



Effect of compost and chemical fertilizer application on soil physical properties and productivity of sesame (*Sesamum Indicum* L.)

Rana Shahzad Noor^{1,2} · Fiaz Hussain² · Irfan Abbas³ · Muhammad Umair² · Yong Sun¹

Received: 5 September 2020 / Revised: 24 September 2020 / Accepted: 2 October 2020 / Published online: 16 October 2020
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Abstract

Sesame (*Sesamum indicum* L.) is an important food and cash crop in Pakistan, although less soil fertility (organic matter) and suboptimal application of fertilizers cause nutrient depletion and yield decline. Extensive use of inorganic fertilizers without soil physiochemical analysis is problematic in terms of soil fertility and crop productivity. The application of compost combined with or without chemical fertilizer is considered as a sustainable agricultural production system because it enhances crop productivity and soil fertility. Therefore, this research was conducted to evaluate the effects of bio-fertilizer (organic compost) (Bio-F), chemical fertilizer (RDF), and controlled (CK) farming treatments on some soil physical properties and crop yield. The seven different farming treatments based on N equivalency (compost nutritional analysis) including sole compost levels (20 and 30 t ha⁻¹), sole chemical fertilizer (NPK, 30 kg ha⁻¹), integrated fertilizer treatments (compost + RDF), and a controlled treatment were laid in a complete randomized design (CRD) with three replications under the same experimental field conditions from 2017 to 2020 cropping seasons. Before sesame production, soil samples at a depth of (0–15 cm, 15–30 cm) were analyzed to determine the effect of different farming treatments on soil physical properties. A significantly higher grain yield of sesame (805.1 kg ha⁻¹) was obtained from Bio-F₃ integrated fertilizer application (30 t ha⁻¹ + ½ RDF). The treatments with higher doses of bio-fertilizer (compost) have a significant reduction in soil weight (bulk density), while the increase has been observed in the porosity values. Compared with sole RDF and Bio-F, integrated farming treatments have significantly improved the soil field capacity, available moisture to plants and wilting point. Therefore, the integrated farming system (chemical fertilizer + compost) is recommended for sustainable agroecology and crop production.

Keywords Agricultural waste · Organic compost · Chemical fertilizer · Sesame crop yield · Soil properties

1 Introduction

Agricultural lands show multi-dimensional variability in physiochemical characteristics of soil and managerial practices of ecosystems, which influences the composition and activity in soil strata. Soil is the composite medium for mutual collaboration of plants and microorganisms to extract

nutrients and water. The organic matter is mainly dependent on microbial biomass which is responsible for maintaining soil fertility and quality [1]. The food consumption has been increased due to the increase in the world population. For this, practices such as fertilization and spraying have started to be used intensively in order to obtain more products from the limited agricultural lands. However, it has been scientifically proven that non-optimum agricultural activities (fertilization, irrigation, spraying, etc.) threaten human and animal health, contamination of underground water resources, degradation of natural plant and soil pattern, and damage to biodiversity. The degradation of productive lands made it necessary to increase the amount of product to be produced from the unit area [2]. With multi-crop cultivation, it is aimed to purchase more than one crop per year from the same field, thus, to protect ecological conditions and productivity of agricultural lands with different crop patterns [3].

✉ Yong Sun
sunyong@neau.edu.cn

¹ Department of Agriculture, Biological, Environment and Energy Engineering, College of Engineering, Northeast Agricultural University, Harbin 150030, China

² Faculty of Agricultural Engineering & Technology, PMAS-Arid Agriculture University, Rawalpindi 46000, Pakistan

³ School of Agricultural Equipment Engineering, Jiangsu University, Zhenjiang 212013, China

The continuous application of sole inorganic fertilizer has been adopted by all producers today resulted in deterioration of soil health in terms of soil physiochemical and biological properties and a caused decrease in the amount of soil organic matter [4]. Even if the soils that are problematic in terms of physiochemical properties are fertilized with commercial fertilizers in the most appropriate ways, it is impossible to get high yields from them [5]. Organic fertilizer application has been reported to improve crop physiological growth by supplying plant nutrients including micronutrients as well as improving physiochemical and biological properties of the soil, thereby providing a better environment for root development by improving the soil structure [6].

The sole application of inorganic or organic fertilizers did not bring a sustainable increase in yields [7]. The use of organic fertilizer (FYM) together with low rates of mineral fertilizers could be an alternative solution for sustainable fertility management [8]. Likewise, Abay and Tesfaye [9] suggested that the use of mixed chemical and organic fertilizers not only production can be kept at the optimum level but also the rate of chemical fertilizers to be used can be reduced, which had negative impacts on cost production and environments. Getachew and Tilahun [10] found higher barley biomass yield of 8259 and 8065 kg ha⁻¹, and other agronomic parameters were obtained with the application of 5 t ha⁻¹ FYM in combination with 75% inorganic NP.

Limited agronomic studies on integrated nutrient demand to conduct more researches on integrated nutrient management practices and recommend best practices in order to maximize the yield potential of crops [11]. Integrated use of organic and mineral fertilizers for tackling soil fertility depletion and sustainably increasing crop yields had paramount importance [5, 10, 12]. Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity [13]. Integrated soil fertility management involving the judicious use of combinations of organic and inorganic resources is a feasible approach to overcome soil fertility constraints and contribute high crop productivity in agriculture [14]. Hence, no information is available on the yield potential with integrated nutrient management practice. The integrated use of chemical and organic fertilizer rate is needed to investigate in order to utilize the potential yield.

