*Proceedings of the Pakistan Academy of Sciences:*
*B. Life and Environmental Sciences* 58(3): 95-108 (2021)

ISSN (Print): 2518-4261; ISSN (Online): 2518-427X
http://doi.org/10.53560/PPASB(58-3)635

Pakistan Academy of Sciences

Research Article

# Comparative Evaluation of Compost, Wheat Straw and Sawdust on Soil Structural Stability, Plant Available Water and Sorghum (*Sorghum biocolor* L.) Yield

**Aqila Shaheen[1*], Saba Munsaf[1], Abdul Khaliq[1], and Nafeesa Zahid[2]**

[1]Department of Soil and Environmental Sciences, University of Poonch, Rawalakot, Azad Jammu & Kashmir
[2]Department of Botany, Mirpur University of Science and Technology, Mirpur 10250, Azad Jammu &Kashmir

**Abstract:** The decreased soil structural stability with a resultant reduction in soil porosity, availability of water and nutrients has declined the crop yield. Compost, wheat straw and sawdust, the organic wastes can be effectively used as soil amendments to improve soil structure, porosity and water holding capacity and the crop yield. The study was conducted in randomized complete block design (RCBD) and three types of amendments i.e. compost (CM), wheat straw (WS) and sawdust (SD) were applied at three rates of 0, 4 and 8 t $ha^{-1}$. The higher sorghum growth was at 8 t $ha^{-1}$, however, 4 t $ha^{-1}$ also indicated statistically comparable trend. The highest grain yield of 1357 kg $ha^{-1}$ and 1374 kg $ha^{-1}$ was observed in amended soils and type of amendments showed statistically ($P \leq 0.05$) similar yield. The water contents at field capacity (35.4 %), wilting point (22.5 %) and plant available water (13.25 %) were higher in WS 8 t $ha^{-1}$ amendment. The higher soil structure stability of 90.78 % was observed in WS with rates of 8 t $ha^{-1}$. The crop residue WS 8 t $ha^{-1}$ have the potential to increase soil water retion and soil structure stability as well. The CM, WS and SD amendments significantly improved organic matter (OM), porosity, nitrogen ( N) and phosphorus (P) of soil in 4 and 8 t $ha^{-1}$ than control. The low bulk density (BD) of 1.07 g $cm^{-3}$ was in WS 8 t $ha^{-1}$ and the lower pH was recorded in CM 8 t $ha^{-1}$. The study showed that all three types of amendments (CM, WS and SD) at 4 and 8 t $ha^{-1}$ rates have potential to improve the soil structural stability, plant available water and yield of grain sorghum.

**Keywords:** Compost, Wheat straw, Sawdust, Water retention, Sorghum growth, Yield

## 1. INTRODUCTION

Land degradation lowers the soil quality and reduce the potential productivity of the soil [1] Aggregate stability is considered to be an indicator of soil structure. Organic matter serves as a binding material that lead to the formation of water stable aggregates through the formation of clay, humus complex [2]. Different organic matter inputs have a potential to improve soil water at field capacity and wilting point [3]. Organically amended soils increased soil organic carbon (SOC) by 49 % and 29% than an unfertilized and fertilized control, respectively [4]. Compost additions have increased SOC significantly [5]. The slow release of nutrients, especially N [6] from organic amendments builds up mineralizable N and increase the crop yield. The existence of a large quantity of water stable macroaggregates controls the degradation of soil to a great extent [7].

Sorghum (*Sorghum bicolor* L.) is one of an important kharif (summer) season crop of Pakistan that known as jowar. It is grown both in rain-fed and in irrigated areas of Pakistan for fodder and grain purpose [8]. It belongs to Poacea family. With regard to economic importance, sorghum attains fifth position worldwide among different cereal crops that give production of about 60 million tons annually. In Pakistan, it is cultivated in an

Received: December 2020; Accepted: September 2021
*Corresponding Author: Aqila Shaheen <aqeela.shaheen@gmail.com>

area of 214 000 hectares that give approximate 137 000, tones sorghum grain production [9]. Sorghum has a wide adaptability to different types of soil however, subsoil compaction due to poor structural condition of soil usually decreases root growth of the crop. This limits the availabilityy and uptake of nutrients and water by plants which results in reduction in grain yield of the crop [10]. Grain yield of sorghum is also severely diminishes if water is scarce at the critical stages of crop [11]. Water stress at the vegetative stage alone can reduce yield more than 36 %, and water stress at the reproductive stage can reduce yield more than 55 % [12]. For that reason, this crop needs better management measures such as moisture conservation, enhanced nutrients availability, soil temperature maintenance and low soil compaction.

Organic matter of soil usually decreases due to exhaustive cropping of soils [13]. Physical deterioration of soil due to extensive agriculture activities without proper management of soil is a serious and alarming issue in Pakistan. It causes crop yield reduction and this problem can be overcomed by applying organic inputs in soil [14]. Organic amendments play a major role in the improvement of physical, chemical as well as biological properties of soils [15, 16]. Many studies [17, 18] proved that organic amendments improve the quality of degraded soils. These materials supply nutrients and organic matter to the soils. Amongst the most important organic amendment compost application trials resulted in increased SOM concentrations [19]. Compost has a potential to sustain good soil tilth, better aeration and nutrients supply, thus makes its greatest contribution to soil productivity [20]. It has been studied that application of composted organic wastes in a silt loam soil result in better aggregate stability [21].

Sawdust is also an additional plant residue or organic waste that is a rich carbonaceous substance. Once applied in soil, sawdust has a promising role in supplying humus that lead better soil hydro-physical properties [22]. Similarly, crop residues, e.g. straw also improve and increase soil properties and crop yield. Compared with control, the average soil available potassium (K), available P and available N and SOC levels were higher in the 0–40 cm soil layers after straw incorporation treatments [23].

Most of the soils of Rawalakot (latitude 33º51′32.18″N and longitude 73º45′34.93″E) Azad Jammu and Kashmir are usually low in fertility, compacted, eroded and prone to crusting. These soils have degraded structure, higher runoff and low infiltration. The study was conducted with the hypothesis to improve the soil physico-chemical properties and subsequent increase in sorghum yield by organic inputs i.e. compost, wheat straw and sawdust. These soil amendments are low in cost, easily available in this area and have potential to improve physical properties of soil, restoring soil fertility and enhancing crop yield.

