12}	6.15	6.90
S.Em.±	6.02	7.41
C.D. at 5 %	0.56	0.24
C.V. %	NS	0.69

Soil organic carbon status

The soil organic carbon pool comprises of active, intermediate/slow and passive pools, which act as highly sensitive indicators of soil quality. The active pools generally contribute about 10-20% towards total SOM, whereas the stable or passive pools have 50-90% contribution towards total SOM (Brady and Weil 2002). Results presented in table 2 indicated that significantly the highest organic carbon of soil was observed under treatment receiving FYM @ 25 t ha^{-1} (T_9) in 1st as well as 12th year and was at par with T_8. Significantly the highest organic carbon (8.40& 6.15 g kg^{-1}) was observed under treatment T_9 in 12th and 1st year respectively. Status of organic carbon increased to the tune of 36.51% with application of FYM @10 t ha^{-1} during 12 year span.

Reason attributed is the direct incorporation of organic matter, better root growth and more plant residues addition after harvest of crops. These findings are in agreement with the observation of Kumar and Yadav (2003) and Varalakshmi *et al.,* (2005). Katyal *et al*. (2003) studying the soil fertility status also found application of FYM to be highly essential for maintenance of organic carbon, reducing the pH and increase CEC of soil. Such improvements in chemical properties have also been observed in long term fertilizer experiments.

Active pools of soil organic carbon

Soil microbial biomass carbon

The soil microbial biomass acts as the transformation agent of the organic matter in the soil. As such, the biomass is both a source and sink of the carbon, nitrogen and phosphorus contained in the organic matter. It is the centre of majority of biological activity in soil and therefore, the knowledge of the microbial biomass carbon is essential. The soil microbial biomass carbon content of soils of different treatments under the LTFE are presented in Table 3. Significantly higher SMBC (316.5 and 243 ppm) was observed under treatment T_8 (50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t ha^{-1} to G'nut and 100 % N P K to Wheat) which was at par with T_9 (FYM @25 t ha^{-1}) in 12th year and 1st year respectively. The addition of FYM alone and FYM in combination with in organics almost doubled the biomass compared to that on soils treated with NPK alone in 1st and 12th years. SMBC increased to the tune of 30.24 % in 12 year span due to application of FYM with inorganics. Similar results were also found by Verma and Mathur(2007). The supply of additional mineralizable and readily hydrolysable C due to organic manure application resulted in higher microbial activity and higher SMBC.

Table 3. Influence of different treatments on status of active pools of organic carbon in 1st and 12th year of LTFE soils in groundnut-wheat sequence

Treatments	SMBC (ppm)		SMBN (ppm)		SMBP (ppm)	
	1st Year	12th Year	1st Year	12th Year	1st Year	12th Year
T_1	87.7	134.5	6.70	14.85	12.5	9.4
T_2	104.8	150.5	6.96	13.18	11.3	8.7
T_3	101.0	294.5	7.04	13.70	14.4	7.1
T_4	100.8	270.5	7.88	13.83	12.9	9.9
T_5	232.5	272.5	8.00	14.48	10.1	8.0
T_6	184.3	247.5	6.95	14.88	11.7	6.3
T_7	180.5	235.5	8.18	11.68	14.3	8.9
T_8	243.0	316.5	10.18	18.90	16.8	9.9
T_9	222.3	310.5	8.85	17.63	15.0	8.9
T_{10}	196.3	235.5	7.08	13.68	14.0	7.0
T_{11}	124.3	170.5	7.88	9.83	14.2	4.9
T_{12}	86.5	123.5	6.40	9.90	8.5	4.2
S.Em.±	7.0	8.3	0.40	0.93	0.5	0.4
C.D. at 5 %	20.2	23.9	1.10	2.6	1.5	1.4
C.V. %	9.0	7.2	10.3	13.4	8.0	12.7