For sustainable management of soil fertility and to protect the productivity of agricultural lands, it is imperative to improve the physicochemical properties of soil. This research study was conducted to produce organic compost, evaluating the physical and chemical properties of compost before application to the soil. This research was to investigate the effects of sole application of organic compost and chemical fertilizer and also, their different integrated combinations on the yield of the sesame and the soil fertility to promote the use of organic nutrient option and decreasing application of chemical fertilizer to face the soil deterioration and preserve soil

resources under the rainfed agriculture production system in the Potohar region.

2 Materials and method

2.1 Nutritional analysis of organic compost (bio-fertilizer) production

The feedstocks used in the preparation of compost were green waste (tree branches with leaves), crop residue (wheat and corn), and fresh animal manure (cow and buffalo). Dry weights of compost feedstocks were taken into consideration in equal proportions. Green waste, crop residues, and animal dung were collected from orchard tree pruning, crop harvested field, and animal shed of Rana Agric. Farm Jatoi, Dera Ghazi (DG) Khan, Pakistan. The sorted forest and agricultural wastes were dried and crushed to a size of 2 cm [15]. The mixed feedstocks in the ratios stated above and were feed in the composting pit (15 × 15 × 10 feet) covered with the nylon sheet (Fig. 1). Each composting pit was installed a water sprinkler above the pit to maintain optimum moisture in the pit. The compost pile was mixed with the scoop once a month. The moisture content of compost material was maintained by the gravimetric method. During the entire composting process, 50–65% moisture content was maintained for the optimum waste decomposition process. Aeration was done by turning of compost material after a week. It has been determined that approximately after 4.5 months since starting the composting process based on the C/N ratio, the maturing compost material was sieved (8-mm mesh) and filled into the compost bags. The figure showed the feeding pattern of feedstock into the pit. The basement of the pit was provided with a layer (1.5 feet) of coarse uncrushed plant leaves and branches for quick and maximum drainage of leachate produced during the composting process. Above the coarse layer, four layers shredded crop and plant waste (1.75, 1.75, 1.25, 1.25 feet) covered with a layer of animal dung (9, 9, 6, 6 inches) were filled alternatively in the pit. A fermenter was provided with a pump to collect leachate and spray again to composting material to maintain the moisture content of organic waste.

Temperature variations were noted during the entire composting process. The temperature of compost material was measured six times a day (9:00, 11:00, 13:00, 15:00, 17:00, and 19:00) at 2-, 4-, 6-, and 8-foot depths from the top layer of the compost profile. Five subsamples of compost material were taken from the different locations in the compost digester because of non-uniform sample characteristics in the digester. Then all these subsamples were mixed thoroughly to get a representative sample from all these materials and dried at 65 °C for 24 h. Samples pH and EC were measured by pH meter (Cole Parmer, 05669-2) and EC meter, respectively. Total phosphorus was measured by wet digestion method by using ammonium hepta-molybdate metavanadate [(NH₄)₆Mo₇O₂₄·4H₂O+NH₄VO₃] solution.

