ACADEMIC RESEARCH and REVIEWS in AGRICULTURE, FORESTRY and AQUACULTURE SCIENCES

EDITOR

Assoc. Prof. Dr. Atilla ATIK Ph. D

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EDITOR:

Assoc. Prof. Dr. Atilla ATIK Ph. D

Academic Research and Reviews in Agriculture, Forestry and Aquaculture Sciences,
Editor: ***Assoc. Prof. Dr. Atilla ATİK***

Editor in chief: Berkan Balpetek
Cover and Page Design: Duvar Design
Printing : First Edition-Mayıs 2021
Publisher Certificate No: 49837
ISBN: 978-625-7680-76-9

853 Sokak No:13 P.10 Kemeraltı-Konak/Izmir/ Turkey
Phone: 0 232 484 88 68
www.duvaryayinlari.com
duvarkitabevi@gmail.com

Printing and Binding: Vadi Grafik Tasarım ve Reklamcılık Ltd. Şti.
İvedik Org. San. 1420. Cad. No: 58/1
Yenimahalle/ANKARA
Phone: 0 312 395 85 71
Certificate No: 47479

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• Chapter-1 •

INNOVATIVE APPROACH FOR ENGINEERED WOOD PRODUCTS: SCRIMBER

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INTRODUCTION

Timber is a highly sustainable and efficient building material (Fink et al., 2018). However, timber in structural dimensions is a nonhomogeneous material that contains natural and artificial defects such as cross-grain, knots, zones with compression wood, oblique fibre orientation, and so on (Thelandersson 2003; Grippa 2009). Therefore, the strength of the timber decreases due to those defects. Engineered wood products (EWPs), also called composite wood, are the concept of manufacturing large timber elements from a range of derivative wood products which consists of wood veneers, chips, strands, and fibers bonded together by a structural adhesive. The reason for manufacturing EWPs is to obtain more uniform and stronger than conventional lumber (Guss 1995). EWPs can be divided into four main parts; Structural Composite Lumbers, Structural Composite Boards, Glued Laminated Timber, and Wood I-joist (Nelson 1997). Structural Composite Lumber (SCL) is manufactured by veneer sheets (laminated veneer lumber (LVL) or parallel strand lumber (PSL)) or strands (laminated strand lumber (LSL) or oriented strand lumber (OSL)) or other small wood elements (scrimber) with structural adhesives (Kurt and Çavuş, 2011). In general, there are three primary manufacturing methods to produce EWPs from a log: stranding, peeling, and sawing (AWC, 2004). However, although scrimber is a member of EWPs, the manufacturing process of scrimber is different than the traditional manufacturing process of EPWs as shown in Figure 1.

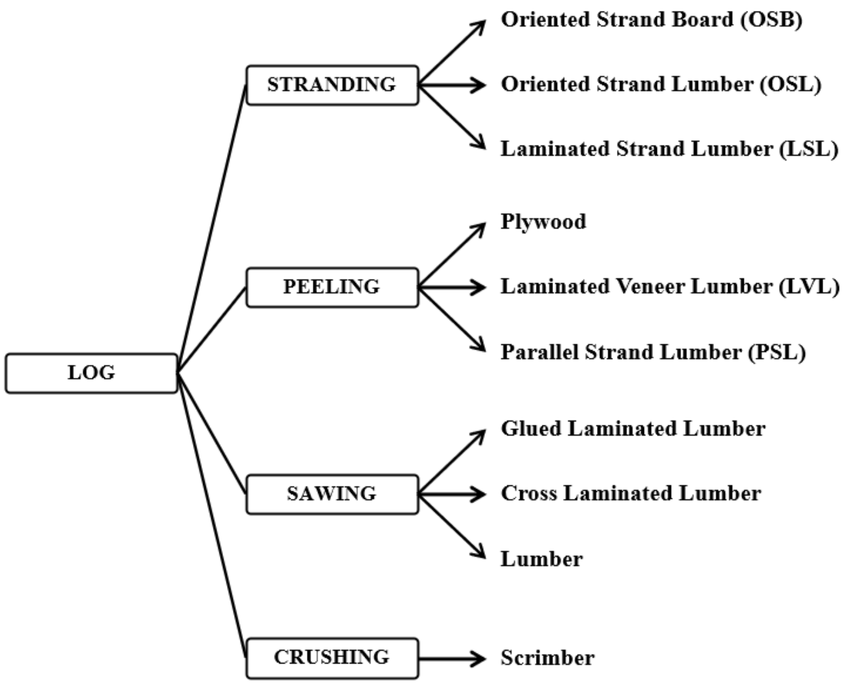
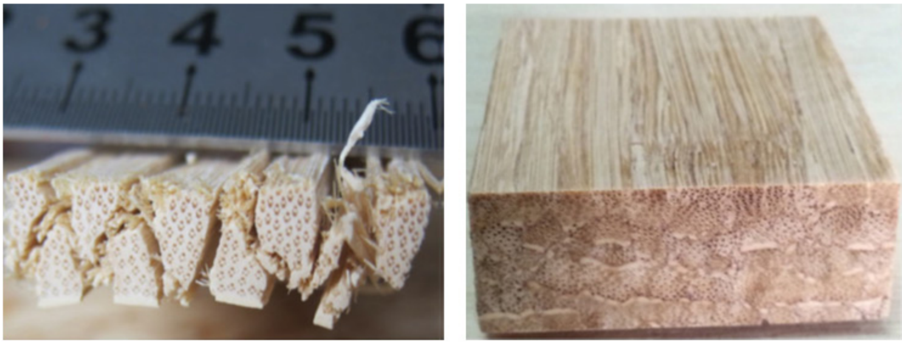


Figure 1 Manufacturing methods of engineered wood products (EWPs)

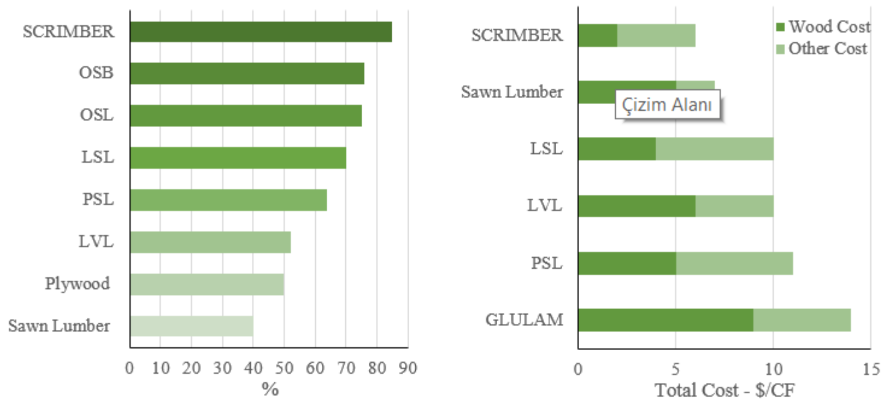
Scrimber is a new structural composite timber product (Linton et al., 2008) that was developed and patented in 1975 by Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. Scrimber was also produced with different names of TimTek (Barnes et al., 2010), Quetschholz (Joscak et al., 2006), Superposed Strand Timber (SST), and Scrimtec. Scrimber has the potential for structural applications because of its excellent mechanical properties (Huang et al., 2019). In the production process, a series of rollers are used to make whole-logs flat and split them into strands, then the strands are bonded together by adhesive and compressed to beams (Edgar 2003; Joscak et al., 2006; Barnes et al., 2010) as shown in Figure 2.



(a) (b)

Figure 2 Scrimber: (a) bamboo bundle and (b) bamboo scrimber (Yu et al., 2015)

It is possible to obtain larger-sized products in both width and length direction in scrimber production although the size of the structural materials produced from timber is limited. Fast-growing wood species, smaller logs, juvenile trees, crooked logs, and branches could be used in the production process. Scrimber is manufactured from fast-growing wood species such as poplar (Zhang et al., 2018), eucalyptus, bamboo (Chung and Wang 2018), aspen (Wei-zhu 2001), and mulberry branches (Yu et al., 2015). In recent years, researchers have shown a great interest in scrimber because it is an excellent SCL product that allows an impressive material utilization yield and lower manufacturing costs (Edgar 2003). Figures 3 and 4 show the comparison of material utilization yield and manufacturing costs for various SCL products, respectively. Scrimber uses wood fiber up to 90% which is much more efficient than sawn lumber (40%) and other types of EWPs (52% for LVL, 64% for PSL, 70% for LSL, and 75% for OSL). In the production of EWPs, although fast-growing wood species and small diameter of logs are used, other costs such as the cost of adhesive, labor, energy consumption affect the production costs of EWPs.



(a) **(b)**

Figure 3 Comparison of (a) material utilization yield and (b) manufacturing cost for various SCL products (Edgar 2003)

MANUFACTURING PROCESS OF SCRIMBER

Scrimber is a new engineered wood material developed in Australia with the idea of using fast-growing wood species and small diameter of logs (Linton et al., 2008). Small diameter of logs (10-20 cm), crooked logs, and branches that have non-commercial value in the production of scrimber provide a competitive advantage, unlike other SCL products (Edgar 2003; Weight 2007). Scrimber is a unique SCL product that minimizes all wastes, except the bark. About 90 percent of the log is utilized compared with the 40 percent utilization obtained in the production of sawn lumber. Scrimber that is manufactured from the small diameter of logs is a valuable product with consistent density, high strength and stiffness, good fastener holding properties, and smooth surface (Weight, 2007). In the manufacturing process of scrimber, various wood species have been used such as aspen (Wei-zhu 2001), dahurian larch (Wei-zhu 2001), mulberry (Yu et al., 2015), poplar (He et al., 2016; Zhang et al., 2018), bamboo (Chung and Wang 2018), radiata pine (Weight 2007). The main production method of scrimber includes crushing, drying, resin application, forming, hot-pressing, and cutting and finishing as shown in Figure 4.

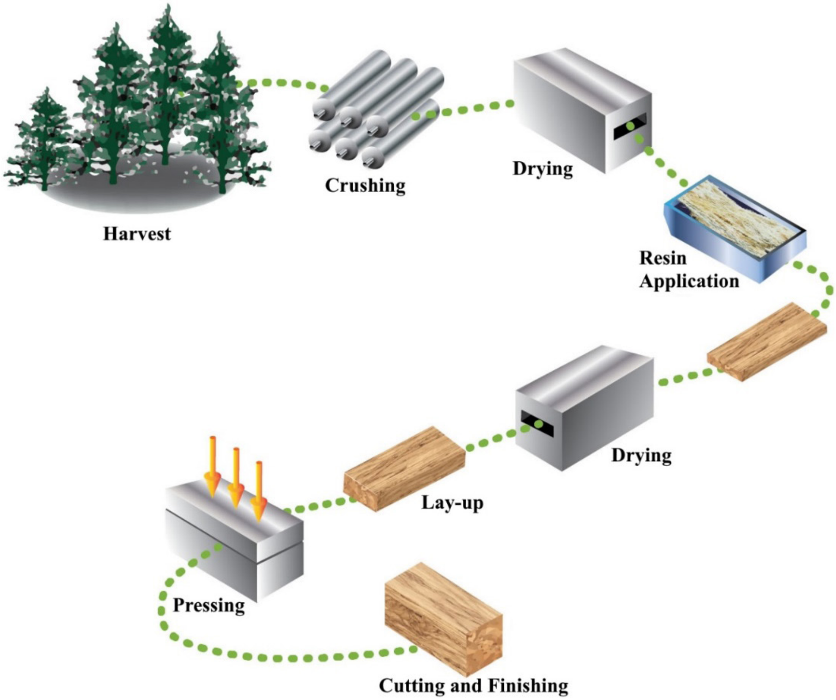


Figure 4 General manufacturing process of scrimber (URL, 2019)

In the manufacturing process, the logs are first debarked because the bark that serves as a protective layer around the log has lower specific gravity, short fibers, and low strength (Suchsland and Woodson 1987). Then the log passed through a series of rollers with different height levels to obtain mats of interconnected strands in the longitudinal direction as a result of being crushed as shown in Figure 5. In the crushing process, the first roller just applies enough pressure to crack the log. Then, the logs are passed through the rollers with different height levels. The last roller separates the cracked fiber into multi-strand mats (Linton et al., 2010). These rollers produce the mat with a thickness of 6-7 mm and a length of 2.1-2.4 m (Linton et al., 2008; Barnes et al., 2010).

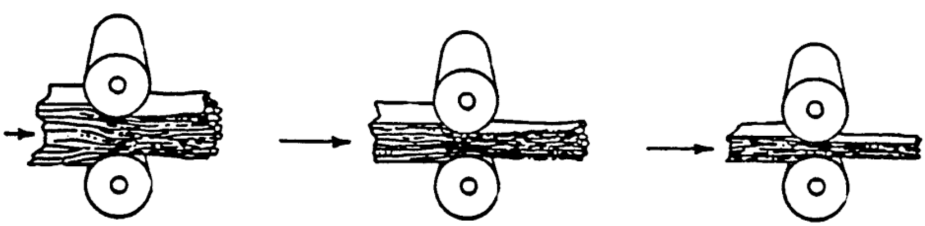


Figure 5 Principles of the crushing process (Stickland 1994)

After crushing the mats, they are dried, and the moisture content (MC) is ranged from 3 to 15% as shown in Table 1. Table 1 shows the characteristics of the material production for Scrimber, TimTek, Quetschholz, and SST. In the production of Scrimber and TimTek, the dried mats are immersed into a glue basin for 5 to 20 seconds whereas the glue is sprayed onto the mats in the production of Quetschholz and SST (Joscak et al., 2006). Structural adhesives such as phenol-formaldehyde (PF) and melamine-formaldehyde (MF) resins are mainly used in SCL products due to the requirements of strength (Moody et al., 1999). However, urea-formaldehyde (UF) or tanin-formaldehyde (Tanin-F) resin, which is a type of semi-structural adhesive, was applied to the original production of scrimber (Hutchings and Leicester 1988; Joscak et al., 2006).

Table 1 Characteristics of the material production (Joscak et al., 2006)

	Scrimber	**TimTek**	**Quetschholz**	**SST**
Moisture Content (%)	5	-	6	3-15
Glue Type*	UF/ TaninF	PF	PF (IC)	PF (IC)
Glue Content (%)	5-12	10-12	10-20	5
Press	RF platen-press	steam-injection	platen-press	steam-press
Press Temp. (^{o}C)	20-60	140	20	10-25
Density (g/cm^3)	0.540-0.670	0.688-0.720	0.700-0.750	0.460-0.660
Thickness Swelling (%)	5-20	8-12	10-18	27-41

*UF: urea-formaldehyde, Tanin-F: tanin-formaldehyde, PF: phenol-formaldehyde, IC: isocyanate

After the resin application, the mats are pressed at 4.0 MPa (Wei-zhu 2001) for a pressing time of 1 min/mm. However, the curing temperature can change based on the types of adhesive and press that are used (Table 1). Several types of heating press are used in SCL production: hot oil, steam injection, radio frequency (RF), and microwave (Edgar 2003). The glue is cured by RF platen-press in the scrimber process whereas a steam-injection, platen-press, and steam-press are used in the production of TimTek, Quetschholz, and SST, respectively. RF heating has two main advantages: reducing curing time and uniform heat distribution throughout the mats (Edgar 2003).

PHYSICAL AND MECHANICAL PROPERTIES OF SCRIMBER

Scrimber shows excellent mechanical performance and improved behavior in water absorption and swelling as a construction material. Some studies have investigated the effect of factors on the physical properties of scrimber (Chung and Wang 2018; Guan et al., 2012; Yu et al., 2015; Yu et al., 2017; Zhang et al., 2017). It was found that the water absorptions decreased with increasing resin loadings (Yu et al., 2017) and densities (Kumar et al., 2016). Yu et al. (2015) investigated the water absorption and dimensional stability of a bamboo scrimber with different loadings of phenol-formaldehyde (PF) resin. The results showed that the water absorption, thickness, and width swelling behavior of the scrimber significantly improved when the resin loading was increased.

Yu et al. (2017) found that the thickness and width swelling behavior of the scrimber were affected more by resin loadings whereas the water absorption and mechanical behaviors were affected more by densities. The influence of density on the mechanical and water absorption properties of bamboo scrimber was studied by Kumar et al. (2016). Based on the results, the tensile, compressive, bending strength, and water absorption significantly improved with increasing density. Wei-zhu (2001) and He et al. (2016) mentioned that the mechanical properties of scrimber such as bending strength (MOR) and modulus of elasticity (MOE) have higher than those of particleboard and medium-density fiberboard. The mechanical properties of scrimber boards produced from mulberry branches were investigated at five density levels (ranging from 0.81 to 1.24 g/cm3) by Yu et al. (2015). According to the results, the mechanical properties of the scrimber improved by increasing the density and the maximum values for MOR and MOE obtained when the density ranged from 1.02 to 1.10 g/cm3. He et al. (2016) compared the mechanical performances of the scrimber manufactured from poplar wood with other species or products such as sitka spruce, spruce-pine-fir (SPF) glulam, and douglas-fir LVL. The results show that the compressive and tensile strength of the scrimber were significantly larger than the others in the parallel- and perpendicular-to-grain directions. Comparisons of some mechanical properties of the scrimber with LVL, OSL, and PSL are shown in Table 2.

