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Review

Organic Amendments: Enhancing Plant Tolerance to Salinity and Metal Stress for Improved Agricultural Productivity

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Abstract: Salinity and metal stress are significant abiotic factors that negatively influence plant growth and development. These factors lead to diminished agricultural yields on a global scale. Organic amendments have emerged as a potential solution for mitigating the adverse effects of salinity and metal stress on plants. When plants experience these stresses, they produce reactive oxygen species, which can impair protein synthesis and damage cellular membranes. Organic amendments, including biochar, vermicompost, green manure, and farmyard manure, have been shown to facilitate soil nitrogen uptake, an essential component for protein synthesis, and enhance various plant processes such as metabolism, protein accumulation, and antioxidant activities. Researchers have observed that the application of organic amendments improves plant stress tolerance, plant growth, and yield. They achieve this by altering the plant's ionic balance, enhancing the photosynthetic machinery, boosting antioxidant systems, and reducing oxidative damage. The potential of organic amendments to deal effectively with high salinity and metal concentrations in the soil is gaining increased attention and is becoming an increasingly popular practice in the field of agriculture. This review aims to provide insights into methods for treating soils contaminated with salinity and heavy metals by manipulating their bioavailability through the use of various soil amendments.

Keywords: biochar; abiotic stress; soil pollutant; green manuring crops; soil health; *Lemna minor*

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1. Introduction

Salinity and metal stress are pressing concerns that pose significant threats to soil microbial communities, soil fertility, food security, biodiversity, and the sustainability of agriculture [1,2]. Climate change and global warming contribute to rising sea levels, which, in turn, result in new areas becoming saline and barren each year. In addition, human activities such as the use of sewage water for irrigation, industrial operations, mining, and the overuse of pesticides further contribute to the toxicity of soils [3]. These anthropogenic and geogenic actions are responsible for the accumulation of salts and toxic metals like arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg), posing risks to both plants and the environment [4,5]. Although some metals are harmless or even beneficial at low concentrations, they become toxic as their levels increase [1].

Organic amendments (OAs), such as *Sesbania rostrata* biomass, vermicompost (VC), compost, biochar (BC), and poultry and farmyard manures (FYMs), provide an alternative approach to alleviate these abiotic stresses [6–8]. These high-nitrogen organic amendments contribute to the improvement of soil quality and promote plant growth by reducing the bioaccumulation and translocation of metal stress under salinity [9]. Additionally, they have the added benefit of enhancing soil health by increasing nutrient availability, reducing the uptake of harmful metals, and strengthening antioxidant defenses in plants. According to multiple studies, OAs significantly contribute to the improvement of soil health, increase nutrient uptake, enhance the stability of cellular membranes in plants, and also decrease the bioavailability of pollutants [10]. This results in increased biomass production in soils affected by salinity and metal contamination. Organic amendments act by increasing the content of soil organic matter, which, in turn, stimulates the activity of soil microorganisms [11,12]. These microorganisms convert nutrients into forms that are readily available for plant uptake. Moreover, OAs have a positive impact on the physical and chemical properties of the soil, thereby enhancing soil health, crop yield, and quality [13–16]. Furthermore, phytoextraction of metals by using different plants like *Brassica rapa*, *Cannabinus sativa*, *Helianthus annuus* and *Zea mays* is also found effective to remove metal pollution from soil [17]. Given these benefits, it is crucial for researchers and agriculturalists to adopt a more comprehensive approach to improve soil fertility and bolster plant defenses against abiotic stresses. Several studies have already validated that the application of OAs is an environmentally sound, economically viable, and agronomically effective technique [18].

The objective of this study is to explore the impact of various OAs on mitigating the detrimental effects of salinity and metal stress in plants. This review will focus specifically on how the application of OAs can restore plant morphophysiological and biological parameters that have been compromised by salinity and metal stress.

2. Effects of Salinity and Metal Stress

2.1. Impact of Salinity on Soil Properties

Saline soils are characterized by high concentrations of dissolved salts such as sodium (Na^+), calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), chloride (Cl^-), sulfate ($SO_4{}^{2-}$), carbonate ($CO_3{}^{2-}$), and bicarbonate ($HCO_3{}^-$). These soils have an electrical conductivity (EC) greater than 4 dS m^{-1} at 25 °C. Excessive Na^+ content adversely affects soil quality by reducing soil permeability, structural stability, and bulk density [19] (Figure 1). It also decreases the soil's water-holding capacity and rate of water infiltration. High salt concentrations inhibit the activity of nitrifying bacteria, leading to reduced nitrification, which is crucial for nitrogen (N_2) release in soil for plant growth [20]. Soil enzyme activities and respiration are also hindered by salinity. According to Sritongon et al. [21], a negative correlation exists between electrical conductivity and soil properties such as organic matter (OM), organic carbon (OC), and soil enzyme activities.