## 2. MATERIAL AND METHODS

The field experiment was performed to assess the effect of amendments (compost, wheat straw and sawdust) on soil structural stability, plant available water and sorghum (*Sorghum bicolor* L.) yield at the Research Farm of the University of the Poonch Rawalakot, Azad Jammu & Kashmir during the year 2016. The study was conducted in randomized complete block design (RCBD) having two factors; (i) types of organic amendments (compost CM; wheat straw WS and sawdust SD) and (ii) rates of amendments. i.e. 0, 4 and 8 t $ha^{-1}$. There were a total of nine treatment combinations with three replications. Net plot size was $4m^2$. The variety of grain sorghum (*Sorghum bicolor* L.) "Johar" was grown. The distance maintained from plant to plant was 15 cm and the distance from row to row was 60 cm after germination of the crop. The recommended rates of NPK fertilizers (100 kg $ha^{-1}$ nitrogen, 50 kg $ha^{-1}$ $P_2O_5$ and 40 kg $ha^{-1}$ $K_2O$) were also applied to sorghum crop as basal dose to all treatments.

Presowing composite and post-harvest soil samples from each replication were collected from a depth of 0-15 cm and analyzed for physico-chemical properties of soil.

### 2.1 Soil Analyses

To determine the texture of the soil the Boyoucos hydrometer method was used [24]. The suspension ratio of soil and water was 1:2 to measure the pH [25]. The 1:2 soil and water suspension were used to measure the soil electrical conductivity of extract ECe. The ECe reading was noted on EC meter by inserting an electrode into suspension [26]. The Nelson and Sommers, [27] method were followed in the determination of soil organic matter (OM). The OM as percent oxidizable organic carbon (OC) was then determined. By multiplying % organic carbon with factor 1.724, the percentage of OM was computed. To determine the bulk density (BD), core method as proposed by Blake and Hartage, [28] was used. For that an intact soil sample was taken with the help of core sampler. The intact sample was placed in moisture can. Then moisture can weight was measured prior to and after drying in oven at temperature of 105 ºC.

"BD (g $cm^{-3}$) = Oven dry weight of soil (g)/volume of core sampler"

Determination of particle density (PD) was done by method of Bray [29].

Percent pore space (PS) was computed as:

% PS = 1-Db/Dp x100

Where % PS = percent pore space; Db = bulk density; Dp = particle density

The Kjeldahl method [30] was applied to determine the total nitrogen in soil. The available P was measured by the AB-DTPA method. The absorbance of the blue colour of the solution at 880 nm was measured on a spectrophotometer [31]. Soil structural stability was measured by wet sieving method [32, 33]. The plant available water (PAW) was determined by the pressure plate apparatus. The method determines soil water content at the Permanent wilting point (PWP at 15 bars) and field capacity (FC at 1 bar) thus calculates PAW as difference between PWP and FC [34].

PAW (%) = FC-PWP

FC = Field capacity (%); PWP = Permanent wilting point (%)

### 2.2 Crop Growth Parameters

The crop growth parameters including plant height, leaf surface area, number of leaves per plant chlorophyll content of leaf, biological yield, grain yield, dry matter yield, harvest index were also determined. To measure chlorophyll contens a piece of leaf (1 $cm^2$) was taken and put into a test tube and five ml acetone was also decanted in a tube. It was placed in dark for overnight [35]. The spectrophotometer was then used to read the absorbance at 663 nm and 645 nm for chlorophyll a and b. Then total chlorophyll content was computed as described:

Total Chlorophyll = 8.02 x (A 663 nm) + 20.2 x (A 645 nm)

### 2.3 Plant Analyses

Kjeldahl's method as prescribed by Bremmer and Mulvaney, [30] was used to calculate the total nitrogen in plant. Instead of soil, plant material was used in this case. However, all other steps were almost same in this method as adopted for total nitrogen analysis in soil. To measure P in plant Olsen and Sommers, [36] method was used. Spectrophotometer was used to measure the color intensity at wavelength 410 nm.

### 2.4 Total N and P Uptake

Uptake was calculated as total N and P uptake (kg $ha^{-1}$) = " [percent N and P content of yield x yield (kg $ha^{-1}$)]/100"

### 2.5 Statistical analysis

The Statistica 8.1 software was applied to analyze the data. The variations between the means of different treatments were observed using LSD test at the 5 percent level of probability [37].

## 3. RESULTS AND DISCUSSION

### 3.1 Pre-Sowing Properties of Soil

The pre-sowing properties of soil are given in Table 1. shows neutral pH with no salinity or alkalinity problem. The bulk density and particle density were within the range of mineral soil. The soil porosity 43.34 %. The total N was 0.55 g $Kg^{-1}$, available P 7.27 mg $Kg^{-1}$ and OM was 1.37 %. The soil texture was sandy loamy.

### 3.2 Growth and Yield of Sorghum

Plant height, number of leaves per plant, leaf surface area and chlorophyll content of sorghum plants as

**Table 1.** Presowing properties of experimental field

| Soil properties | Values |
|---|---|
| Soil pH | 7.21 |
| ECe ($dSm^{-1}$) | 0. 34 |
| BD ($g\ cm^{-3}$) | 1.49 |
| PD ($g\ cm^{-3}$) | 2.63 |
| Soil porosity (%) | 43.34 |
| N ($g\ kg^{-1}$) | 0.55 |
| Available P ($mg\ kg^{-1}$) | 7.27 |
| OM (%) | 1.37 |
| Sand (%) | 52.4 |
| Silt (%) | 31.6 |
| Clay | 16 |
| Texture | Sandy loam |

affected by the interactive effect of amendments types x rates of amendments are given in Table (2). The results showed that all the growth characters had positive response when all three types of amendments were applied.

The maximum plant height of 175.93 cm in CM 8 t $ha^{-1}$ was recorded and it was 12 % higher than no amended soils. Whereas the leaf surface area was maximum (74.25 $cm^2$) in case of SD 8 t $ha^{-1}$ that was 25 % higher than no amended soils.

The high chlorophyll contents of 11.5 mg $cm^{-2}$ were observed in CM 8 t $ha^{-1}$ compared to rest of the treatments. This high rate was 59 % than its no amended soils. All the growth characters of sorghum were minimum at zero rates of all three amendments.

The yield data (Table 3) showed a higher grain yield (1454.2 kg $ha^{-1}$) at treatment CM 8 t $ha^{-1}$ and it was statistically comparable with WS 4 t $ha^{-1}$. The means of amendment types showed 25 % higher grain yield in CM compare to WS and SD, however, rates of amendments showed higher yields at 4 and 8 t $ha^{-1}$ compared to no amendments. The percent increase was 25 and 27 at rates of 4 and 8 t $ha^{-1}$, respectively compare to zero amendments.

The highest dry matter yield (7469 kg ha-1) was obtained in WS 8 t ha-1 that was at par with WS 4 t $ha^{-1}$ (7453 kg $ha^{-1}$) and SD 4 t $ha^{-1}$ (7456.8 kg $ha^{-1}$). The lowest dry matter yield (5098.5 kg $ha^{-1}$) was recorded in WS0. The means of amendment type had higher yield with WS and SD compare to CM. The percent increase compare to respective control was 31, 24 and 9 by WS, SD and CM, respectively. The zero rate of amendment showed a minimum yield.

