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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON DEHYDROGENASE ACTIVITY, SOIL ORGANIC CARBON AND SOIL MOISTURE VARIABILITY IN A MANGO ORCHARD ECOSYSTEM

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ABSTRACT

The organic carbon content in the soils of mango orchards in subtropical region of Uttar Pradesh, is very low affecting the soil quality and nutrient release pattern. The microbial and enzyme activities of the soil are closely related to the organic matter content and influenced by hydrothermal regimes of the soil. Keeping this in view, effect of different organic and inorganic substrates was studied on dehydrogenase activity, soil organic carbon and moisture content in mango orchard soil. The soil samples across three different depths with respect to their dehydrogenase activity indicated spatial variation across soil depths and treatments. The univariate analysis showed higher variability of dehydrogenase activity in the soil surface layer as compared to the deeper depths. The highest dehydrogenase activity was observed as 2.09, 1.58 and 1.30 µg TPF g^{-1} hr^{-1} and the lowest as 0.92, 0.50 and 0.21 µg TPF g^{-1} hr^{-1} in 0-10, 10-20 and 20-30 cm depth, respectively. The results recognized that NPK application had a major role in dehydrogenase activity. Frequency distribution reveled that even after a short-term use of organic and inorganic amendments, improvement of SOC content was not above 0.50%. Higher moisture content was observed from the treatments where organic mulching and biofertilizers were added when compared with control. The results thus indicated that mango orchard soils of low fertility regions of semi-arid areas should be amended with organic substrates to enhance moisture retention, organic carbon build up and microbial activity.

Key words: Mango orchard, Integrated nutrient management, Dehydrogenase activity, Moisture retention, SOC.

INTRODUCTION

Mango orchard soils of Malihabad belt of Uttar Pradesh are poor in soil organic matter and essential nutrients (Singha *et al*., 2012). Restoration of orchard soil is important and essential from view point of sustainability and orchard productivity (Tejada *et al*., 2006). Soil rejuvenation with organic substrates is an important orchard groundfloor management strategy to improve the health status of soil (Arancon *et al*., 2006). Albiach *et al*. (2000) observed that under conventional horticultural cropping, deterioration of soil physical, chemical and biological properties were related to various activities of continuous soil removal, tillage and intensive use of pesticides and fertilizers. Although mineral fertilization provides readily available nutrients for plant growth, it does not contribute to improve soil physical condition. Organic matter inputs through organic amendments, in addition to supplying nutrients, stimulate microbial diversity and activity and improved soil aggregation, which had positive effects on soil water content, temperature, aeration and mechanical impedance (Ferreras *et al*., 2006). Biological and biochemical properties of the soil have often been proposed as early and sensitive indicators of soil ecological stress or other environmental changes (Marinari *et. al*., 2006). Since dehydrogenase activity is only present in viable cells, it is thought to reflect the total range of oxidative activity of soil microflora and consequently may be considered a good indicator of microbial activity (Wlodarczyk, 2000). Generally, the enzyme activities in the soil are closely related to the organic matter content and strongly influenced by the hydrothermal regimes.

Furthermore, there have been many reports that organic fertilizers can increase soil microbiological activity (Bulluck *et al*., 2002) and many enzymatic activities have been reported to be correlated with total organic C, soil moisture, temperature and organic sources (Bell *et al*., 2008). The increase of dehydrogenase activity in organically treated soil may be attributed to intense activity of the soil microorganisms in degrading easily metabolizable compounds, with subsequent decreases in activity, attributed to the decreases in quantities of easily biodegradable substances. Since, enzymatic activity differs both at temporal and spatial scale within a filed level, it is important to understand the dynamics of its activity along with their correlation with other soil factors; of course, short-term or long-term orchard soil management had impact on soil processes (Singha *et al*., 2011; Hazarika *et al*., 2011; Singh *et al*., 2012; Adak *et al*., 2012; Kumar *et al*., 2012). However, substrate addition and its quality and quantity sometimes determine the rate and qualitative changes in soil processes under short-term soil management. Since, mango orchard soils of Indo-Gangetic belt in India are very poor in organic matter owing to high temperature and intense microbial activities, addition of different kinds of organic substrates as organic sources of nutrition through FYM, composting, vermicomposting, organic mulching, bioinoculants, etc. may be a viable option for maintaining soil health and orchard sustainability. Keeping this in view, the present study was conducted to assess the changes in dehydrogenase activity, soil organic carbon and soil moisture content under field conditions.