Table 2 Comparisons of some mechanical properties of the scrimber with other products

Product*	Wood Material	Density (g/cm^3)	MOR (MPa)	MOE (MPa)	Reference
Scrimber	Aspen	0.931	83.26	8,690	Wei-zhu (2001)
	Dahurian larch	1.063	89.93	11,901	Wei-zhu (2001)
	Mulberry	1.240	118.80	14,780	Yu et al. (2015)
	Poplar	0.885	140.00	22,310	He et al. (2016)
	Bamboo	1.020	173.00	16,900	Chung and Wang (2018)
LVL	Rubber	0.718	86.00	9,218	Kamala et al. (1999)
	Poplar	0.590	104.70	9,500	Shukla and Kamdem (2009)
OSL	Bamboo	0.820	61.00	11,109	Malanit et al. (2011)
PSL	Bamboo	0.730	133.00	12,300	Ahmad and Kamke (2011)

*LVL: laminated veener lumber, OSL: oriented strand lumber, PSL: parallel strand lumber.

CONCLUSION

Effective utilization of natural resources has become inevitable. Many factors such as the removal of knots and fiber curls that limit the structural use of wood materials during production, being more homogenous than solid wood, and having predetermined resistance properties, reveals the importance of scrimber production. In addition, the effective use of small diameter of logs or even branch woods in the production of EWPs makes this product superior compared to other engineering products. However, scrimber production has some disadvantages: the crushing rate of different kinds of trees varies based on their density, the growth of some tree species with irregular fiber structure, significant damage to wood fibers during crushing, and special equipment needed for production. For the production of scrimber, it is necessary to examine different kinds of wood materials and to eliminate the disadvantages of the work. For this purpose, it is required to support the relevant academic researches, to facilitate for their widespread use in the structural area, and to investigate the estimated market shares.

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• Chapter-2 •

RECYCLING of SEWAGE SLUDGE in AGRICULTURE

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Waste Problem

With the transfer of settlements from rural to cities and increasing industrialization, waste has become a big problem for humanity. Reducing the wastes generated and searching for environmentally friendly and economical recycling of these wastes are among the priorities of our age. The efforts to increase environmental awareness in the society and the solid waste recycling facilities established made the cities' garbage problem manageable even if it is not a complete solution. However, another aspect of the problem is waste water. It is known that discharging these waters, which can be of domestic and industrial origin, to receiving environments such as seas, lakes and streams without any treatment may cause serious environmental and health problems (1, 2). For this reason, waste water treatment plants serve the society in order to eliminate the negative effects that may be caused by the discharge of domestic and industrial waste water to receiving environments. These facilities are projected according to the characteristics and amount of wastewater targeted to be cleaned (3). Wastewater treatment plants, the first examples of which we encountered in the beginning of the 20th century, are in a much better place today with the contribution of increasing knowledge and technological opportunities. Today, a significant part of the wastewater of modern cities is treated and discharged from these facilities.

Sewage Sludge

However, the increasing number of facilities significantly solves the wastewater problem and brings about a new problem awaiting a solution. As a result of the treatment of wastewater at the facility, a new waste material called sewage sludge accumulates. The amount of sewage sludge in the world is increasing day by day (4). It is known that this material may cause serious environmental problems if it is left to nature without any process due to its physical, chemical and biological properties (5). Since the main factor that determines the properties of sewage sludge is the source of wastewater, it is possible to generalize under three headings. These are: drinking water, waste water and industrial waste water sourced sewage sludge (6). Sewage sludgeconsist of solids that can spontaneously collapse during the treatment of domestic and industrial wastewater and substances that result from biological and chemical processes. The solid matter content may vary between 0.25% and 12%. The material has a fluid property in this state (7). The characteristics of the sewage sludge are determined by the pollution factors in the wastewater and the treatment process of the facility. These sludges are also called pre-sedimentation sludges that occur with the precipitation of suspended solids, chemical sludges that flocculate and precipitate during the process involving chemicals, biological sludges that occur in the biological treatment process, and alum sludges from drinking water treatment processes (8).

Sewage sludgehave different pollution loads at every stage they spend in waste water treatment plants. This situation causes the resulting sludge to differ. They are named as primary sewage sludge, secondary sewage sludge and chemical sewage sludge according to the stage they pass in the facility. Rather, in the primary stage of physical treatment, the solids and foam that can collapse are removed. The materials collected in the sedimentation pool bottom are called primary sewage sludge. In secondary treatment, active agents are microorganisms, and the transformation of organic substances into CO2 and biomass is achieved by bacterial growth. Thus, the biological oxygen requirement is met. The necessary oxygen is supplied to the system by air pumps. Since microorganisms take part in the process intensively, it is also called biological treatment (9). Aerobically digested sludge emerges at the end of the secondary treatment (10). The systems established in addition to secondary treatment processes to remove unwanted dissolved organic materials, metal salts and nutrients (nitrogen and phosphorus) that are formed as a result of physical processes, chemical processes and microorganism activities in the wastewater treatment process are called advanced treatment systems. For this purpose, with the addition of special chemicals to the targeted pollution, the pollution is separated from the water by chemical coagulation process and chemical sewage sludge emerge (11). Advanced treatment is necessary to ensure receiving environment discharge standards. The formation of ammonia and nitrate in the environment is toxic and nitrogen removal is a biological process that develops with nitrogen formation. Each step is carried out with specific bacteria and different conditions are needed for its development (12).

Sewage sludge emerges at the end of the wastewater treatment process as a liquid-solid mixture containing 0.25% to 12% solid matter by weight. This material, called raw sludge, is stabilized to a sufficient level with various methods in order to reduce its negative properties such as organic matter content, pathogen contamination and odor problem, so that it can be stored and evaluated more easily before final removal. Sewage sludges that pass through this process are defined as stabilized sewage sludge (13, 14). By processing sewage sludge, reducing the damage to the environment as much as possible is as important as the treatment of waste water in terms of environmental health. For this purpose, sewage sludge are subjected to biological, chemical or heat treatment. Thus, the organic matter content is adjusted (transforming it into a more stable or inert organic and inorganic state), the species and number of pathogenic organisms are suppressed. While providing toxicity control, it is also aimed to reduce the odor problem and reduce the gas generation potential. For this purpose, after a series of biological or chemical treatments applied to the sewage sludge, the sewage sludge is stabilized (15). Commonly used methods for bio-stabilizing sewage sludge are aerobic digestion, anaerobic digestion, alkali stabilization and composting. Stabilization of sewage sludge using lime is one of the most preferred methods in chemical stabilization processes (16, 17).

Sewage Sludge Problem in Turkey and the World

According to the estimates of researchers Turkey in the amount of sludge is expected to occur in 2025 847 326 tonnes of dry matter per year while in 2040 this value was calculated to be 911 069 tonnes of dry matter (18). Another study, this value was estimated at 580,000 tons for Turkey in 2004 (19). When the dry matter production of sewage sludge of other countries is analyzed, it was 6.514.000 tons in the United States in 2004; Birezilya 372,000 tons in 2005; China 2,966,000 tons and Japan 2,000,000 tons in 2006; In 2008, it was estimated that Iran was 650,000 tons, Jordan 300,000 tons, Australia 360,000 tons and New Zealand 360,000 tons (19). The dry matter production of sewage sludge by the European Union countries as of 2010 was calculated as 8.909.000 tons (20). The current amount of sewage sludge emerging in the world and predictions about the future once again show the importance of sewage sludge.

Properties and Disposal of Sewage Sludge

When the multi-year data of wastewater treatment plants are examined, it is seen that the amount of wastewater treated in the world and in our country is increasing day by day. This shows that the amount of sewage sludge that needs to be disposed increases at the same rate (21). At this point, it is important to understand the properties of the material and the environmental effects of these properties in order to be able to dispose of the material in an environmental and economic way. The most important factors determining the properties of sewage sludge are the source of the waste water and the processes applied at the facility (22, 23). Approximately half of the costs of wastewater treatment plants are spent on safe disposal of the resulting sewage sludge (24).

Although the composition of the sewage sludge varies according to their sources and the stages they pass through during the treatment process, generally the prominent features of the sewage sludge; They are organic matter, nitrogen, phosphorus, potassium, calcium, toxic organic compounds, heavy metals and pathogens (25). Some of these substances are organic matter and plant nutrients with agricultural value, as well as unwanted contents such as heavy metals, organic pollutants and pathogens that restrict the disposal of waste. Leaving muds, whose risky properties are not reduced to acceptable limits, on the land unplanned may cause pollution of surface and groundwater together with the problem of malodor and pathogenic microorganisms (26). For the disposal of sewage sludge, application to soil, incineration, dumping into the sea or utilization as field filling material are among the methods used. However, it is important that the method chosen for the disposal of sewage sludge that increases day by day is sustainable. Among the options, applying the material to the soil often provides more advantages than alternative methods. It is economical and environmentally friendly for the method to provide a permanent solution in the long term and to restore the beneficial elements in the material to the soil. With the application of sewage sludge to the soil, the risks that may occur in the soil, water and living system should be evaluated carefully, if the current risk is within acceptable limits, it should be remembered that the application of the material to the land is one of the best methods (27, 28).

Many factors such as the fact that sewage sludge and soil properties are specific to the region, the difference of laws and regulations according to countries and technical possibilities make it impossible to choose a common method for the disposal of sewage sludge (29). Domestic wastewater generally has less risk than industrial wastewater. However, many of the pollutant microorganisms in domestic wastewater can be pathogenic for living things, as well as Coliform bacteria, which are indicators of contamination with human-sourced wastes. Algae density in these waters can cause serious odor problems from time to time. For this reason, an effective biological treatment process with bacteria and subsequent stabilization is essential (30). Industrial-sourced wastewater is water with less chemical pollution, relatively less organic material coming from facilities such as food, mineral, glass, textile, chemistry, petrochemical, leather, metal, furniture, machinery and spare parts industry (31). Chemical pollution can form acids, alkalis, metal salts, phenols, oxidizers, dyes, sulfates, hydrocarbons, oils, heavy metals, organic phosphorus and nitrogen, depending on the type of industrial facility from which the wastewater comes (32). However, the risk of encountering this type of pollution is low in sewage sludge obtained from facilities where heavy industrial waste water is not mixed or only urban waste water is treated. For this reason, it is known that pollutant concentrations are low in sewage sludge obtained from urban waste water treatment plants (33). The economical and environmentally friendly disposal of these sewage sludge is relatively easy.

The most frequently used methods for disposal of sewage sludge are incineration, landfill or land application. 40% of the sewage sludge emerging in European countries is disposed of in landfills, 37% in agricultural areas, 11% in incinerators, and 12% by other methods (34). In the first years of wastewater treatment plants, the sewage sludge, which emerged due to incomplete knowledge and experience, was poured into the seas all over the world. However, as the damage caused by this method to the environment and humanity has been realized over time, it has been less preferred and has been banned since January 1, 1999 (35).

Before the regular storage process, the water of the sewage sludge should be taken naturally or mechanically in order to use the existing storage area more economically and to keep the waste under control. The material should be laid in the storage area where necessary measures have been taken in terms of environmental health and safety and should be covered (36, 37). During the dewatering stage of the sewage sludge, 900-1300 kWh of energy is required for each ton of water to evaporate, depending on the drying technique, so dewatering is very costly for the facility (38). For this reason, the number of facilities utilizing solar energy has increased in recent years due to its economic and environmental advantages in sludge drying process (39). landfilling of waste in Turkey while 27 533 dated 26.03.2010 and published in the Official Gazette of waste should comply with the Directive on the Landfill (40). The European Union encourages the recycling of sewage sludge by using in the field. In the directive no 1999/31 / EC regarding the landfill of solid wastes published for this purpose, it restricted the disposal of wastes by burying more than 50% as of 2013 and 35% as of 2020 (41, 42).

Another method used in the disposal of sewage sludge is incineration. Sewage sludge is burned alone or with other materials in furnaces specially designed for this purpose. With the incineration process, the material becomes less dangerous and more stable, and a reduction of up to 90% in volume and 75% in weight can be achieved. The heat energy obtained by combustion is frequently used in electricity generation and recovery is provided (43). Denmark obtains 4% of the electricity it needs and 18% of the heat energy by burning waste in its 34 incinerators (44). the waste incineration process in Turkey 06.10.2010 date and must comply with the regulations published in the Official Gazette No. 27721. The calorific value of lignite coal used in power plants is around 4 Kcal / kg. Sewage sludge vary depending on the processes they undergo, but their temperature values vary between 6 Kcal / kg (raw pre-sedimentation sludge) and 3 Kcal / kg (anaerobic decomposed sludge) (45).

Disposal of Sewage Sludge by Applying to Soil

Disposal of sewage sludge, which accumulates day by day with the increasing number of facilities, without harming the environment is of critical importance for our world. Researchers state that when choosing the final disposal method for sewage sludge, the method chosen primarily must comply with the regulations. In addition, it is recommended to consider expectations such as compliance with local conditions, general acceptance by the society, minimizing energy need, and enabling material and energy recovery or re-evaluation (46). For this reason, with the economic advantage it provides among many methods used, the use of sewage sludge for agricultural purposes has recently become more preferred (47). Especially, domestic stabilized sewage sludge has a high chance of being used in agriculture (48). With the effect of the problems encountered in landfill and legal restrictions (such as the EU directive 1999/31 / EC), interest in studies and practices related to the agricultural use of sewage sludge has increased (49).

In order to prevent the unconscious use of sewage sludges, which show wide variation in chemical substance quality and quantity, in an area such as agriculture that may directly or indirectly affect the environment and human health, legal restrictions have been brought in the world and in our country based on scientific criteria (50). Limit values applied for the use of sewage sludge in agriculture vary according to states. For example, the United States of America (USA) regulates the relevant permissions according to the regulation called "Part 503 Rule" prepared by the US Environmental Protection Agency (US EPA) within the framework of the clean water law to regulate the application of stabilized sewage sludge to agricultural areas. In this law, limits are set for contaminating metals, pathogens and vectors are limited by standards (51). Similarly, on June 12, 1986, the Council of the European Union issued a regulation named "Sewage Sludge Directive for the Protection of Nature and Soil During the Use of Sewage Sludge in Agriculture (86/278 / EEC)" (52). With this regulation, the European Union proposes pollutant concentration ranges for the seven components in sewage sludge in order for the member countries to make their own standards. Each member state has the right to set standards for itself that are stricter than the recommended values. With this regulation published by the European Union, while encouraging the correct use of sewage sludge, it also aims to regulate its use in agriculture and prevent the harmful effects of sewage sludge on soil, plants, animals and humans. The use of sewage sludge in the soil in our country is regulated by the "Regulation on the Use of Domestic and Urban Sewage sludge in Soil" published in the Official Gazette dated 03.08.2010 and numbered 27661. All practices in this regard should primarily comply with this regulation (53).

Turkey has been determined that regulations compared to most tolerant country of sewage sludge for agricultural purposes in the United States on the use related to the agricultural use of sludge in the European Union and the United States (54). This situation shows that the risk perception regarding the use of sewage sludge in agriculture is the lowest in the USA compared to other countries. In Turkey in compliance with the relevant regulations in the current interval imposed for polluting elements in the EU's top official regulations adopted values. Thus, in Turkey and provide criteria related to the EU integration process as well as possible the possibility of the use of sewage sludge in agriculture is keeping quite extensive.

Advantages Provided by Application of Sewage Sludge to Soil

Sewage sludge have high organic matter (40-70%) and significant macro (N, P, K) and micro (Fe, Zn, Mn, Mo, Cu, B) nutrient content. For a long time, sewage sludge has been used as an alternative to fertilizer or as a support in agriculture. By giving the sewage sludge to the soil properly, both the final disposal of the material is provided and the input costs in agricultural production are reduced (55, 56). The macro and micro plant nutrients in the sewage sludge contain a useful fertilizer (57); The high organic matter content gives it a good soil improvement material. Due to its agronomic features, most authorities favor the use of these products in agriculture, and application of the material to the soil is becoming widespread in many countries (58, 59). It has been reported that cation exchange capacity increases with the application of sewage sludge especially in light textured soils (60). There are also studies showing that it prevents erosion (61).

In developed countries, after the contents of sewage sludge are determined in detail, it is used as fertilizer by taking necessary precautions for its safe use in agriculture (62, 63, 64). As of 1993, 33% of the sewage sludge emerging in America was used in the field. 67% of the sewage sludge used in the field was used in agricultural areas, 3% in forest areas, 9% in areas that need improvement, 9% in green areas, and 12% was packaged and sold. When we look at the use of sewage sludge in agriculture in the European example, we see that 37% of the sewage sludge emerging according to 1992 data is used in agricultural areas (65). The European Union environmental policy promotes the safe recycling of sewage sludge in agricultural land rather than regular storage or incineration disposal (66, 67). Spain, which has an important share in agricultural production in the world, recycles 64% of sewage sludge in agricultural production (68). According to 1990 data of sewage sludge, usage percentages in agriculture are as follows in other countries; Belgium 57%, Denmark 43%, France 27%, Germany 25%, Greece 10%, Ireland 23%, Italy 34%, Luxembourg 80%, Netherlands 53%, Portugal 80%, England 51% (69). utilization of sewage sludge in agriculture in Turkey is estimated to be about 5% -10% level (70).

