International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:10, No:9, 2016

Influence of Environment-Friendly Organic Wastes on the Properties of Sandy Soil under Growing *Zea mays* L. in Arid Regions

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Abstract**—**Environment-friendly organic wastes of Brewers' spent grain, a byproduct of the brewing process, have recently used as soil amendment to improve soil fertility and plant production. In this work, treatments of 1% (T1) and 2% (T2) of spent grains, 1% (C1) and 2% (C2) of compost and mix of both sources (C1T1) were used and compared to the control for growing *Zea mays* L. on sandy soil under arid Mediterranean climate. Soils were previously incubated at 65% saturation capacity for a month. The most relevant soil physical and chemical parameters were analysed. Water holding capacity and soil organic matter (OM) increased significantly along the treatments with the highest values in T2. Soil pH decreased along the treatments and the lowest pH was in C1T1. Bicarbonate decreased by 69% in C1T1 comparing to control. Total nitrogen (TN) and available P varied significantly among all treatments and T2, C1T1 and C2 treatments increased 25, 17 and 11 folds in TN and 1.2, 0.6 and 0.3 folds in P, respectively related to control. Available K showed the highest values in C1T1. Soil micronutrients increased significantly along all treatments with the highest values in T2. After corn germination, significant variation was observed in the velocity of germination coefficients (VGC) among all treatments in the order of C1T1>T2>T1>C2>C1>control. The highest records of final germination and germination index were in C1T1 and T2. The spent grains may compensate deficiencies of macro and micronutrients in newly reclaimed sandy soils without adverse effects to sustain crop production with a rider that excessive or continuous use need to be circumvented.

Keywords**—**Spent grain, compost, micronutrients, macronutrients, water holding capacity, plant growth.

I. INTRODUCTION

AGRICULTURAL areas may reach 1.2–1.5 billion ha as crop land and 3.5 billion ha as pasture land. Land use may cause regressive dynamics in vegetation cover affecting OM contents, soil nutrients and structural stability, thus reducing soil resistance to erosion [1]. Crop rotation, animal manure and plant residue applications were practiced in traditional agriculture to maintain soil fertility and health. However, to meet projected increase in food demand due to an exponential growth in human population, these traditional methods have been replaced by application of mineral fertilizers. Commercially available mineral fertilizers possess advantages such as high solubility, facilitating the nutrient uptake by plants and better means of storage and handling [2]. However, enormous additions of these chemical fertilizers contribute to soil degradation, damage to the environment and loss of biodiversity. Most importantly, these chemicals have contaminated groundwater in many regions making it unfit for human consumption [3]. The long-term application of OM to soils raises significantly the soil organic carbon pools. The continuous application of compost achieved equilibrium in soil organic carbon pools for 5 years. Soil OM is an important source of nutrients for plant growth that needs to be maintained for agricultural sustainability [4]. The addition of organic material of various origins (e.g. manure, green manures) to soil has been one of the most common practices to improve soil properties [5]. Organic amendments improve soil structure and aggregate stability, as well as moisture retention capacity [6] and consequently increasing soil microbial activity [7]. Organically fertilized soils show significant increase in soil micro and macronutrients, microbial biomass and enzymatic activities compared with those found under inorganically fertilized plots. Combined organic/inorganic fertilization both enhanced C storage in soils and reduced emissions from N fertilizer use [8]. Similar to other microbial processes, nitrification and denitrification rates increase with temperature. The main objective of this work was to use spent grain and compost as soil amendments to improve the main soil physical and chemical characteristics of new reclaimed sandy soils and develop sustainable system might be able to alleviate environmental and economic problems of excess waste and degraded soils.

II. MATERIALS AND METHODS

A. Study Area and Sampling

Sandy soils are collected from the College of Agricultural farm, Damanhour University, El Beheira Governorate, Egypt. Soils are sampled from 0-30 cm depth, then, air-dried and sieved at 2-mm sieve prior to the experiment setup and soil analyses. Sub-samples of air-dried soil were analysed for their soil chemical and physical characteristics (Table I).

