Agriculture **2015**, *5*, 221-230; doi:10.3390/agriculture5020221

OPEN ACCESS

agriculture

ISSN 2077-0472

www.mdpi.com/journal/agriculture

Review

Effectiveness of Organic Wastes as Fertilizers and Amendments in Salt-Affected Soils

Mariangela Diacono [1,]* and Francesco Montemurro [2]

[1] Consiglio per la Ricerca e l'analisi dell'economia Agraria, CRA-SCA, Research Unit for Cropping Systems in Dry Environments, Via Celso Ulpiani 5, 70125, Bari, Italy

[2] Consiglio per la Ricerca e l'analisi dell'economia Agraria, CRA-SCA, Research Unit for Cropping Systems in Dry Environments (Azienda Sperimentale Metaponto), SS 106 Jonica, km 448.2, 75010, Metaponto (MT), Italy; E-Mail: francesco.montemurro@entecra.it

* Author to whom correspondence should be addressed; E-Mail: mariangela.diacono@entecra.it; Tel.: +39-080-5475252; Fax: +39-080-5475023.

Academic Editor: Stephen R. Smith

Received: 19 February 2015 / Accepted: 21 April 2015 / Published: 24 April 2015

Abstract: Excessive salt rate can adversely influence the physical, chemical, and biological properties of soils, mainly in arid and semi-arid world regions. Therefore, salt-affected soils must be reclaimed to maintain satisfactory fertility levels for increasing food production. Different approaches have been suggested to solve these issues. This short review focuses on selected studies that have identified organic materials (e.g., farmyard manures, different agro-industrial by-products, and composts) as effective tools to improve different soil properties (e.g., structural stability and permeability) in salt-affected soils. Organic fertilization is highly sustainable when compared to other options to date when taken into consideration as a solution to the highlighted issues. However, further experimental investigations are needed to validate this approach in a wider range of both saline and sodic soils, also combining waste recycling with other sustainable agronomic practices (crop rotations, cover crops use, *etc.*).

Keywords: salts; salinization; Mediterranean environment; agro-industrial by-products; organic fertilization

---

1. Introduction

The expected increase in the world's population (9.6 billion by 2050) needs food productivity to step up within a few decades [1,2]. Unfortunately, extensive areas of irrigated lands are unproductive, due to the accumulation of salts in the soil profile occupied by root systems. It is estimated that about 15% of the total land area of the world has been degraded by salinization and soil erosion, which are among the major causes of desertification [3]. Dajic [4] reported that the total world area affected by saline and sodic soils is 397×10^6 and 434×10^6 ha, respectively. On this matter, according to the Joint Research Centre Institute for Environment and Sustainability (European Commission), soil salinization affects an estimated one to three million hectares in the EU [5].

Soil salinization and drought stress mainly occur in the arid and semiarid regions of Mediterranean area, which are characterized by high evapotranspiration rates and low rainfall. In these areas, the leaching of salts is very low, therefore, salt accumulates in soil surface layers. Since high salts content may adversely influence soil properties and crop yields, food security could be limited as a consequence. Therefore, salt-affected soils must be reclaimed to maintain satisfactory levels of fertility for sustaining food production.

To date, different approaches have been suggested to solve these issues, such as soil leaching with water, chemical amendment, and phytoremediation [6,7]. On the other hand, the implementation of sustainable farming practices may prevent and, in some cases, reverse soil salinization conditions. For example, rational management of brackish water for land-irrigation should be employed and, in rain-fed agriculture, crops rotation can be promoted for improving the balance between rainfall and water use by crop. Biotechnological strategies and application of breeding and screening methodologies to enhance the tolerance of crops to salinity conditions, as well as organic fertilization for reclaiming saline and sodic soils, and increase their fertility, have also been assessed [8].

This paper provides a brief overview of the present knowledge regarding organic fertilization by different waste-recycling in soils that are under stress due to salinization conditions. The overview, focusing on recently-published data, aimed to investigate the main approaches and effects of this agronomic practice on some soil properties, thus, verifying the potential of organic amendments to restore soil quality.