The use of sewage sludge in agriculture is considered as organic material application containing plant nutrients. At this point, when the sewage sludge application to the soil and farm manure application are compared in general, it is seen that the nitrogen and phosphorus content of the sewage sludge is richer, but the potassium content is lower than the farm manure (71). With the use of sewage sludge in agriculture, physical and chemical properties of the soil can be improved for a limited time (72). Although the organic content of domestic sewage sludge varies according to the conditioning and sewage methods, it is generally more than 50% on dry basis. The organic matter content of the sewage sludge is a valuable resource for soil improvement. Research has shown that adding mud to the soil increases soil porosity, thus promoting soil porosity, which helps the soil-plant-water relationship (73). With the use of sewage sludge in agriculture, it has been determined that characteristics such as aeration in the soil, water holding capacity (74, 75), porosity, field capacity, useful water amount and aggregation percentage (76) improved.

Although sewage sludge are intended to be considered as fertilizer substitutes in agricultural production, the fact that the plant nutrient ratio they contain is different from the formulation of commercial fertilizers causes some difficulties in the use of the material. Unconscious application of sewage sludge to the soil may disrupt the N / K ratio against potassium. When planning sewage sludge applications, the plant nutrient content of the material should be determined and the amount of plant nutrients needed by the grown plant should be considered. If necessary, production should be supported by chemical fertilization (77, 78). Chemical fertilizers used in agricultural production contain different percentages of plant nutrients. The percentage distribution of N / P / K in the most consumed fertilizers is 8: 8: 8 and 5:10:10, respectively. The percentage of N / P / K in sewage sludge is lower than chemical fertilizers. Because sewage sludge loses some of the plant nutrients it contains as a result of the treatment processes it undergoes. The percentages of N / P / K in domestic sewage sludge are generally around 3: 2: 0 (79). Sewage sludge generally contain lower amounts of plant nutrients than chemical fertilizers. If the plant nutrients needed by the plant cannot be provided at a sufficient level with the application of sewage sludge, cells with high water content may be formed in the plant. This situation causes a decrease in protein content in plant tissues as well as decreases the disease-pest resistance of the plant (80). Sewage sludge generally contain 1–6% nitrogen in dry matter. Unlike chemical fertilizers, nitrogen in sewage sludge is in both organic and inorganic (ammonium, nitrate) forms. In order for the organic form of nitrogen in the sewage sludge to be taken up by the plants, it must be mineralized. This process depends on the stabilization method of the sewage sludge, climate, soil structure, microorganism activities and many other factors directly or indirectly, so it depends on time. This situation causes that all of the nitrogen in the material cannot be taken by the plant in the first year. Nitrogen release in the material may decrease and overflow over the following years (81). A similar situation is frequently encountered in farm manure applications. In a study investigating the effects of farm manure and chemical fertilizer on one-year turf (Lolium Multiflorum Lam.) Plant, chemical fertilizer applications and farm manure applications were compared. The results showed that the nutrients in chemical fertilizers affect the yield and quality of the plant in a shorter time compared to the farm fertilizer, since it can be taken easily and quickly by plants. The fact that the mineralization of the farm manure takes time allows the plants to benefit from only a part of the manure in the same year. On the other hand, due to the complexity of the factors affecting minarlisation, it is not possible to provide the plant with the nutrients required by the plant in a balanced way by using only farm manure (82).

Another agriculturally important plant nutrient in the sewage sludge is phosphorus. The phosphorus content of the material varies between 0.8% and 6.1% in dry matter. Phosphorus element, like nitrogen element, is found in both organic and inorganic forms in sewage sludge. Since some of the phosphorus contained in the sewage sludge is in an unsuitable form for the plant, the calculation is made by assuming that half of the available phosphorus is generally useful (81). Potassium content of sewage sludge is more limited than nitrogen and phosphorus contents. Generally, sewage sludges contain potassium at ratios ranging from 0.5% to 1% (83).

Risks of Applying Sewage Sludge to Soil

Plant, soil and climatic factors should be taken into consideration while planning the details regarding the use of sewage sludge in agriculture. While aiming to provide the soil with plant nutrients such as nitrogen and phosphorus in appropriate amounts, the limit values should not be exceeded (84). The application of high amount of sewage sludge to the soil, besides many undesirable effects, may cause bad odor problems due to the ammonia gas, which occurs intensively at the beginning with the decomposition of the material. It can also suppress the germination and development of the seed. In order to prevent this situation, especially excessive sewage sludge applications to the soil at one time should be avoided. As a precaution, sewage sludge can be applied to the soil some time before sowing the seeds (36). It is known that the application of organic matter to the soil provides a positive effect on the soil mirobial life (85, 86). Similar to other organic materials, sewage sludge increases soil microbial activity when applied in appropriate doses to the soil (87). It has been shown in many studies that excessive use of organic matter negatively affects microbial activity and mineralization of plant nutrients (88, 89,90). For this reason, it is critical to apply the sewage sludge to the soil in the right dose, as with other organic substances. In addition, excessive use of the material should be avoided, as the high nitrogen content of sewage sludges may cause nitrogen immobilization and nitrate accumulation. At this point, the sewage sludge being a waste material and distributing it free of charge to the farmer creates the risk of overuse. Studies conducted on the subject have shown that the costs of sewage sludge are very low compared to other agricultural inputs, causing the risk of uncontrolled delivery of this material to the soil at high rates. With such a wrong application, even the material whose content is the most suitable for the limit values is likely to cause heavy metal toxicity in the soil. Heavy metals can threaten the entire ecosystem, especially with the repetition of extreme practices, and there is a risk of passing on humans via the food chain (91). In materials with relatively high unit prices, such as vermicompost, the risk of excessive use is low as it will increase production costs. However, studies show that vermicompost, which is applied much less to the soil than sewage sludge, increases yield and quality even though it is used at low doses (92) and promotes soil microbial life (93).

Organic pollutant, pathogenic microorganism and toxic metal content are the primary features of sewage sludge that can be harmful to the environment. The risk factors contained in the material are the most important constraint that limits its disposal. The use of sewage sludge with high potential toxic element content or insufficient pathogen control in agricultural lands as fertilizer is a major risk in terms of environment and public health (94). It is possible to reduce the presence of organic pollutants and pathogens that limit the disposal of sewage sludge by composting, oxygen-free digestion and heat treatment applications in wastewater treatment plants. However, the sewage sludge inevitably contains heavy metals, as the heavy metals present in the wastewater eventually accumulate in the sewage sludge. The quality and quantity of heavy metals contained in sewage sludge depends on the source of the waste water. Heavy metals cannot be effectively removed or reduced from sewage sludge. For this reason, the most important factor limiting the disposal of sewage sludge, especially with soil applications, is the heavy metal content (95; 96). Heavy metal contents are of great importance in the application of treatment sludge to the land and for agricultural use. For this reason, the use of sewage sludge in Turkey published in the Official Gazette dated 03.08.2010 date and 27 661 "in the Regulation on the Use of Domestic Soil and Sewage Sludge" was organized. Heavy metal limit values in soil in Annex 1-A section of the regulation; In ANNEX 1-B section, the maximum permissible heavy metal limit values in stabilized treatment sludge that can be used in the soil are given (53).

There are more than 35 metals that are common in nature. Although a clear and complete definition is not made, the density of these metals is heavier than 5 g / cm^3 and the atomic number is greater than 20; Metals that cause toxicity and pollution are called heavy metals. There are 23 heavy metals (97). Lead (Pb), cadmium (Cd), chromium (Cr), iron (Fe), cobalt (Co), copper (Cu), nickel (Ni), mercury (Hg) and zinc (Zn) are heavy metals frequently encountered (98, 99). Heavy metals, which are mostly produced as a result of human activities, tend to accumulate in soil, sediment, clean water sources and sea water, so they can cause acute problems besides damaging the ecological balance (100).

Plants absorb plant nutrients from the soil quickly and efficiently, depending on their species, soil properties and some other factors. In this way, heavy metals are also taken into the plant. Some of the heavy metals are essential plant nutrients (such as Cu, Fe, Mn, Zn). While the plant needs these elements up to certain doses, they are adversely affected above the limit dose. Some of them (Cd, Cr, Hg, Pb, Ti) are elements that the plant does not need and cause toxicity even at low doses. These elements are dangerous to plants and other creatures that consume plants in toxicity doses. In order to understand the roles of heavy metals on metabolic events in plants, it is very important to understand the responses and adaptation mechanisms of plants to heavy metal stress. Events such as photosynthesis, transpiration, enzyme activity, chlorophyll biosynthesis, and germination that plants perform to maintain their vitality are adversely affected by the presence of heavy metals (101).

Studies have reported that heavy metals reduce the chlorophyll content in the plant, inhibit plant growth and respiration, change the structure of cell organelles, change the activity and amount of key enzymes in various metabolic pathways, thus causing metabolic disorders (102). If plants grow in soils with high heavy metal content, they are generally adversely affected by this situation. With the increased uptake of heavy metals by the plant, these metals bind to the sulfhydryl groups of the proteins, causing loss of function or deterioration of the structure. Thus, the absorption of essential elements (such as Zn, Mg, Ca and Fe) by the plant is not only prevented, but also the functions of these elements in the plant are interrupted. On the other hand, heavy metals can trigger the formation of free radicals or cause oxygen-dependent reactions and thus oxidative stress (103,104). The toxicity of metals disrupts the structure of proteins, nucleic acids, and fats by causing the formation of reactive oxygen species and eventually leads to cell death (105). Plants growing in soils with high heavy metal content have developed a number of mechanisms to overcome this adversity. For example; as a result of excessive heavy metal uptake into the plant and its transport to the plant upper organs; the shape of the cell periphery changes where mucilage is produced. In addition, passage through the endodermal caspari strip or cell wall is stopped. Plants with high heavy metal accumulation capacity carry heavy metals to their vacuoles, where they bind via organic acid, amino acid or metal-binding peptides, removing their toxicity (detoxification) (106).

Some physiological and molecular responses of plants against heavy metals can be listed as follows (107, 108):

1) Reducing uptake through extracellular secretion and binding to the cell wall.

2) Storage in vacuoles or tonoplasts.

3) Adding organic acids, amino acids, etc. to the structure of molecules.

4) Increasing the production of protein or antioxidative enzymes.

5) To carry out the modification and activation of metabolism in order to repair when the cell structure is broken and to ensure that the metabolic pathways are sufficiently functional

It has been determined that the bioavailability of cadmium, copper, nickel and zinc in soils treated with sewage sludge is higher than lead, mercury and chromium. However, even for mobile elements, it is stated that less than 0.05% of the amount of metal added every year with sewage sludge passes into the product. At the same time, sewage sludge has a different feature than most of the other heavy metal-containing sources, which is that the sewage sludge contains a significant amount of organic matter, adsorbents such as iron and manganese. Generally, zinc, copper and nickel are phytotoxic for plants before reaching a level that would harm human health in plant tissue, and also the phytotoxic effect of these three elements in the plant only occurs in acidic soils (29). With the decrease of soil pH, the amount of active aluminum increases significantly. The natural amounts of manganese, iron and aluminum in the soil are generally higher than the amounts to be applied with sewage sludge. The phytotoxic effect of aluminum and manganese is seen only in acidic soils. While acidification of the soil increases the concentration of heavy metals (such as Cd, Cr, and Pb) that adversely affect plant growth and development, it causes the concentrations of basic cations (such as Ca, Mg and K) to decrease (102). Therefore, soil pH and lime level are an important soil feature when deciding on the application and application dose of sewage sludge.

Conclusion

Although the final material from the waste water treatment plant is named with a single name, the sewage sludge differs from each other under the influence of many factors such as the quality of the waste water, the facility's technology, stabilization and drying processes. This situation inevitably customizes the chemical composition of the sewage sludge. It is known that even sewage sludge from the same facility in different periods can differ significantly. On the other hand, soil characteristics and the needs of the plant to be grown have a say on the final success of the applications. When all these factors are evaluated, it is not possible to make a generalization about the application of sewage sludge to the soil and to present a valid prescription under all conditions. For this reason, chemical analysis of the sewage sludge and the soil to be applied should be done. The appropriate sewage sludge dosage should be determined by considering the plant needs. If needed, it should be supported with chemical fertilizer applications. In this way, sewage sludge, an important source of organic matter and plant nutrients, whose disposal becomes a problem, will find an opportunity for economic and environmentally friendly gain in agriculture.

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• Chapter-3 •

EVALUATION of the EFFECTS of ORGANIC AMENDMENTS on SOIL MICROBIAL DYNAMICS in TERMS of SUSTAINABLE SOIL FERTILITY

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INTRODUCTION

The most important component that gives fertility to soils is organic matter. Soil organic matter is defined as mixing of plant and animal tissue residues with the soil, decomposition under various factors, mineralization and transformation into new organic compounds (1, 2). Soil organic matter is an absolutely necessary substance for soil biology and especially microorganisms. On the one hand, it improves the physical properties of the soil and prepares the most suitable living environment for living things, on the other hand, it serves as a source of food and energy (3). It has long been known that organic amendments (organic fertilization material/organic fertilizer) positively affect the physical and chemical properties of the soil (4). Studies conducted in different parts of the world have shown that organic fertilizers improve soil properties and increase the yield of crops (5, 6, 7). In addition, these fertilizers stimulate the biological activity in the soil at significant levels. Some studies were carried out on the effects of organic fertilizers on C and N mineralization in soil (8), microbial groups (9) and enzyme activity (10). Reganold (11) found that organic fertilizer applications significantly increased the amount of biomass, which is an important microbial parameter, as well as the physical and chemical properties of soils.

In the case of organic fertilizers applied alone or in combination with chemical fertilizers, it was demonstrated in detail with the studies that the physical and chemical soil properties improve together with the plant yield (12). However, it is noteworthy that there are fewer studies on the effects of organic fertilizers on soil biology, which is one of the most important indicators of soil fertility. With this review, made in order to better understand the importance of the subject, the effects of some organic fertilizer applications on the microbial dynamics of the soil were evaluated. In this way, it is underlined that sustainable soil fertility should not be understood as simply enriching the soil with nutrients.

Sustainable soil fertility and soil microbial dynamics

Among the most important components of soil fertility, besides available plant nutrients, the amount of organic matter and the diversity, number and activity of microorganisms are also included (13). The microorganism diversity, number and activity of the ecosystem in which the plant root is located in the soil is called "soil microbial dynamics" (14). Three main groups constitute the soil organic matter, which is closely related with this microbial dynamic. These are dead organic matter (humus), plant roots and edaphone (living part) (Figure 1).

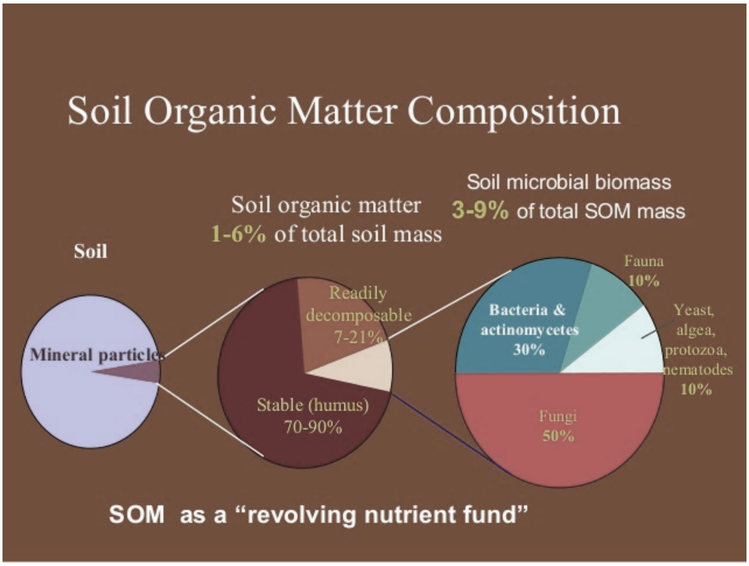

Figure 1. Soil organic matter composition

The dead part of the soil organic matter and the living part consisting of microorganisms are in constant interaction and activates the microbial dynamics. The healthy functioning of this dynamic structure essentially represents soil fertility. Microorganisms, which play an active role in maintaining soil fertility, are the drivers of nutrient cycles, which are of great importance for all living things. Soil microorganisms have to obtain the nutrients necessary for them from the organic substances in the environment. As long as the nutrients in plant and animal wastes falling into the soil remain in high polymer compounds, higher plants and microorganisms cannot directly benefit from them. In order for microorganisms to benefit from organic substances with large molecules in the soil, they must release their enzymes and break these compounds down into simple compounds large enough to absorb them. With these responsibilities, soil microorganisms provide the conditions necessary for the continuity of the nutrient cycle and soil fertility.

The effects of organic fertilization materials on soil microbial dynamics

In order to ensure sustainability in soil fertility, methods that improve soil quality are needed. One of these methods is to increase the presence and activity of beneficial microorganisms in the soil with organic fertilizers. Organic fertilizers applied to the soil increase soil fertility and microbial diversity by enriching organic matter and prevent soil pollution by reducing the need for chemical fertilizers. Therefore, organic fertilizers are economical and widely effective fertilizers, and their use should be expanded to maintain soil fertility (2). It is known that farmyard manure (cattle, cow, sheep, goat etc.) and chicken manure are used by many farmers in order to maintain soil fertility by contributing to the amount of organic matter in the soil, while some farmers use compost obtained from waste. In addition, recently, leonardite and partially sewage sludge were used.