B. Experimental setup

Greenhouse pot experiment was carried out during summer

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2014. The sandy soils incubated for a month to decompose the applied organic wastes before growing the *Zea mays* L.

TABLE I
GENERAL SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS

Parameter[a]	Sandy soil
Sand (%)	94.4±0.21
Silt (%)	2.20±0.11
Clay (%)	3.40±0.01
Texture	Sandy
pH	8.00±0.02
Electrical conductivity (EC) (dS/m)	0.70±0.03
TN (%)	0.0043±0.0001
Available phosphorus (P_{AV}) (mg/kg)	8.96±0.23
Available potassium (K_{AV}) (mg/kg)	91.80±0.22
$CaCO_3$ (%)	3.30±0.05
CEC ($Cmol^+$/kg)	4.70±0.31
OM (%)	0.195±0.04
OC (%)	0.113±0.06
TOC (%)	0.003±0.0007
Ca^{2+} (mg/kg)	69.6±1.20
Mg^{2+} (mg/kg)	34.8±0.38
Na^+ (mg/kg)	14.26±0.64
K^+ (mg/kg)	4.68±0.24
CO_3^{2-} (mg/kg)	0.00
HCO_3^- (mg/kg)	135.4±1.25
SO_4^- (mg/kg)	8.64±0.09
Fe^{2+} (mg/kg)	1.69±0.041
Zn^{2+} (mg/kg)	0.74±0.004
Mn^{2+} (mg/kg)	1.03±0.009
Cu^{2+} (mg/kg)	0.21±0.001
B^+ (mg/kg)	0.09±0.0003
Cl^- (mg/kg)	163.6±0.145

C. Amendments (Organic Wastes)

Two types of amendments were used (compost and spent grain). The compost is containing animal wastes and plant residues. The spent grain, a by-product from beer industry, was obtained from Al-Ahram Beverages Company, Abu Hammad, Al-Sharkia Governorate, Egypt. The general characteristics of compost and spent grain were determined and reported in Table II.

TABLE II
AMENDMENTS CHARACTERIZATION

Parameter[a]	Compost	Spent grain
pH	7.2±0.01	4.16±0.3
EC (dS/m)	5.81±0.21	1.45±0.21
OM (%)	33.2±1.23	75±0.57
TN (%)	2.10±0.32	3.12±0.68
TP (%)	1.03±0.52	1.86±0.54
TK (%)	0.57±0.01	1.74±0.63
C:N ratio	9.16±0.35	13.9±0.12
OC (%)	19.25±0.12	43.5±0.94
Fe^{2+} (mg/kg)	960±2.97	1130±3.87
Zn^{2+} (mg/kg)	220±5.34	368±2.34
Mn^{2+} (mg/kg)	100±2.14	210±1.98
Cu^{2+} (mg/kg)	61±1.21	98±1.54

[a] parameters; TP = Total phosphorus; TK = Total potassium; C/N = Carbon/nitrogen ratio; OC = Organic carbon.

D. Germination Experiment

Two different concentrations of amendments were used. The first one was 1% on weight base of either compost or spent grain while the second was 2% of those amendments. Additionally, a mixture of both amendments at 1% of either one was used. The first treatment of compost was referred by C1 while T1 for the first concentration of spent grain. The corresponding symbols for the second concentration were C2 and T2. The mixture concentration was referred by C1T1. Table III summarizes the application rates of amendments. Two controls were used as well for comparison with the suggested concentrations of organic wastes. The controls include zero level of NPK (negative control) and the second 50% of the recommended dose of NPK (positive control). All application rates were well mixed with 8 kg of sandy soil and packed in polyethylene pots on the 2nd of April, 2014. The pots were placed in the open field in a randomized complete block design with four replicates for each treatment. The amended soils were equilibrated at 65% saturation capacity.