The higher harvest index (19.89 %) was found in CM 4 t $ha^{-1}$ followed by HI (18.2%) recorded in CM 8 t $ha^{-1}$. Among the amendment type, CM 8 t $ha^{-1}$ had higher HI (18.12 %) while the rates of amendments showed statistically similar HI.

### 3.3 Concentration and Uptake of Nutrients

The results in Table (4) illustrating the response of total nitrogen to the treatments and data showed the highest soil total N (0.720 g $kg^{-1}$) in SD 4 t $ha^{-1}$ and it was similar with CM 8 t $ha^{-1}$ (0.677 g $kg^{-1}$) and SD 8 t $ha^{-1}$ (0.680 g $kg^{-1}$). Whereas WS 8 t $ha^{-1}$ (0.537 g $kg^{-1}$) and CM 8 t $ha^{-1}$ (0.577 g $kg^{-1}$) did not show a marked increase in total soil nitrogen. However, the lowest total soil nitrogen 0.33 g $kg^{-1}$ was observed in SD0. The means of amendment types had higher total N with SD and it was 24 % than its control and means of rates had higher N at 4 t $ha^{-1}$ and it was 55 % higher than no amendment.

**Table 2.** Effect of compost, wheat straw and sawdust on growth parameters of sorghum

| **Rates of organic amendments (t ha$^{-1}$)** | **Types of organic amendments** | | | **Means** |
|---|---|---|---|---|
| | Compost | Wheat straw | Sawdust | |
| **Plant Height (cm)** | | | | |
| 0 | 156.43$^{d}$ | 156.17$^{d}$ | 163.80$^{bcd}$ | 158.80$^{b}$ |
| 4 | 171.80$^{ab}$ | 166.27$^{abc}$ | 159.73$^{cd}$ | 165.93$^{a}$ |
| 8 | 175.93$^{a}$ | 167.57$^{abc}$ | 166.53$^{abc}$ | 170.01$^{a}$ |
| Means | 168.06 | 163.33 | 163.36 | |
| **Leaf surface area (cm$^2$)** | | | | |
| 0 | 56.43 | 59.03 | 59.56 | 58.34b |
| 4 | 71.75 | 73.63 | 63.88 | 69.76a |
| 8 | 69.84 | 67.27 | 74.25 | 70.45a |
| Means | 66.00 | 66.64 | 65.90 | |
| **Chlorophyll content** | | | | |
| 0 | 7.29 | 7.26 | 7.29 | 7.28 |
| 4 | 8.70 | 9.16 | 8.03 | 8.63 |
| 8 | 11.57 | 10.11 | 8.49 | 10.06$^{a}$ |
| Means | 9.19$^{a}$ | 8.84$^{ab}$ | 7.94$^{b}$ | |

The different letters in columns are statistically significant at $P \leq 0.05$

**Table 3.** Effect of compost, wheat straw and sawdust on yield of sorghum

| **Rates of organic amendments (t ha$^{-1}$)** | **Types of organic amendments** | | | **Means** |
|---|---|---|---|---|
| | Compost | Wheat straw | Sawdust | |
| **Grain yield (kg ha$^{-1}$)** | | | | |
| 0 | 1024.0$^{d}$ | 1098.2$^{c}$ | 1135.8$^{c}$ | 1086.0$^{b}$ |
| 4 | 1346.7$^{b}$ | 1413.3$^{a}$ | 1311.3$^{b}$ | 1357.1$^{a}$ |
| 8 | 1454.2$^{a}$ | 1335.0$^{b}$ | 1334.2$^{b}$ | 1374.4$^{a}$ |
| Means | 1274.9 | 1282.2 | 1260.4 | |
| **Dry matter yield(kg ha$^{-1}$)** | | | | |
| 0 | 5274.7$^{c}$ | 5098.5$^{c}$ | 5218.2$^{c}$ | 5197.1$^{b}$ |
| 4 | 5422.7$^{c}$ | 7453.0$^{a}$ | 7456.8$^{a}$ | 6777.5$^{a}$ |
| 8 | 6544.5$^{b}$ | 7469.0$^{a}$ | 6677.5$^{b}$ | 6897.0$^{a}$ |
| Means | 5747.3$^{b}$ | 6673.5$^{a}$ | 6450.8$^{a}$ | |
| **Harvest index (%)** | | | | |
| 0 | 16.25$^{cde}$ | 17.81$^{bc}$ | 17.93$^{bc}$ | 17.33 |
| 4 | 19.89$^{a}$ | 15.79$^{de}$ | 14.67$^{e}$ | 16.78 |
| 8 | 18.21$^{ab}$ | 15.19$^{de}$ | 16.70$^{bcd}$ | 16.70 |
| Means | 18.12$^{a}$ | 16.26$^{b}$ | 16.43$^{b}$ | |

The different letters in columns are statistically significant at $P \leq 0.05$

The lowest available phosphorus (7.24 mg kg$^{-1}$) was found in CM0. The highest available phosphorus (10.077 mg kg$^{-1}$) was found in CM 8 t ha$^{-1}$ followed by WS 8 t ha$^{-1}$ (8.813 mg kg$^{-1}$). The means had higher P with CM and it was 18 % higher than its control and among rates higher P was at 8 t ha$^{-1}$ and this was 23 % higher than no amendments.

The higher total N uptake was at WS 8 t ha$^{-1}$ and higher P uptake was also in the same treatment. The means of amendment types showed higher total N uptake of 149.83 kg ha$^{-1}$ by WS compare to CM and SD. The higher total N uptake of 172. 62 kg ha$^{-1}$ was at rate of 8 t ha$^{-1}$. Similar trend was shown by total P uptake, the type of amendments had higher p uptake of 18.16 kg ha$^{-1}$ by WS and at rate of 8 t ha$^{-1}$ the higher total p uptake was 21. 61 kg ha$^{-1}$.

### 3.4 Soil Water Content at Field Capacity, Wilting Point and Plant Available Water

Data as depicted in Figure 1 showed that at field capacity the higher water content of 35.4 % at WS 8 t ha$^{-1}$ was found and each control had minimum water contents. The means of amendments showed higher water contents at field capacity (32.1 %; SD ± 3.9) in WS and means of rates had higher water content of 33.1%; SD± 2.0 at 8 t ha$^{-1}$. The higher water contents at wilting point were 22.5 % at WS 8 t ha$^{-1}$. The amendments mean had higher water contents (22.5 %; SD ± 0.91) at WS and means of rates had higher water content of 21.7 % ; SD ± 0.7 at 8 t ha$^{-1}$.