Farmyard manure

The farmyard manure, which is rich in organic and mineral substances, consists of solid and liquid feces of cattle and sheep and herbal materials used as bedding. Generally, it occurs as a result of maturing animal feces under farm conditions. However, recently, farmyard manures are produced as fermented by the activities of commercial enterprises engaged in agricultural production (15). These manures are important resources that should be evaluated for the fertility of soils (Table 1).

Table 1. Properties of farmyard manure from some farms in Turkey (15)

	pH	Organic matter %	N %	C:N
Mean	7.62	77.80	1.17	27:1
Max.	8.48	85.58	1.88	43:1
Min.	6.62	62.48	0.72	20:1

Since farmyard manure constitutes an energy source for heterotrophic microorganisms, it also positively affects the biological properties of the soil. Many studies were carried out on the change of biological properties in the soil by applying farmyard manure to the soil. The effects of farmyard manure on microbial biomass (C, N, P), which is one of these properties, were revealed by various researchers. Nandita and Singh (16) determined that the application of farmyard manure increased the organic C of the soil by 7-31%, the total N by 13 - 19% and the microbial-biomass C by 20 - 79%. Goyal et al. (17) examined soils in terms of biomass C and N u in a study they conducted under tropical conditions and found that microbial biomass increased in soils where farmyard manure was applied, but the C content did not change much. Santhy et al. (18) found that the highest microbial C and N content emerged in the combined applications of farmyard manure and inorganic manure in tropical garden soils where corn is grown. In a long-term field experiment conducted in the Czech Republic, Kubat et al. (19) found that soil organic C content, basal respiration rate and average bacterial count increased twice with high doses of farmyard manure, whereas organic C content in soils treated with mineral fertilizers decreased by half.

Many studies were conducted examining the effect of farmyard manure on microbial enzymes that play an important role in the decomposition of organic matter in the soil. Guan (20) determined that the application of farmyard manure increased the urease and phosphatase activity of soils. Similarly, Tiwari (21) determined that chemical fertilizer combined with farmyard manure has a greater effect on the enzyme activity and microbial population than chemical fertilizer application alone, and reported that the use of farmyard manure will be beneficial to obtain the highest benefit from chemical fertilization in the soil. Laic et al. (22) applied the fertilizer alone and in combination with nitrogen to soil in their study. In addition, they also measured other soil properties including total-N, organic C, useful P and pH during the development period. As a result, they found that the enzyme activities reached the highest values in the fertilization methods containing farmyard manure + 1/3 chemical N and farmyard manure + 2/3 chemical N. They also reported that there were significant correlations between the investigated enzymes and organic C and total N.

Chicken manure

Chicken manure, which increases day by day due to the proliferation of chicken breeding, is an important source of organic origin plant food. There are generally three different types of manure obtained from the poultry sector; cage and ground laying hen and broiler chickens. While almost all of the cage laying hen manure consists of feces, the feces of ground laying hen and broiler chickens are mixed with the litter material. Therefore, the composition and amount of fertilizer; the way chickens are raised depends on factors such as the nature and amount of feed and bedding used (23). Composted chicken manure is an organic substance that can be biodegradable by microorganisms. While microorganisms decompose this organic matter, they convert it into CO_2 and inorganic substances (24). Since chicken manure is an organic-based fertilizer, it is a good source of nutrients for plants, especially rich in nitrogen as well as other plant foods (Table 2).

Table 2. Properties of chicken manure of different origin (24)

Growing form	pH	Humidity %	Organic matter %	N %	C:N
Ground	6.6	9.5	41.9	3.6	7:1
Broiler	6.8	10.3	44.70	4.9	5:1
Cage	7.6	8.2	29.70	2.2	8:1

By measuring the ecto-enzymes secreted by microorganisms to transform nutrients bound to organic matter in the soil and the amount of CO_2 released by the respiration of these organisms, the fertility conditions of the soils can be revealed. As a matter of fact, the contribution of nutrient-rich chicken manure to soil fertility within the framework of the parameters mentioned above was investigated by some researchers. Cetin (25) investigated the effects of chicken manure mixed with soil on nitrogen mineralization, mineral nitrogen, C / N ratio, catalase enzyme activity and aggregate stability. As a result of the research, it was determined that chicken manure increased the nitrification capacity of the soil, mineral nitrogen, catalase enzyme activity, CO_2 output and aggregate stability. Ozdemir et al. (26) investigated the effect of different organic wastes on the urease activity of soils in their study and determined that at the end of the 3-month incubation period, tobacco factory waste, paddy stalk, vetch and chicken manure significantly increased the urease enzyme activity. Cenkseven et al. (27) conducted a study under laboratory conditions (constant humidity, 28^{o}C) using three different rates of sterile and non-sterile composted chicken manure [(K = compost, T = soil), K + T1: 6, K + T1: 10 and K + T1: 12] applied to the soils of kermes oak (*Quercus coccifera* L., Fagaceae). They reported that the C (CO_2) values of the soil increased with the incubation period in all compost trials, and that both 1:10 and 1:12 compost: soil ratios provided more favorable soil conditions than 1: 6 ratio for microorganism activity.

Compost

By subjecting organic wastes to microbial decomposition under conditions with or without O_2, the final product containing plant nutrients, rich in organic matter, harmless in terms of health, stable in humus appearance is called compost, and this process is called composting (28). Municipal sewage waste (29, 30), various industrial plant waste such as beer, cork and paper industry (31), supermarket and restaurant waste (32), processed potato waste, poultry and cattle and it is possible to obtain garbage compost or farm compost by using animal wastes from ovine breeding (33) and organic wastes generated as a result of plant production (Table 3).

Table 3. Properties of composts from different wastes (28)

Parameter	Garbage compost	Farm compost
Organic matter %	33	60
C %	18	35
N %	0.8	2.8
C:N	22.5	12.5

It was determined by many researchers that soil microbial existence and respiration have changed as a result of applying composts obtained from different wastes to the soil. Chitravadivu et al. (34) applied the compost and farmyard manure they obtained from food waste to the hazelnut garden soil and found that the bacterial, fungal population and microbial biomass of the soil increased. Similarly, by Lee et al. (35) lettuce cultivation was carried out in greenhouse environment with the application of food residue compost and farmyard manure. They reported that these fertilizers increase the growth of bacteria, fungus population, enzyme activities and lettuce in the soil, but also that fertilizers increase the total N and organic matter content of the soil. Cengel et al. (36) investigated the microbiological effects of bone meal, fish meal and garbage compost applications on soils and found that the most stimulating effect on soil respiration and microbial groups was the litter compost. The fact that the garbage compost has a high organic matter content of 56.8% was the most important factor in the emergence of this effect.

Various studies examining the effect of compost application on microbial-derived enzymes that play an important role in the degradation and decomposition of organic matter in the soil are available in the literature. The changes caused by N, applied together with organic wastes, in the biological properties (CO_2 production, dehydrogenase, catalase, urease, phosphatase and β-glycosidase) of the soil, which was applied by Surucu et al. (37) were investigated with a 3-month incubation experiment. At the end of the study, it was determined that CO_2 production, dehydrogenase, catalase and phosphatase activity increased the most by tobacco fabrication waste compost applied with N, urease and β-glycosidase activity increased the most by vetch plant waste compost. Madejon et al. (38) investigated the changes in the enzymatic properties of soils (dehydrogenase, urease, etc.) by applying compost obtained by maturing the forest debris layer with urban solid waste, paper industry waste and agricultural waste. According to the results, it was determined that the enzyme activities of soils in all three organic wastes increased compared to the control. However, although urban solid waste application increases dehydrogenase activity at the beginning of the incubation, it was found to decrease it in the later incubation periods. Sajjad et al. (39) investigated the changes caused by different herbal waste composts (wheat, corn and sesbania) in the biological properties of a sandy-loam soil. As a result of the experiment, they reported that the organic C content of the soil was increased by the wheat waste compost the highest, and the highest N content and dehydrogenase activity were obtained with sesbania waste compost application.

Leonardite

Leonardite is a natural chelating agent that transforms the carbon and humines contained in the gray-black soil layer, which does not burn on lignite coal deposits and cannot complete its carbonization, into humus by soil microorganisms. Leonardite contains humic material (humic + fulvic acid) in the range of 20-90% (40). Humic substances are macromolecules consisting of many organic compounds including carbohydrates as well as groups such as carboxyl, phenolic hydroxyl, and methoxyl (41). Being an important source of humic fulvic acid due to its organic structure, leonardite contributes to the sustainability of soil fertility. However, leonardites, which can have different contents according to their place of formation, are divided into various qualities (Table 4).

Table 4. Leonardite quality classification (42)

	Poor quality	**Medium quality**	**High quality**
Humic acid %	35-50	50-65	65-85
Organic matter %	Min. 35	Min. 50	Min. 65
pH	6.5	5.5	4
C:N	21	19	17
Volume weight (g/cm^3)	1.4	1.2	0.8
Base resolution	Low	Medium	High

Humic substances have direct and indirect effects in maintaining soil fertility. While its direct effect is a source of nutrients for plants and microorganisms, its indirect effects include keeping water in the soil, increasing aeration, and helping to increase cation exchange capacity. As a matter of fact, studies have shown that leonardite, which is rich in humic substances, directly or indirectly affects nutrient utilization of plants (43, 44). Leonardite also promotes root development in plants. This effect is thought to be due to the fact that leonardite humic substances affect the absorption metabolism of nutrients (40). Some studies have revealed positive relationships between humic substances and plant and root development (45, 46, 47).

Due to its high organic content (35-65%), it is thought that leonardite constitutes a good food source for microorganisms in the soil (42). Studies have shown that microorganisms secrete large amounts of enzymes to benefit from this valuable nutrient and that the microorganism biomass and respiration increase in the environment enriched with nutrients. As a matter of fact, Tamer and Karaca (48) determined that the soil organic matter contents increased in three materials compared to the control, accordingly urease, β-glucosidase, alkaline phosphatase and aryl sulfatase activities increased in three materials, as a result of their study by applying charcoal leonardite, leonardite with humus and crude lignite to the soil. They also reported that there was a positive correlation between organic matter and the mentioned enzyme activities. Similarly, Turgay et al. (49) applied the same leonardite materials (charcoal, humus leonardite and crude lignite) to the soil. According to the results of the study, it was determined that high-dose leonardite charcoal applications increased microbial biomass more than low-dose other applications. On the other hand, in the study conducted by Karaca et al. (50), charcoal leonardite was applied to the soil alone and in combination with chemical fertilizers containing 6% and 9% N:P. As a result, they found that the combination containing 6% N:P + leonardite increased the microbial biomass C, respiration and enzyme activities of soils more than other combinations.

Sewage sludge

In wastewater treatment, in physical and chemical treatment processes, the materials that are removed from the wastewater by floating or sedimentation and the dissolved substances as a result of biological treatment are transferred to the microorganism and the microorganisms are floated or precipitated from the system and the liquid wastes containing 95-99.5% water are called sewage sludge (51). Although the composition of sewage sludges varies according to their sources and the stages they pass through during the treatment process, they generally consist of organic matter, nitrogen, phosphorus, potassium, toxic organic compounds and heavy metals (Table 5). Although the organic content of domestic sewage sludge varies according to the conditioning and treatment methods, it is generally more than 50% on dry basis. It is stated that it would be beneficial to use waste sludge as organic fertilizer in agricultural production since it is rich in organic matter and nutrients (52, 53).

Table 5. Average values of sewage sludge properties obtained from waste water treatment plants operated by municipalities in Turkey (54)

Treatment plant	Organic matter %	N %	P %	K %	C:N
Ankara	55.23	3.73	0.87	0.22	8.58
Eskişehir	80.49	5.23	0.46	0.14	8.92
Kayseri	61.64	4.49	1.05	0.38	7.96
İnegöl	63.43	4.15	0.65	0.28	8.86
Bafra	79.43	7.81	0.86	0.31	5.89
Bursa	52.83	2.48	0.41	0.25	12.35

It is aimed to increase the level of organic matter and nutrients in the soil by applying sewage sludge to agricultural areas. The basic principle of utilizing sewage sludge in agricultural production is to apply the sludge to agricultural lands at agronomic rates. In other words, the sludge should be loaded in such a way that the current N and / or P amount in the product does not exceed the annual N and / or P amount required by the product, which is given with the sludge on an annual loading basis (54). Sewage sludges can also be used as a valuable soil conditioner if applied above agronomic loading rates. Sewage sludge added to soft clay soils transforms the soil into a more loose and friable structure and facilitates air and water intake by increasing the pore size. In coarse sandy soils, it increases the water holding capacity of the soil and provides chemical zones for nutrient exchange and adsorption (55, 56).

It shows that the effects of sewage sludge application on enzyme activities, which reflect the microbial activity in the soil and are considered as indicators of changes in the soil, vary greatly depending on the sludge properties and application rates. In a study aimed at determining how sewage sludge application affects the microbial population and enzyme activities in the soil in the long term, a field experiment lasting 8 years was conducted and two different types of sludge were given to the soil at the rate of 50 and 100 tons / ha / year and the changes in enzyme activities were monitored. The results showed that the application of sewage sludge contributed to the breakdown of organic matter and increased microbial activity in the soil (57). Marinari et al. (58) determined that the acid phosphatase, dehydrogenase and protease activities of the soil increased with the application of sewage sludge originating from the domestic wastewater treatment plant to the soil mixed with sand and clay. Albiach et al. (59) reported that they detected a noticeable increase in the dehydrogenase, alkaline phosphomonoesterase, phosphodiesterase, arylsulfatase and urease enzyme activities 5 years after applying sewage sludge to the soil. Pascual et al. (60) applied different doses of sewage sludge to arid soil and observed that all of the dehydrogenase, catalase, urease, casein-hydrolysis protease, alkaline phosphatase and-glycosidase activities of the soil increased at the end of the 360-day incubation period.

Some studies have also been conducted to determine the negative effects of metals in sewage sludge on enzyme activities. In a study conducted by Dar (61) dehydrogenase, alkaline phosphatase and arginine-amonification activities in the soil increased by 18-25%, 9-23% and 8--12%, respectively, when only sewage sludge was applied, in the case of adding 10 µg g-µ level cadmium. It was determined that there was no change in these parameters, but that cadmium at a concentration of 50 µg g^{-1} significantly inhibited enzyme activities. Similarly, Lee et al. (62) also found that cellulase, dehydrogenase, urease and alkaline phosphomonoesterase enzymes in the soil were inhibited significantly depending on the type and amount of sludge during the 5-year application period.

CONCLUSION

Soil microbial dynamics is related to the diversity, numbers and activities of soil microorganisms that live only 5-10 cm below the soil surface. Soil microorganisms are an important component that has many key roles in micro-ecosystems found in a wide variety of soil groups. It's most important tasks include supporting organic matter pools by separating plant and animal residues and organic fertilizers, forming a structure along the soil profile, realizing nutrient cycles (C, N, P, S etc.) and the formation of various life forms with plants. Due to these properties, soil microorganisms are seen as the guarantee of maintaining soil fertility. Insufficient organic matter in the soil threatens the sustainability of soil fertility in agricultural areas. In order to eliminate this negativity, organic fertilization materials applied to the soil have an extremely important role. It is widely known that the application of organic fertilizers improves the physical and chemical properties of the soil, but the effect of these fertilizers on the biology of the soil is less known. The effect of organic fertilizers on soil microbial dynamics should be well understood not only by scientific circles but also by farmers. In this way, sustainable soil fertility that prioritizes microbial dynamics can be supported.

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• Chapter-4 •

COMPARISON OF THE POSSIBLE EFFECTS OF ORGANOMINERAL FERTILIZERS AND MINERAL FERTILIZERS ON SOIL FERTILITY AND CROP PRODUCTION

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INTRODUCTION

Parallel to continuously increasing world population, demands for food production and agricultural production are increasing. In this sense, fertilizer uses are also increasing in agricultural productions and such a case makes agriculture more dependent on mineral fertilizers. According to Kacar and Katkat (2006), mineral fertilizers alone may improve yields 50% and more. About 15% of production costs are constituted by mineral fertilizers. Rising mineral fertilizer prices then increase the production costs. Farmers then try to alter quantity and quality of the fertilizers to be applied or search for alternative sources of fertilizers. Besides mineral fertilizers and farmyard manure treatments, organic, organomineral, soil stabilizers and microbial fertilizers have recently been used to improve yields levels in plant production (Asri et al., 2011).

The organic fertilizers (compost, bone meal, harvest residues, livestock manure, plant and animal-originated compounds) applied to soil convert soil nutrients into available forms and improve plant uptake of nutrients. These fertilizers also improve soil physical, chemical and biological characteristics (Sarkar et al., 2003; Olaniyi et al., 2010; Eifediyi et al., 2013). Livestock manure is the greatest source of organic material. However, it is hard to find livestock manure all the time at sufficient maturity and appropriate periods and use of livestock manure is a laborsome issue. Thus, growers are not in search of other alternatives (Demirtaş et al., 2005). Just because of availability and applicability, use of organomineral fertilizers is getting more common (Asri et al., 2011). Another reason increasing the use of organomineral fertilizers is the improvements achieved in soil physical, chemical and biological characteristics and increase in organic matter contents with these fertilizers. Different results were reported in yield studies about the effects of organomineral fertilizers. Some studies indicated greater and some others lower rate of increase in yields with organomineral fertilizers as compared to mineral fertilizers. On the other hand, it has been reported that organomineral and mineral fertilizers have similar yield properties (Cengiz and Irget, 2018).