2. Salinity: Causes and Effects

In order to identify proper strategies of organic fertilization of soils in salinized areas, it is essential to understand how salinity develops in the soil. Salinity can be defined as an accumulation of dissolved mineral salts in soil water, and an excess of sodium ions in the rizosphere [9]. The origin of soil salts can be natural (*i.e.*, primary salinization) or human-induced (*i.e.*, secondary salinization). The main natural source of salinity is the weathering of minerals in rocks, sediments, and soils. Other common sources of soil salts are the atmospheric deposition of oceanic salts and the intrusion of seawater into the groundwater of coastal areas, where the over-exploitation of water can considerably move down the normal water table [5,9]. Under high water table conditions, salts can move upward due to evaporation and evapotranspiration processes.

Secondary salinization can be the result of irrigation, which is, also, sometimes carried out with brackish water on saline soils. This use of unconventional water helps to face the current scarcity of water resources for farming, which is determined by the competition with different human and industrial uses. Attention must be paid, however, on the quality of the water used, as well as on the fact that seasonal/temporary salinization can be partially controlled by fulfilling appropriate leaching requirements [10]. In addition, repeated application of animal manures and sewage sludge to cropland may be considered as an anthropogenic source of salts. Therefore, appropriate wastes management strategies, such as controlled biodegradation processes (*i.e.*, composting), are crucial to minimize the potentially negative environmental impact of waste application prior to their use in agriculture [11].

The distribution of soluble salts in the soil profile is influenced by leaching and evaporation from soil surfaces. Some of the accumulated specific ions (such as Cl^-) can be directly toxic, depending on plant-specific tolerance, and may induce physiological disorders. Excessive amounts of salts can inhibit the uptake of mineral nutrients, cause premature senescence, and reduce the photosynthetic activity to a level that cannot sustain crop growth and yields [12]. Water deficit or osmotic effects are among the major factors that brings decline in cell division and reduction of plant growth, thus, limiting crop production [9].

In addition, excess of salts may adversely influence the biological, physical, and chemical properties of soil. Sodicity (*i.e.*, excess of Na^+ in the rhizosphere) is a secondary consequence of salinity, which is typical for clayey soils and affects their physical properties. In these soils, the exchangeable Na^+ is bound to the negative charges of clay, thus, causing deflocculation of clayey particles. As Lauchli and Epstein [13] highlighted, the high exchangeable Na^+ percentage can lead to swelling and dispersion of clays, as well as breaking of soil aggregates. As a consequence, both water infiltration and water-holding capacity could be reduced. Saline soils are easier to be reclaimed than sodic ones, because, generally, the former requires leaching of soluble salts, while the latter also requires a Ca^{2+} source to replace the excess Na^+.

Salinity also affects soil chemical properties, such as pH, cation exchange capacity (CEC), exchangeable sodium percentage (ESP), soil organic carbon, and alters the osmotic and matric potential of the soil solution [14]. Most salt-affected soils are deficient in several nutrients, thus, more fertilizer applications may be required. Micronutrient deficiency appears to be a side-effect of salinization and may derive both from soil alkalinization and ions competition [15]. Moreover, Garcia and Hernandez [16] showed that an increase in soil salinity inhibits several soil enzymatic activities, such as alkaline phosphatase and β-glucosidase, while Rietz and Haynes [17] indicated the effects of salinity, both on soil microbial biomass carbon and enzyme activities. In particular, the fungal part of the microbial biomass was strongly reduced in saline soils [18]. Therefore, effective tools to improve soil properties in salt-affected soils are crucial to guarantee an income for farmers particularly in arid world regions.

3. Organic Fertilization on Salt-Affected Soils: Organic Wastes Recycling

It is known that several organic materials, such as farmyard manures, agro-industrial by-products and composts can be used as amendments to enhance and sustain the overall soil fertility [19,20]. The same amendments could likely be considered for soil remediation in the salt-affected areas due to their high organic matter content. In fact, organic matter has several beneficial effects on agricultural fields, such as the slow release of nutrients, soil structure improvement, and the protection of soils against erosion [21].