The higher PAW of 13.25 % was observed in WS 8 t ha$^{-1}$. The means of amendments showed higher water contents (10.5 %; SD ± 0.91) at WS followed by SD. Among rates 8 t ha$^{-1}$ showed higher PAW of 11. 6 %; SD ± 0.7.

### 3.5 Soil structure Stability

Data (Fig. 2) revealed that the interaction among rates x types of amendments significantly increased soil structural stability (%). The WS 8 t ha$^{-1}$ had resulted in the highest soil structural stability (90.78%) followed by CM 8 t ha$^{-1}$. i.e. 88.5 %. The

**Table 4.** Effect of compost, wheat straw and sawdust on concentration and uptake of nutrients

| Rates of organic amendments (t ha$^{-1}$) | Types of organic amendments | | | Means |
|---|---|---|---|---|
| | Compost | Wheat straw | Sawdust | |
| **Tota N (g kg$^{-1}$)** | | | | |
| 0 | 0.55$^{e}$ | 0.54$^{e}$ | 0.66$^{de}$ | 0.58$^{c}$ |
| 4 | 0.89$^{bc}$ | 0.74$^{cd}$ | 1.07$^{a}$ | 0.90$^{a}$ |
| 8 | 0.92$^{ab}$ | 0.79$^{bcd}$ | 0.73$^{d}$ | 0.81$^{b}$ |
| Means | 0.79$^{b}$ | 0.68$^{b}$ | 0.82$^{a}$ | |
| **P (mg kg$^{-1}$)** | | | | |
| 0 | 7.24$^{d}$ | 7.30$^{d}$ | 7.34$^{d}$ | 7.29$^{c}$ |
| 4 | 8.33$^{bc}$ | 8.09$^{c}$ | 8.37$^{bc}$ | 8.26$^{b}$ |
| 8 | 10.08$^{a}$ | 8.81$^{b}$ | 8.06$^{c}$ | 8.98$^{a}$ |
| Means | 8.548$^{a}$ | 8.07$^{b}$ | 7.92$^{b}$ | |
| **Total N Uptake (kg ha$^{-1}$)** | | | | |
| 0 | 97.80$^{e}$ | 92.00$^{ef}$ | 91.31$^{f}$ | 93.70$^{c}$ |
| 4 | 143.29$^{d}$ | 177.66$^{a}$ | 171.30$^{b}$ | 164.08$^{b}$ |
| 8 | 177.09$^{ab}$ | 179.82$^{a}$ | 160.95$^{c}$ | 172.62$^{a}$ |
| Means | 139.39$^{b}$ | 149.83$^{a}$ | 141.19$^{b}$ | |
| **P uptake (kg ha$^{-1}$)** | | | | |
| 0 | 11.47$^{e}$ | 10.75$^{e}$ | 10.28$^{e}$ | 10.83$^{c}$ |
| 4 | 15.33$^{d}$ | 21.12$^{b}$ | 18.12$^{c}$ | 18.19$^{b}$ |
| 8 | 23.38$^{a}$ | 22.62$^{a}$ | 18.84$^{c}$ | 21.61$^{a}$ |
| Means | 16.73$^{b}$ | 18.16$^{a}$ | 15.75$^{c}$ | |

The different letters in columns are statistically significant at $P \leq 0.05$

amendment types had soil structure stability of 75.49 % (P ≤ 0.05; SD ± 17) with WS and rates of amendments showed higher soil structure stability of 87.27 % (SD ± 4.3) at 8 t $ha^{-1}$. The statistically lower soil structure stability was found in non amended soils.

### 3.6 Physico-chemical Properties

The response of soil physico-chemical properties of different amendments applications is shown in Table (5). At 0 rate, all plots (without amendments) had higher pH compared to amended ones (Table 5). The interaction of rates x amendments had a lower soil pH (6.41) with CM 8 t $ha^{-1}$ while type of amendments had pH 6.78 with SD and rates of amendments showed lower pH compare to no amended soil.

The highest percentage of OM 2.462 % was recorded for WS 8 Mg $ha^{-1}$. Meanwhile CM 8 t $ha^{-1}$ and SD 8 Mg $ha^{-1}$ had also resulted in a slight increase in OM i.e. 2.387 % and 2.364 %, respectively. The lowest OM was recorded for WS0 that was 1.423 %. The means of amendment types showed higher OM of WS followed by CM and SD. However, the rate 8 t $ha^{-1}$ showed higher OM (2.41) compared to 4 t $ha^{-1}$ and no amended soils.

The lower BD of 1.073 Mg $m^{-3}$ was observed in WS. The amendment types showed lower BD with CM and it was statistically similar to WS. The no amended soils had a higher BD (1.23 Mg $m^{-3}$) than amended ones. The lower PD (2.20 Mg $m^{-3}$) was

**Table 5.** Effect of compost, wheat straw and sawdust on post-harvest soil physico-chemical properties

| Rates of organic amendments (t $ha^{-1}$) | Types of organic amendments | | | Means |
|---|---|---|---|---|
| | Compost | Wheat straw | Sawdust | |
| **pH** | | | | |
| 0 | 7.10 | 7.13 | 7.18 | 7.14$^{a}$ |
| 4 | 6.51 | 6.68 | 6.63 | 6.61$^{b}$ |
| 8 | 6.42 | 6.58 | 6.52 | 6.51$^{c}$ |
| Means | 6.68$^{b}$ | 6.80$^{a}$ | 6.78$^{a}$ | |
| **Organic matter (%)** | | | | |
| 0 | 1.43$^{g}$ | 1.42$^{h}$ | 1.43$^{h}$ | 1.43$^{c}$ |
| 4 | 2.25$^{e}$ | 2.27$^{d}$ | 2.22$^{f}$ | 2.25$^{b}$ |
| 8 | 2.39$^{b}$ | 2.46$^{a}$ | 2.36$^{c}$ | 2.40$^{a}$ |
| Means | 2.02$^{b}$ | 2.05$^{a}$ | 2.00$^{c}$ | |
| **Bulk density (g $cm^{-3}$)** | | | | |
| 0 | 1.21$^{ab}$ | 1.24$^{a}$ | 1.22$^{ab}$ | 1.22$^{a}$ |
| 4 | 1.09$^{ef}$ | 1.12$^{de}$ | 1.18$^{bc}$ | 1.13$^{b}$ |
| 8 | 1.12$^{def}$ | 1.07$^{f}$ | 1.15$^{cd}$ | 1.11$^{b}$ |
| Means | 1.14$^{b}$ | 1.15$^{b}$ | 1.18$^{a}$ | |
| **Particle density (g $cm^{-3}$)** | | | | |
| 0 | 2.40$^{a}$ | 2.39$^{a}$ | 2.38$^{a}$ | 2.39$^{a}$ |
| 4 | 2.36$^{ab}$ | 2.367$^{ab}$ | 2.26$^{c}$ | 2.32$^{b}$ |
| 8 | 2.27$^{c}$ | 2.32$^{b}$ | 2.20$^{d}$ | 2.26$^{c}$ |
| Means | 2.34$^{a}$ | 2.36$^{a}$ | 2.28$^{b}$ | |
| **Pore space (%)** | | | | |
| 0 | 48.18$^{f}$ | 49.16$^{def}$ | 49.10$^{ef}$ | 48.82$^{b}$ |
| 4 | 52.33$^{ab}$ | 50.04$^{cde}$ | 51.917$^{ab}$ | 51.43$^{a}$ |
| 8 | 53.05$^{a}$ | 50.77$^{bcd}$ | 51.35$^{bc}$ | 51.72$^{a}$ |
| Means | 51.19$^{a}$ | 49.99$^{b}$ | 50.79$^{ab}$ | |