Organomineral fertilizers are composed either of mixture or combination of organic and mineral fertilizers (Ayeni, 2008; Toprak, 2019). According to Antille et al. (2013), organomineral fertilizer can be defined as “a fertilizer obtained by blending, chemical reaction, granulation or dissolution in water of inorganic fertilizers”. Livestock manure, domestic wastes, food wastes, plant wastes, biowastes, industrial wastes and wastewater treatment sludge are commonly used in production of organomineral fertilizers (Chassapis and Roulia, 2008; Rady, 2012; Kominko et al., 2017). Especially poultry manure with greater nutrient contents is largely used in production of organomineral fertilizers.

1. ASSESSMENT OF THE EFFECTS OF ORGANOMINERAL FERTILIZERS ON SOIL PHYSICAL PROPERTIES AND FERTILITY

The materials used as fertilizer are divided into two groups as of mineral and organic. There are various mineral fertilizers used by the growers. Since mineral fertilizers are rich in nutrients, they are directly available and mineralized in soil in a short time. Mineral fertilizers could improve plant growth and development and ultimately yield levels faster and at greater quantities (Yıldız, 2018). On the other hand, increasing chemical fertilizer uses result in groundwater pollution, depletion of soil organic matter, increased soil acidity, distortion of soil physical characteristics and accelerated soil erosion (Gordon et al., 1993; Adeoluwa and Adeogun, 2010). As indicated by Isherwood (2008), continuous use of mineral fertilizers increases yields in short run, but result in destruction of soil physical characteristics in long run. Mineral fertilizers have a high production cost, thus they are less preferred by the growers just because of price disadvantage (Adeniyan and Ojeniyi, 2005).

There is a need also for organic fertilizers to improve soil physical characteristics and to maintain soil fertility. In places where livestock raising activities are intensively practiced, organic fertilizers constitute an important alternative of mineral fertilizers (De Conti et al., 2016). Intensive organic fertilizer uses increase soil Ca, Mg, P, micronutrient contents and organic carbon contents. However, as indicated before, it is hard to find organic fertilizers at sufficient maturity all the time and at proper periods and difficulties encountered in transportation and applications limit the potential use of organic fertilizers on agricultural fields (Andreola et al., 2000; Demirtaş, 2005; Brunetto et al., 2012; Lourenzi et al., 2016). Organic fertilizers are slowly decomposed, decomposition largely relies on temperature and soil moisture and they release nutrients at slow rates. Organic fertilizers have low nutrient contents, thus it is hard to meet plant nutrient requirements solely from organic fertilizers (Morris et al., 2007). Due to soil improving effects of organic fertilizers and benefits of mineral fertilizers in plant nutrition, organic and mineral fertilizers are used together to achieve better outcomes (Lombin et al., 1991). Organic compounds and mineral nutrients are blended to produce organomineral fertilizers and they are served to producers. They constitute an alternative source of growers (Sá et al., 2017). As compared to organic fertilizers and chemical fertilizers, organomineral fertilizers better improved soil physical characteristics and fertility (Akanbi et al., 2004). Organic matter of organomineral fertilizers increases mineral holding capacity (cation exchange), water and air holding and trace element levels, balances pH levels and regulates of the soils and regulates microorganism balance of the soils. Organomineral fertilizers storge rainwater and reduce soil erosion and loss of nutrients (Makinde et al., 2011; Süzer and Çulhacı, 2017). Organic matter, humic and fulvic acids of organomineral fertilizers have significant contributions to preservation of soil physical, chemical and biological characteristics. Kurmysheva and Efremov (1998) investigated the effects of mineral and organomineral fertilizers on soil chemical properties and reported that sole application of mineral fertilizer did not increase soil humus quantity and organomineral fertilizer treatments yielded better outcomes in terms of soil fertility.

Soil pH is an important factor influencing availability of the nutrient. Organomineral fertilizers and mineral fertilizers have different effects on soil pH (Matseevska, 1996). Ojeniyi et al. (2009) reported that organomineral fertilizer treatments yielded better improvement of soil pH levels as compared to mineral fertilizer treatments and control treatments without fertilizers. Ayeni and Ezeh (2017) reported increasing pH levels with organomineral fertilizer treatment and decreasing pH levels with mineral fertilizer treatments. Soil salinity reducing soil fertility is another challenging problem. Organomineral fertilizers applied in saline soils reduce soil bulk density and significantly increase total porosity, field capacity and useful pores of the soils. Therefore, just because of these soil improving characteristics, organomineral fertilizer (5:2:1 mixture of green waste compost, elemental sulphur and humic acid) treatments were recommended in eggplant farming on saline soils (ECe = 6.47 dS m^{-1}) (Semida et al., 2014). Rady (2012) indicated that organomineral mineral (2:10:1 mixture of calcium sulphate, ground rice bran, and humic acid) applications to saline soils (EC = 8.9 dS·m^{-1}) increased plant growth and yields in tomatoes. Paungfoo-Lonhienne et al. (2012) indicated organic compounds as a source of nutrients able to increase yields without increasing soil pollution and having any negative impacts on soil health.

According to Omueti et al. (2000), organomineral fertilizers increase soil nutrient contents. Fast rate of release of nutrients from organomineral fertilizer compounds and slow rate of release of nutrients from organic matter allow continuous and better plant growth and development (Ipinmoroti et al., 2002). It was reported that mineral fertilizers improved phosphorus uptake efficiency with the aid of organic fertilizers and soil stabilizers (Jat and Ahlawat, 2006; Alam et al., 2007; Makinde et al., 2011). According to Bello et al. (2014), organic matter increased solubility of rock phosphate. Also, phosphorus passes into soil solution while the mineralization of the organic matter. Decomposed organic matter may constitute 30-37% of soil phosphorus (Brohi et al., 1995; Güneş et al., 2000). In phosphorus-fixating soils, organic fertilizer increased available phosphorus quantity of the compost (Zhang et al., 2009) and phosphorus absorption varied based on type of soil and organic fertilizer (Bolster and Sistani, 2009). Since K-humate incorporated into the soil makes soil phosphorus and soil applied phosphorus more available for plants, mineral fertilizers are combined with K-humate for better outcomes (Korkmaz et al., 2020). In terms of phosphorus uptake efficiency in maize, organomineral fertilizer treatments did not yield positive impacts as compared to mineral fertilizers. Slow release of inherent minerals is another important characteristic of organomineral fertilizers. According to Paul and Beauchamp (1993), plants are able to use the nitrogen of compost for at least 3 years. Organomineral fertilizers improve nitrogen use efficiency (Antille et al., 2013) and reduce nitrogen losses by about 16% as compared to organic fertilizers (Tejada et al. 2004). According to Zebarth et al. (2005), in terms of nitrogen availability, organomineral and mineral fertilizers exhibit similar behaviors. It was reported in another study that organomineral fertilizer treatments improved N, P, K uptakes as compared to mineral fertilizer and the control treatments without fertilizer (Ojeniyi et al., 2009). Organic and organomineral fertilizers have slow rate of release for P, but similar rate of release for N and K with the other fertilizer sources (Mumbach et al., 2019). Organomineral fertilizers prepared with the mixture of treatment sludge and NPK fertilizers increased soil organic matter and nitrogen contents, but did not influence heavy metal accumulation (Kominko et al., 2017). It was pointed out that organomineral fertilizer treatments increased micronutrients, especially Cu, Mn and Zn contents in plant tissues as compared to mineral fertilizers (Ayeni and Ezeh, 2017). Organomineral fertilizers also release some organic compounds into soil during the decomposition of the fertilizers and such compounds promote plant growth and development (Mumbach et al., 2019).

2. ASSESSMENT OF PLANT YIELD AND QUALITY CHARACTERISTICS

Organomineral fertilizers are mostly experimented on vegetables. Research on vegetables revealed that organomineral fertilizers improved plant growth and development, increased yields and quality, chlorophyll and vitamin C contents as compared to mineral fertilizers (Li et al., 1999). Organic and mineral fertilizer combinations improved yield and plant performance of vegetables (Babatola et al., 2002; Ogunlade et al., 2011). It was reported that organomineral fertilizer treatments significantly increased plant growth and development, thus the yields in tomatoes as compared to mineral fertilizers applied at the same quantities (Ayeni and Ezeh, 2017). Mineral and organic fertilizer mixtures also had significant effects on plant growth and development and thus yield of eggplant (Ullah et al., 2008). The greatest onion yields were achieved with mineral +

organic fertilizers (Serrano Vazquez et al., 1995). With the use of organomineral fertilizers, 23% yield increase was achieved in carrot and 2-3 times yield increase was achieved in pepper (Layaskovskyii, 2003). Separate applications of organomineral, mineral and organic fertilizers had different effects on cabbage (*Brassica oleracea* L.) plants, organomineral fertilizer treatments increased head diameter and lengths, thus the yields (Olaniyi and Ojetayo, 2010). In okra, plant growth, fruit yield, quality and nutrient contents were significantly influenced by inorganic, organomineral fertilizers and their combinations. The greatest okra yield was obtained from combined treatment (75kg ha^{-1} NPK + 3 t ha^{-1} organomineral fertilizer) (Olaniyi et al., 2010). Similar findings were also reported for cucumber (*Cucumis sativus* L.), lettuce (*Lactuca sativa* L.) and pumpkin (*Telfaira occidentalis*) plants (Olaniyi and Akanbi, 2007; Olaniyi, 2008 and 2009). In cucumber cultivation, organomineral fertilizer treatments at different rates had a potential to offer practical solutions against water stress and it was observed that organomineral fertilizer treatments may improve yield and quality as well as water use efficiency (Mageed and Semida, 2015). All these studies indicated that organomineral fertilizers had similar effects with mineral fertilizers in terms of plant growth, development and yields (Andreola et al., 2000; Deeks et al., 2013). For instance, in watermelon plants (Sugar baby variety of *C. Lanatus*) organomineral and NPK fertilizers resulted in similar increases in plant growth performance and yields. Researchers indicated that because of price advantage, organomineral fertilizers could replace NPK fertilizers (Ojo et al., 2014).

In fruit culture, organic and mineral fertilizers should be combined to achieve full-success in cultural practices (Özbek, 1981). Combined use of organic and mineral fertilizers plays a great role "sustainable agriculture" system, so called as controlled agriculture system (Çolakoğlu, 1996). A study on pistachio revealed the significance of combined use of organic and mineral fertilizers. Researchers indicated that combined use of organic and mineral fertilizers may increase yields by up to 40% Aslan (2018). Pekcan et al. (2008) conducted a study on Olive cv. Domat (*Olea europaea* L.) and indicated that combined treatments of mineral fertilizers and livestock manure significantly increased yields as compared to sole mineral treatments. Besides, the greatest yields were obtained from the organomineral fertilizer produced through coating with leonardite-originated humus. Colugnati et al. (2003) investigated the effects of organomineral fertilizers on grape (*Vitis vinifera* L.) and reported positive effects of organomineral fertilizers on grape yield, vegetative growth and fruit ripening. Increasing iron-rich organomineral fertilizer doses increased leaf N, P, K and Fe contents and decreased Ca, Mn, Zn and Cu contents of apples (Toprak, 2019). Organomineral fertilizer treatments at regeneration periods provided positive outcomes in highly acidic tea fields (Özyazıcı et al., 2013). Yield differences were not observed in coffee (*Coffea arabica* L.) plants grown in sandy soils fertilized with solid form of organomineral fertilizer and mineral fertilizers (Fernandes et al., 2007).

It was reported that organomineral fertilizers could be used in wheat farming as an alternative of mineral fertilizers since it provided similar yields (Mumbach et al., 2019). It was also indicated that organomineral fertilizers prepared through the mixture of treatment sludge and NPK fertilizers provided similar yields with mineral fertilizers (Kominko et al., 2017). Süzer and Çulhacı (2017) recommended a balanced fertilization program including organomineral fertilizers as base fertilizer and inorganic fertilizers as dressing fertilizers in winter wheat farming fields. Besides, organomineral fertilizers were reported to increase plant growth and development more and improved agricultural performance (Eifediyi et al., 2013; Olaniyi et al., 2010). Mineral and organomineral fertilizer combinations yielded successful outcomes in terms of yield and quality in cotton farming (Mehasen et al., 2012). Kurmysheva and Efremov (1998) compared the effects of mineral and organomineral fertilizers on yield. Researchers worked on potato, barley + alfalfa, 2 years only alfalfa, winter wheat, potato, barley, maize, winter wheat rations and achieved the best results from the organomineral fertilizer-treated plots. It was pointed out in a study investigating the effects of some registered organomineral fertilizers on yield and quality traits of bread wheat that organomineral fertilizers had significant effects on yield, thousand-grain weight and plant heights (Akıncı et al., 2007). In a greenhouse study, organomineral and mineral fertilizers were applied to wheat plants and it was indicated that organomineral fertilizers increased root growth, root/shoot ratio, nitrate reductase enzyme activity, yield, protein and amino acid contents (Lyaskovskii, 2003). Audu and Samuel (2015) reported that organomineral fertilizer prepared with the mixture of N:P:K (9:3:3), urea, rock phosphate, wood ash, neem seed, blood meal, cotton seed cake, manure and poultry manure improved growth parameters of paddy plants. Akanni et al. (2011) reported that organomineral fertilizer prepared with the mixture of treatment sludge, poultry manure, livestock manure, urea and superphosphate fertilizers increased soil organic matter content and increased N, P, K, Ca and Mg contents of maize, pepper and Amaranthus plants. Bojinova et al. (1997) reported 15.2% greater plant growth and yield of barley in organomineral fertilizer-treated plots than in sole ammonium nitrate and superphosphate-treated plots. Silva et al. (2017) conducted a study on lavender and indicated that mineral and organomineral fertilizers provided slow release of nutrient within root rhizosphere and thus increased yields accordingly. Organomineral fertilizers were reported as the most efficient treatment in nettle (*Urtica dioica* L.) plants (Çalışkan and Ayan, 2011).

There are various materials used as fertilizers in plant nutrition. Composition and characteristics of these materials are quite different from each other. In present study, organic fertilizers, mineral fertilizers and organomineral fertilizers (combined use of organic and mineral fertilizers) were compared. Organomineral fertilizers containing various organic compounds improve soil physical and biological characteristics. Different outcomes were reported in previous studies about yield and quality traits. While some studies reported more positive effects of organomineral fertilizers than the mineral fertilizers, some others reported similar outcomes. Due to potential benefits, cheap and easy access and easy application, organomineral fertilizers are preferred by the growers as an alternative source of nutrient for plants.

Today, studies about organomineral fertilizers are quite limited. Therefore, further research is recommended to be conducted with different plant species and different fertilizer combinations. Previous studies on organomineral fertilizers mostly focused on plant growth and development, yield and quality traits. Thus, further research on organomineral fertilizers should also focus on soil stabilization, soil and water pollution, heavy metal accumulation and environmental issues. Economic analysis of organomineral fertilizers, offered to growers as an alternative source, should be conducted and economic aspects of organomineral fertilizers should be compared with the other fertilizer sources.

Conflict of interest: Authors declare that they have no competing interests.

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• Chapter-5 •

CHANGES IN SOIL PROPERTIES, QUALITY, AND PRODUCTIVITY FOLLOWING PIG SLURRY APPLICATION, IN SEMIARID REGION OF SPAIN.

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INTRODUCTION

Manure, as well as composts and biosolids, is a renewable resource and an excellent source of macro- (N, P, K, Ca, Mg, and S) and micronutrients (Zn, Cu, Fe, Mn, etc.) that are essential for growing plants. For centuries manure was used throughout the world for improving soil fertility and enhancing crop productivity.

Pig manures may increase soil fertility, and thus the crop production potential possibly by changes in soils physical and chemical properties including nutrient bioavailability, soil structure, water holding capacity, cation exchange capacity, soil pH, microbial community and activity etc. (Walker et al., 2004; Agbede et al., 2008; Muhammad and Khattak, 2009).

Using pig slurry (PS) as fertilizer in agriculture is the most correct and natural way of decomposing it and also saves a great deal of chemical fertilizers which, apart from their high cost, are already contributing to pollution in some areas (Torres, 1993). Considering both its fertilizer value and the increasing cost of chemical fertilizers, the economic value of slurry is beyond doubt.

The recycling of pig slurry in agricultural soils is an alternative and valuable practice in countries such as Spain. This is particularly the case since many regions are arid and are comprised of poor soils (‹1% organic matter) that support intense mineralization. A healthy soil in properly-functioning ecosystem is often characterized by good quality SOM where essential nutrients such as N, P, S, K, Ca, Na, and Mg are readily available to support growth of plants and organisms (Sollins et al., 2006; Ottenhof et al., 2007). In Spain, nearly 2.5×10^6 Mg (dry wt.) of pig manure is collected annually (Bigeriego, 1995), and it has been acknowledged (MAPA, 1997) that approximately 50% of this manure is spread on agricultural land.

The objectives of this study were to: 1) investigate the extent to which rate of PS applications can affect soil characteristics, quality, and productivity, 2) determine optimum dose of PS in terms of sustainable agriculture.