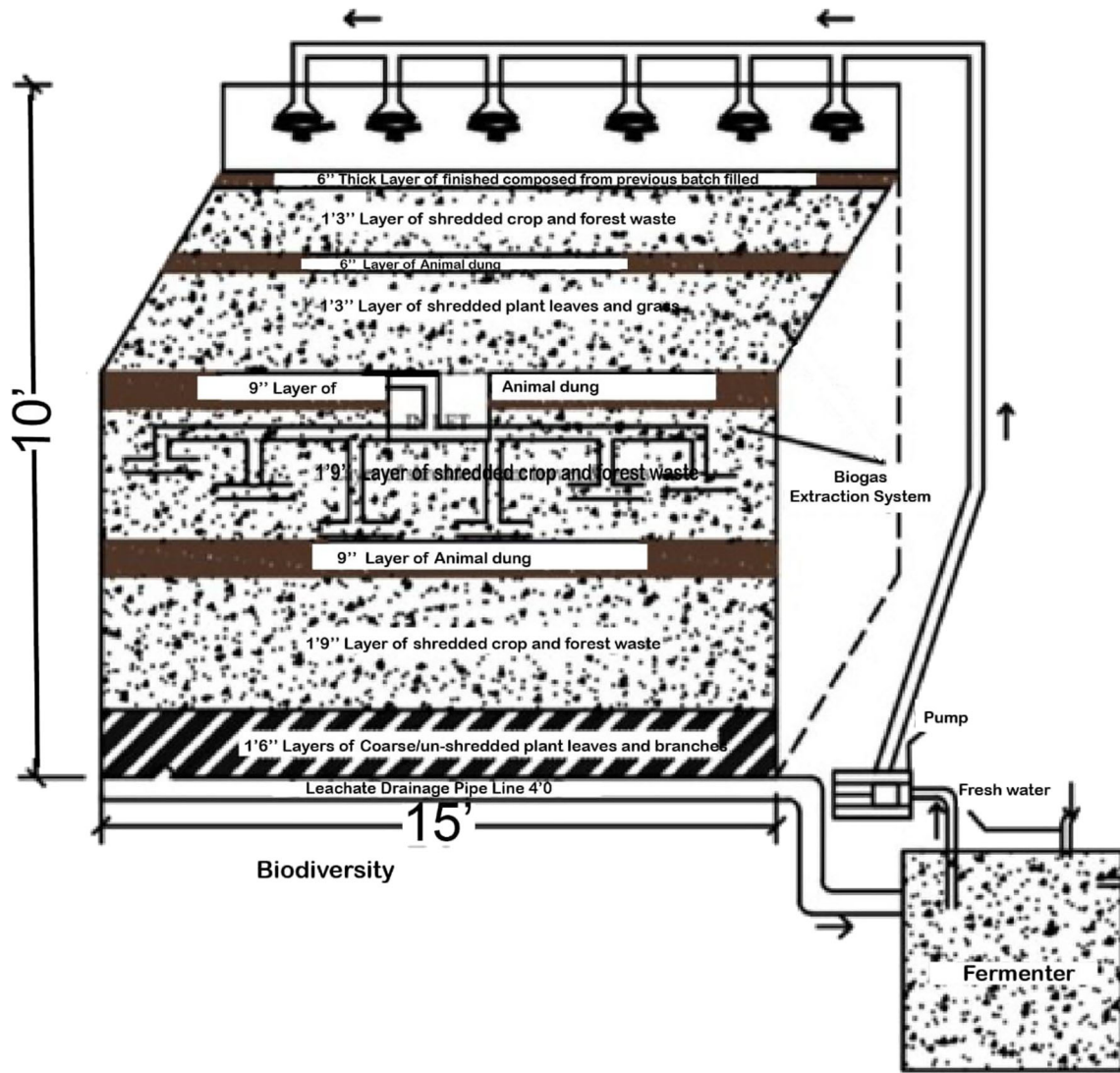


Fig. 1 Schematic diagram of organic waste compost digester

Phosphorus concentration on the spectrophotometer was measured at 410-nm wavelength and determined its concentration by fitting the reading in the calibration curve (Eq. 1). Olsen phosphorous was measured as mentioned [16]. The blue color intensity method was used to measure water-soluble phosphorous and citric acid-soluble phosphorous using spectrophotometer [17]. Potassium content was measured directly by the flame photometer (JENWAY PEP 7). Potassium readings obtained from flame photometer were fitted into the calibration curve. In this way the final potassium value of digested filtrate was obtained (Eq. 2).

$$P = \text{mg kg}^{-1} \text{ P (from calibration curve)} \times \text{Dilution factor} \tag{1}$$

$$K = \text{mg kg}^{-1} \text{ K (from calibration curve)} \times \text{Dilution factor} \tag{2}$$

The moisture content was measured by the oven dry method. Compost organic content (OC), total N, and moisture content (%) were determined in the laboratory before application in the soil. Compost OC was measured by Walkley and Black method [18] and total N by Kjeldahl method [19].

2.2 Field experiments

The field trials were performed at Rana Agric. Farm Jatoi, DG Khan. The research trial field was prepared equally and divided into 21 plots for seven farming treatments with three replications (Fig. 2). The dimension of each treatment plot was taken as 32 × 100 feet. Seven different farming treatments with fertilizer dose and description are described in Table 1. The weighed materials for under each farming treatment were distributed homogeneously in the soil by hoeing with the

Fig. 2 Experimental layout for seven different farming treatments

Field boundary								
Field boundary	Chemical fertilizer	Bio-fertilizer		Integrated fertilizer			Controlled	Field boundary
	RDF	Bio-F ₁	Bio-F ₂	Bio-F ₃	Bio-F ₄	Bio-F ₅	CK	
	Path							
	Controlled	Integrated fertilizer			Bio-fertilizer		Chemical fertilizer	
	CK	Bio-F ₃	Bio-F ₄	Bio-F ₅	Bio-F ₁	Bio-F ₂	RDF	
	Path							
	Bio-fertilizer		Chemical fertilizer	Controlled	Integrated fertilizer			
	Bio-F ₁	Bio-F ₂	RDF	CK	Bio-F ₃	Bio-F ₄	Bio-F ₅	
Field boundary								

rototiller [20]. One week later, sesame was planted so that the distance between the rows and over the row was 60 cm and 10 cm, respectively. Soil physical properties, bulk density, field capacity, wilting point, soil available moisture, soil porosity, and soil saturation, were measured after the application fertilizer treatments [21]. At crop maturity, the yield of sesame crop was from all treatments in kilogram per hectare.

2.3 Statistical analysis

Statistical analysis of collected data was performed by using SPSS-22 (SPSS, Inc., Chicago, IL, USA) statistical package by using (ANOVA) test and data was analyzed according to the completely randomized design (CRD). The mean difference was acknowledged at ($p < 0.05$) significance level.

3 Results and discussion

3.1 Temperature variation in composting material

Temperature indicates different chemical reactions during composting resulting the increase in the temperature

of compost material. The variations of ambient and compost temperatures are interpreted in Fig. 3. This study revealed the temperature of compost material in mesophilic (35–45 °C) and thermophilic (> 45 °C) stages. In the beginning, an increase in temperature had been observed after the arrangement of raw material in the compost digester. At 4th day of composting, the temperature reached the thermophilic range and decreased gradually from the thermophilic range to the mesophilic range till the 17th day of composting. Highest temperature (48 °C) was noted on day 13th against the ambient temperature (31 °C). The compost material was turned after every 15 days to aerate microbial activity inside compost material. This turning of material resulted in the fluctuation of compost temperature (Fig. 3) due to the mixing of compost layers having different temperature conditions. The temperature increased after every turning stage because of an increase in microbial activity which showed a higher rate of decomposition of compost material.