The different letters in columns are statistically significant at $P \leq 0.05$

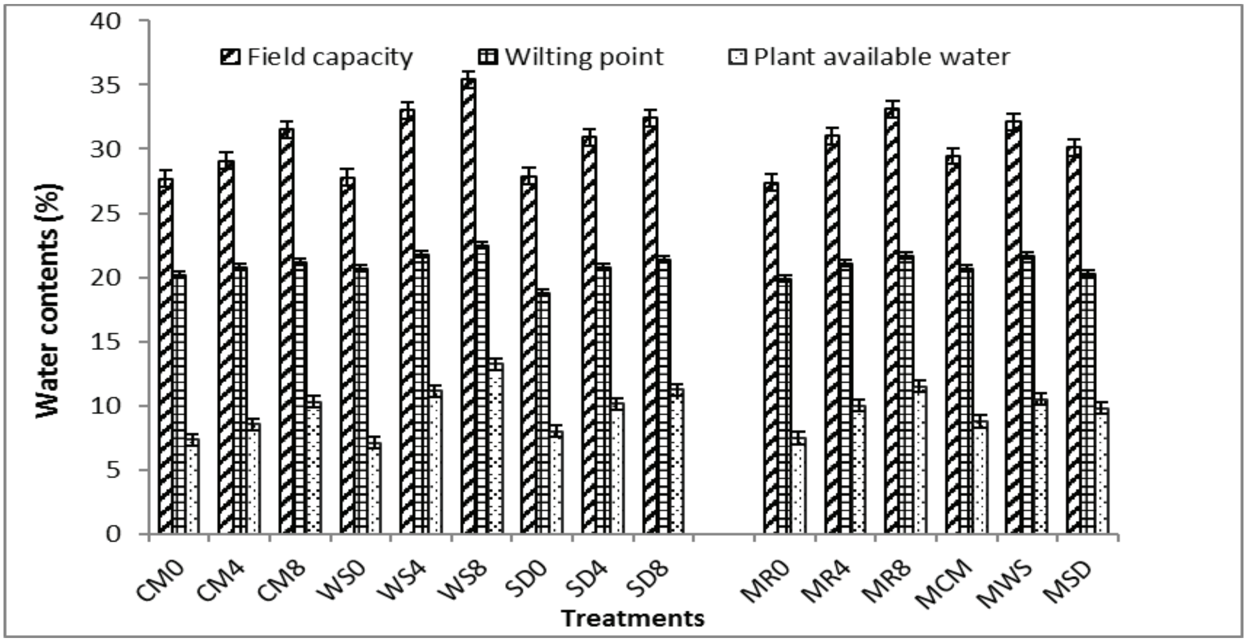


**Fig. 1.** Effect of compost, wheat straw and sawdust on soil water contents at field capacity, permanent wilting point and plant available water.

CM=Compost; WS= wheat straw and SD= sawdust. 0,4,8 t ha$^{-1}$ are rates (R) of CM, WS and SD; M= means

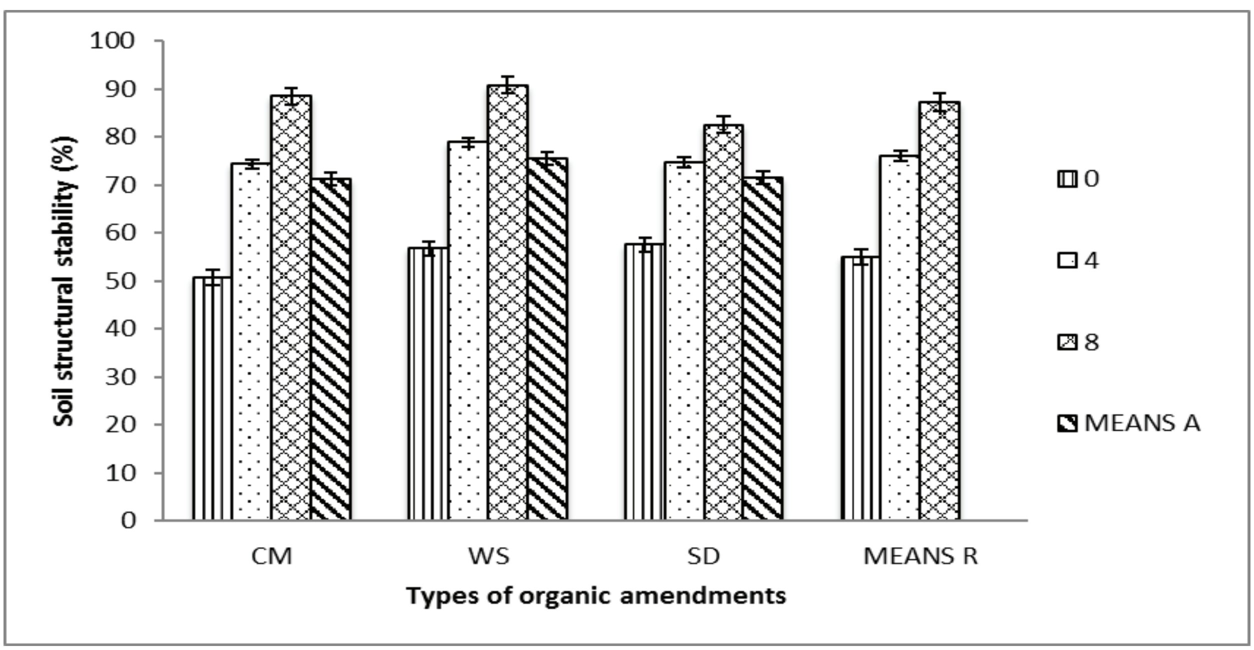


**Fig. 2.** Effect of compost, wheat straw and sawdust on soil structure stability.

CM=Compost; WS= wheat straw and SD= sawdust. 0,4,8 t ha$^{-1}$ are rates of CM, WS and SD; Means R= means of rates of amendments; Means A= means of types of amendments observed in SD 8 t $ha^{-1}$. The means of amendment types showed lower PD of 2.28 Mg $m^{-3}$ followed by CM and WS. However, the means of rates showed PD of 2.26 Mg $m^{-3}$ with a rate of 8 t $ha^{-1}$ followed by 4 t $ha^{-1-1}$.