TABLE III
AMENDMENT APPLICATIONS (OVEN DRY WEIGHT BASIS)

Treatments[a]	Incubation Experiment	Germination Experiment	Growth experiment
	Application rate (g/kg)		
Control	No amendment applied		NPK*
T1	12.8	12.8	12.8
T2	25.5	25.5	25.5
C1	23.5	23.5	23.5
C2	47.0	47.0	47.0
C1T1	C1+T1	C1+T1	C1+T1

[a] Treatments; control = soil without amendments, T1 = 1% of spent grain, T2 = 2% of spent grain, C1 = 1% of compost, C2 = 2% of compost, C1T1 = mix of 1% of compost and 1% of spent grain.

* 50% of NPK recommended dose.

After the incubation period of 30 days, the sandy soil was sown with 15 corn seeds. All pots were watered with tab water using Romanenko's equation [9]; it is used to maintain adequate moisture for seed germination. The germination experiment lasted for 15 days. The number of germinated seeds was recorded every 24 h. The germination status was evaluated using coefficient of velocity of germination (VGC), final germination percentage (FG), germination index (GI) and the fresh and dry weights. The VGC was calculated as:

$$VGC = \frac{G_1 + G_2 + \cdots + G_n}{1 \times G_1 + 2 \times G_2 + \cdots + n \times G_n} \tag{1}$$

where G is the number of germinated seeds and n is the number of days for germination. The FG was obtained by dividing the final number of germinated seeds in each pot by the total number of sown seeds, multiplied by 100. GI was calculated as:

$$GI = \frac{G_1}{D_1} + \cdots + \frac{G_n}{D_n} \tag{2}$$

where G_1 is the number of germinated seeds at the first day (D_1) and G_n is the number of germinated seed at the final day (D_n). To evaluate the effect of organic sources on plant growth, a representative plant was left in each pot after thinning all other plants. The selected plant was supplied with adequate water using Romanenko's equation [9]. The plants were grown for 45 days then its fresh and dry weights were measured.

E. Soil Analyses

Soil samples from all treatments were air-dried, ground, sieved through a 2-mm sieve and then analyzed for the subsequent analyses. The soil pH was measured in 1:2.5 soil suspension. The electrical conductivity (EC) was determined in 1:1 soil-water extract. Cation exchange capacity (CEC) was determined using 1 M ammonium acetate method. Total carbonate content was determined using calcimeter. Soluble ions were measured in the 1:1 soil water extract. Soluble calcium, magnesium, carbonate, bicarbonate and chloride were measured by titration method. Soluble sodium and potassium were determined by flame photometer according to [10], [11]. TN was determined by Kjeldehl method. Soil organic carbon (OC) was determined by the modified Walkley-Black method [10]. Available K was extracted by 1 N ammonium acetate solution. Total dissolved organic carbon (TOC) was determined using the TOC analyzer (Torch Combustion TOC/TN Analyzer - Teledyne Tekmar, Ohio, USA) at 700 °C [11]. Available zinc, copper, iron and manganese were extracted by diethylenetriaminepentaacetic acid (DTPA) solution. Total phosphorus (TP) was determined by colorimetric measurement after digestion with $HClO_4$–H_2SO_4. Available phosphorus (P_{av}) was extracted with 0.5 N $NaHCO_3$. The Particles-size distribution was determined by the hydrometer. The soil water-characteristic curve was measured for the site soil using pressure plate extractors in a matric potential range of (0-40 m).

F. Plant Growth

Fresh and dry weights recorded at the end of the experiment. The harvested plants were washed using distilled water then oven dried at 65 °C for 24 h. Moisture contents were determined.

G. Statistical Analysis

Statistical analysis was carried out using statistical program statistics 10 of statsoft Inc. 2010. To test the statistical difference among means, variance analysis (ANOVA) was conducted followed by Least Significant Difference (LSD) at a 5% level of significance for mean comparisons. Factor analysis was carried out using the analyzed parameters of all the treatments simultaneously.