Selected studies (from literature of the last 10–15 years) are summarized in Table 1, focusing on the effects of application of organic matter (*i.e.*, different organic waste materials) to salt stressed soils. In particular, such effects can be referred to chemical, biological, and physical soil properties, as it will be discussed in the next subsections. The reported findings offer powerful evidence on the potential of organic fertilizers in improving soil properties.

Table 1. Effects of various organic matter inputs under soil salinity conditions (essential data).

Organic Materials	Soil Salinity/Salt Levels	Effects	Reference
Cotton gin crushed compost and poultry manure	ESP 15.7 EC 9 $mS \cdot cm^{-1}$ pH 8	Improving soil structure, reducing (by 50%) the ESP and increasing different enzyme activities	[8]
Mixture of green waste compost, sedge peat and furfural residue	ESP 15.8 EC 3.69 $mS \cdot cm^{-1}$ pH 7.75	Decreasing bulk density, EC, and ESP and increasing total porosity and organic carbon. The combination of amendments had substantial potential for ameliorating saline soils, working better than each amendment alone	[14]
(i) Pig manure (ii) Pig manure+rice straw (iii) Rice straw (iv) control	Total salts 3.3 $g \cdot kg^{-1}$ pH 8.86	Urease activity increased by more than 150% in the mixed treatment, compared to the control. The incorporation of organic manure into the soil significantly increased soil alkaline phosphatase activity and soil respiration rate	[22]
Green manure mixed with farmyard manure	1%–2% salt EC 8.5–20.4 $mS \cdot cm^{-1}$ pH 4.58–4.79	The OM application in paddy fields could effectively alleviate the problem of soil salinity, also resulting in yield improvement	[23]
Cassava-industrial waste compost and vermicompost with or without earthworms	EC 4.26 $mS \cdot cm^{-1}$ pH 7.30	Compost and vermicompost amendments decreased electrical conductivity, improved CEC, soil organic carbon, total nitrogen and extractable phosphorus	[24]
Compost produced from by-products of the olive oil industry and poultry manure	EC 1.85 $mS \cdot cm^{-1}$ pH 7.7	Increasing soluble and exchangeable-K^+ (thus limiting the entry of Na^+ into the exchange complex) as well as CEC	[25]
Farmyard manure + saline water (EC 2.25 $mS \cdot cm^{-1}$)	EC 4.8–6.3 $mS \cdot cm^{-1}$	Improvement of infiltration rate by about 89%, and decreasing soil sodicity by 41.3%. Decreasing soil bulk density, allowing an enhancement of soil porosity and aeration, and improving saline water leaching	[26]
Compost (animal wastes and plant residues)	ESP 34–37 EC 4.03–5.11 $mS \cdot cm^{-1}$ pH 8.62–8.75	Decreasing EC and sodium adsorption ratios of the saturation extracts of the soils. Organic amendments co-applied with chemical amendments seemed to have a high value for reducing soil pH, soil salinity, and soil sodicity	[27]
Municipal wastewater	EC 60 $mS \cdot cm^{-1}$ pH 7.48	Decreasing soil pH and bulk density, while increasing EC and OM content of soil	[28]

Table 1. *Cont.*

Organic Materials	Soil Salinity/Salt Levels	Effects	Reference
Farm yard manure	EC 3.7–5.0 $mS \cdot cm^{-1}$ pH 8.69–9.18	Gypsum + sulfuric acid + Farm yard manure decreased bulk density but increased the porosity, void ratio, water permeability and hydraulic conductivity	[29]
Municipal solid waste compost and sewage sludge	EC 75 $mS \cdot cm^{-1}$ pH 8.2	13.3 $g \cdot kg^{-1}$ of compost significantly improved soil physical-chemical properties, especially C and N contents. Enzyme activities were substantially promoted in presence of both amendments	[30]

Note: ESP, exchangeable sodium percentage; EC, Electrical conductivity; OM, organic matter; CEC, cation exchange capacity.