Soil porosity also positively affected in response of treatments. The lowest soil porosity (48.18 %) was recorded in $CM_0$ at par with soil porosity in WS0 (49.10 % and $SD_0$ (49.16 %). The highest soil porosity (53.04 %) was found in CM 8 t $ha^{-1}$ statistically similar with CM 4 t $ha^{-1}$ (52.33 %) and SD 4 t $ha^{-1}$ (51.91 %). The means of amendment types showed lower porosity of 49.99 % with WS. However, the means of rates showed lower porosity of 48.8 % with no amended soils compare to amended soils.

## 4. DISCUSSION

The organic amendments stimulate plant growth and yield by providing essential plant nutrients and improved soil properties [15, 16]. The three organic amendments increased crop growth while rates of the amendment also showed higher growth (Table 2) compared to no amended soils. The performance of co-applied fertilizers might have increased with organic amendments. Therefore, organic amendments could be a good strategy to sustain and improve yield in the long term [38]. The highest yield (Table 3) in organically amended soil could be due to supplementation of essential nutrients and improvement of soil physical properties. Previous studies showed that organic inputs had recovered degraded soils by sustaining soil properties [39, 40]. Studies showed that organic amendments lower the soil compaction by improving water penetration and aeration [41]. The higher content of total N and P in amended soils (Table 4) shows the decomposition of organic material during growing season of crops. The organic wastes were found to increase the availability of $NO_3$-N in soil [15, 42]. The positive response of waste on plant growth was also reported [43]. Wei *et al.* [23] reported that soil with straw incorporation had higher available K, available P, available N, SOC compared to no amended soils. Our results also showed higher nutrients and organic matter in amended soils. Similarly, the amendment compost was found to improve not only soil properties but also has improved crop production and quality [19]. Compost has significant amounts of macro nutrients, and have beneficial effects on the plant-soil syetem [44, 45]. Therefore, compost can be termed as multi nutrient organic fertilizer [46].

Total N and P uptake (Table 4) were higher in wheat straw amended plots and 8 t $ha^{-1}$ showed higher uptake than 4 t $ha^{-1}$ and no amended soils. It might be attributed to higher yield in wheat straw amended plots. Straw incorporation into the soil has improved the soil physical and chemical properties [47]. It improves soil structure [48-50] and also increased use efficiency of nutrient [51-53]. The post-harvest soil properties (Table 5) showed lower pH with amended soils and it is attributed to release of organic acids as organic material decomposed and this release was higher in 8 t $ha^{-1}$. The higher organic matter content with wheat straw showed higher decomposition rate compare to other amendments. Straw enhances soil organic matter [54] and also provide soil nutrients, thus improve the soil quality and increase the soil productivity.

The organic amendments by improving the status of soil OM had also decreased soil BD and improved soil pore space. The particle density was also found lower due to impact of organic matter accumulation in amended soils (Table 5). Eldridge *et al.* [5] showed increase in SOC following compost additions. The organic amendments had increased SOC by 49% compared to non amended and 29% compared to an inorganic fertilized control [4]. Blanchet *et al.* [55] reported higher SOC with organic inputs compared to inorganic inputs. Comparable results were reported by Nest *et al.* [56]. Most of the studies [57-59] revealed same results as present study showed that the addition of manure has reduced BD, increased porosity and SOC and consequently overall improved soil mechanical properties.

Among the soil amendments, the crop residue retention and organic manure are important for improving soil quality. In eroded soils of Rawalakot Azad Jammu and Kashmir the indigenous organic amendments have the potential to improve soil structure stability, water retention and OM. Environmental changes that result in increases in soil OM will increase available water contents [60]. The higher plant available water in amended soils with higher rates of residues (Figure 1) could be due to improvement of soil physical conditions. The organic amendments had improved soil physical fertility by decreasing soil BD and by enhancing soil aggregate stability [61, 62]. The organic amendments have also improved water contents at field capacity and wilting point [63]. Liang *et al*. [64] reported that in long term study corn straw in combination with inorganic fertilizer had significantly increased soil water content in the plow layer, reduced soil bulk density, and increased plant available water contents in the top soil. Higher soil structure stability was observed in amended soils and with 8 t $ha^{-1}$ (Figure 2) that could be due to higher OM. Soil OM enhances soil aggregation and the development of soil porosity. It further improves the rate of soil infiltration and retention of water that is ultimately available to plants.

## 5. CONCLUSION

Organic amendments improved soil OM status, which is contributing factor for improving physico-chemical properties of soil and associated soil productivity. The indigenous organic amendments have the potential to improve the poor physical condition, water retention and yield of degraded soils. The three types of amendments increased yield compared to no amendments. There is the need to apply organic amendments in degrades soils to enhance both sustainability and productivity.