Soil microbial biomass nitrogen

The soil microbial biomass nitrogen content of soils of different treatments under the LTFE is presented in Table 3. Significantly higher SMBN (18.90 and 10.18 ppm) was observed under treatment T_8(50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t ha^{-1} to G'nut and 100 % N P K to Wheat.) However, it was at par with treatment T_9 (FYM @25 t ha^{-1}) in 12th year and 1st year respectively. The SMBN increased to the tune of 85.65 % in 12 year spandue to application of FYM with inorganic. SMBN varied from 6.70 ppm (control) to 10.18 ppm (T_8) in 1st year and 9.83 ppm (control) to 18.90 ppm (T_8) in 12th year. Application of FYM in combination with inorganic fertilizers resulted in significantly higher soil microbial biomass nitrogen (SMB-N) content as compared to the rest of the treatments. But these two treatments were at par with each other. High soil organic carbon content, more root proliferation and additional supply of N by FYM to microorganisms might be responsible for increasing the level of SMB-N. Farmyard manure is not only rich in C but also in N and other macro- and micronutrients. But the availability of nutrients to the crop from FYM is generally lower than N from inorganic fertilizer because of the slow release of organically bound N and volatilization of NH_3 from the manure, especially in calcareous soils (Beauchamp 1983). Therefore, a combined application of FYM and fertilizer in the present study apparently provided supply of nutrients in balanced proportion which was reflected in terms of increased amount of microbial biomass N.

Soil microbial biomass phosphorus

Soil Microbial biomass phosphorus content of soils of different treatments under the LTFE is presented in Table 3. Significantly the highest SMBP (16.8 & 9.9 ppm) were observed under treatment T_8(50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t ha^{-1} to G'nut and 100 % N P K to Wheat.) A significant increase in the microbial phosphorus was observed in all the treatments over control. Continuous application of chemical fertilizers either alone or incombination with FYM increased the soil microbial biomass phosphorus (SMB-P) content as compared to unfertilized plots. The SMBP decreased in all the treatments in 12 year span. The low SMB-P content in control plot could be due to no addition of any external input into the soil over the years and also the poor crop productivity. Low content of SMB-P in 100% N alone was observed. Reason attributed is the reduction/death of microbial cells due to absence of any phosphate substrate. The addition of higher levels of phosphorus through external sources might have influenced the metabolism of microorganisms, which are responsible for higher levels of SMB-P.Similar elevation in SMB-P with the application of super-optimal dose of NPK was observed by Bolton *et al*., (1985); rise in content of SMB-P was also reported by Santhy *et al*., (2004).

Water soluble carbon and carbohydrates

Water soluble organic carbon is considered as the most labile and mobile form of SOC and an immediate organic substrate for microorganisms and the water soluble carbohydrates (WS-CHO) are the most readily available source of energy for microorganisms and contribute to soil quality through their role in the formation and stabilization of soil structure. Water soluble carbon and water soluble carbohydrates content of soils of different treatments under the LTFE is presented in Table 4. Significantly higher water soluble carbon(44.5 & 51.8 ppm) was observed in the treatments receiving treatment T_8

Table 4. Influence of different treatments onStatus of organic carbon and active pools in 1st and 12th year of LTFE soils in groundnut-wheat sequence

Treatments	WSC (ppm)		WS-CHO (ppm)		DHA(µg TPF^{-1} 24 hr^{-1} g^{-1} soil)	
	1st year	12th Year	1st Year	12th Year	1st Year	12th Year
T_1	24.0	31.5	36.5	46.5	36.5	26.5
T_2	30.0	37.5	37.5	46.0	42.5	32.5
T_3	38.0	46.3	38.5	42.8	30.0	30.5
T_4	34.8	47.8	31.5	40.0	46.5	31.5
T_5	29.5	38.5	41.5	48.3	33.5	22.5
T_6	34.5	41.3	40.5	48.5	38.3	33.5
T_7	36.5	44.0	33.5	43.0	46.5	36.5
T_8	44.5	51.8	46.5	55.0	52.5	42.5
T_9	40.5	50.8	42.5	51.0	49.5	35.5
T_{10}	21.5	30.5	27.5	36.0	31.5	21.5
T_{11}	28.5	40.0	41.0	47.5	40.5	28.5
T_{12}	20.5	32.5	26.5	35.0	29.5	19.5
S.Em.±	31.9	41.0	36.9	44.9	39.7	30.0
C.D. at 5 %	1.3	1.6	1.3	2.3	2.3	1.5
C.V. %	3.7	4.8	3.9	6.7	6.6	4.4