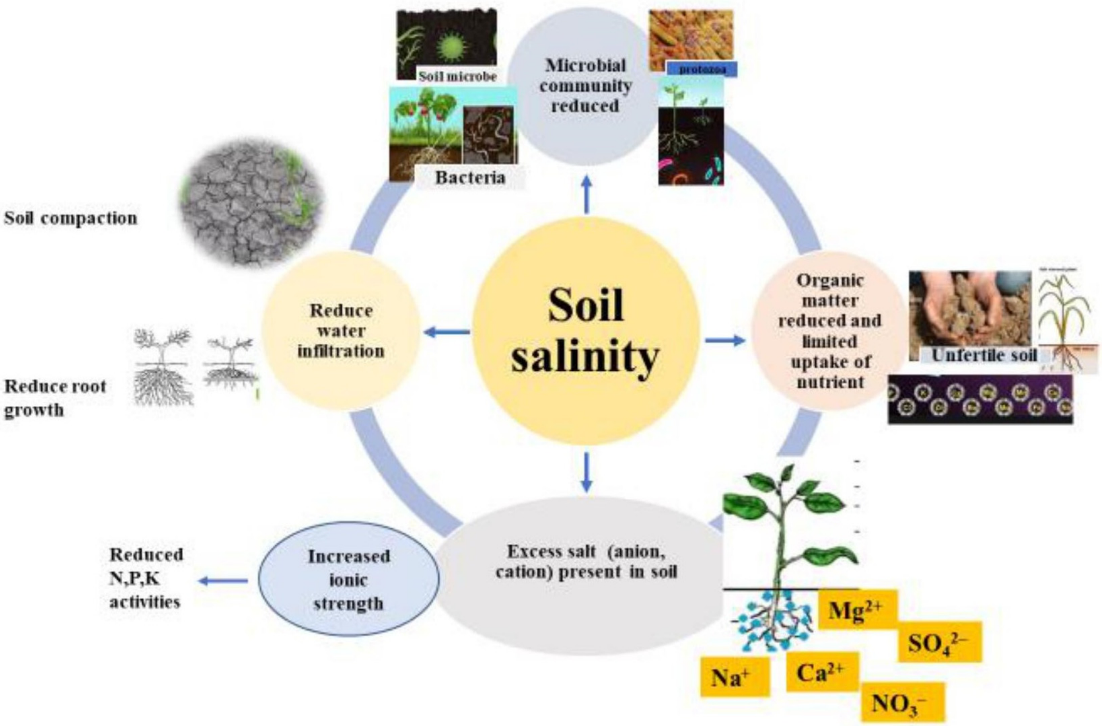

Figure 1. Effect of salinity on soil properties.

2.2. Impact of Metal Stress on Soil Properties

Soil is a natural source of heavy metals (HMs), originating from the weathering of metal-bearing rocks. Human activities (industrial activities, agricultural activities, and metal-containing wastes) have increased these concentrations, causing environmental damage [22,23]. When contamination reaches certain levels, HMs obstruct phytoremediation and reduce plant growth and production [24]. Heavy metals negatively impact soil quality, affecting the structure and abundance of soil microorganisms [25]. Heavy metals reduce enzymatic activities by decreasing urease and catalase activities, along with the reduced mineralization of soil organic matter (SOM), and affect their accumulation, resulting in hampered soil quality. However, Kumar et al. [26] argue that HMs enhance oxidative stress in plants, damage cell structures, and disrupt ionic homeostasis. The process of photosynthesis, which is essential for plant development and productivity, can be interfered with by HMs. For instance, photosystem II is inhibited by Hg, which lowers the amount of chlorophyll (chl) and decreases the effectiveness of light absorption and energy conversion. Similar to this, lead disrupts photosystem I's electron transport chain, which hinders the production of ATP and NADPH needed for carbon absorption.

2.3. Impact of Salinity on Crop Productivity

Salt stress suppresses plant growth and productivity by affecting the availability of nutrients, which is regulated by rhizosphere microbial activity [27]. Salinity causes osmotic stress, reduced shoot growth, and stomatal closure owing to the accumulation of Na^+ and Cl^- in leaves, where photosynthesis takes place [28,29]. It also accelerates the senescence of older leaves through chl degradation [30,31]. Higher Na^+ accumulation in the intracellular space (cytosolic apartment) can inhibit enzyme activities and reduce water relations, photosystem II (PS II), and CO_2 assimilation in plants [31]. Salinity stress can reduce shoot biomass by 24–41% and grain yield by 7–30% in foxtail millet [32]. Excessive salinity impairs antioxidant activity, causes lipid peroxidation, denatures proteins and nucleic acids, and increases reactive oxygen species (ROS), causing cellular damage [33,34].