MATERIALS AND METHODS

A field experiment was conducted in experimental farm of Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow (26.54^{0}N Latitude, 80.45^{0}E Longitude and 127 m above mean sea level), Uttar Pradesh, India located in the semiarid region with dry hot summer and cold winters having a mean annual rainfall of 1000 mm of which 80 percent received during July-September. The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium with well drained sandy loam texture. Taxonomically, the soil is mixed hyperthermic *Typic Ustocrepts* with pH and electrical conductivity ranging from 6.64 to 8.18 (Mean 7.48) and 0.04 to 0.13 dS/m (mean 0.08 dS/m), respectively. Initial soil organic carbon was 0.21%, available N, P and K were recorded as low. The field experiment was continuing since 2007 with treatments consisting of different organic (FYM, vermicompost, mulching) and inorganic (N, P, K) sources of nutrition including bioinoculants (*Azotobacter*, PSM and *Trichoderma harzianum*).The experiment was laid out with mango cv Dashehari which is planted at a spacing of 8 × 8 m in a randomized block design with four replications. The treatments comprised T_1-10 kg FYM + 100, 50, 100 g N, P and K / tree /year of age (control), T_2-10 kg FYM + 100, 50, 100 g N, P and K / tree / year of age + *Azotobacter* + PSM + Organic mulching, T_3-10 kg FYM + 100, 50, 100 g N, P and K / tree / year of age + *Azotobacter* + *Trichoderma harzianum* + Organic mulching, T_4-10 kg FYM + 100, 50, 100 g N, P and K / tree / year of age + PSM + *Trichoderma harzianum* + Organic mulching, T_5- 10 kg FYM + 100 g N and 50 g P / tree / year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching, T_6- 10 kg FYM + 100 g N + 100 g K / tree / year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching, T_7- 10 kg FYM + 50 g P + 100 g K / tree / year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching, T_8- 100, 50,100 g N, P and K / tree / year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching and T_9- 10 kg FYM + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching. FYM, NPK, and bioinoculants were applied during September. Organic mulching consisted of weeds, grasses and leaf litter. Orchard soils were thoroughly ploughed up by tractor twice a year during August-September and December-January to control weeds and pests and pathogen. Three irrigations during fruit development, first at marble size and other two at 20 days interval were given to the crop. The treatments were applied to the tree basin and appropriate intercultural practices were followed. Soil samples were collected from 0-10, 10-20 and 20-30 cm soil depths from the tree basin of all the treatments before application of treatments each year. Samples were air dried at room temperature and passed through a 2 mm sieve and homogenized. Dehydrogenase activity was estimated using 2, 3, 5 triphenyal tetrazolium chloride using 1 g of air-dried soil (<2 mm) and expressed as µg of triphenylformazan (TPF) formed per gram of soil per 24 hours (Casida *et al.* 1964). Soil organic carbon and soil moisture content were determined using wet digestion (Walkley and Black 1934) and gravimetric method respectively. For all parameters, data were analyzed by analysis of variance (ANOVA) procedure for a randomized block design. Comparison of means was performed by the Duncan's multiple range test at 95% level of probability. All statistical analyses were performed using SPSS version 12.0. Histogram was developed using SPSS software and univariate statistical analysis was conducted in MS Excel software.