III. RESULTS AND DISCUSSION

A. Soil Physical Properties

OM and its proper management are vital in farming to maintain soil productivity. Ratios of WHC of organic treated soil compared to the control were 1.20, 1.50, 1.20, 1.30 and 1.50 for T1, T2, C1, C2 and C1T1 treatment, respectively. Ratios of air-dry water contents of organic treated soil compared to the control were 1.20, 1.52, 1.16, 1.26 and 1.4 for the same order. The organic treated soil at T2 was the highest. The C1 and C2 gave slightly lower ratios than T1 and T2. OM content resulted the key factor increasing water retention capacity. Addition of compost fertilizer and cow dung treated separately increased soil water content [12]. The soil characteristic curves of the studied sandy soil were shown in Fig. 1. These curves are expressed as water content ratios (organic treated soil/control). The ratio increased as the soil matric suction increased. It is obvious that the influence of organic source on soil retaining water was great at high suction (low soil matric potential) in comparison to low suction values. Influences of organic source on the retained water content followed the order of T2>C2>C1T1>C1>T1. The T2 affected positively the soil retained water greater than C2. Accordingly, the soil retained water depends on the amount and type of organic sources. The corresponding ratios of soil water content at soil suction of 4000 cm were 53, 29, 80, 22, 18 and 16 for T2, C2, C1T1, C1 and T1, respectively. These ratios were 5.83, 377, 3.35, 194 and 2.84 at soil water suction of 2000 cm. As OM content increased, the volume of water held at field capacity increased at a much greater rate (slope average = 3.6) than that held at the permanent wilting point (slope average = 0.72) in sandy, silty loam and silty clay loam soils.

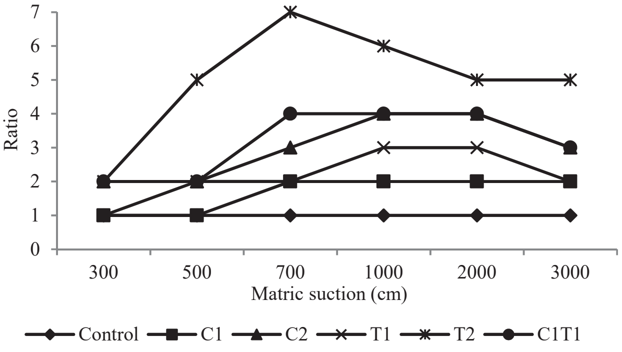

Fig. 1 Ratio of water contents in organic treatment to the control

B. Soil Chemical Properties

EC of organic treated soils increased greatly compared to the control. The mean EC values were 0.78±(e), 1.70(d), 2.20(c), 1.14(b), 1.34(a) and 2.06(a) dS/m for the control, T1, T2, C1, C2 and C1T1 treatments, respectively. Different litters (a-e) indicate significant differences among all treatments ($LSD_{0.05}$=0.169). The increase in EC may be due to the releasing of inherent soluble salts and mineralizing some others during decomposition process of organic sources. The soil EC is mainly due to the presence of K^+, Cl^-, SO_4^{2-} and NO_3^- that generate through organic source mineralization and transformation [13].

The soil acidity (pH) decreased slightly by the incubation of organic components in this sandy soil. The mean values were 8.0(a), 7.82(b), 7.59(d), 7.80(b), 7.50(c) and 7.47(d) for the control, T1, T2, C1, C2 and C1T1 treatments, respectively. Increasing the application level of organic source showed a reasonable decrease in the soil pH compared to the control treatment. Different litters (a-d) indicate significant differences among all treatments ($LSD_{0.05}$=0.073). The C1T1 possessed the lowest pH with respect to others. This reduction is might be due to the increase of carboxyl and phenol groups as a result of decomposing organic residues and the reduction of bicarbonate in soil [14]. Decreases of pH might be due to the presence of phenolic and fatty acids resulted from the decomposition of organic materials that reduces soil pH sharply. Generally, the soil OM is considered as a pH buffering. Application of solid cattle manure moves soil pH towards neutrality in acidic and alkaline soils, thus improving nutrient availability especially for P and micronutrient. Organic source should be regarded not only as a store of nutrients, but also as a beneficial soil conditioner.