3.1. Effects of Organic Materials on Soil Chemical Properties

As Hu and Schmidhalter [31] highlighted, the uptake of phosphorous (P) by crops is reduced in dry-soil conditions and the availability of this macronutrient can be reduced in saline soils. Conversely, during the mineralization process, organic matter releases humic substances, which may convert soil phosphates into available forms, improving release from hardly soluble rock minerals due to high total acidity [32]. Additionally, under saline soils the available fraction of potassium (K) can increase through the increase of CEC linked to organic matter content. In particular, the application of poultry manure and compost to soil can increase both the CEC and the soluble and exchangeable-K^+, which is a competitor of Na^+ under sodicity conditions, thus, limiting the entry of Na^+ into the exchange complex [25]. Moreover, K^+ is likewise important to maintain the turgor pressure of plant under drought and salinity stress. In a recent study, a mixture of green waste compost, sedge peat, and furfural residue (1:1:1 by volume) significantly reduced $Na^+ + K^+$ content and improved CEC and the contents of available N, P, and K [14].

Hao and Chang [33] showed that the soluble ions and the adsorption ratios of Na^+ and K^+ increased with 25 years of high rates of cattle manure application, particularly under non-irrigated conditions. Another study suggested that, even in a region with abundant rainfall, there was potential risk for secondary soil salinization by successive applications of chicken and pigeon manure [34]. Therefore, proper selection of organic fertilizers as nutrient sources, timing, as well as method of their application to soil, can be considered equally important [19]. As regards to method of application, Khaled and Fawy [35] found that the effect of interaction between salt and soil humus application was statistically significant showing that, under salt stress, both soil and foliar application of humic substances in corn field increased the uptake of nutrients. In particular, soil application of humus increased the N uptake, whereas foliar application increased the uptake of other macro- and micronutrients. The authors indicated to not exceed 2 g of well-humified organic matter/kg in the soil to obtain benefit from humic substances under salt conditions.

3.2. Effects of Organic Materials on Soil Biological Properties

Biological soil properties are very reactive to small changes occurring in management practices, therefore, it is possible to use them for evaluating the effects of the application of organic matter on soil characteristics [19].

Salinization may greatly disturb a large variety of microbially mediated processes in soil. Sardinha *et al.* [36] demonstrated that in different sites affected by saline liquid residues, microbial biomass C, biomass N, and fungal ergosterol had the highest values at the low-saline site (content of soluble salts 2.1 $mg \cdot g^{-1}$ soil) and the lowest at the high-saline site (soluble salts 9.7 $mg \cdot g^{-1}$ soil).

Exogenous organic matter applications to cropland are known to improve soil biological functions, also showing positive effects in the salt-affected soils. Liang *et al.* [22] showed that, in soil derived from alluvial and marine deposits (with 3.3 $g \cdot kg^{-1}$ total salts), soil urease and alkaline phosphatase activity, and respiration rate were significantly stimulated by incorporation of organic manure. Similarly, Chandra *et al.* [37] pointed out that, at low concentration, salts had a stimulating effect on carbon mineralization, but they can become toxic to microorganisms with increasing concentrations. Soil salinity can alter the organic matter turnover process, and the response pattern of C and N mineralization to salinity stress could depend on the type of organic material incorporated into the soil [18]. In particular, rice straw, plus pig manure treatment had higher significant effects on enzymatic and microbial activity in salt-affected soil, than rice straw and manure alone [38]. This result confirms that incorporation of organic manure can be an effective low-input agro-technological approach to minimize toxicity conditions induced by salinization. In addition, it has been demonstrated that non-composted manure and compost application to a saline soil in dryland conditions can reduce ESP (by 50% than unamended soil), at the same time, significantly increasing different enzyme activities (e.g., urease, alkaline phosphatase, and dehydrogenase) [8]. Amendment incorporation under high soil salinity or sodicity may also provide a buffer of pH in saline and alkaline soils, influencing the activity of microorganisms [32].