Temperature variation in the composting process determined the rate at which different bio-chemical activities occurred in compost material [22]. Rose in temperature of compost mixture up to thermophilic range considered as satisfactory regarding the killing of

Table 1 Fertilizer strategies, description, and their doses

Fertilizer material	Farming treatments	Description with dose
Bio-fertilizer (compost)	CK	Control (No fertilizer applied)
Chemical fertilizer (NPK)	Bio-F1	Compost (20 t ha ⁻¹)
	Bio-F2	Compost (30 t ha ⁻¹)
	Bio-F3	Compost (30 t ha ⁻¹) + ½ NPK
	Bio-F4	Compost (20 t ha ⁻¹) + ½ NPK
	Bio-F5	Compost (40 t ha ⁻¹) + ¼ NPK
	RDF	NPK Recommended (30 kg each)

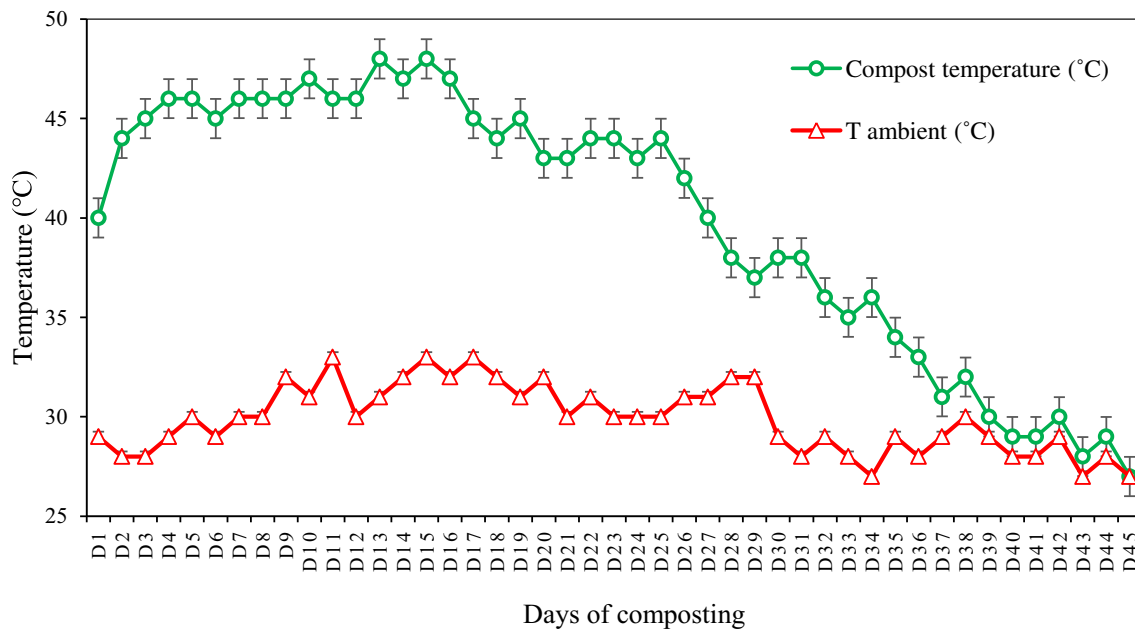


Fig. 3 Variation in compost material temperature and ambient temperature during composting process

pathogen and higher decomposition rate of organic waste [23, 24]. In this study, the temperature compost was in the thermophilic range and quickly increased in temperature was also observed as reported by Lopez-Gonzalez et al., [25] in green waste composting. The quick rise in compost temperature could be due to decomposition of low molecular weight elements present in compost mixture (crop waste) by microorganisms; a similar effect was reported by [26]. Sharif et al., [27] stated that high temperature in composting could be due to enhancing air-filled spaces through the turning of compost material, resulting in more O_2 for aerobic decomposition

3.2 Nutritional analysis of organic compost production

To investigate different physical and chemical characteristics of composting material, the nutritional analysis was performed during different stages of the composting process and at the maturity stage. The compost organic matter (OC) was 26.24%; total N (1.8%), C:N ratio (15.29), and moisture content were measured as 19.8%. The obtained values proved that the use of compost could enhance soil fertility. Zarina et al., [28] reported physiochemical characteristics of organic compost; moisture content (14.73%), total N (1.74%), OC (22.5%), and C:N ratio as (15.3).

Compost pH values varied slightly throughout the composting process (Fig. 4). Initially, pH varies from 8.44 to 8.71 during the 1st month of the composting process. After one month the pH of all the treatments decreased significantly during the 3rd month of the

composting (8.17) and continued till the maturity of the composting process (8.15). The electrical conductivity (EC) of composting material indicated the presence of soluble salts, either they are in high quantity or in low concentration. Initially, EC was 3.11 dSm^{-1} and showed a decreasing trend from the initial value. At compost maturity, EC (1.67 dSm^{-1}) was noted.

During all stages of the composting, EC values were found within the acceptable EC range ($< 4 \text{ dSm}^{-1}$). Total phosphorous (total P) content increased during the composting process in all the treatments. At the start of composting, the total P content ranged from 0.51 g kg^{-1} while after 30 days of composting, the total P content was 1.65 g kg^{-1} . At maturity of composting, the maximum total P content was noted as were noted at the start of composting. It ranged from 0.51 g kg^{-1} at 1st day to 2.06 g kg^{-1} at 90th days of composting. Water-soluble phosphorous (WSP) is one of the most important bio-available forms of P generally taken up by plants. Olsen phosphorous (Olsen-P) and citric soluble P are very important indicators of available P in compost prepared by different organic waste materials. WSP, Olsen-P, and citric soluble P contents showed increasing trend throughout the composting process. It ranged from (39 mg kg^{-1} , 0.85 g kg^{-1} , 0.41 g kg^{-1}) at 1st day to (73 mg kg^{-1} , 1.28 g kg^{-1} , 0.73 g kg^{-1}) at 90th days of composting. Total potassium (total K) content of compost was significantly increased with the progress of the composting period. Total K content varied from 0.73 g kg^{-1} at 1st day of composting to 1.95 g kg^{-1} on the 90th day of composting. At compost maturity, all the treatments showed increased total K content compared with the initial total K content. At the end of composting, the highest total K content (1.95 g kg^{-1}) was noted.