RESULTS AND DISCUSSION

Dehydrogenase activity (DHA): DHA showed spatial variation across depths and treatments and histographic analysis indicated mean value lying around 1.14 µg TPF g^{-1} hr^{-1} (Fig. 1). Furthermore, it was inferred that highest frequency distribution of >10 % followed in the range of 1.0 to 1.5 µg TPF g^{-1} hr^{-1} while all other values lie below 8% frequency range. Few samples recorded higher dehydrogenate activity in the range of >2.0 µg TPF g^{-1} hr^{-1} and were distributed in <2% frequency range. Univariate analysis showed higher variability of dehydrogenase activity at the surface soil layer as compared to the deeper soil layers (Fig. 2). Across the treatments and the depths, the highest dehydrogenase activity was observed as 2.09, 1.58 and 1.30 µg TPF g^{-1} hr^{-1} and lowest as 0.92, 0.50 and 0.21 µg TPF g^{-1} hr^{-1} in 0-10, 10-20 and 20-30 cm depth, respectively. Significantly higher dehydrogenase activity was recorded in upper surface soil layer of 0-10 cm as compared to deeper depths of 10-20 and 20-30 cm across all the treatments. This may due to the fact that soil microbial activity was generally higher at the surface soil owing to higher organic matter than in deeper depths. It was observed from the pooled data (Table 1), that T_4 recorded the highest value of 1.63 µg TPF g^{-1} hr^{-1} and T_1 as the lowest (0.82 µg TPF g^{-1} hr^{-1}). Significantly, lower average dehydrogenase activity was recorded in T_7 where mineral nitrogen was not applied than the treatment where NPK, only NP or NK were applied. Absence of N in T_7 and T_9 reduced dehydrogenase activity in soil as compared to the treatments with its presence. The results suggested that NPK application had a major role in dehydrogenase activity. Without N application, the PK treatment resulted in a significant decrease of the dehydrogenase activity as compared to the NPK treatment. Similar results repeated in long-term fertilizer experiment found by Chu *et al.* (2007). Maximum dehydrogenase activity was achieved where a combination of NPK, PSM, *Trichoderma harzianum* and organic mulch was applied. In the treatment T_8 where FYM was not applied but organic mulching was included; significantly higher dehydrogenase activity was found in upper layer of soil (0-10 cm) as compared to lower depth (20-30 cm). This may be because of the fact that residue decomposition from the organic litter may have added synergizing effect on microbial activity at the upper layer. Similar results were observed by Floch *et al*. (2009). The increase may be due either to the addition of microorganisms and enzymes in the amendment or indirectly by the addition of available organic substrates that promote the growth of indigenous microorganisms. T_9 treatment was found to be statistically *at par* with T_1. This may be due to application of bioinoculants that have increased dehydrogenase activity and compensated the effect of NPK. Actually, soil dehydrogenase activity is a function of soil processes as it is directly or indirectly influenced by the soil management systems (Kaur *et al.*, 2005; Chu *et al.*, 2007; Guo *et al.*, 2011; Akmal *et al*., 2012). Dehydrogenase activity was also impacted by the changes in soil organic carbon (Aon *et al.*, 2001) as higher level of organic carbon stimulated microbial activity and therefore, enzyme synthesis.

Soil organic carbon (SOC): The univariate analysis indicated spatial variability of soil organic carbon content, higher at the surface layer as compared to the deeper depths. This high SOC content at the surface layer may be due to substrate decomposition and higher microbial activity. The histographic presentation inferred that majority of the soil samples had SOC content below 0.40%. Moreover, it was revealed from the frequency distribution of SOC content that the mango orchard soil had SOC content with highest frequency of >25 per cent in the range of 0.20 to 0.30%, while others followed <10%. 0.50% SOC content was observed in only few soil samples having frequency distribution <2 per cent. Thus, from the frequency distribution of the 81 soil samples it was revealed that even after a short-term use of organic and inorganic amendments, SOC content did not exeed 0.50% (Fig. 3). Therefore, the present study required to be continued for next few years as an index of long-term soil management strategy to improve the SOC content for at least to a medium value of 0.75% and also to confirm positive effect of long-term effect of organic fertilization in order to maintain or improve soil quality in rainfed semiarid orchard ecosystem of subtropical region. Spatial distribution showed that values of soil organic carbon content followed a decreasing trend with the increasing soil depth. Higher microbial activity and organic mulching decomposition may be the reason for higher content at surface soil layer.