(50 % N P K of recommended doses in G'nut - Wheat sequence + FYM @ 10 t ha^{-1} to G'nut and 100 % N P K to Wheat.) followed by treatment T_9 (FYM @ 25 t ha^{-1}) in 1st & 12th year, respectively. The water soluble carbon increased to the tune of 16.40 % in 12 year span due to 50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t ha^{-1} to G'nut and 100 % N P K to Wheat. This built-up was after decades as a result of large amount of clay particles enriched with water soluble carbon through addition of FYM and chemical fertilizers (Liang *et al.,* 1995). Thus balance fertilization favoured enrichment of water soluble carbon.

Significantly higher water soluble carbohydrate (WS-CHO) (46.5 and 55.0 ppm) was observed under treatment T_8 (50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t ha^{-1} to G'nut and 100 % N P K to Wheat.) However, it was at par with treatment T_9 (FYM @ 25 t ha^{-1}) in 1st & 12th year, respectively. The water soluble carbohydrate increased up to 18.27 % in 12 year span due to application of FYM along with inorganics. The water soluble carbohydrates serves as source and sink for mineral nutrients and organic substrates in a short-term and as a catalyst for conversion of plant nutrients from over a longer period and there four influence crop productivity and nutrient cycling (Geeta Kumari *et al*., 2011).

Dehydrogenase Activity

All biological reactions in soil are catalysed by enzymes. Soil enzyme activities are believed to indicate the extent of specific processes in soil and in some cases act as indicators of soil fertility. The activity of dehydrogenase enzyme was strongly affected by long-term fertilizer use. The dehydrogenase activity of soils of different treatments under the LTFE are presented in Table 3. Significantly higher Dehydrogenase activity (52.5 & 42.5 ìg TPF^{-1} 24 hr^{-1} g^{-1} soil) was recorded under treatment T_8 (50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t ha^{-1} G'nut and 100 % N P K to Wheat) in 1st and 12th year, respectively. Application of N fertilizers half as well as full doze although affect the activity because of Dehydrogenase activity is strongly influenced by the presence of nitrate, which serves as an alternative electron acceptor resulting in low *Dehydrogenase* activity (Sneh *et al.,* 1998).

CONCLUSION

Beneficial and significant effect of FYM along with in organics was found on status of organic carbon and its different pools. Significant increased in organic carbon status and different pools with 12 years span with application of FYM alone or combined with inorganics**.**

REFERENCES

1. Beauchamp, C. Response of corn to nitrogen inpre-plant and side-dress applications of liquid dairy cattle manure. *Can. J. Soil Sci.*, 1983; **63:** 376-386.
2. Bolton, H. Jr., Elliott, L.F., Papendick, R.I. and Bezdieek, D.F. Soil microbial biomass and selected soilenzyme activities: Effect of fertilization and cropping practices. *Soil Bio. Biochem*. 1985; **17:** 297-302.
3. Brookes, P. C, Landman; A., Pruden, G. and Jenkinson, D. S. Chloroform fumigation and release of soil a rapid direct extraction method to measure microbial biomass N in soil. *Soil Bio. Biochem.* 1985; **17:** 837-842.
4. Brookes, P. C, Powlson, D**.** S. and Jenkinson, D. S. Measurement of microbial biomass phosphorus in soils. *Soil Bio. Biochem.* 1982. **14:** 319-321.
5. Casida, L. E., Jr. Klein, D. A. and Santoro, R. Soil dehydrogenase activity. *Soil Science.* 1964; **98:** 371-378.
6. Chebhire and Mundie. Hydralytic extraction of carbohydrates from soil by H_2S0_4. *Soil Sci.* **17 (2)**: compounds in soils. *Pochvovedeme.* 1966; **12:** 1430-1439.
7. FAO. Sustainable development and natural resource management. Food and Agriculture Organization of the United Nations, Rome, *FAO Agriculture series No*. 1989; **22: (3)** pp. 84-90.
8. Feller and Beare. Physical control of soil organic matter dynamics in the tropics. *Geoderma* 1997; **79:** 69-116.
9. Geeta Kumari, Mishra, B. Kumar, R., Agarwal, B. K. and Sing, B. P. Long term effect of manure, fertilizer and lime application on active and passive pools of soil organic carbon under maize-wheat cropping system in an alfisols. *J. Ind. Soc. Soil Sci.* 2011; **59:3**, pp 245-250.
10. Jenkinson, D. S. and Ladd, J. N. Microbial biomass in soil. Measurement and turnover In Soil Biochemistry (E. A. Paul and J.N. Ladd, Eds), 1981; pp 415-471. Dekker, New York.
11. Jenkinson, D. S. and Powlson, D. S.. The effects