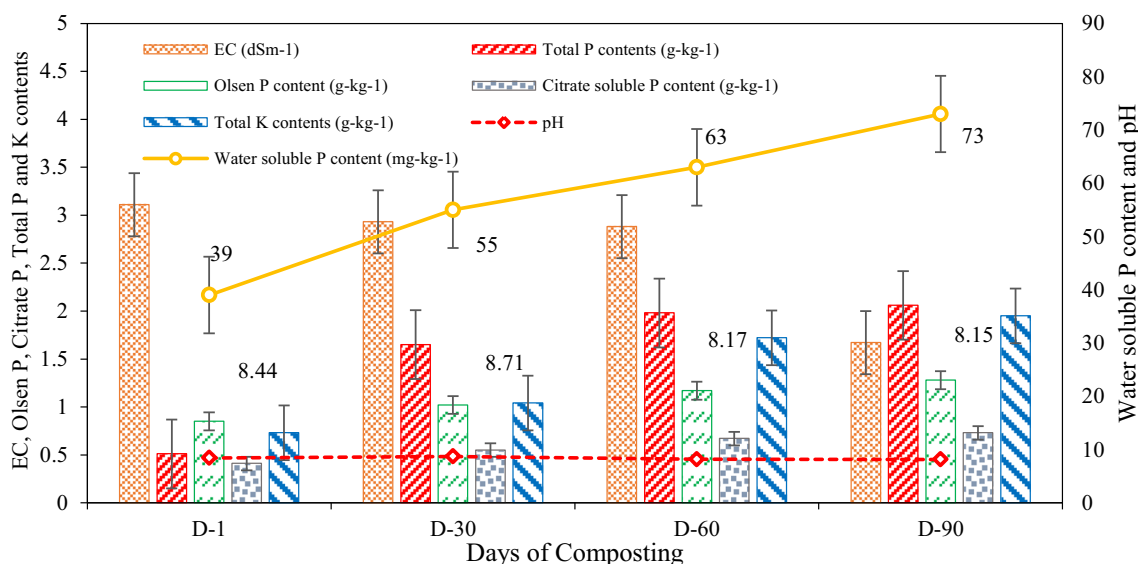


Fig. 4 Nutritional values of compost calculated at different stage of composting process

During the first 30 days of composting, pH showed an increasing trend. The similar pH trend in green waste composting was also reported Lopez-Gonzalez et al., [25] that the rise in pH during the initial stage was due to acid degradation organic waste and the release of different NH_4^+ compound during composting. Zhang and Sun [29] stated that the activities of microorganisms are significantly affected by pH, and a favorable pH value for optimal microbial activities was 7.5–8.5. In our research, pH values were in the optimum range for maximum microbial degradation throughout the composting process.

EC is the best indicator of soluble salts which are present in the form of carbonates, bicarbonates and sulfates of sodium, potassium, calcium, and magnesium. EC also specifies the quality of compost mixture because it revealed the salinity content of materials and correctness of compost for plant growth [30]. In our research, EC showed a decreasing trend during the entire process; a similar effect was reported by [23]. They reported that, treatments having high EC, showed low pH value and vice versa, it could be due to the release of acids and soluble salts. At maturity, all the treatments had EC in acceptable range (4 dSm^{-1}) [30].

Increased in total P content was due to the increased the decomposition process of organic matter during composting process. This increased in total P content was proportional to the decreased in organic matter during the breakdown of waste material as reported by Nishanth and Biswas [31]. Wei et al., [32] recognized as concentration effect as a result of the decomposition of organic C material in compost mixture, which reduced the volume of heap but maintained P content. They reported that it was due to the concentration effect as a result of organic matter degradation. WSP content was increased throughout the composting process. It could be due to release

of soluble P content due to the decomposition of organic material during composting process [33].

Higher Olsen-P content could be due to the release of other soluble content of P during the decomposition of organic waste material of the composting process as reported by Biswas and Narayanasamy [34] that was due to the presence of a larger quantity of total and available forms of P like citric acid-soluble and water-soluble P which showed the increased in Olsen-P content. During the decomposition process, different types of organic acids like acetic, citric, tartaric, gluconic, oxalic, and α -ketogluconic acids are generated. These organic acids are capable to dissolve organic minerals of P to inorganic compound, which could be plant available. Overall total K content was increased from initial to compost maturity. This increased in total K content was described by Bustamante et al. [35]. They reported that compost prepared from distillery and winery industries waste material showed an increase in the total K content from 32 to 46 g kg^{-1} from 0 day to compost maturity.

3.3 Soil characteristics analysis

3.3.1 Field capacity, wilting point, and soil available moisture

Soil structure, organic matter content, and total porosity are associated with many factors. Table 2 shows that the compost application has increased in the field capacity of the soil within the scope of soil available moisture content (MC). This is an expected situation because of the most important factors affecting the field capacity, which constitutes the upper limit of soil available moisture content are the amount of organic matter and soil structure [36].