MATERIAL AND METHODS

Description of the Study Area and Samplings

The study area is located southeast of Lorca, Murcia region, Southeast of Spain (Guadelentin Valley-37° 55’ 27, 87” N -1° 49’ 37, 84” W), which has 18 m. with 3.4 % slope. Climate is semiarid, with mean annual average rainfall of 300 mm and mean annual temperature of 18^0C and potential evapotranspiration is >900 mm yr^{-1} (López-Bermúdez et al., 2002). Soil series is Typic Haplocalcid in the study area according to Soil Survey Staff (2010). Texture classification was silty loam. pH were changed between 7.2 and 7.8, salinity problem was not observed. Organic carbon (OC) was ranged between 13.08 and 14.31. Very low contents of total nitrogen (TN) (app.0.5 g kg^{-1}) and cation exchangeable capacity (CEC) (8.7-18.3 cmol $^{(+)}$ kg^{-1}, high contents of lime ($CaCO_3$) (app. 55%) and phosphorus (P) (6.3-62.0 mg kg^{-1}) were observed in the profile.

Pig slurries characteristics are given in Table 1. Some parameters such as pH, density, humidity, copper (Cu), and zinc (Zn) contents of PS were not changed in the first and second year. Density was approximately 1 g mL^{-1}. Humidity was changed between 95% and 96.3 % in each year. The dry matter content of the PS of first year application were higher than the second year, electrical conductivity of applied PS in the second year was similar with first year. Total nitrogen of PS was changed between 1.0 and 1.4 g L $^{-1}$ in first year, which was higher than second year.

Table 1. Characteristics of applied PS from the study area (n:3)

Parameter	1st year			2nd year		
	Content		**SD**	**Content**		**SD**
Density (g mL^{-1})	1.0	±	0.0	0.9	±	0.1
pH	7.2	±	0.0	7.6	±	0.1
EC(Ms cm^{-1})	16.1	±	0.1	16.7	±	2.0
Humidity (%)	95.0	±	1.3	96.3	±	1.5
Dry Matter (g L^{-1})	9.5	±	2.6	36.9	±	5.1
Cu (g mL^{-1})	0.7	±	0.0	0.5	±	0.3
Zn (g mL^{-1})	3.4	±	0.3	3.9	±	2.0
Fe (g mL^{-1})	3.8	±	0.7	6.5	±	2.6
Mn (g mL^{-1})	0.4	±	0.1	0.7	±	0.2
Mg (g mL^{-1})	71.1	±	2.5	144.9	±	15.4
Ca (g mL^{-1})	113.1	±	5.5	140.7	±	13.5
K (g mL^{-1})	836.0	±	11.6	1020.3	±	95.1
Na (g mL^{-1})	868.4	±	18.8	1194.3	±	29.6
TN (g mL^{-1})	1.0	±	0.1	1.4	±	0.0
AN (g mL^{-1})	0.8	±	0.1	1.2	±	0.0
PO_4 (g mL^{-1})	360.0	±	26.5	580.0	±	27.7
P (g mL^{-1})	117.7	±	8.6	184.3	±	24.8

(TN: Total Nitrogen, AN: Amoniacal Nitrogen, PO_4: Phosphate, P: Phosphorus)

The area of each plot was 25 m^2 (5x5). Single doses (D_1), double doses (D_2), and triple doses (D_3) of PS were applied to each plot. They were calculated the agronomic rate of N-requirement as 170 kg N ha^{-1} yr^{-1} (European Directive 91/676/CEE), 340 kg N ha^{-1} yr^{-1} and 510 kg N ha^{-1} yr^{-1} respectively. Soil samples were collected from surface and subsurface horizons (0-30 cm and 30-60 cm). The time of samplings and PS applications are given in Table 1. Totally, seven soil sampling and two PS application results are evaluated. The experiment was established in 2009 until 2011. PS was applied once per a year, especially in August. Plants samples were harvested once per a year during three year.

Analytical Methods and Statistical Analysis

The collected soil samples were air-dried in the lab for 7 days, passed through a 2-mm sieve, homogenized, and stored in plastic bags at room temperature prior to laboratory analyses. We analyzed pH (1:2,5), EC, organic carbon, nitrogen, cation exchange capacity according to Peech´s method (1965), Bower and Wilcox (1965), Duchaufour (1970), Chapman (1965), respectively.

Barley plants were taken in each plot from 1 m^2 at harvest time. Samples were separated and dried in an oven at 60 ° C for 48 hours. The grain samples were ground and stored in the special glass containers to determine chemical characteristics of plants.

In order to determine nutrients and phosphorus content in plant samples; 0.7 g. plant samples were weighted and ashed in a muffle furnace at 480°C for 24 h. The ash residue was digested in 6 N nitric acid and the solution used to determine nutrients (Na, K, Ca, Mg, Zn, Cu, Fe and Mn) by an atomic absorption spectrophotometer and phosphorus by a spectrophotometer. Plant asimilable phosphorus (P_2O_5) was measured according to Watanabe and Olsen (1965), based on the extraction of phosphorus $NaHCO_3$ 0.5 M solution (Olsen and Dean, 1965) and photo colorimetric determination of molybdenum blue (Murphy and Riley, 1962), by UVmini-1240 Spectrophotometer Shimatzu. Total Nitrogen was measured by Kjeldahl method, as described Duchaufour (1970), with some modification does not affect the essence of the method, such as simultaneous distillation and titration of NH_3 on a distillation vapor stream (KjelFlex Büchi K-360) and titration with HCl by automatic titrater Metrohm 702 SM Titrino.

Selected chemical properties of applied PS were analyzed following the routine methods. We determined pH (Peech, 1965), electrical conductivity (EC) (Bower and Wilcox, 1965), Total Nitrogen (TN) with Kjeldahl method (Duchaufour, 1970), Total phosphorus (Olsen and Dean., 1965). Raw PS was diluted (1/10) in a 100 ml flask, manually shaken 1 minute, then filtered with Albet paper No 242. This extract was kept to measure trace element (Cu, Zn, Fe and Mn) by atomic absorption flame (800 Atomic Absorption Spectrometer AAnalyst, Perkin Elmer Precisely).

All data were analyzed by parametric multifactor analysis of variance

(ANOVAs) and if need nonparametric test with using the software package "SPSS Version 19.0" since the interaction between factors and processes was significant differences between soils/plants for selected subsets of data.

RESULTS

Selected Soil Properties

Changes of soil properties were given in Table 2 and 3 in the surface and subsurface horizons, respectively. Soil pH were changed between 7.44 and 7.69 in surface, 7.44 and 7.72 in subsurface horizon. A slightly decline was observed with D_2 and D_3 applications and pH ranges was approximately stable with D_1 application in the surface horizon. pH content was slightly decreased with D_1 and D_2 application, an increment was observed with D_3 application in the subsurface horizon. The results showed that pH was more affected by PS application in D_2 and D_3 plots than D_1 plots.

Remarkable effect of PS was not observed on salinity in the surface horizon (Table 2) except of D_3 application, whereas soil salinity was slightly increased with D_2 and D_3 application in the subsurface horizon (Table 3).

Because, applied high amount of PS were infiltrated from surface and accumulated in the subsurface horizon, which were increased soil salinity.

Lime contents were changed between 50 and 70%, which were not significantly affected by PS application except of D_3 application in studied soils. D_3 application was slightly increased $CaCO_3$ content in the surface and subsurface soil horizon.

Cation exchange capacity (CEC) results were changed between 6.0 and 17.0 cmol $^{(+)}$ kg^{-1}. There were significantly differences with applied PS in terms of CEC. The different doses of PS application were not significantly affected on CEC content in surface and subsurface horizons. The reason of this cations remaining can be uptake by plant.

Soil P results in the surface and subsurface horizons results showed that, PS applications were affected and increased on plant bioavailable P in the soil with all applications. P contents were increased with this order D_3›D_2›D_1›C in the subsurface horizon. PS has more quantity of bioavailable phosphorus that is the reason of increases phosphorus in the soil.

The results of SOC are given in Fig 1. They were changed between 10 and 20 g kg^{-1}, which was increased with all doses application and remarkable increased were observed with D_2 and D_3 application in the study area. As we know, PS had high organic matter contents compared to the other fertilizers, high organic matter were given to soil with high dose application. Our results showed that; quantities of SOC were increased with PS application.

Table 2. Distrubition of soil properties in the surface horizons (n:3, S: Sampling, D: Doses).

S	D	pH	EC ($dS\ m^{-1}$)	$CaCO_3$ (%)	CEC ($cmol^{(+)}\ kg^{-1}$)	SOC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	C/N (%)	P ($mg\ kg^{-1}$)
		Soil Properties							
1		7,44ab(0,18)	0,12a(0,04)	57,21ab(1,32)	16,55b(0,77)	10,69ab(0,84)	0,62a(0,08)	17,32a(0,98)	62,09a(0,81)
2		7,69b(0,04)	0,17a(0,02)	54,37ab(1,05)	9,32a(0,75)	10,58ab(0,85)	0,56a(0,01)	19,06a(0,90)	62,65a(0,95)
3		7,55ab(0,08)	0,14a(0,03)	57,09ab(0,87)	9,01a(0,03)	15,81abcd(0,75)	0,43a(0,05)	37,53b(0,76)	61,58a(0,81)
4	C	7,48ab(0,05)	0,20ab(0,04)	56,98ab(0,95)	8,50a(0,11)	13,14abc(0,47)	0,53a(0,01)	24,80a(0,45)	60,65a(0,54)
5		7,61ab(0,00)	0,16a(0,00)	60,53abc(0,00)	8,57a(0,00)	10,06a(0,81)	0,08a(0,00)	33,88ab(0,73)	62,02a(0,68)
6		7,44ab(0,00)	0,17a(0,00)	59,57abc(0,00)	8,74a(0,00)	10,48a(0,25)	0,55a(0,00)	19,20a(0,70)	60,87a(0,88)
7		7,53ab(0,00)	0,16a(0,00)	60,05abc(0,00)	8,65a(0,01)	10,27a(0,15)	0,31a(0,00)	33,07ab(0,68)	61,31a(0,19)
1		7,45ab(0,03)	0,33ab(0,01)	56,05ab(0,39)	10,88a(0,73)	10,91ab(0,84)	0,66a(0,10)	19,00a(0,48)	56,87a(0,92)
2		7,64b(0,05)	0,19ab(0,02)	53,48ab(0,59)	9,74a(0,27)	12,20ab(0,85)	0,66a(0,02)	19,66a(0,26)	70,29a(0,52)
3		7,58ab(0,04)	0,20ab(0,03)	59,39abc(0,15)	8,84a(0,72)	14,50abc(0,75)	0,65a(0,05)	23,88a(0,55)	88,98a(0,98)
4	D_1	7,49ab(0,05)	0,21ab(0,01)	52,50a(0,78)	8,15a(0,46)	15,64abcd(0,47)	0,66a(0,06)	24,20a(0,97)	81,26a(0,65)
5		7,45ab(0,01)	0,29ab(0,04)	61,31abc(0,88)	10,61a(0,29)	11,97ab(0,77)	0,74a(0,02)	17,62a(0,43)	98,03ab(0,61)
6		7,45ab(0,04)	0,19ab(0,02)	61,55abc(0,64)	8,88a(0,66)	13,09abc(0,45)	0,67a(0,09)	19,60a(0,80)	97,05ab(0,46)
7		7,45ab(0,01)	0,24ab(0,03)	61,43abc(1,02)	9,74a(0,96)	12,53abc(0,15)	0,70a(0,04)	18,38a(0,78)	105,90ab(0,40)
1		7,37a(0,07)	0,31ab(0,01)	56,22ab(0,66)	9,56a(1,39)	17,21bcd(0,90)	1,66ab(0,08)	14,49a(0,99)	74,18a(0,90)
2		7,62b(0,03)	0,26ab(0,04)	59,38abc(0,53)	10,74a(0,79)	18,92abc(0,51)	1,04a(0,05)	20,50a(0,84)	90,10a(0,49)
3		7,59ab(0,03)	0,20ab(0,03)	54,72ab(0,83)	8,15a(0,38)	14,28cd(0,98)	0,63a(0,08)	23,13a(0,71)	126,67ab(0,34)
4	D_2	7,54ab(0,03)	0,24ab(0,05)	57,15ab(0,33)	8,00a(0,79)	12,20ab(0,88)	0,55a(0,07)	22,67a(0,53)	100,41ab(0,84)
5		7,43ab(0,10)	0,40ab(0,05)	61,50abc(0,66)	9,30a(0,39)	15,67abcd(0,64)	0,90a(0,05)	19,41a(0,74)	201,38bc(0,68)
6		7,46ab(0,04)	0,34ab(0,08)	63,49bc(0,60)	8,08a(0,16)	16,29abcd(0,82)	0,75a(0,14)	21,44a(3,24)	144,49ab(0,80)
7		7,44ab(0,03)	0,37ab(0,06)	62,49abc(0,56)	8,69a(0,12)	15,98abcd(0,98)	0,82a(0,11)	19,96a(0,73)	132,56ab(0,61)
1		7,40a(0,05)	0,48abc(0,04)	57,10ab(0,64)	10,59a(0,59)	12,54abc(0,83)	1,22ab(0,14)	10,34a(0,99)	234,57bc(0,93)
2		7,72c(0,07)	0,49bc(0,04)	68,08c(1,06)	8,45a(1,08)	15,17abcd(0,68)	0,88a(0,06)	34,14ab(0,73)	246,03c(0,79)
3		7,55ab(0,08)	0,65bc(0,03)	50,52a(0,47)	11,29a(0,99)	18,27cd(0,46)	2,71b(0,09)	8,64a(0,49)	255,75c(0,79)
4	D_3	7,53ab(0,07)	0,78c(0,02)	56,73ab(0,30)	8,97a(0,73)	16,39bcd(0,60)	2,41b(0,07)	9,89a(0,80)	203,53bc(0,66)
5		7,63b(0,00)	0,22ab(0,00)	64,62bc(0,00)	7,34a(0,13)	17,83bcd(0,56)	0,72a(0,00)	24,76a(0,20)	227,67bc(0,29)
6		7,51ab(0,00)	0,35ab(0,00)	63,78bc(0,00)	6,80a(1,08)	20,33d(0,73)	0,85a(0,00)	23,87a(0,43)	180,66ab(0,86)
7		7,57ab(0,00)	0,28ab(0,00)	64,20bc(0,00)	7,07a(0,47)	19,08cd(0,68)	0,79a(0,00)	24,28a(0,29)	209,46bc(0,42)
	f	**5,72***	**6,58***	**5,30***	**4,00***	**1,70**	**7,85***	**5,02***	**2,73***

Total nitrogen (TN) results were increased only with D_1 application in the surface horizon. Nitrogen is very important and necessary for plants. High nitrogen content in soil is desirable situation. Nitrogen content was statistically significant with application doses, which was slightly increased with D_1 application. TN content was statistically significant with application doses, which were not changed with PS application in the subsurface horizon.

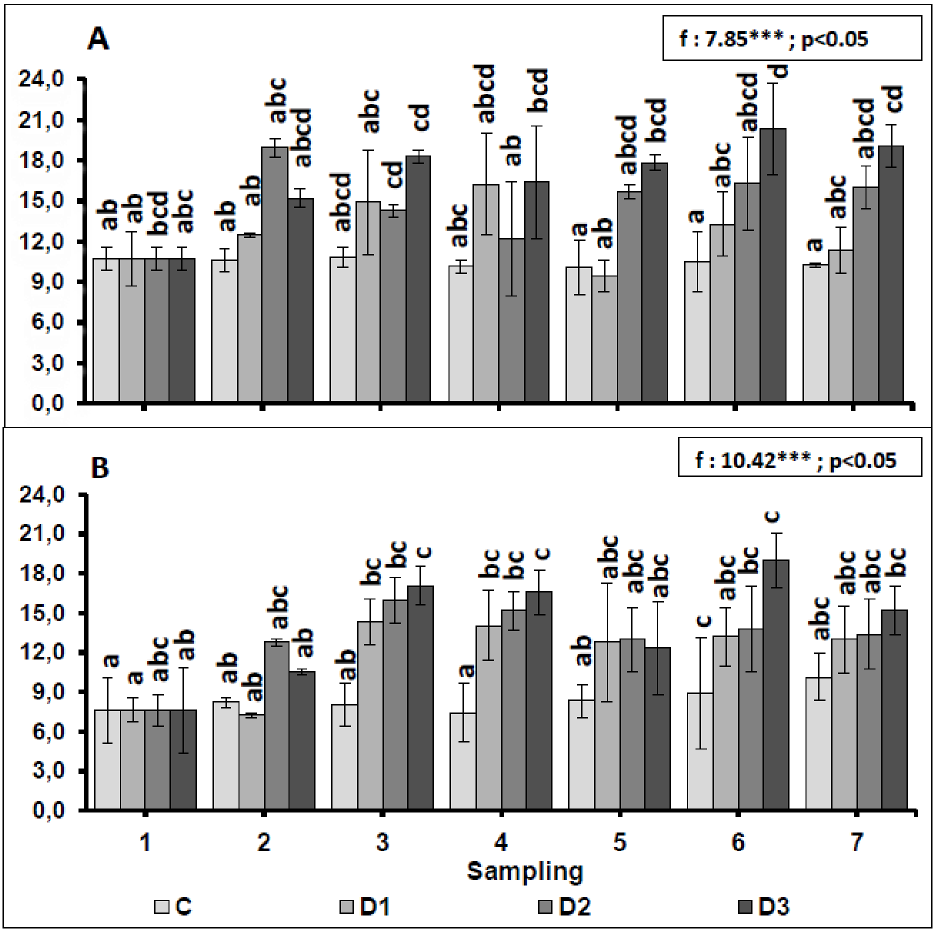

Fig.1. Evolution of Soil Organic Carbon (g kg^{-1}) **A**-Surface, **B**-Subsurface Horizon (n:3)

Table 3. Distrubition of soil properties in the subsurface horizons (n:3, S: Sampling, D: Doses).