Moreover, Rao and Pathak [39] found that organic matter (green manure) improved microbial activity at salinities of EC ≤ 26, showing an increase in urease activity of saline and alkali soils following the amendment addition.

3.3. Effects of Organic Materials on Soil Physical Properties

Organic matter promotes the stability of soil aggregates through the bonding or adhesion properties, both of waste products of bacteria (polysaccharides) and fungal and/or bacterial hyphae [19]. The improvement of aggregate stability can also be obtained by a reduction of soil sodicity. In fact, the Ca^{2+} contained in composts could decrease the proportion of Na^+ in the exchange complex and step up the leaching of exchanged Na^+ [40]. The flocculation of clay minerals is, thus, promoted, playing an important role in the control of erosion in saline soils. Oo *et al.* [24] reported that combinations of organic amendments resulted in substantial flocculation and in the formation of a large number of soil aggregates. As a consequence of aggregate stability, soil porosity, water infiltration, and water-holding capacity of soil are improved, thus minimizing the impact of drought. Sodium adsorption ratio of the soil decreased significantly when soil was treated with sulfuric acid, gypsum, farm yard manure, and their various combinations [29]. Moreover, another study found that the physical properties of the soil, such as structural stability, infiltration rate, and water holding capacity, were considerably improved by municipal solid waste application in a soil salinized by saline water irrigation, during tomato crop cultivation [41]. A direct correlation between organic matter additions and decrease of soil bulk density was also commonly found. This decrease can allow the enhancement of soil porosity and, consequently, the improvement of saline water leaching [8,26]. However, repeated and/or elevated application rates of animal manures or composts could not be sustainable in the case of their relatively high salt contents.

Recently, the above reported study by Wang *et al.* [14] found that a mixture of organic wastes decreased bulk density, EC, and ESP by 11%, 87%, and 71%, respectively, and increased total porosity and organic carbon by 25% and 96% respectively, than the control. These results suggest the effectiveness of combination of different amendments for reclaiming salt-affected soil.

4. Conclusions

In this short review we attempted to highlight some crucial aspects of organic fertilization in salt-affected soils. Basic recommendations for organic fertilization in non-saline conditions are also suitable for high saline soils, therefore, it is important to properly select organic materials, taking into account nutrients content, timing and method of application. As a matter of fact, organic fertilization in saline and sodic soils fulfils the sustainability of resources use, being able to recycle wastes locally stored, thus, contributing to solve the disposal problem of different agro-industrial sectors.

From the review of existing data it can be concluded that most of the well-known effects of organic materials on the chemical, biological, and physical properties of soil are of particular relevance under conditions of salinization, and the achievable effect size is relevant. Therefore, appropriate use of organic amendments must be considered an effective measure to restore soil quality in salt-affected soils.

However, further experimental investigations are needed to validate the application of different organic materials and to step up organic fertilization use in a wide range of saline and sodic soils. Moreover, the combination of waste recycling with different proper agronomic practices (e.g., crop rotations, cover crops use, *etc.*) should be promoted.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Pitman, M.G.; Läuchli, A. Global impact of salinity and agricultural ecosystems. In *Salinity: Environment-Plants-Molecules*; Läuchli, A., Lüttge, U., Eds.; Kluwer Academic Publishers: Dodrecht, The Netherlands, 2002; pp. 3–20.
2. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects: The 2012 Revision. Volume I: Comprehensive Tables ST/ESA/SER.A/336*; United Nations: New York, NY, USA, 2013.
3. Tóth, G.; Montanarella, L.; Rusco, E. *Updated Map of Salt Affected Soils in the European Union Threats to Soil Quality in Europe*; Official Publications of the European Communities: Luxembourg, Luxembourg, 2008; pp. 61–74.
4. Dajic, Z. Salt Stress. In *Physiology and Molecular Biology of Stress Tolerance*; Madhava Rao, K.V., Raghavendra, A.S., Janardhan Reddy, K., Eds.; Springer: Dordrecht, The Netherlands, 2006; pp. 41–99.