Table 2 Variation in the field capacity, wilting point, and soil available moisture content under different farming treatments both before and after harvest

Farming treatments	Soil sample depth (cm)	Field capacity (%)			Wilting point (%)			Soil available moisture content (%)		
		Pre-sowing	Post-harvest	(%) change	Pre-sowing	Post-harvest	(%) change	Pre-sowing	Post-harvest	(%) change
CK	0–15	30.8 ± 0.5	30.4 ± 0.6	– 1.2	20.5 ± 0.5	20.4 ± 0.4	– 0.4	10.0	10.0	– 0.1
	15–30	31.6 ± 1.0	30.7 ± 0.3	– 2.8	21.2 ± 0.8	21.4 ± 1.3	0.8	10.4	9.3	– 10.2
Bio-F ₁	0–15	31.7 ± 0.5	32.2 ± 0.8	1.7	21.3 ± 0.7	21.5 ± 0.6	0.7	10.4	10.8	3.9
	15–30	32.1 ± 1.4	33.0 ± 0.9	2.9	21.9 ± 1.3	22.2 ± 0.3	1.5	10.2	10.8	5.8
Bio-F ₂	0–15	31.1 ± 1.0	32.1 ± 0.3	3.3	21.4 ± 1.2	22.1 ± 1.2	3.1	9.7	10.0	3.7
	15–30	32.0 ± 0.3	33.1 ± 0.3	3.4	21.7 ± 1.1	22.3 ± 0.5	3.0	10.4	10.8	4.3
Bio-F ₃	0–15	32.5 ± 1.6	34.3 ± 0.8	5.6	22.2 ± 0.9	22.8 ± 0.5	2.7	9.7	10.9	11.3
	15–30	31.8 ± 0.9	32.9 ± 1.5	3.4	21.7 ± 0.4	22.4 ± 0.4	3.2	10.1	10.7	4.1
Bio-F ₄	0–15	32.2 ± 0.1	33.7 ± 0.7	4.7	22.5 ± 1.5	22.9 ± 0.2	1.6	11.3	11.5	1.8
	15–30	32.0 ± 0.5	33.1 ± 1.2	3.4	21.8 ± 1.5	22.5 ± 0.9	3.1	10.2	10.5	3.7
Bio-F ₅	0–15	31.3 ± 0.8	32.6 ± 0.9	4.2	21.6 ± 0.6	22.1 ± 0.6	2.0	9.7	10.6	9.3
	15–30	31.2 ± 0.9	32.6 ± 1.5	4.8	22.1 ± 0.6	22.8 ± 1.3	3.2	9.1	9.9	8.7
RDF	0–15	31.2 ± 1.2	31.4 ± 1.2	0.8	22.1 ± 0.0	22.5 ± 0.3	2.0	9.1	8.9	– 2.2
	15–30	31.3 ± 0.9	31.9 ± 0.6	1.9	21.4 ± 0.5	21.9 ± 0.8	2.3	9.9	10.0	0.9

In control farming treatment (CK), a slight decrease in field capacity was observed after harvest, while a slight increase in field capacity was observed in chemical fertilizer (RDF) application. However, this increase in chemical fertilizer application was found to be considerably lower than the bio-fertilizer (Bio-F) treatments. Among bio-fertilizer farming treatments, the highest increase in field capacity was measured in Bio-F₃ application at a soil depth of 0–15 cm with 5.6%. Similarly, Hortenstine et al. [37] studied the compost applications of 0 t ha⁻¹, 16 t ha⁻¹, 32 t ha⁻¹, 64 t ha⁻¹, and 128 t ha⁻¹ for sorghum production in sandy soil. They investigated the effect of soil on the water-holding capacity; they reported that compost applications increased the water holding capacity of the soil and that the highest increase in field capacity was achieved in 2.45% to 128 t ha⁻¹ of compost application.

The wilting point is the value that forms the lower limit of useful moisture content capacity. According to another definition, the wilting point is water that can be held at a pressure of 15 bar. The water after this limit cannot be used by the plant [38]. Table 2 indicates that the wilting point values did not change significantly in terms of control while the bio-fertilizer application increased the wilting point. An increase was observed in the wilting point values with the increase in the amount of compost applied, and a decrease was observed in the compost applications higher as shown in Bio-F₅ treatment. In the RDF treatment where chemical fertilizer was applied, the wilting point values were lower than the general compost treatments but higher than the controlled (CK) farming treatments. Considering the values related to the wilting point in Table 2, the highest

increase was found in Bio-F₃ treatment with 2.7–3.2%. Similarly, Demir and Dogan [39] reported that despite the increase in the wilting point with compost application, these increases were not significant.

Since the soil available moisture content (MC) that the plant can use is the difference between field capacity and wilting point, it is affected by common factors affecting field capacity and wilting point [40]. As it can be seen in Table 2, there is no significant difference in the amount of available moisture content after harvest, but there has been an increase in the amount of available moisture content after harvest compared with the amount of available moisture content before planting within bio-fertilizer (compost) treatments. Increases in the amount of available moisture content after harvest were mostly achieved in Bio-F₃ and Bio-F₅ farming treatments. In chemical fertilizer treatment (RDF), it was found that there was no significant difference in the amount of available moisture content after harvesting. On the CK treatment, it was observed that there was no change in the amount of available moisture content at a depth of 0–15 cm and a decrease of 10% at a depth of 15–30 cm.