					Soil Properties				
S	**D**	**pH**	**EC (dS m^{-1})**	**$CaCO_3$ (%)**	**CEC (cmol$^{(+)}$ kg^{-1})**	**SOC (g kg^{-1})**	**TN (g kg^{-1})**	**C/N (%)**	**P (mg kg^{-1})**
1		7.52ab(0,06)	0,14a(0,04)	53,59ab(0,52)	12,05b(0,38)	7,62a(0,45)	0,30ab(0,04)	25,86a(0,55)	34,37a(0,36)
2		7.66bc(0,09)	0,16a(0,01)	51,94a(0,51)	7,61ab(0,47)	8,21ab(0,37)	0,37ab(0,01)	22,37a(0,50)	46,97ab(0,57)
3		7.59abc(0,04)	0,14a(0,03)	63,29bc(0,42)	6,94a(0,91)	10,03ab(0,64)	0,22a(0,02)	46,32ab(0,62)	56,61ab(0,56)
4	**C**	7.47a(0,02)	0,12a(0,01)	61,95abc(0,44)	8,59ab(0,43)	7,44a(0,20)	0,36ab(0,04)	21,51a(0,44)	61,14ab(0,51)
5		7.60abc(0,00)	0,14a(0,00)	67,59c(0,00)	8,44ab(0,00)	8,33ab(0,24)	0,15a(0,00)	55,56ab(0,00)	60,77ab(1,35)
6		7.46a(0,00)	0,15a(0,00)	66,92bc(0,00)	6,63a(0,00)	15,89c(0,22)	0,32ab(0,00)	48,93ab(0,66)	58,06ab(0,44)
7		7.53ab(0,00)	0,14a(0,00)	67,26bc(0,00)	7,54a(0,01)	12,11abc(0,79)	0,24a(0,00)	51,03ab(0,85)	63,16b(0,52)
1		7.55ab(0,03)	0,16a(0,03)	59,85abc(0,34)	10,06ab(0,73)	6,82a(0,73)	0,31ab(0,01)	22,29a(0,38)	30,39a(1,20)
2		7.64bc(0,13)	0,18a(0,03)	53,93ab(0,40)	8,82ab(0,22)	7,82ab(0,14)	0,36ab(0,04)	22,45a(0,41)	36,79a(1,23)
3		7.61bc(0,01)	0,12a(0,04)	61,50abc(0,66)	8,08ab(0,54)	14,47bc(0,73)	0,37ab(0,10)	40,37ab(1,26)	58,94ab(1,56)
4	**D_1**	7.49ab(0,03)	0,18a(0,06)	53,05a(0,31)	8,10ab(0,35)	14,94bc(0,70)	0,44ab(0,08)	38,86ab(0,68)	65,64b(0,80)
5		7.55ab(0,02)	0,19a(0,05)	63,53bc(0,92)	9,94ab(0,76)	11,88abc(0,54)	0,38ab(0,09)	34,01ab(0,59)	64,28b(0,81)
6		7.44a(0,10)	0,17a(0,05)	64,70bc(0,43)	9,93ab(0,28)	12,97abc(0,20)	0,43ab(0,01)	39,94ab(0,68)	70,28b(0,89)
7		7,50ab(0,05)	0,18a(0,03)	64,12bc(0,46)	9,94ab(0,78)	12,43abc(0,55)	0,41ab(0,05)	34,28ab(1,09)	81,75b(0,41)
1		7.57abc(0,04)	0,20a(0,05)	62,49abc(0,33)	8,58ab(0,39)	12,22abc(0,24)	0,3ab(0,06)	41,26ab(1,12)	37,53a(1,11)
2		7.70c(0,01)	0,22a(0,06)	68,09c(0,31)	8,84ab(0,15)	12,78abc(0,26)	0,24a(0,04)	55,59ab(0,37)	48,75ab(1,40)
3		7.61abc(0,02)	0,21a(0,05)	57,18ab(0,41)	7,05a(0,54)	15,94bc(0,71)	0,22a(0,04)	74,26b(1,95)	62,76b(1,43)
4	**D_2**	7.51ab(0,04)	0,17a(0,08)	58,16abc(0,96)	8,42ab(0,53)	15,15bc(0,51)	0,24a(0,01)	64,01ab(1,27)	60,72ab(0,46)
5		7.59abc(0,03)	0,27a(0,02)	64,73bc(0,75)	7,97ab(34)	13,00abc(0,47)	0,2a(0,06)	66,28b(1,63)	71,36b(1,16)
6		7.47a(0,05)	1,76b(0,03)	67,45bc(0,25)	7,06a(0,97)	13,78bc(0,26)	0,28ab(0,07)	53,63ab(1,17)	70,75b(0,98)
7		7.53ab(0,01)	1,01ab(0,08)	66,09bc(0,81)	7,51a(0,43)	13,39abc(0,67)	0,24a(0,05)	58,25ab(0,86)	124,38c(3,40)
1		7.47a(0,03)	0,52a(0,07)	62,42abc(0,65)	10,44ab(0,98)	10,07ab(0,27)	0,56b(0,03)	19,73a(1,03)	58,38ab(1,21)
2		7.72c(0,04)	0,47a(0,06)	68,95c(0,73)	8,12ab(0,63)	10,56ab(0,21)	0,42ab(0,04)	27,32ab(0,66)	71,30b(0,69)
3		7.71c(0,10)	0,43a(0,03	61,03abc(0,03)	7,49a(0,36)	17,07c(0,48)	0,37ab(0,06)	46,72ab(0,69)	62,37b(1,18)
4	**D_3**	7.58abc(0,06)	0,47a(0,06)	65,67bc(0,93)	6,19a(0,48)	16,60c(0,69)	0,49ab(0,03)	42,49ab(0,96)	63,17b(0,58)
5		7.56abc(0,00)	0,45a(0,00)	66,90bc(0,00)	7,02a(0,24)	12,35abc(0,51)	0,30ab(0,00)	40,72ab(1,23)	68,26b(0,87)
6		7.58abc(0,00)	0,81ab(0,00)	68,81c(0,00)	6,34a(0,61)	19,01c(1,08)	0,36ab(0,00)	52,54ab(0,92)	79,36b(0,72)
7		7.57abc(0,00)	0,63a(0,00)	67,86c(0,00)	6,68a(0,89)	15,68bc(0,83)	0,33ab(0,00)	47,15ab(0,97)	168,31c(2,82)
	f	**9,85*** **	**2,84*** **	**9,14*** **	**3,30*** **	**1,33ns**	**10,42*** **	**2,61*** **	**4,11*** **

Soil Macro-Micro Nutrients

Soil macro-micro nutrient contents in the surface and subsurface horizons were given in Table 4 and Table 5, respectively. There was not remarkable difference results were observed in terms of sodium (Na) contents with PS application in the study area. Different doses of PS application were not significantly affected on potassium (K) content of surface horizons in the study area. In the subsurface horizon, K contents were showed similar results with the surface horizons. Calcium (Ca) contents were slightly increased in the surface and subsurface horizon with different doses of PS application. Furthermore, remarkable effect of different dose of applied PS was observed on Ca content in the study area. Magnesium (Mg) is a very important essential element for plants. D_2 and D_3 application were decreased Mg content in the surface horizon. Whereas, Mg content were slightly increased with D_1 and D_2 application, not changed with D_3 application.

Copper (Cu), Manganese (Mn), Zinc (Zn), Iron (Fe) results were given in Table 4 and 5, which are an essential element for plant, and it has sufficient quantity in PS. Copper (Cu) contents were not statistically significant changed with all doses of PS application. Manganese (Mn) content showed that; D_1 application was not remarkable, but Mn was decreased with D_2 and D_3 applications in the surface horizon. Zinc (Zn) contents showed; there were not statistically significant differences with different doses PS application in the surface soil horizon. However, D_3 application was increased Zn content in the subsurface soil. On the other hand, Zn quantity was slightly decreased with D_3 application in the subsurface soil horizon. The results of Fe contents showed that; slightly decreased were observed with D_2 and D_1 application, but remarkable differences were not observed with D_3 application in the surface horizon.

The impact of pig manure application on metal content in the soil was a soil quality issue that was of both agronomic and environmental interest. Pig manures contained plant functional nutrient metals such as Cu, Zn, Mn, and Fe. The effect of pig manure addition on bioavailability of metals in the soil could be direct and/or indirect. Mg, Cu, Mn, Zn, Fe contents of PS was passed into soil with application and accumulated in the soil, then passed into underground water, because of this reason Mg, Cu, Mn, Zn, Fe contents were decreased in the soil. Although Na, Cu, Fe contents were not significant changed with D_1 application, they were decreased with D_2 and D_3 application in the subsurface horizon.

Table 4. Distrubition of soil nutrients in the surface horizons (n:3, S: Sampling, D: Doses).

S	D	Soil Nutrient Contents							
		Na ($cmol^{(+)}$ kg^{-1})	K ($cmol^{(+)}$ kg^{-1})	Ca ($cmol^{(+)}$ kg^{-1})	Mg ($cmol^{(+)}$ kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})
1		0,89a(0,04)	1,65ab(0,12)	23,98a(1,30)	0,90a(0,08)	2,43a(0,17)	23,34a(0,71)	3,98a(0,50)	3,56a(0,29)
2		1,06b(0,02)	0,38a(0,13)	62,31c(1,00)	0,70a(0,04)	2,04a(0,37)	22,22ab(0,63)	0,32a(0,27)	6,05abc(0,67)
3		0,16a(0,01)	0,36a(0,09)	16,59a(1,06)	0,69a(0,02)	2,02a(0,15)	15,40a(0,66)	0,51a(0,04)	3,54a(0,60)
4	C	0,39a(0,04)	0,42a(0,04)	23,52a(1,15)	0,71a(0,03)	2,65a(0,25)	16,73a(0,79)	0,46a(0,18)	3,6ab(0,05)
5		0,65a(0,09)	0,24a(0,00)	70,27c(0,00)	0,91a(0,00)	1,81a(0,00)	22,47a(0,47)	0,42a(0,00)	4,46ab(0,00)
6		1,3a(0,08)	0,28a(0,00)	15,88a(0,00)	0,65a(0,00)	1,12a(0,00)	11,59a(0,24)	0,32a(0,00)	1,70a(0,00)
7		0,98a(0,03)	0,26a(0,05)	23,07b(0,87)	0,78a(0,05)	1,47a(0,00)	17,03a(0,35)	0,21a(0,00)	3,08a(0,00)
1		1,26a(0,04)	1,05a(0,05)	24,71a(0,26)	1,01a(0,06)	2,04a(0,12)	28,53a(0,44)	3,69a(0,06)	3,99ab(0,21)
2		1,61a(0,05)	0,83a(0,06)	64,69c(0,78)	0,86a(0,01)	2,56a(0,06)	68,15b(0,97)	4,85a(0,51)	7,16abc(0,40)
3		0,18a(0,01)	1,10a(0,11)	16,16a(0,38)	0,81a(0,06)	2,42a(0,05)	20,85a(0,76)	3,29a(0,47)	3,82ab(0,32)
4	D_1	1,22a(0,09)	1,07a(0,11)	21,67a(0,58)	0,85a(0,07)	2,53a(0,24)	20,80a(0,37)	2,91a(0,06)	3,75ab(0,07)
5		0,95a(0,06)	1,00a(0,11)	58,91bc(0,86)	1,17a(0,05)	2,29a(0,16)	27,63a(0,25)	4,48a(0,31)	4,56ab(0,36)
6		1,47a(0,09)	0,84a(0,03)	15,85a(0,92)	0,79a(0,03)	1,17a(0,14)	14,75a(0,91)	2,20a(0,02)	1,76a(0,26)
7		1,21a(0,04)	0,92a(0,04)	37,38ab(0,69)	0,98a(0,01)	1,73a(0,15)	21,19a(0,80)	3,34a(0,17)	3,16a(0,31)
1		3,08a(0,09)	1,67ab(0,09)	22,12a(0,29)	3,15b(0,05)	3,95a(0,17)	49,66(0,70)	14,96a(0,13)	5,91abc(0,45)
2		0,85a(0,05)	0,62a(0,21)	48,19bc(0,88)	1,76a(0,05)	4,82a(0,23)	106,37ab(0,70)	18,26a(0,74)	14,34ab(0,82)
3		1,28a(0,03)	0,79a(0,08)	15,17a(0,42)	1,47a(0,03)	2,38a(0,34)	25,03b(0,66)	9,40a(0,97)	5,01ab(0,90)
4	D_2	0,63a(0,04)	0,77a(0,23)	19,63a(0,77)	1,33a(0,15)	2,14a(0,22)	19,31a(0,79)	7,31a(0,66)	4,40ab(0,41)
5		1,34a(0,08)	1,30ab(0,31)	53,16bc(1,01)	1,78a(0,30)	2,78a(0,30)	33,07a(0,47)	16,29a(0,21)	6,80abc(0,27)
6		0,78a(0,04)	1,47ab(0,17)	12,54a(0,55)	1,24a(0,01)	1,34a(0,35)	16,13a(0,24)	7,04a(0,79)	2,81a(0,87)
7		1,06a(0,07)	1,38ab(0,13)	32,85ab(1,10)	1,51a(0,14)	2,06a(0,16)	24,60a(0,35)	11,67a(0,43)	4,80ab(0,13)
1		2,55a(0,18)	1,48ab(0,35)	26,21a(0,29)	2,05ab(0,37)	4,23a(0,15)	39,96a(0,44)	11,82a(0,01)	3,98ab(0,22)
2		1,86a(0,24)	1,00a(0,31)	55,10bc(0,67)	1,87a(0,46)	4,10a(0,15)	50,61ab(0,97)	17,71a(0,54)	8,29bc(0,48)
3		0,86a(0,08)	2,73b(0,42)	12,55a(0,62)	4,26a(0,53)	10,86b(0,14)	38,44ab(0,76)	46,30b(0,60)	10,20c(0,36)
4	D_3	1,12a(0,09)	2,79b(0,34)	15,87a(0,67)	3,40b(0,44)	9,97b(0,16)	43,07ab(0,37)	35,26ab(0,85)	8,45bc(0,91)
5		1,34a(0,09)	0,40a(0,00)	60,94c(0,00)	1,06b(0,00)	2,85a(0,00)	23,56a(0,25)	13,99a(0,00)	6,46abc(0,00)
6		0,38a(0,02)	1,41ab(0,00)	14,22a(0,00)	1,69a(0,00)	2,35a(0,00)	17,14a(0,91)	13,25a(0,00)	4,20ab(0,00)
7		0,86a(0,01)	1,51ab(0,13)	37,58ab(0,00)	1,38a(0,08)	2,60a(0,00)	20,35a(0,89)	13,62a(0,00)	5,33ab(0,00)
f		**5,96*****	**1,70***	**4,55*****	**48,21*****	**13,83*****	**5,96*****	**12,81*****	**7,55*****

Table 5. Distrubition of soil nutrients in the subsurface horizons (n:3, S: Sampling, D: Doses).