5. Joint Research Centre. Soil Themes > Soil Salinization. Available online: http://eusoils.jrc.ec.europa.eu/library/themes/Salinization/ (accessed on 8 February 2012).
6. Sharma, B.R.; Minhas, P.S. Strategies for managing saline/alkali waters for sustainable agricultural production in South Asia. *Agric. Water Manag.* **2005**, *78*, 136–151.
7. Ahmad, R.; Chang, M.H. Salinity control and environmental protection through halophytes. *J. Drain. Water Manag.* **2002**, *6*, 17–25.
8. Tejada, M.; Garcia, C.; Gonzalez, J.L.; Hernandez, M.T. Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. *Soil Biol. Biochem.* **2006**, *38*, 1413–1421.
9. Tanji, K.K. Salinity in the soil environment. In *Salinity: Environment-Plants-Molecules*; Läuchli, A., Lüttge, U., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2002; pp. 21–51.
10. Maggio, A.; de Pascale, S.; Fagnano, M.; Barbieri, G. Saline agriculture in Mediterranean environments. *Ital. J. Agron*. **2011**, *6*, 36–43.
11. Montemurro, F.; Diacono, M.; Vitti, C.; Debiase, G. Biodegradation of olive husk mixed with other agricultural wastes. *Bioresour. Technol.* **2009**, *100*, 2969–2974.
12. Romero-Aranda, R.; Soria, T.; Cuartero, J. Tomato plant-water uptake and plant-water relationships under saline growth conditions. *Plant Sci.* **2001**, *160*, 265–272.
13. Lauchli, A.; Epstein, E. Plant response to salinity and sodic conditions. In *Agricultural Salinity Assessment and Management*; Manual and Reports on Engineering Practice 71; Tanji, K.K., Ed.; American Society of Civil Engineers: New York, NY, USA, 1990; pp. 113–137.
14. Wang, L.; Sun, X.; Li, S.; Zhang, T.; Zhang, W.; Zhai, P. Application of organic amendments to a coastal saline soil in North China: Effects on soil physical and chemical properties and tree growth. *PLoS ONE* **2014**, *9*, e89185, doi:10.1371/journal.pone.0089185.
15. Grattan, S.R.; Grieve, C.M. Salinity-mineral nutrient relations in horticultural crops. *Sci. Hort.* **1999**, *78*, 127–157.
16. Garcia, C.; Hernandez, T. Influence of salinity on the biological and biochemical activity of a calciothid soil. *Plant Soil* **1996**, *178*, 255–263.
17. Rietz, D.N.; Haynes, R.J. Effects of irrigation-induced salinity and sodicity on soil microbial activity. *Soil Biol. Biochem.* **2003**, *35*, 845–854.
18. Walpola, B.C.; Arunakumara, K.K.I.U. Effect of salt stress on decomposition of organic matter and nitrogen mineralization in animal manure amended soils. *J. Agric. Sci.* **2010**, *5*, 9–18.
19. Diacono, M.; Montemurro, F. Long-term effects of organic amendments on soil fertility: A review. *Agron. Sustain. Dev.* **2010**, *30*, 401–422.
20. Montemurro, F.; Vitti, C.; Diacono, M.; Canali, S.; Tittarelli, F.; Ferri, D. A three-year field anaerobic digestates application: Effects on fodder crops performance and soil properties. *Fresenius Environ. Bull.* **2010**, *19*, 2087–2093.
21. Roy, R.N.; Finck, A.; Blair, G.J.; Tandon, H.L.S. *Plant Nutrition for FOOD Security. A Guide for Integrated Nutrient Management*; FAO Fertilizer and Plant Nutrition Bulletin 16; Food and Agriculture Organization of the United Nations: Rome, Italy, 2006; p. 347.