Soil OM values were 0.11%(f), 0.91%(d), 1.70%(a), 0.98%(e), 1.97%(b) and 1.66%(c) for the control, T1, T2, C1, C2 and C1T1 treatments, respectively. Different litters (a-f) indicate significant differences among all treatments ($LSD_{0.05}$=0.038). The T2, C1T1 and C2 treatments possessed the greatest values, respectively. Generally, it is obvious that high organic percentages are consistent with the low pH values in the present study. Soil pH showed negatively correlated with soil OM ($pH = –0.294\ OM + 8.054$; $r=–0.978$, $p<0.01$). Addition of organic manure increases OM content which in turn increases the levels of Ca^{2+}, K^+ and Mg^{2+} [15].

The TOC values were 0.06%(f), 0.55%(d), 1.14%(a), 0.52%(e), 0.98%(b) and 0.96%(c) for the control, T1, T2, C1, C2 and C1T1 treatments, respectively. Different litters (a-f) indicate significant differences among all treatments ($LSD_{0.05}$=0.020). The T2 possessed the highest value of TOC while the control showed the lowest value. The trend of TOC was similar to soil OM. The high OM content enhanced the production of soil OC as a result of soil microbial activity during the mineralization process of OM [16]. Generally, the mineralized OC increased as the application rate of spent grain and compost increased.

Dissolved organic carbon (DOC) showed 0.007%(e), 0.021%(c), 0.12%(a), 0.016%(d), 0.082%(b), and 0.093%(b) for the control, T1, T2, C1, C2 and C1T1, respectively. Different litters (a-g) indicate significant differences among all treatments ($LSD_{0.05}$=0.0142). It is obvious that T2, C2 and C1T1 have the greatest DOC values, in consistent with soil OM and TOC values. The high DOC in amended soil could be due to the high microbial activity during mineralization process of organic components. Presence of high amount of organic source enhances the microorganism activity and transformation to produce a dissolved carbon [11].

The HCO_3^- concentrations varied greatly among all treatments. The bicarbonate values were 420.44(a), 179.19(e), 188.49(d), 220.21(c), 258.49(b) and 131.15(f) mg/kg for the control, T1, T2, C1, C2 and C1T1, respectively. The highest value recorded in control soil while, the lowest one detected in C1T1. There were significant differences ($LSD_{0.05}$=6.704) in the concentrations of bicarbonate among the treatment indicated by the letters (a-e). The HCO_3^- values were lower in the spent grain treated soil than the compost treated soil for both levels of applications. The trend of bicarbonate was coincided with the trend of pH. A high pH is corresponding to high HCO_3^- concentration. The low level of bicarbonate is leading to low pH, increase in micronutrients availability and available phosphorous. Increasing P availability occurs when soil pH is within 6.0-7.5. If pH is lower than 6, P starts forming insoluble compounds with Fe and Al and if pH is higher than 7.5, P starts forming insoluble compounds with Ca. Most nutrient deficiencies can be avoided at pH 5.5-6.5, provided that soil minerals and OM contain the essential nutrients to begin with.

Application of both spent grain and compost increased the availability of calcium Ca^{2+}. The Ca^{2+} concentrations showed 68.55, 141.00, 144.00, 212.60, 283.25 and 271.10 mg/kg for the control, T1, T2, C1, C2 and C1T1, respectively. The differences in calcium contents varied significantly among the treatments. The contribution of compost to Ca^+ is greater than the contribution of spent grain at both applications rates (1% and 2%). Similarly, Mg^+ concentrations were 33.45, 43.23, 51.87, 66.57, 70.56 and 61.53 mg/kg for the control, T1, T2, C1, C2 and C1T1, respectively. However, Mg^+ in all treatments was lower than Ca^+ due to the low inherent Mg^+ concentrations in soil and in the organic source used. The Mg^+ concentration varied significantly among all organic treatments. The contribution of compost in the Mg^+ was greater than the spent grain contribution. The soluble Mg^+ increased as the compost and spent grain application rate increased. The addition of organic source might provide supplemental exchangeable ions such as Ca^{2+}, Mg^{2+} and Na^+.