Soil Moisture: Moisture content of soil showed a gradual improvement with increasing soil depth. The ranges varied from 9.95 to 18.70 percent. Higher moisture content was recorded in the treatments where organic mulching was applied as compared to control. The organic mulching on the soil surface might have contributed to the energy exchange processes that determine the rate of substrate decomposition and enzymatic activity (Lal, 1995; Uwah and Iwo, 2011). The reason for higher moisture content in the lower horizons might be due to water stored in soil pores with minimum evaporation loss as in treatment T_1, lower moisture retention at deeper depths was observed which may be due to absence of mulching. Frequency distribution indicated that average moisture content lies in the range of 12 to 17 % with a frequency of >8% (Fig. 4). Variability of soil moisture content was higher in the lower depths as compared to surface soil layer as indicated by the univariate statistics. Ploughing of surface soil may have resulted in homogenized condition. Since soil moisture variability is a deterministic factor for assessing change in hydrological processes over wide spatial and temporal scale (Zhang *et al*., 2011), understanding its dynamics under organically treated soils, inherently poor in soil organic carbon and low water holding capacity, is of immense importance from view point of improving water retention capacity of orchard soils (Adak *et al*., 2011).

Table 1. Dehydrogenase activity, soil organic carbon and moisture content in orchard soil

	Treatment	Soil depth (cm)			Mean
		0-10	10-20	20-30	
Dehydrogenase activity (µg TPF g^{-1} hr^{-1})	T_1	1.01 ± 0.38	1.09 ± 0.42	0.37 ± 0.09	0.82 ± 0.40
	T_2	1.85 ± 0.75	1.53 ± 0.30	0.96 ± 0.86	1.45 ± 0.45
	T_3	1.34 ± 0.23	1.23 ± 0.14	0.98 ± 0.28	1.18 ± 0.19
	T_4	2.01 ± 0.80	1.58 ± 0.12	1.30 ± 0.21	1.63 ± 0.36
	T_5	1.82 ± 0.45	1.12 ± 0.23	1.09 ± 0.23	1.34 ± 0.41
	T_6	1.26 ± 0.24	1.31 ± 0.40	0.84 ± 0.33	1.14 ± 0.25
	T_7	0.92 ± 0.55	0.50 ± 0.31	0.48 ± 0.31	0.63 ± 0.25
	T_8	2.09 ± 0.23	1.10 ± 0.35	0.21 ± 0.07	1.13 ± 0.94
	T_9	1.73 ± 0.39	0.74 ± 0.28	0.49 ± 0.12	0.99 ± 0.66
	CD (p<0.05)	0.76	0.50	0.36	0.53
Soil organic carbon (%)	T_1	0.24 ± 0.04	0.19 ± 0.08	0.18 ± 0.01	0.21 ± 0.03
	T_2	0.24 ± 0.04	0.22 ± 0.03	0.19 ± 0.07	0.22 ± 0.03
	T_3	0.39 ± 0.01	0.27 ± 0.03	0.23 ± 0.05	0.29 ± 0.08
	T_4	0.37 ± 0.03	0.32 ± 0.05	0.21 ± 0.03	0.30 ± 0.08
	T_5	0.35 ± 0.03	0.33 ± 0.03	0.22 ± 0.04	0.30 ± 0.07
	T_6	0.27 ± 0.04	0.21 ± 0.05	0.19 ± 0.04	0.22 ± 0.04
	T_7	0.26 ± 0.03	0.22 ± 0.06	0.19 ± 0.05	0.22 ± 0.04
	T_8	0.24 ± 0.02	0.20 ± 0.06	0.18 ± 0.04	0.21 ± 0.03
	T_9	0.25 ± 0.02	0.20 ± 0.05	0.19 ± 0.02	0.21 ± 0.03
	CD (p<0.05)	0.12	0.09	0.06	0.05
Soil moisture content (%)	T_1	10.43 ± 1.07	9.60 ± 2.97	7.30 ± 2.36	9.11 ± 1.62
	T_2	11.30 ± 1.44	13.30 ± 1.62	14.25 ± 2.85	12.95 ± 1.51
	T_3	13.63 ± 2.49	14.07 ± 1.25	16.98 ± 2.15	14.89 ± 1.82
	T_4	20.19 ± 0.99	21.10 ± 3.91	18.45 ± 5.22	19.91 ± 1.35
	T_5	17.70 ± 3.47	18.43 ± 1.82	18.70 ± 0.92	18.28 ± 0.52
	T_6	14.75 ± 1.48	15.45 ± 1.05	15.85 ± 2.96	15.35 ± 0.56
	T_7	14.35 ± 2.80	15.85 ± 3.44	17.77 ± 2.88	15.99 ± 1.71
	T_8	9.95 ± 1.81	12.90 ± 3.51	13.10 ± 2.05	11.98 ± 1.76
	T_9	14.35 ± 2.25	15.50 ± 2.27	17.32 ± 2.80	15.72 ± 1.50
	CD (p<0.05)	3.38	4.52	5.04	1.85