22. Liang, Y.C.; Yang, Y.F.; Yang, C.G.; Shen, Q.Q.; Zhou, J.M.; Yang, L.Z. Soil enzymatic activity and growth of rice and barley as influenced by organic matter in an anthropogenic soil. *Geoderma* **2003**, *115*, 149–160.
23. Cha-um, S.; Kirdmanee, C. Remediation of salt-affected soil by the addition of organic matter—An investigation into improving glutinous rice productivity. *Sci. Agric.* **2011**, *68*, 406–410.
24. Oo, A.N.; Iwai, C.B.; Saenjan, P. Soil properties and maize growth in saline and nonsaline soils using cassava-industrial waste compost and vermicompost with or without earthworms. *Land Degrad. Dev.* **2013**, *26*, 300–310, doi:10.1002/ldr.2208.
25. Walker, D.J.; Bernal, P.M. The effects of olive mill waste compost and poultry manure on the availability and plant uptake of nutrients in a highly saline soil. *Bioresour. Technol.* **2008**, *99*, 396–403.
26. Kahlown, M.A.; Azam, M. Effect of saline drainage effluent on soil health and crop yield. *Agric. Water Manag.* **2003**, *62*, 127–138.
27. Mahdy, A.M. Comparative effects of different soil amendments on amelioration of saline-sodic soils. *Soil Water Res.* **2011**, *6*, 205–216.
28. Mojiri, A. Effects of municipal wastewater on physical and chemical properties of saline soil. *J. Biol. Environ. Sci.* **2011**, *5*, 71–76.
29. Hussain, N.; Hassan, G.; Arshadullah, M.; Mujeeb, F. Evaluation of amendments for the improvement of physical properties of sodic soil. *Int. J. Agric. Biol.* **2001**, *3*, 319–322.
30. Lakhdar, A.; Scelza, R.; Scotti, R.; Rao, M.A.; Naceur, J.; Gianfreda, L.; Abdelly, C. The effect of compost and sewage sludge on soil biologic activities in salt affected soil. *R.C. Suelo Nutr. Veg.* **2010**, *10*, 40–47.
31. Hu, Y.; Schmidhalter, U. Drought and salinity: A comparison of their effects on mineral nutrition of plants. *J. Plant Nutr. Soil Sci.* **2005**, *168*, 541–549.
32. Lakhdar, A.; Rabhi, M.; Ghnaya, T.; Montemurro, F.; Jedidi, N.; Abdelly, C. Effectiveness of compost use in salt-affected soil. *J. Hazard. Mater.* **2009**, *171*, 29–37.
33. Hao, X.; Chang, C. Does long-term heavy cattle manure application increase salinity of a clay loam soil in semi-arid southern Alberta? *Agric. Ecosys. Environ.* **2003**, *94*, 89–103.
34. Yao, L.-X.; Li, G.-L.; Tu, S.-H.; Sulewski, G.; He, Z.-H. Salinity of animal manure and potential risk of secondary soil salinization through successive manure application. *Sci. Total Environ.* **2007**, *383*, 106–114.
35. Khaled, H.; Fawy, H.A. Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil Water Res.* **2011**, *6*, 21–29.
36. Sardinha, M.; Müller, T.; Schmeisky, H.; Joergensen, R.G. Microbial performance in soils along a salinity gradient under acidic conditions. *Appl. Soil Ecol.* **2003**, *23*, 237–244.
37. Chandra, S.; Joshi, H.C.; Pathak, H.; Jain, M.C.; Kalra, N. Effect of potassium salts and distillery effluent on carbon mineralization in soil. *Bioresour. Technol.* **2002**, *83*, 255–257.
38. Liang, Y.; Nikolic, M.; Peng, Y.; Chen, W.; Jiang, Y. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. *Soil Biol. Biochem.* **2005**, *37*, 1185–1195.
39. Rao, D.L.N.; Pathak, H. Ameliorative influence of organic matter on biological activity of salt-affected soils. *Arid Soil Res. Rehabil.* **1996**, *10*, 311–319.

40. Qadir, M.; Oster, J.D. Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. *Sci. Total Environ.* **2004**, *323*, 1–19.
41. Lax, A.; Diaz, E.; Castillo, V.; Albaladejo, J. Reclamation of physical and chemical properties of a salinized soil by organic amendment. *Arid Soil Res. Rehabil.* **1994**, *8*, 9–17.