The TN values were 0.003 (f), 0.037(d), 0.113(a), 0.027(e), 0.054(c) and 0.079(b) % for control, T1, T2, C1, C2 and C1T1 treatments, respectively (Fig. 2), different litters (a-f) indicate significant differences among all treatments ($LSD_{0.05}$=0.0057). Obviously, spent grain had the greatest TN at both levels in comparison to compost. Also, the 2% of spent grain provided the greatest TN among all treatments and was higher than C1T1 and C2. The high content of OM source (spent grain or compost) encouraged the mineralization of OM and hence produced nitrogen in available form. However, high TN may enhance nitrogen losses by nitrogen conversion to gases and the subsequent loss to the atmosphere. The primary N losses involve denitrification and ammonia volatilization. Incubation of some organic materials with soil supplies various structures of secondary nutrients and micronutrients [8]. In addition, some compost contains other growth-promoting substances such as B vitamins, natural hormones and organic acids. Moreover, use of organic fertilizer resulted in higher soil OM, soil N and available P and K [4].

The soluble P is considered as the most available P pool for plant uptake. The concentrations of available P were 8.83(f), 11.23(d), 20.37(a), 9.74(e), 12.06(c) and 14.52(b) mg/kg for the control, T1, T2, C1, C2 and C1T1, respectively (Fig. 2), different litters (a-f) indicate significant differences among all treatments ($LSD_{0.05}$=0.676). Application of both organic compounds increased the available P due to the reduction of pH as a result of OM decomposition. Water extractable P significantly increased by applying biosolids, hog manure, cattle manure and commercial P fertilizer. Use of organic fertilizer resulted in higher soil OM, soil N and available P and K [4]. The highest value of available P recorded at T2.

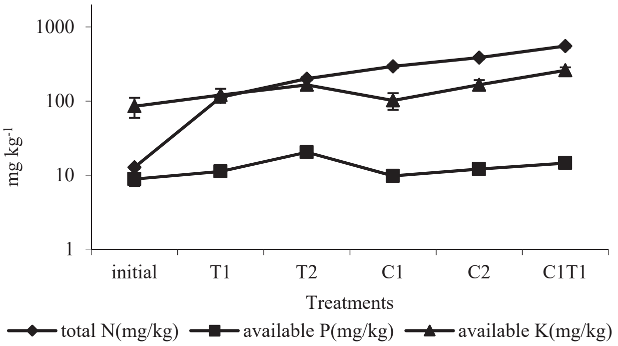

Fig. 2 Effect of organic source incubation on TN in sandy soil

The available K values were 85 (c), 120.5(bc), 219.03(b), 101.75(bc), 165.6(bc) and 259.5(a) mg/kg for control, T1, T2, C1, C2 and C1T1 treatments, respectively (Fig. 2), different litters (a-d) indicate significant differences among all treatments ($LSD_{0.05}$=67.72). The spent grain increased greatly the available K compared to the compost. The C1T1 gave the highest available K among all treatments. Addition of manure generally increased the OM content which in turn provides supplemental exchangeable ions.

The C/N ratios were 39.39(a), 14.45(bc), 10.0(bc), 20.0(c), 15.35(bc) and 12.19(c) for the control, T1, T2, C1, C2 and C1T1, respectively. Different litters (a-c) indicate significant differences among all treatments ($LSD_{0.05}$=8.74). The C/N ratio for the organic treated soil was reduced greatly compared to the control. The reduction in C/N ratio is due to the release of N from the decomposed organic sources [16]. This reduction is related to the biological and chemical processes that accelerate the rate of decomposition and transform organic materials into a more stable humus form in a soil. Nitrogen immobilization into litter and its release in mineral forms are mainly controlled by the initial chemical composition of the residues. Nitrogen-release can be explained by fundamental stoichiometric balance of decomposers activity. Decomposers immobilize C and N from organic substrates and exchange inorganic nutrients with the environment to maintain their stoichiometric balance [6].