2.4. Impact of Metal Stress on Crops

Pedogenic and anthropogenic activities are the primary sources of soil metal pollution, which adversely affects plant growth and productivity. Metals like iron (Fe), cobalt (Co), copper (Cu), manganese (Mn), zinc (Zn), and molybdenum (Mo) serve as micronutrients at low concentrations but become toxic at higher levels, hampering plant development [35]. For instance, toxic levels of Cu hampered photosynthesis and plant growth. Heavy metal deposition disrupts various biochemical, physiological, and morphological processes in plants, thereby reducing agricultural yield [36]. In addition, inhibition of photosynthesis, chlorosis, low biomass accumulation, altered nutrient absorption, water balance, disturbing the redox balance, and causing oxidative stress are typical harmful impacts of Cd HM [37] (Figure 2).

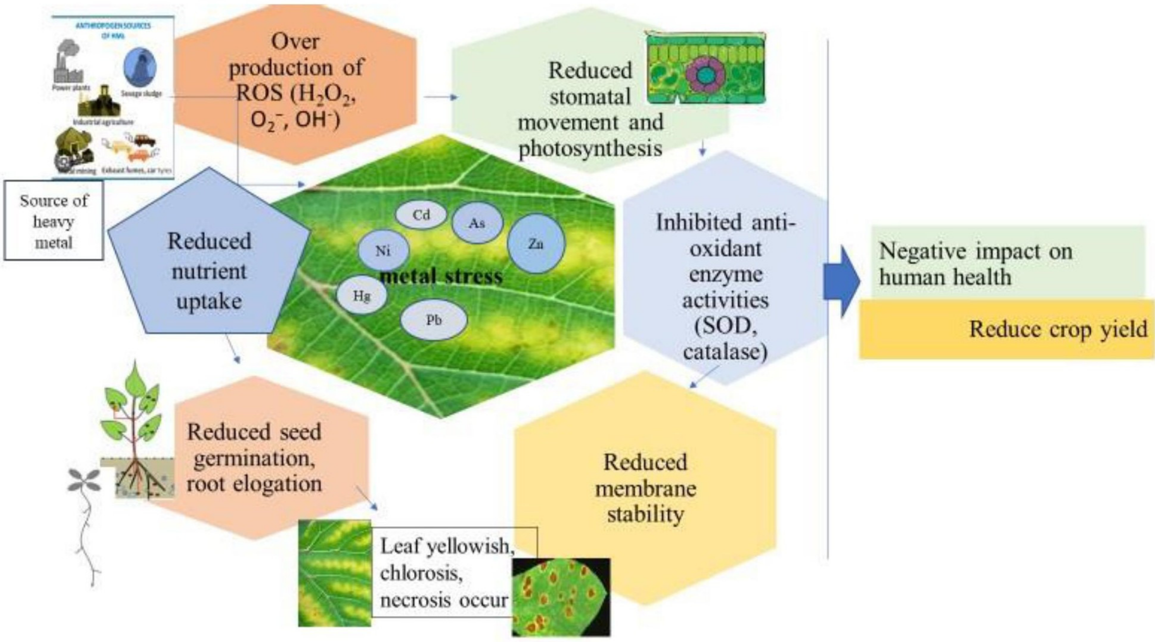

Figure 2. Effects of metal stress on crops.

3. Types and General Role of Organic Amendments

Organic amendments positively amend degraded soil structures and enhance soil productivity and quality. Originating from both plants and animals, their types are illustrated in Figure 3.