		Soil Nutrient Contents							
S	**D**	**Na (cmol(+) kg-1)**	**K (cmol(+) kg-1)**	**Ca (cmol(+) kg-1)**	**Mg (cmol(+) kg-1)**	**Cu (mg kg-1)**	**Mn (mg kg-1)**	**Zn (mg kg-1)**	**Fe (mg kg-1)**
1		0,89(0,14)	0,60ab(0,03)	23,97a(0,32)	1,24ab(014)	1,17abc(0,07)	15,03abc(0,42)	0,53a(0,09)	2,96ab(0,30)
2		3,82(0,27)	0,18a(0,04)	64,20bc(0,61)	0,75a(0,08)	1,91bc(0,05)	39,02c(0,80)	0,16a(0,01)	6,21bc(0,24)
3		2,46(0,37)	0,21a(0,01)	13,79a(0,78)	0,68a(0,03)	1,24abc(0,10)	13,76abc(0,62)	0,42a(0,10)	3,46abc(0,28)
4	**C**	2,33(0,36)	0,30a(0,05)	23,83a(0,31)	0,73a(0,10)	1,99bc(0,03)	14,15abc(0,71)	0,21a(0,07)	3,82abc(0,27)
5		0,93(0,00)	0,17a(0,00)	66,56c(0,00)	0,95ab(0,00)	1,58abc(0,00)	21,80c(0,00)	0,43a(0,00)	5,02abc(0,00)
6		2,36(0,00)	0,10a(0,00)	14,85a(0,00)	0,64a(0,00)	0,58a(0,00)	9,62a(0,00)	0,30a(0,00)	1,10a(0,00)
7		1,65(0,10)	0,13a(0,08)	40,70ab(0,50)	0,80a(0,16)	1,08ab(0,00)	15,71abc(0,00)	0,21a(0,00)	3,06ab(0,00)
1		0,99(0,24)	0,42ab(0,02)	23,24a(0,21)	0,82a(0,08)	1,10ab(0,02)	13,97abc(0,36)	0,13a(0,01)	3,26ab(0,45)
2		1,66(0,20)	0,19a(0,02)	55,07bc(0,31)	0,81a(0,03)	1,45abc(0,02)	38,08c(0,98)	0,27a(0,09)	5,46bc(0,38)
3		1,21(0,20)	0,43ab(0,06)	16,47a(0,38)	0,78a(0,04)	1,73abc(0,09)	16,41abc(0,33)	0,73a(0,09)	4,06abc(0,25)
4	**D_1**	1,57(0,09)	0,38ab(0,20)	21,21a(0,27)	0,89ab(0,06)	1,76abc(0,11)	17,05abc(0,42)	0,28a(0,02)	3,44abc(0,41)
5		1,79(0,30)	0,31a(0,05)	64,03bc(0,47)	1,33ab(0,05)	1,51abc(0,09)	20,38bc(0,51)	0,73a(0,09)	4,28abc(0,37)
6		0,44(0,09)	0,18a(0,02)	15,39a(0,31)	0,81a(0,07)	0,86ab(0,17)	13,44ab(0,30)	0,11a(0,04)	2,06a(0,33)
7		1,11(0,14)	0,25a(0,03)	39,71ab(0,52)	1,07ab(0,11)	1,18abc(0,05)	16,91ab(0,24)c	0,42a(0,11)	3,17ab(0,04)
1		1,66(0,23)	0,57ab(0,15)	27,12a(0,31)	1,19ab(0,13)	1,13ab(0,09)	14,42abc(0,86)	0,39a(0,10)	3,13ab(0,51)
2		1,48(0,23)	0,64ab(0,19)	54,46bc(0,26)	1,12ab(0,07)	1,16abc(0,06)	42,94c(0,63)	0,33a(0,07)	5,85bc(0,41)
3		0,47(0,11)	0,28a(0,05)	16,53a(0,39)	1,18ab(0,31)	1,05ab(0,06)	18,07bc(0,71)	0,89a(0,06)	3,55abc(0,46)
4	**D_2**	0,80(0,06)	0,24a(0,03)	18,39a(0,42)	1,14ab(0,13)	1,02ab(0,07)	15,44abc(0,83)	0,19a(0,02)	3,32abc(0,23)
5		0,72(0,19)	0,74ab(0,53)	50,98bc(0,58)	1,92b(0,40)	0,94ab(0,11)	17,89bc(0,44)	0,88a(0,05)	3,75abc(0,27)
6		0,80(0,13)	0,24a(0,16)	13,45a(0,69)	1,09ab(0,11)	0,58a(0,12)	11,77abc(0,61)	0,49a(0,07)	1,39a(0,36)
7		0,76(0,20)	0,49ab(0,24)	32,22ab(0,85)	1,51b(0,25)	0,76a(0,12)	14,83abc(0,50)	0,68a(0,06)	2,57ab(0,32)
1		3,37(0,21)	0,44ab(0,10)	26,55a(0,85)	1,02ab(0,13)	1,26abc(0,11)	14,76abc(0,75)	0,69a(0,08)	2,87ab(0,40)
2		2,23(0,55)	0,27a(0,06)	60,16bc(0,65)	1,21ab(0,13)	1,85abc(0,14)	41,46c(0,92)	4,82b(0,85)	6,51c(0,59)
3		0,73(0,24)	1,00b(0,25)	17,04a(0,39)	1,25ab(0,16)	1,39abc(0,11)	17,76abc(0,98)	1,51ab(0,20)	3,21ab(0,29)
4	**D_3**	1,86(0,45)	0,68ab(0,29)	19,32a(0,34)	1,31ab(0,12)	2,28c(0,18)	16,89abc(0,45)	5,09b(0,92)	8,45c(0,67)
5		0,59(0,00)	0,25a(0,00)	81,86c(0,00)	0,84ab(0,00)	1,13ab(0,15)	16,75abc(0,00)	1,43ab(0,00)	3,46abc(0,00)
6		4,76(0,00)	0,43ab(0,00)	16,00a(0,00)	1,07ab(0,00)	0,59a(0,20)	8,86a(0,00)	1,54ab(0,00)	0,68a(0,00)
7		2,68(0,55)	0,34ab(0,20)	48,93b(0,25)	0,96ab(0,25)	0,86ab(0,12)	12,80ab(0,39)	1,48ab(0,00)	2,07a(0,00)
f		**4,95*** **	**1,33ns**	**2,79*** **	**46,27*** **	**5,62*** **	**4,95*** **	**43,88*** **	**2,65*** **

Crop Yield

Plant characteristics were given in Table 6. All parameters were significantly affected by PS application except of Cu contents, which were increased with PS application depending on quantity of PS. According to the plant nutrient results (Table 6), Na uptakes were increased with D_1 and D_2 applications. D_3 applications were not significantly effected on plant Na uptake. Cereal K uptakes were increased with all different doses of PS application. Ca and Mg uptakes were not significant with all PS applications.

Plant phosphorus (P) were changed between 7.93 and 11.18 g kg^{-1} in the first year; 7.95 and 10.83 g kg^{-1}in the second year; 9.36 and 12.47 g kg^{-1} in the third year, respectively. Plant P uptakes were slightly increased with D_2 and D_3 applications. Total Nitrogen (TN) are changed between 16.14 and 27.10 g kg^{-1} in the first year; 12.30 and 19.89 g kg^{-1}in the second year; 15.66 and 20.86 g kg^{-1} in the third year, respectively. TN was decreased with consequently application of PS (especially with D_2 application) owing to the microbial activity. Zn, Fe and Mn uptakes of plants were increased with all doses of PS applications whereas; Cu uptakes of plants were not statistically significant. The results showed that the optimum application rate were D_1 application under field conditions in terms of plant production (Data of P and TN are not shown).

Table 6. Distribution of plant nutrient contents (n:3, S: Sampling, D: Doses).

		Plant Nutrient Contents							
D	S	Na (g kg^{-1})	K (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	Cu (g kg^{-1})	Zn (g kg^{-1})	Fe (g kg^{-1})	Mn (g kg^{-1})
C	2009	0,32 a (0,05)	4,61 a (0,41)	0,56 a (0,04)	0,59 a (0,07)	2,04 (2,09)	12,14 a (3,54)	30,71 ab (1,91)	14,19 a (1,47)
	2010	0,50 ab (0,04)	4,19 a (0,33)	0,5 a (0,03)	0,94 bc (0,06)	3,06 (2,49)	19,86 ab (2,89)	21,94 a (1,56)	17,20 a (1,2)
	2011	0,42 ab (0,04)	4,97 ab (0,33)	1,03 c (0,03)	1,21 c (0,06)	5,46 (2,49)	17,23 a (2,89)	39,04 bc (1,56)	18,95 bc (1,2)
D_1	2009	0,45 ab (0,03)	5,83 ab (0,24)	0,51 a (0,02)	0,68 a (0,04)	4,04 (1,49)	17,68 a (2,04)	28,02 ab (1,1)	16,67 a (0,85)
	2010	0,24 a (0,03)	3,95 a (0,24)	0,58 ab (0,02)	0,83 ab (0,04)	2,41 (1,49)	17,99 ab (2,04)	21,7 a (1,1)	15,89 a (0,85)
	2011	0,72 ab (0,03)	6,52 bc (0,19)	0,82 b (0,02)	1,05 bc (0,03)	5,70 (1,83)	28,1 ab (1,67)	40,91 c (0,9)	23,00 c (0,69)
D_2	2009	0,96 c (0,05)	7,63 c (0,41)	0,6 ab (0,04)	0,88 ab (0,07)	8,50 (2,09)	32,15 b (3,54)	34,8 bc (1,91)	27,18 bc (1,47)
	2010	0,41 ab (0,04)	3,83 a (0,33)	0,65 ab (0,03)	0,8 ab (0,06)	2,70 (2,49)	22,95 ab (2,89)	25,38 a (1,56)	16,78 a (1,2)
	2011	0,95 c (0,04)	6,92 bc (0,33)	1,14 c (0,03)	1,35 c (0,06)	7,33 (2,49)	57,54 c (2,89)	45,52 c (1,56)	31,6 c (1,2)
D_3	2009	0,28 a (0,05)	6,44 bc (0,41)	0,46 a (0,04)	0,57 a (0,07)	2,75 (2,09)	22,99 ab (3,54)	32,21 ab (1,91)	14,8 ab (1,47)
	2010	0,4 a (0,04)	4,66 a (0,33)	0,73 ab (0,03)	1 bc (0,06)	3,12 (2,49)	28,36 ab (2,89)	31,99 ab (1,56)	26,85 ab (1,2)
	2011	0,62 ab (0,04)	6,84 bc (0,33)	0,99 c (0,03)	1,14 bc (0,06)	8,20 (2,49)	41,14 b (2,89)	43,57 c (1,56)	24,08 c (1,2)
f		**33,28*****	**17,70*****	**64,32*****	**18,68*****	**0,54^{ns}**	**19,52*****	**36,93*****	**23,38*****

DISCUSSION

Effects of Application on Soil Properties, Nutrients and Quality

Soil pH was greatly influenced by addition of organic matter (OM) through different organic amendments and changed in pH varies with the nature of OM (Walker et al., 2004). Whalen et al. (2000) reported that; effects of pig manure on soil pH would depend on the pig manure source and soil characteristics. Manures of high organic matter and carbonate content would be most effective in raising the pH of an acid soil and also buffering against changes in pH once in the soil (Greer and Schoensu, 1997). The effect of PS addition on pH, which was more evident at large amendment rate, was similar to that reported previously by other authors (Ukrainetz et al., 1996; Chang et al. 1990). Chang et al. (1990) observed a decrease in soil pH with time and suggested that some soils might eventually become acidic with consequently application of manure. Results of Chang et al. (1990) were not observed in our study, and this could be the reason of application term/period.

Soil salinity was increased with synthetic fertilizers due to insufficient rainwater in arid-semiarid climate regions. Animal manures could contain appreciable amounts of salts and excessive application of solid or liquid manures can result in salt accumulations that could damage crops and soil structure. Chang et al. (1990) observed a linear increase in electrical conductivity over time with increasing rates of cattle manure application.

Soil salinity was one of the most important factors reducing soil quality and productivity (Shortall and Liebhardt 1975). Salinization usually occured over the first few days following slurry application (Diez et al. 2001), but it decreased because of rainfall and irrigation. Our results showed that salinity was increased with high doses applications. Because, PS had more sodium concentration and soluble salts were accumulated in soil horizon with high doses application.

The study showed that; there were similar lime contents before and after PS application according to Doner and Lynn (1989). According to Porta (1999), the cation exchange capacity increased as more slurry was added when the soil had low clay content, giving rise to a good correlation between the values of organic carbon and exchange capacity.

The impact of pig manure application on metal content in the soil was a soil quality issue that is of both agronomic and environmental interest. Pig manures contained plant functional nutrient metals such as Cu, Zn, Mn, and Fe. The effect of pig manure addition on bioavailability of metals in the soil might be direct and/or indirect. Direct effects would include increases in the amount of an element in soil due to that element being present in the pig manure added. An example of this was Cu and Zn. Pig manure added to the soil could increase the total and bioavailable concentrations of metal. Some researcher found similar results (Qian et al.2003; Chang et al., 1991). When PS added to the soil, could increase the total and bioavailable concentrations reported by Schoenau et al. (2004). Our results were similar with Schoenau et al. (2004).

Mg, Cu, Mn, Zn, Fe contents of PS was passed into soil with application and accumulated in the soil, then passed into underground water, because of this reason Mg, Cu, Mn, Zn, Fe contents were decreased in the soil. Although Na, Cu, Fe contents were not significant changed with D_1 application, they were decreased with D_2 and D_3 application in the subsurface horizon.

Hooda et al., 2001 found that similar results; Olsen extractable-P in the fields that received high rates of P inputs across the sites ranged from 28 to 106 mg P kg^{-1} compared with 10-35 mg P kg^{-1} in the fields with low or no P inputs. The distribution of organic and inorganic forms of P in agricultural soils varied widely, depending on soil type, management history and climatic condition (Barberies et al., 1996).

Phosphorus was the second most limiting nutrient for terrestrial plant growth after nitrogen. Transport of soluble P by diffusion to the root surface is normally the rate-limiting step in the supply of P for plant uptake (Chesworth et al., 2008, Sanchez, 2007). The assessment of available phosphorus was interest to establish the characteristics of soil fertility, and that together with potassium and calcium, is the most extracted by plants.

Soil organic carbon was very important parameter to determine soil quality, which was an indicator of decomposed organic matter in soil. The effect of different doses application on soil organic carbon was found statistically significant. Soil organic carbon was increased with application doses. The reason of this increase was high organic carbon content of applied PS, which was passed into soil with application.

Effects of manure addition on increasing soil organic matter content would be more pronounced on soils of lower organic matter content and low fertility (Loro et al., 1997). The application of manure could increase the soil organic matter (SOM) and SOM contributed to nutrient supply, improvement of soil physical and chemical properties (Jimenez et al., 2002). Many researchers had observed such as our study increases in soil organic matter following repeated applications of manure (Campbell et al., 1997; Larney et al., 2000).

Our results showed that; manure, like commercial fertilizer, could directly and indirectly influence the soil properties and quality (McLaughlin et al., 1994; Weggler-Beaton et al. 2000). PS was a renewable resource and an excellent source of macro- (N, P, K, Ca, Mg, and S) and micronutrients (Zn, Cu, Fe, Mn, etc.) that was essential for growing plants (Eghball and Barbarick., 2002), especially, which was a natural and easy source of carbon.

Effect of Application on Crop Yield

Lal and Marthur (1989) observed similar result that manure applications had positive effect on crop yield in the first year application. There was positive correlation with PS application rate and crop yield. The application rate of pig manure increased crop yields, but yields varied depending on actual rate and method of application, type of soil and growing conditions.

Pig manure had been shown to increase crop quality by increasing plant nutrient concentration not only in the year of application but also in succeeding years. Sutton et al. (1982) was found similar results as our study. The results showed that; nutrients contents were increased with PS application. The manure application on the field had been reported to supply plant nutrients and increase soil organic matter and our results were similar with Charles (1999) and Schoenau et al., (2004).

Kornegay et al. (1976) reported increased corn leaf Cu, Zn, P, and K with pig manure with pigs feeding high Cu diets (250 to 370 mg Cu kg^{-1}). In other studies, Zhu et al. (1991) reported increased plant growth and Cu uptake from Cu-amended hog manure compared to non-amended manure (Bailey and Buckley, 1998). Our results showed that PS applications increased trace elements uptake by plants.

The PS application was influenced on P concentration, which was greater magnitude than N concentration in plants. Similarly, Grant et al., (2001) reported that additions of PS were significantly increased P concentration than N concentration (Qian and Schoenau, 2000).

Diez et al. (2001) indicated that application of high rates of slurry appeared to increase plant N uptake without increasing grain production. In some studies was reported liquid hog manure application were increased leaf or seed nitrogen and phosphorus concentrations (Sutton et al. 1982; Faz et al., 2004). They concluded that nutrients in excess of quantities removed by crops were potential pollutants in surface and ground water, or soil. Excessively high rates of hog manure application to pastures might result in high levels of NO_3-N in the forage making it unsafe for ruminants (Burns at al. 1992). Similarly, our results showed that high rate of PS affected plant growth, yield and soil properties.

The beneficial effects of organic materials on crop growth and soil properties were directly related to the application rate and chemical composition of the organic manure (Shen and Shen., 2001). The results showed that the optimum application rate were D_1 application under field conditions in terms of plant production.

CONCLUSIONS

The use of organic manure to fertilize agricultural lands is positive from the perspective of a recycling economy. Application of organic matter to soils directly maintains an adequate level of soil organic matter, a critical component of soil fertility and productivity. There are many factors to be considered when attempting to assess the overall net impact of a management practice on soil quality and productivity.

PS has very large effects on the long-term productivity of soil, relative to applying no nutrients, and thus the addition of nutrients in either form must be regarded as essential for the maintenance of soil quality. PS has greater effect on increasing soil organic matter levels. Because of this, the long-term application of PS can also positively effect on some soil physical properties. Despite this, it appears that typical applications of PS over many years confer no advantage to soil productivity. Only when there are large inputs of manures over many years, such that there are large accumulations of soil organic matter, do PS has benefits for soil productivity over and above the nutrients they contain.

Consequently, D_1 application so this dose is the agronomic rate of N-requirement (170 kg N/ha/yr) (European Directive 91/676/CEE), is very appropriate in term of sustainable agriculture and also this dose can improve physical, chemical and biological soil properties. It is concluded therefore that the long-term use of PS with low dose may necessarily enhance soil quality in the long term. There are many factors to be considered when attempting to assess the overall net impact of a management practice on productivity. Additions of pig manure to soils at agronomic rates (170 kg N ha^{-1} yr^{-1}) to match crop nutrient requirements are expected to have a positive impact on soil productivity in the semiarid region. Therefore, the benefits from the use of application depend on management of PS, carbon and environmental quality. However, PS has high micronutrient contents, for this reason application of high doses can be polluted soils and can be damage human, animal and plant health, not suitable in term of sustainable agriculture.

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