The iron Fe^{2+} concentrations were 1.57, 3.75, 7.77, 2.15, 4.72 and 9.04 mg/kg for the control, T1, T2, C1, C2 and C1T1, respectively (Fig. 3). Organic sources increased Fe^{2+} level significantly in comparison to the control. So, the organic sources provided a supplemental iron to enrich the sandy soil. The mineralization of organic compounds led to low pH which increases the iron availability in soil. Spent grain (1% and 2%) was superior to the compost for providing iron to soil. So, it is recommended using spent grain or a combination of spent grain and compost to enrich such a soil by iron [17].

Similar to iron concentration presented previously, the spent grain provided the greatest concentrations of manganese in comparison to other organic compost or the control condition (Fig. 3). The Mn^{2+} concentrations were 1.03, 1.35, 4.58, 1.26, 1.92, 3.62 mg/kg for control, T1, T2, C1, C2 and C1T1 treatments, respectively. The T2 and C1T1 possessed the greatest manganese contents compared to the control. The differences among the treatments in the manganese concentration were significant. Accordingly, the application of spent grain to enrich a soil with manganese is highly recommended. Lowering the pH in organic treated soils as a result of OM mineralization encouraged the release of manganese in available form for plant uptake.

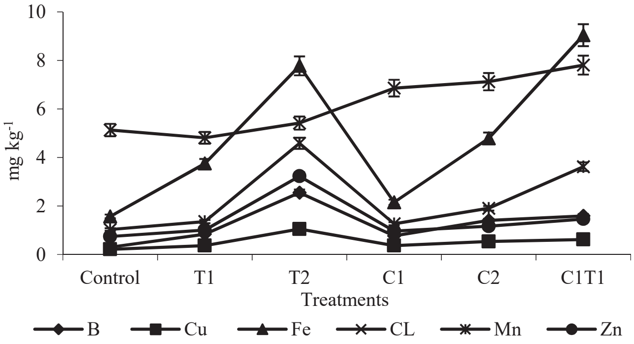

Fig. 3 Effect of organic source incubation on micro nutrients in sandy soil

Fig. 3 shows the concentrations of zinc, copper and boron. The concentrations of Zn^{2+} ranged from 0.74 mg/kg (control) to 3.277 mg/kg (2% spent grain). The Zn^{2+} contents varied significantly among all treatments. The Cu and B followed the order of T2>C1T1>C2>T1>C1>control. According to the reported Zn^{2+} concentrations, the spent grain application rates were superior to the compost application rates due to initially high OM, low pH and high Zn^{2+} content. Manure addition increased the available micronutrients (Cu^{2+}, Zn^{2+}, and Mn^{2+}) in soil [15]. Addition of these wastes significantly increased the availability of Cu^{2+}, Zn^{2+}, Fe^{2+} and Mn^{2+} metals in this sandy soil and consequently may increase dry matter yield of mays grown in the amended soils.

C. Germination and Growing of Corn

After corn germination in sandy soil, significant variation was observed in the VGC among all treatments in the order of C1T1>T2>T1>C2>C1>control. The VGC increased 72% and 50% in C1T1 and T2, respectively when compared to control treatment. The FG increased 76% and 58% and the GI increased 278% and 224% in C1T1 and T2 with respect to control, respectively. The fresh weights varied significantly among all treatments with higher values in T2 and C1T1 (Fig. 4).

D. Statistical Analysis Trend

Factor analysis was tried in order to find statistical evidence on the dynamics occurred in these amended organic treatments [18]. The first two factor structures explained the most significant part of the variance within the analysed variables.