## 6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

## 7. REFERENCES


1. R. Lal. Restoring Soil Quality to Mitigate Soil Degradation. *Sustainability*. 7: 5875-5895 (2015).
2. K.K. Bandyopadhyay, and R. Lal. Effect of land use management on greenhouse gas emissions from water stable aggregates. *Geoderma* 232: 363-372 (2014).
3. K. Ouattara, B. Ouattara, A. Assa, and P.M. Sédogo. Long-term effect of ploughing, and organic matter input on soil moisture characteristics of a Ferric Lixisol in Burkina Faso. *Soil and Tillage Research* 88(1-2): 217–224 (2006).
4. Y. Chen, M. Camps-Arbestain, Q. Shen, B. Singh, and M.L. Cayuela. The long-term role of organic amendments in building soil nutrient fertility: a meta-analysis and review. *Nutrient Cycling in Agroecosystment* 111:103–125 (2018).
5. S.M. Eldridge, K.Y. Chan, N.J. Donovan, F. Saleh, L. Orr, and I. Barchia.. Agronomic and economic benefits of green-waste compost for peri-urban vegetable production implications for food security. *Nutrient Cycling in Agroecosystment* 111:155–173 (2018).
6. S. Mukai. Historical role of manure application and its influence on soil nutrients and maize productivity in the semi-arid Ethiopian Rift Valley. *Nutrient Cycling in Agroecosystment* 111:127–139 (2018).
7. Bayhanan, A.K., A.A Isisdar, and M. Akgul. 2005. Tillage impacts on aggregate stability and crop productivity in a loam soil of dry land inTurkey.*Acta Agriculturae Scandinavi a-SP.*55: 214- 220.
8. A.F. Malik, A.I. Shahid, and H. Manzoor. Yield response of fodder sorghum to seed rate and row spacing. *Journal of agriculture and social sciences.* 3: 95-97 (2007).
9. Anonymous. Economic survey of Pakistan 2011-12. Ministry of food, agriculture livestock (Federal Bureau of Statistics). Islamabad, 22pp (2012).
10. W.Y. Peng, M. L. Peng, and X.Z. Wu. No-tillage effects on crop yield. *Agricultural Research in the Arid Area.* 29: 95-98 (2011).
11. V. Bandaru, B.A. Stewart, R.L. Baumhard, S. Ambati, C. A. Robinson, and A. Schlegel. Growing dryland grain sorghum in clumps to reduce vegetative growth and increase yield. *Agronomy Journal.* 98: 1109-1120 (2006).
12. Y. Assefa, S. A. Staggenborg, and V.P.V. Prasad. Grain sorghum water requirement and responses to drought stress: A review. *Online. Crop Management* (2010).
13. R. Lal. Organic Matter, Effects on Soil Physical Properties and Processes. In: Gliński J., Horabik J., Lipiec J. (eds) Encyclopedia of Agrophysics. Encyclopedia of Earth Sciences Series. Springer, Dordrecht (2011).
14. D.R. Montgomery. Dirtthe erosion of civilizations. University of California Press, Berkeley, CA. (2007).
15. J. Wang, B. Zhu, J. Zhang, C. Muller, and Z. Cai. Mechanisms of soil N dynamics following long-term application of organic fertilizers to subtropical rain-fed purple soil in China. *Soil Biology & Biochemistry* 91: 222–231 (2015).
16. N. Ling, C. Zhu, C. Xue, H. Chen, Y. Duan, C. Peng, S. Guo, and Q. Shen. Insight into how organic

amendments can shape the soil microbiome in long-term field experiments as revealed by network analysis. *Soil Biology & Biochemistry* 99:137–149 (2016).

17. M.A Galende, J.M. Becerril, O. Barrutia, U. Artetxe, C. Garbisu, and A. Hernandez. Field assessment of the effectiveness oforganic amendments for aided phytostabilization of a Pb–Zn contaminated mine soil. *Journal of Geochemical Exploration.* 145: 181–189 (2014).
18. A. Pena, M.D. Mingorance. and S. Rossini-Oliva. Soil quality improvement by the establishment of a vegetative cover in a mine soil added with composted municipal sewage sludge. *Journal of Geochemical Exploration*. 157: 178–183 (2015).
19. G. Adugna. A review on impact of compost on soil properties, water use and crop productivity. *Agricultural Science Research Journal*. 4(3): 93-104 (2016).
20. S. Edwards, and A. Hailu. How to make compost and use. In: Ching L.L., S. Edwards and H.S. Nadia (eds.). Climate change and food systems resilience in Sub Sarahan Africa. FAO, Italy, 379-436pp (2011).
21. M. Annabi, S. Houot, C. Francou, M. Poitrenaud, and Y. Le Bissonnais. Soil aggregate stability improvement with urban composts of different maturities. *Soil Science Society of America Journal* 71:413–423 (2007).
22. O. Owolabi, A. Adeyeye, B.T. Oladejo, and S.O. Ojeniyi. Effect of wood ash on soil fertility and crop yield in Southwest Nigeria. *Nigerian Journal of Soil Research* 13: 55-60 (2003).
23. T. Wei, P. Zhang, K. Wang, R. Ding, B. Yang, and J. Nie.. Effects of Wheat Straw Incorporation on the Availability of Soil Nutrients and Enzyme Activities in Semiarid Areas. *PLoS ONE* 10(4): e0120994 (2015).
24. G.W. Gee, and J.W. Bauder. Particle-size analysis. In a Klute (ed.). Methods of soil analysis, Part 1. Physical and mineralogical methods. Agronomy Monograph No. 9 (2ed.). American Society of Agronomy/*Soil Science Society of America,* Madison, WI. 383-41pp (1986).
25. E.O. McLean. Soil pH and lime requirement. p.199-224. In A.L. Page *et al*.(ed.) Methods of soil analysis. Part2.2nd ed. Agron.Monogr.9.ASA, Madison, WI. (1982).
26. J.D. Rhoades. Soluble salts (Electrical conductivity). Methods of soil analysis. *Journal of United States of America.* 24: 172-173 (1982).
27. D.W. Nelson, and L.E. Sommers. Total carbon, organic carbon, and organic matter. In Methods of Soil Analysis, Part 2. Chemical and Microbiological properties, 2nd ed., A. L. Miller and R. H. Keeney, Eds. Madison, WI: ASA and SSSA, , pp. 539-580 (1982).
28. G.R. Blake, and K.H. Hartge. Bulk density, in: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, edited by: Klute, A., Agr. Monogr., ASA and SSSA, Madison WI, USA, 9, 363±375 (1986).
29. R.H. Bray. *Requirements for successful soil tests. Soil Science*. 66: 83-89 (1948).
30. J.M. Bremner, and C.S. Mulvaney. Nitrogen-Total. In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, A.L., Miller, R.H. and Keeney, D.R. Eds., American Society of Agronomy, *Soil Science Society of America*, Madison, Wisconsin, 595-624 (1982).
31. J. Murphy, and J.P. Riley. A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta*. 27: 31–36 (1962).
32. K.Y Chan, D.P. Heenan, and A. Oates. Soil carbon fractions and relationship to soil quality under different tillage and stubble management. *Soil and Tillage Research* 63:133139.doi:10.1016/S01671987(01)00239-2 (2002).
33. M. Pagliai, N. Vignozzi and S. Pellegrini. Soil structure and the effect of management practices. *Soil and Tillage Research.* 79: 131-143 (2004).
34. H.K Lichtenthaler, and A.R. Welburn. Determination of total cartionoids and chlorophyll A and B of leaf in different solvents. *Journal of Crop Sciences and Biotechnology.* 11: 590-592 (1985).
35. D.S. McIntyre. Water retention and the moisture characteristic. In: Loveday J. (ed.). Methods for analysis of irrigated soils. Technical Communication No 54,Commonwealth Bureau of Soils, Chap 6. (1974).
36. S.R. Olsen, and L.E. Sommers. Phosphorus. pp. 403-430. In: A. L. Page, *et al*. (eds.) Methods of soil analysis: Part 2. Chemical and microbiological properties. Agron. Mongr. 9. 2nd ed. ASA and SSSA, Madison, WI. (1982).
37. R.G.D Steel, J.H. Torrie and D.A. Dicky. Principles and procedures of statistics, a biometrical approach 3rd Edition. McGraw Hill Publishing Co. Boston, Massachusetts, 635pp (1997).
38. L.V. Zwieten. The long-term role of organic amendments in addressing soil constraints to production. *Nutrient Cycling in Agroecosystem.*

111:99–102 (2018).