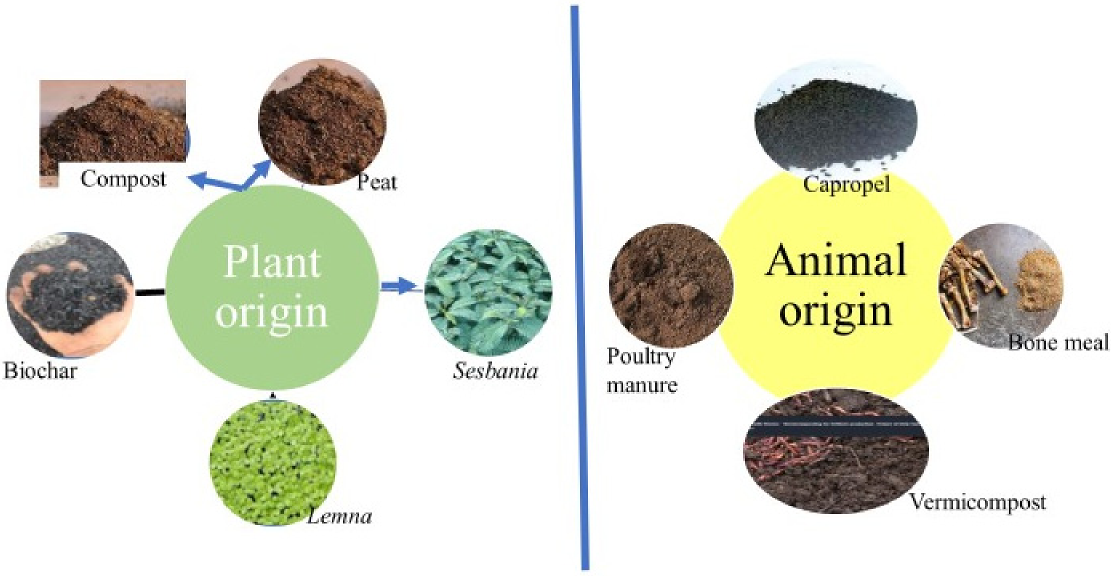

Figure 3. Types of different organic amendments.

3.1. Biochar

Biochar, a carbon © rich byproduct of biomass pyrolysis, contains various amounts of C, hydrogen (H), sulfur (S), oxygen (O_2), N, and minerals. Although almost 70% of its composition is C, the rest depends on the feedstock used to make it. It has recently been recognized for its beneficial economic and environmental impacts on soil and crop productivity. Biochar amends pH, increases CEC, sequesters C, enhances P availability [38], improves soil aeration and porosity [39,40], and enhances soil fertility [41–44]. Additionally, by promoting the rhizosphere's biological environment with biochar, soil enzyme activity and microbial growth are enhanced [45]. It also assists in nutrient retention in soil micropores and supports easy plant nutrient assimilation [46]. Salinity is mitigated by replacing Na^+ from exchangeable soil sites, reducing Na^+ adsorption ratios, and alleviating oxidative stress from NaCl. Researchers have also found that the presence of oxides, hydroxides, and carbonates in BC improves soil productivity. Furthermore, biochar's strong adsorption capacity, particularly in bamboo charcoal, makes it an ideal nutrient preserver and stabilizer for HMs, notably Pb and Cd in polluted soils [47–50]. Biochar's effects on degraded soil and crops are demonstrated in Figure 4.

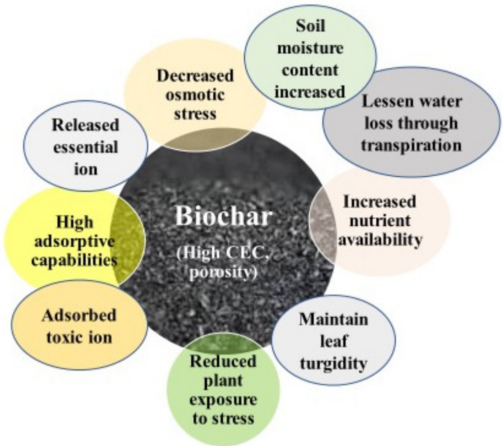

Figure 4. Effect of biochar on soil and crops under salinity.

3.2. Compost

Compost is rich in OM and essential plant nutrients like N, P, and K, fulfilling deficiencies found in saline-affected soils. It also decreases the sodium absorption ratio by increasing Ca^{2+} in the soil solution. Furthermore, compost enhances SOM by binding soil particles into aggregates, thus improving soil air circulation and infiltration, increasing the available micronutrients, and promoting plant and microbial growth [51–53]. As compost alters soil properties [54], it elevates soil fertility for crop production. Moreover, it mitigates oxidative stress, boosts chl content and photosynthesis rates, and promotes crop growth [55,56]. Ahmed et al. [57] advocate for using affordable water hyacinth compost to amend degraded saline-sodic soils and improve crop yields. Composting livestock dung can quickly transform it into a biofertilizer, eliminating harmful chemicals, HMs, pathogens, and antibiotics [58,59].