3.3.2 Bulk density and porosity

Plant roots cannot easily develop in clayey soils, it cannot have enough aeration conditions, and the ingress and movement of water into the soil are limited. For this reason, it is very important to reduce the volume weight in clay soils. Organic materials play a positive role in the development of the soil structure as their bulk density is low and application to the soil can reduce the bulk density of the soil. Farm manure

Table 3 Variation in soil bulk density and porosity under different farming treatments both before and after harvesting

Farming treatments	Soil sample depth (cm)	Bulk density (g cm^{-3})			Porosity (%)		
		Pre-sowing	Post-harvest	(%) change	Pre-sowing	Post-harvest	(%) change
CK	0–15	1.45 ± 0.03	1.43 ± 0.03	1.37	45.4 ± 0.2	46.1 ± 0.4	1.38
	15–30	1.52 ± 0.02	1.44 ± 0.01	1.36	44.7 ± 0.8	45.6 ± 0.8	1.87
Bio-F ₁	0–15	1.51 ± 0.02	1.31 ± 0.11	13.24	46.6 ± 0.6	49.6 ± 0.6	6.44
	15–30	1.41 ± 0.02	1.26 ± 0.06	10.63	48.1 ± 0.9	52.3 ± 0.8	8.51
Bio-F ₂	0–15	1.53 ± 0.01	1.28 ± 0.06	16.33	47.0 ± 0.9	51.8 ± 0.8	10.10
	15–30	1.41 ± 0.02	1.34 ± 0.06	4.96	46.2 ± 0.3	49.2 ± 0.7	6.44
Bio-F ₃	0–15	1.52 ± 0.06	1.34 ± 0.09	11.84	44.6 ± 0.4	49.5 ± 0.3	10.98
	15–30	1.42 ± 0.02	1.34 ± 0.01	5.63	46.2 ± 0.8	49.4 ± 0.4	7.08
Bio-F ₄	0–15	1.51 ± 0.05	1.34 ± 0.07	11.25	45.8 ± 0.8	49.4 ± 0.8	7.75
	15–30	1.50 ± 0.03	1.39 ± 0.04	7.33	44.5 ± 0.3	47.9 ± 0.7	7.52
Bio-F ₅	0–15	1.49 ± 0.05	1.34 ± 0.08	10.06	46.7 ± 0.4	50.2 ± 0.7	7.38
	15–30	1.53 ± 0.02	1.38 ± 0.04	9.80	43.9 ± 0.7	47.8 ± 0.6	9.05
RDF	0–15	1.44 ± 0.04	1.40 ± 0.05	2.77	46.3 ± 0.5	46.9 ± 0.6	1.49
	15–30	1.46 ± 0.01	1.43 ± 0.00	2.05	44.0 ± 0.4	45.9 ± 0.2	4.31

and green manure reduce the bulk density of the soil and increase the amount of water-resistant aggregates [41]. As seen in Table 3, post-harvest bulk density values decreased in all farming treatments. The volume weight values of the composted treatments were lower than those of the control and chemical fertilizers. In the experiment, it has been determined that compost applications reduce the volume weight more than control and chemical fertilizer applications. It is seen that this effect was achieved in Bio-F₁, Bio-F₂, and Bio-F₃ applications with 16.33% and the least effect were achieved with CK application with 13.24%, 1.36%, and 11.84%, respectively. In a similar study, Demir and Dogan [39] reported that garbage compost and barn manure applications slightly decreased the volume weight. Porosity is an important physical property in terms of water and air permeability in soils. Especially for plant root development, high porosity value is desired. In the research, compost application caused a significant increase on porosity. With the application of compost, the tightness in the soil profile is significantly reduced. The increases in control and chemical fertilizer applications and porosity were significantly lower than the composted parcels. The highest increase in porosity with compost application was determined on the Bio-F₃ parcel with 10.98%, and the lowest increase was found on the CK parcel with 1.38%. These findings of Fischer et al. [42] and Celik et al. [43] were supported by the results.

3.3.3 Soil saturation

Although it does not have a significant effect on the values, it is seen that the percentage of saturation

decreases with the application of compost. As seen in Table 4, the highest decrease was 2.66% in Bio-F₃ treatment at 0–15-cm soil depth. The lowest reduction in the percentage of saturation was determined in 0–15-cm soil depth of parcel CK (0.46%). The only increase in saturation was observed in CK and RDF treatments.

3.4 Crop yield

Compound material of agricultural leftover origin applied to the experiment significantly increased the yield of the sesame plant. This can be explained by the fact that organic fertilizers increase the physical, chemical, and biological efficiency of the soil. The yield was 462.1 kg ha⁻¹ in the Control (CK) treatment, while the yield in the RDF treatment was 625.3 kg ha⁻¹, the highest yield was obtained from the Bio-F₃ treatment (805.1 kg ha⁻¹). Compared with the applied compost doses, RDF, and control (CK), the highest yield increase (74.5%) over the controlled treatment (CK) was observed in Bio-F₃ application and the lowest yield increase over CK was in RDF application with 34.4% (Fig. 5). Treatments Bio-F₁ and Bio-F₅ did not show any significant change in sesame yield from the chemical fertilizer treatment (RDF) in local conditions. The results were not only related to the nutrient content of the compost but also to improve the physical and biological properties of the soil. In the applications of integrated treatment Bio-F₃ (30 t ha⁻¹ + 50% RDF), the yield was highest followed by Bio-F₄ (20 t ha⁻¹ + 50% RDF).