Table 2. Univariate analysis of dehydrogenase activity, soil organic carbon and moisture content in orchard soil

Dehydrogenase activity							
Treatment	Mean	SD	Variance	CV%	SE	Skewness	Range
T1	0.82	0.45	0.20	54.40	0.022	0.17	0.29 - 1.43
T2	1.45	0.71	0.50	49.07	0.056	-0.24	0.25 - 2.56
T3	1.18	0.25	0.06	21.38	0.007	-0.67	0.68 - 1.55
T4	1.63	0.52	0.27	32.08	0.030	1.34	1.12 - 2.74
T5	1.34	0.45	0.20	33.68	0.023	1.01	0.86 - 2.18
T6	1.14	0.36	0.13	31.60	0.014	-0.32	0.52 - 1.62
T7	0.63	0.41	0.17	65.08	0.019	0.75	0.21 - 1.39
T8	1.13	0.84	0.71	74.32	0.079	0.12	0.13 - 2.23
T9	0.99	0.62	0.39	62.90	0.043	0.91	0.37 - 2.16
Soil organic carbon (%)							
Treatment	Mean	SD	Variance	CV%	SE	Skewness	Range
T1	0.21	0.05	0.003	25.72	0.0003	0.28	0.12 – 0.29
T2	0.22	0.05	0.002	22.26	0.0003	-1.05	0.11 - 0.29
T3	0.29	0.09	0.009	31.91	0.0010	1.58	0.19 - 0.51
T4	0.30	0.10	0.010	34.04	0.0011	0.78	0.17 - 0.49
T5	0.30	0.09	0.008	30.37	0.0009	1.30	0.20 - 0.50

Treatment	Mean	SD	Variance	CV%	SE	Skewness	Range
T6	0.22	0.05	0.003	22.72	0.0003	0.02	0.15 - 0.30
T7	0.22	0.05	0.003	23.18	0.0003	-0.33	0.13 - 0.28
T8	0.21	0.04	0.002	21.22	0.0002	-0.60	0.14 - 0.26
T9	0.21	0.04	0.001	17.28	0.0001	0.01	0.16 - 0.26
Soil moisture content (%)							
Treatment	Mean	SD	Variance	CV%	SE	Skewness	Range
T1	9.11	2.42	5.86	26.57	0.651	-0.19	4.70 - 13.00
T2	12.95	2.21	4.90	17.10	0.545	0.45	9.75 - 16.75
T3	14.89	2.36	5.58	15.86	0.620	0.40	11.30 - 19.30
T4	11.98	2.70	7.29	22.53	0.810	-0.09	8.25 - 15.15
T5	18.28	2.06	4.25	11.28	0.473	-0.22	14.60 - 28.45
T6	15.35	1.80	3.25	11.75	0.361	0.84	13.05 - 19.05
T7	19.91	3.50	12.23	17.56	1.359	0.30	16.30 - 25.60
T8	15.99	3.03	9.18	18.95	1.020	-0.03	12.10 - 20.55
T9	15.72	2.49	6.19	15.82	0.688	-0.05	11.85 - 19.75

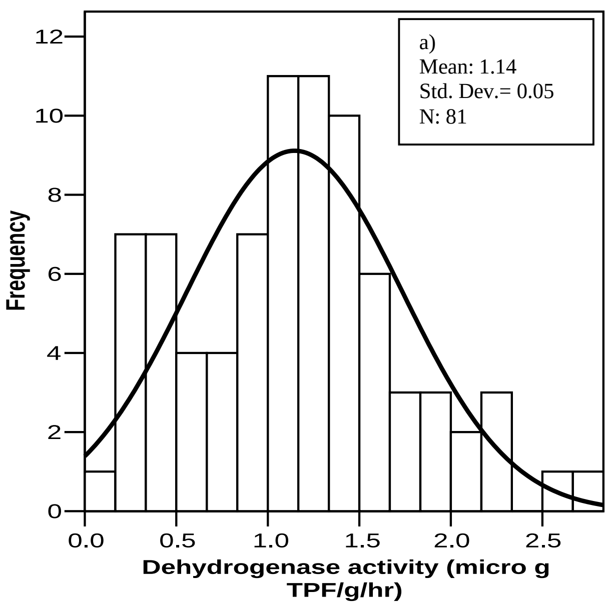

Fig.1. Histogram showing frequency distribution of dehydrogenase activity across depths and treatments