39. K.A Mackie, S. Marhan, F. Ditterich, H.P. Schmidt, and E. Kandeler. The effects of biochar and compost amendments on copper immobilization and soil microorganisms in a temperatevineyard. *Agriculture, Ecosystems & Environment*. 201: 58–69 (2015).
40. A.P Puga, C.A. Abreu, L.C.A. Melo, J. Paz-Ferreiro and L. Beesley. Cadmium, lead, and zinc mobility and plant uptake in a mine soil amended with sugarcane straw biochar. *Environmental Science and Pollution Research* 22: 17606–17614 (2015).
41. P.H. Kuncoro, K. Koga, N. Satta and Y. Muto. A study on the effect of compaction on transport properties of soil gas and water I: Relative gas diffusivity, air permeability, and saturated hydraulic conductivity. *Soil and Tillage Research*. 143, 172–179 (2014).
42. P. Srivastava, A.S. Raghubanshi, R. Singh, and S.N. Tripath. Soil carbon efflux and sequestration as a function of relative availability of inorganic N pools in dry tropical agroecosystem. *Applied Soil Ecology* 96: 1–6 (2015).
43. E. Tampio, T. Salo and J. Rintala. Agronomic characteristics of five different urban waste digestates. *Journal of Environmental Management.* 169: 293–302 (2016).
44. G. Agegnehu, C. VanBeek and M. Bird. Influence of integrated soil fertility management in wheat productivity and soil chemical properties in the highland tropical environment. *Journal of Soil Science and Plant Nutrition.* 14: 532-545 (2014).
45. J. M.Blanco, C. Lazcano, T.H. Christensen , P.Muñoz , J. Rieradevall , J .Møller, A. Antón, A. Boldrin. Compost benefits for agriculture evaluated by life cycle assessment. A review. *Agronomy for Sustainable Development.* 33:721–732 (2013).
46. F. Amlinger, S. Peyr, J. Geszti, P. Dreher, W. Karlheinz, and S. Nortcliff. Beneficial Effects of Compost Application on Fertility and Productivity of Soils. Federal Ministry for Agricultural and Forestry,Environment and Water Management. Lebensministerium: Vienna, Austria (2007).
47. L. Mulumba, and R. Lal. Mulching effects on selected soil physical properties. *Soil and Tillage Research.* 98 (1):106–111 (2008).
48. K. Gangwar, K. Singh, S. Sharma, and O. Tomar. Alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo-Gangetic plains. *Soil and Tillage Research*. 88(1):242–252 (2006).
49. M. Aulakh, T. Khera, J. Doran and K. Bronson. Managing crop residue with green manure, urea, and tillage in a rice-wheat rotation. *Soil Science Society of America Journal.* 65(3):820–827 (2001).
50. S. Wagner, S. Cattle, and T. Scholten. Soil-aggregate formation as influenced by clay content and organicmatter amendment. *Journal of Plant Nutrition and Soil Science.* 170(1):173–180 (2007).
51. Y. Lou, M. Xu, W. Wang, X. Sun and K. Zhao. Return rate of straw residue affects soil organic C sequestration by chemical fertilization. *Soil and Tillage Research.* 113(1):70–73 (2011).
52. M. Dolan, C. Clapp, R. Allmaras, J. Baker and J. Molina. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and nitrogen management. *Soil and Tillage Research.* 89(2):221–231 (2006).
53. X. Tong, M. Xu, X. Wang, R. Bhattacharyya, W. Zhang, and R. Cong. Long-term fertilization effects on organic carbon fractions in a red soil of China. *Catena.* 113:251–259 (2014).
54. Z. Li, M. Liu, X. Wu, F. Han and T. Zhang. Effects of long-term chemical fertilization and organic amendments on dynamics of soil organic C and total N in paddy soil derived from barren land in subtropical China. *Soil and Tillage Research.* 106(2):268–274 (2010).
55. G. Blanchet, K. Gavazov, L. Bragazza, and S. Sinaj. Responses of soil properties and crop yields to different inorganic and organic amendments in a Swiss conventional farming system. *Agriculture, Ecosystems & Environment*. 230: 116–126 (2016).
56. T.V Nest, G. Ruysschaert, B. Vandecasteele, S. Houot, S. Baken,E. Smolders, M. Cougnon, D. Reheul and R. Merckx. The long term use of farmyard manure and compost: effects on P availability, orthophosphate sorption strength and P leaching. *Agriculture, Ecosystems & Environment.* 216:23–33 (2016).
57. M. Liu, F. Hu, X. Chen, Q. Huang, J. Jiao, B. Zhang, and H. Li. Organic amendments with reduced chemical fertilizer promote soil microbial development and nutrient availability in a subtropical paddy field: The influence of quantity, type and application time of organic amendments. *Applied Soil Ecology.* 42: 166–175 (2009).
58. K.A. Gopinath, S. Saha, B.L. Mina, H. Pande, A.K. Srivastva, and H.S. Gupta. Bell pepper yield and soil properties during conversion from conventional to organic production in Indian Himalayas. *Scientia Horticulturae.* 122, 339–345. doi: 10.1016/j.scienta.2009.05.016 (2009).
59. W.B. Achiba, A. Lakhdar, N. Gabteni, G.D. Laing,

M. Verloo, P. Boeckx, O. Van Cleemput, N. Jedidi, and T. Gallali). Accumulation and fractionation of trace metals in a Tunisian calcareous soil amended with farmyard manure and municipal solid waste compost. *Journal of Hazardous Materials.* 176, 99–108. doi: 10.1016/j.jhazmat.2009.11.004 (2010).

60. T.G. Huntington. Available Water Capacity and Soil Organic Matter. In Encyclopedia of Soil Science, Second Edition. Taylor and Francis: New York, Published online. 139-143 (2007).
61. M. Diacono, and F. Montemurro. Long-term effects of organic amendments on soil fertility. *A review, Agronomy for Sustainable Development.* 30: 401-422 (2010).
62. W.T Sun, G. Liang, H.J. Bao, Y. Liu, and Z.X. Sun. Effect of different ratios of organic manure and chemical ferilizer on improving maize yield and soil physical properties. Chin. Agric. Sci. Bull., vol. 27, pp. 80-84, Jun. 2011 (in Chinese).
63. M. Mujdeci, S.Simsek, V. Uygur. The effects of organic amendments on soil water retention characteristics under conventional tillage system. *Fresenius Environmental Bullet.* 26: 6 (2017).
64. W. Liang, X. Wu, S. Zhang, Y. Xing and R. Wang. International Conference on Electrical and Control Engineering. 16-18 Sept in Yichang, China. IEEE (2011).