This result indicates that the compost changes the soil structure in a good way, but in compost applications over 30 t ha⁻¹, there was no further improvement found in soil

Table 4 Changes in saturation values of soils before and after harvest

Farming treatments	Soil sample depth (cm)	Saturation (%)		
		Pre-sowing	Post-harvest	(%) change
CK	0–15	63.0 ± 2.65	64.0 ± 1.00	0.39
	15–30	64.6 ± 1.53	64.3 ± 1.53	– 0.46
Bio-F ₁	0–15	65.3 ± 0.58	64.3 ± 2.31	– 1.53
	15–30	64.3 ± 1.15	60.6 ± 1.15	– 1.08
Bio-F ₂	0–15	66.4 ± 2.65	62.6 ± 1.15	– 1.20
	15–30	68.3 ± 1.15	63.3 ± 2.08	– 1.46
Bio-F ₃	0–15	65.6 ± 1.53	63.6 ± 1.53	– 2.66
	15–30	66.3 ± 2.89	65.3 ± 1.65	– 1.50
Bio-F ₄	0–15	68.3 ± 1.53	64.6 ± 2.52	– 2.48
	15–30	65.6 ± 2.52	62.6 ± 1.53	– 2.51
Bio-F ₅	0–15	66.3 ± 1.53	63.3 ± 1.48	– 2.33
	15–30	61.6 ± 2.52	59.3 ± 1.15	– 2.11
RDF	0–15	68.0 ± 1.00	68.6 ± 0.56	0.88
	15–30	67.6 ± 0.58	68.3 ± 0.58	0.44

properties with the increase in the amount of compost. This result indicated that compost applications higher than the ideal dose decreased the improvement in soil properties in the early period possibly due to mulch formation. In a similar study, Erhart et al., [44] reported that the 10-year average yield increase in potatoes and different cruciferous cultivars under 9, 16, and 23 t ha⁻¹ of compost applied per year were 8, 7, and 10, respectively. In another study related to compost, Li et al. [45] examined yields obtained over the years in the second crop corn-wheat rotation; it was seen that the compost had an effect on the yield in the first and second years and lost its effect in the third year. For this reason, 30–40–50 t ha⁻¹ compost

applied at one time is effective during three production periods. They recommended applying 30 t of compost for three production periods.

4 Conclusion

This study was conducted to investigate the effects of different sole organic waste compost and inorganic fertilizers and also their integrated combinations on sesame yield and some soil physical properties. The nutritional values of compost production were evaluated before the application into the soil. The highest yield (805.1 kg ha⁻¹) was obtained in integrated

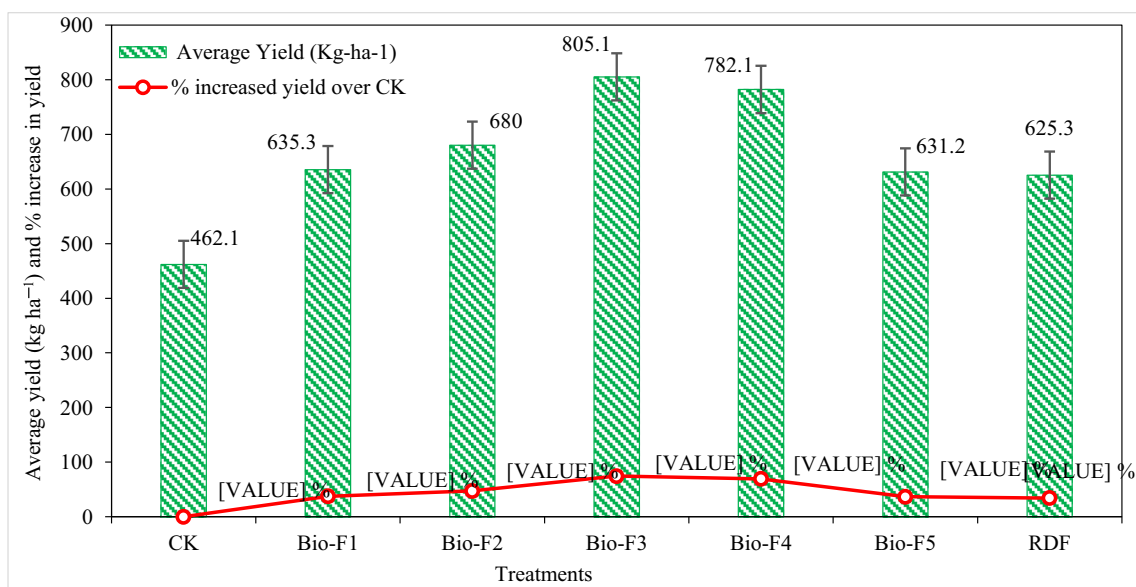


Fig. 5 Sesame yield measured under different farming treatments

fertilizer farming treatments ($30 \text{ t ha}^{-1} + \frac{1}{2}$ dose RDF) application, followed by ($20 \text{ t ha}^{-1} + \frac{1}{2}$ dose RDF) application (782.1 kg ha^{-1}). The lowest yield was obtained from the control treatment with 462 kg ha^{-1} . The effects of different doses of compost on soil properties were found to be positive and at different levels. Significant increases in field capacity, wilting point, and soil available moisture were determined with compost applications, while bulk density was reduced significantly in composted treatments. The highest increase in field capacity and soil porosity was realized in Bio-F₃ farming treatment compared with all other treatments of this study, and the highest reduction of bulk density was detected in Bio-F₂ treatment. It was observed that compost had a positive effect on some physical properties of the soil, as found in similar studies. However, long-term studies are required to see the effects of organic materials applied more clearly and to evaluate many organic materials nationwide have the potential to correct the physical, chemical, and biological properties of soils.

Acknowledgments The authors acknowledge the PMAS-Arid Agriculture University Rawalpindi, Pakistan, for the research facilities. The authors are thankful and acknowledged the Northeast Agricultural University, Harbin, China, for their technical scientific support.

Authors' contributions Rana Shahzad Noor conceived the conceptualization of research study, design and development of the experiment, data collection, formal analysis, investigation, methodology, visualization, writing an original draft, reviewed, supervised, and write-up editing. Fiaz Hussain, Muhammad Umair, and Irfan Abbas contributed in data collection, formal analysis, investigation, methodology, visualization, and writing an original draft. Yong Sun supervised the entire research work and contributed as internal reviewer for the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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