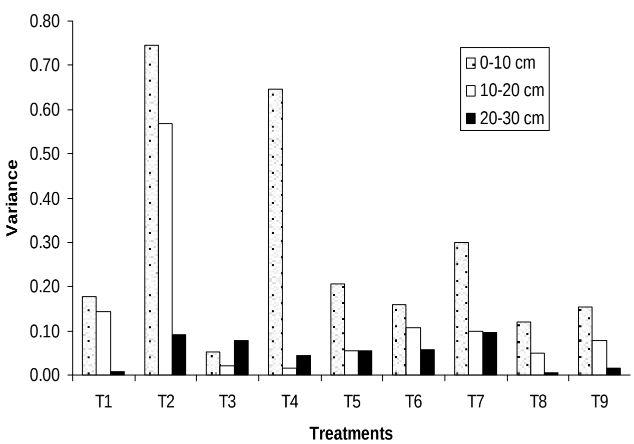

Fig. 2. Variability of dehydrogenase activity across scales

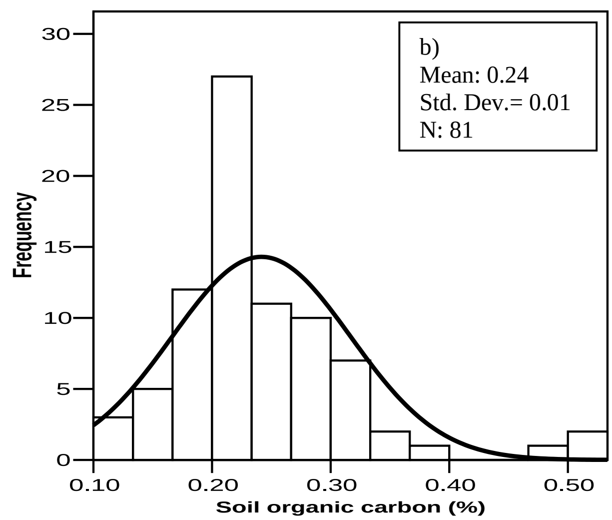

Fig. 3. Histogram showing frequency distribution of soil organic carbon across depths and treatments

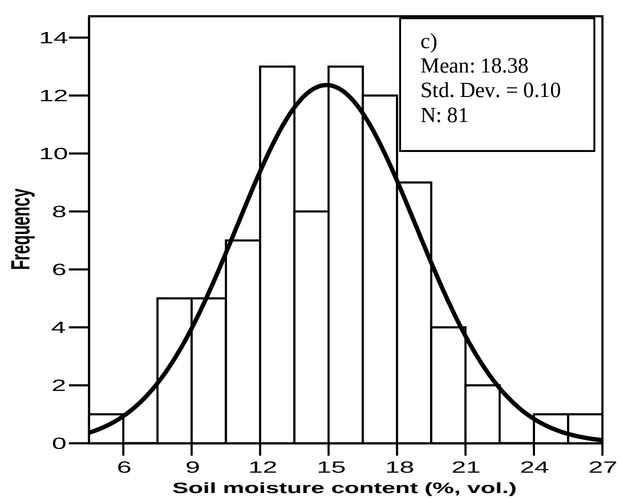

Fig. 4. Histogram showing frequency distribution of soil moisture content

Conclusions: It may be concluded from the study that dehydrogenase activity varied across soil depths and treatments at field level and its higher value and greater variability was found at the surface soil layer. Frequency distribution of soil samples revealed that even after a short-term use of organic and inorganic amendments, improvement of SOC content did not exeed 0.50%. Soil moisture retention was higher in deeper layers of soil which may due to be higher evaporation from surface soil layers.

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