of biocidal treatments on metabolism in soil. A method for measuring soil biomass. *Soil Bio. Biochem.* 1976; **8:** 189-202.

12. Katyal, J. C. Organic matter maintaince, main stay of soil quality. *J. Ind. Soc. Soil Sci.* 2000; **48:** 704-716.
13. Katyal, V., Gangwar, K.S. and Gangwar, B. Long-term effect of fertilizer use on yield sustainability and soil fertility in rice-wheat system in sub-tropical India. *Fertil. News* 2003; **48:**43 - 46.
14. Kumar, A., and Yadav, D. S. Long term nutrient management on for sustainability in rice wheat cropping system. *Fertil. New.* 2003; **48**:27-34.
15. Liang, B. C; Gregorich, E. D. and Schnitzer, M. Mineral nitrogen accumulation in soils as affected by watersoluble organic carbon extracted from composted dairy manure. *Commim. Soil Sci. Plant Analys.* 1995; **26** (15-16): 2711-2723
16. Mahajan, A., & Sharma, R. Integrated nutrient management (INM) system- Concept, need and future strategy. *Agro. News.* 2005; **4** (3) 29-32.
17. Mahajan, A., Choudhary, A.K., & Bhagat, R.M. Integrated plant nutrient management (IPNM) system for sustainability in cereal based cropping system. *Indian Farmer's Digest*. 2002; **35:** (7) 29-32.
18. Meloon,S .J. and Sommcrs, R. S. Acid Extraction Method (Water Soluble Carbon) in Soil. *Soil Bio. and Biochem.* 1996; **35:**511-513.
19. Santhy, P., Vijila, K., Selvi, D. and Dhakshinamoorthy, M. Studies on soil microbial biomass P, labile P and phosphate activity under continuous intensive cultivation in an Inceptisol. *Ann. Agri. Res.* 2004; **25:** 38-42.
20. Sneh, G; Chander, K.; Mundra, M. C. and Kapoor, K. K. Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. *Bio. Fert. Soils.* 1998; **27:** 196-200.
21. Srivastava, S. C. and Singh, J. S. Microbial C, N and P in dry tropical forest soils: Effect of alternate land uses and nutrient flux. *Soil Bio. Biochem*i. 1988b; **23:**2 117-124.
22. Varlakashmi, L. R. Sriniwasamurthy, C. A. and Bhaskar, S. Effect of integrated use of organic manures and inorganic fertilizers on organic carbon, available N, P and K in sustaining productivity of groundnut- finger millet cropping system, *J. Ind. Soc. Soil Sci.*2005; **53** : 315-318.
23. Verma G. and Mathur, A.K. Effect of continuous application of organic and inorganic fertilizers on micronutrient status in maize wheat system on Typic Ustochrept. *Asian J. Soil Sci.* 2007; **2:**146-149.
24. Walkley, A. and Black, C. A. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.* 1936; **37:** 29-38.