A conceptual name was given to each factor as to identify the relevance of the variables [19].

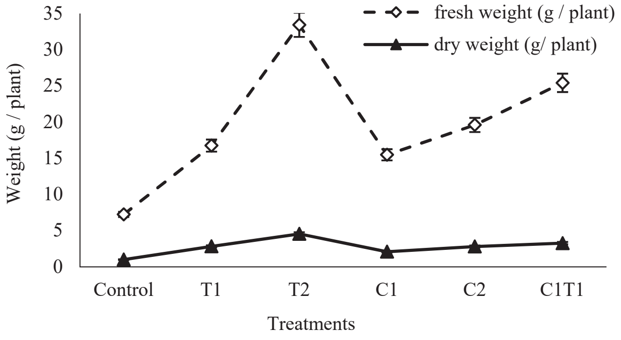

Fig. 4 Effect of organic source incubation on fresh and dry weight

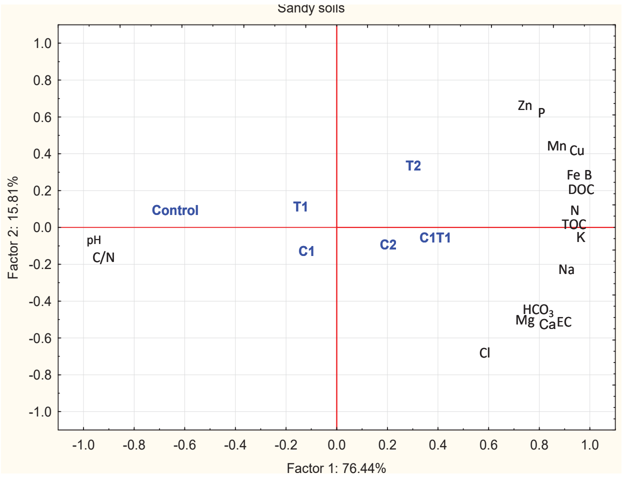

Fig. 5 The distribution of soil variables and treatments along the first two factor structures

In particular, factor analysis was used to check the correlations among all variables used (soil parameters). The first two factors explained 92.25 % of total variance among all variables. The first factor named "soil micro and macro nutrients dynamics" and explained 76.44% of variance with high positive loadings from TN, P_{AV}, soil OM, TOC, DOC, Fe^{2+}, Zn^{2+}, Mn^{2+}, Cu^{2+} and B while high negative loadings from soil pH. The second factor named "soil salinity" and explained 15.81% of variance in the analyzed variables and showed high positive loadings from EC, Cl^{-}, Ca^{2+} and Mg^{2+}.

The first two factors plotted together in order to visualize the distribution of soil variables. In addition, factor score values relevant to each factor structure were located on the presented plot (Fig. 5). The factor score values may help to detect which are the treatments contributed to each factor. Treatments were divided into those more contributing to the soil dynamics in each factor and consequently to the associated variables. From Fig. 5, it can be observed that C1T1, T2 and C2 are the treatments positively contributed to the first factor while treatment of 1% application rates (C1 and T1) showed intermediate contribution to the first factor. The worst contribution was from the control treatment. This worst condition can be directed in general due to the alkalinity of the initial soil conditions.

IV. CONCLUSION

Sandy soils treated with spent grain showed an improvement in their nutrients contents such as (N, P and K). Incubation of both spent grains and compost with sandy soil may enhance soil sequestration of some macro and micro nutrients, increase water holding capacity of soils and improve soil fertility, could enhance crop growth in these soils. In addition, spent grain is non-expensive compared to compost or any other mineral fertilizer.

The increase in the availability of metals was found to be proportional to the application rates. Further research is needed to validate short-term findings and to understand how long-term conservation practices impact soil sustainability.

Likewise, this study recommends the need for more studies concerning effect of spent grain and organic wastes fertilizers (with rates of organic manure), and their interaction on sandy soil under different environments using different growing plants.

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