3.3. Vermicompost

Produced by using earthworms to convert organic waste into nutrient-rich compost, VC has various plant nutrients. It acts as a biosorbent, reducing the negative impacts of salinity [60] and harmful ions like Pb, Cd, nickel (Ni), and chromium (Cr) [61]. In the composting process, earthworms elevate the mineralization and humification rates in soil, increasing soil pore space, water infiltration rates, and water retention, which increase microbial populations and organic C content and promote growth, yield, and fruit quality [62]. Researchers have identified that VC has more nutrients than regular compost, enhancing soil fertility in multiple ways. It bolsters SOM and exchangeable minerals like K^+, Ca^{2+}, and Mg^{2+} in soil, reducing EC. Additionally, VC improves plant physiological factors, reducing harmful effects like oxidative stress and enhancing plant growth [63,64]. It also immobilizes soil HMs like Cd and diminishes their phytoavailability [65], subsequently increasing grain yields by supplying essential plant hormones [66]. The effects of VC on soil and crops are depicted in Figure 5.

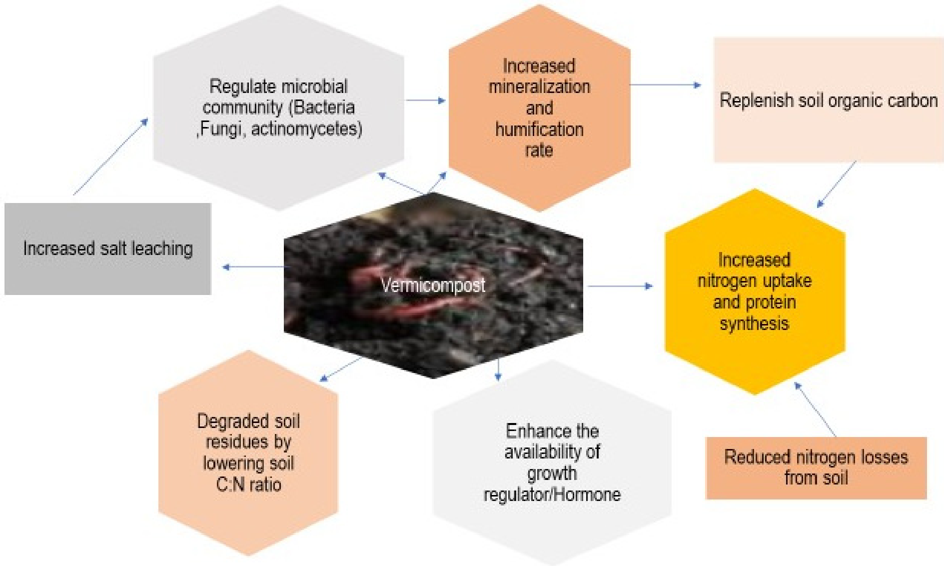

Figure 5. Effect of vermicompost on soil and crops under salinity.

3.4. Green Manure

Various green manuring crops are employed to enhance soil fertility [67] and reclaim soil salinity [11,68]. *Sesbania*, a leguminous plant, is effectively utilized as green manure (GM). It mitigates soil salinity by drawing out excess salt and harnessing it through its biomass, simultaneously improving soil structure and nutrient availability (Figure 6). This leads to optimized crop growth. Decomposed GM crops elevate soil CO_2 concentration, aiding $CaCO_3$ dissolution and hastening the removal of exchangeable Na^+ ions from saline soils [69,70]. *Sesbania* and sunhemp demonstrate significant potential for reducing soil Na^+ and ameliorating soil salinity. Choudhary et al. [71] found that incorporating GM decreases soil pH in saline-sodic soils due to its acidifying effect, which, in turn, boosts the available soil and plant minerals. Organic materials not only ameliorate conditions but also augment the physical attributes of the soil, nutrient availability, and the SOM status in degraded soils. *Sesbania*, given its ample biomass and nodulation, is a widely preferred OA. It enriches the soil with N, P, K, and OAs, enhancing the C:N ratio, Ca^{2+} status, and salinity mitigation [72]. Decomposed GM acts as a slow-release fertilizer, benefiting subsequent crops [73]. Shirale et al. [11] posited GM as a potential gypsum substitute, attributing to its incremental salinity reclamation capabilities and bolstering of biological N fixation and C sequestration. Mustard species, utilized as GM, improve soil fertility due to their rhizosphere activity and phytoremediation potential [74]. Various GM crops, including mustard, phacelia, and borage, have been reported to boost soil respiration and diminish bioaccessible metal amounts, thereby reducing ecotoxicity [75]. Bruning et al. [76] hypothesize that legumes, despite their high salinity levels, can serve as GM due to their growth and atmospheric N fixation abilities.

3.5. Duckweed and Water Hyacinth

Over recent decades, phytotechnologies, which utilize plants for pollutant removal, have gained prominence. Both terrestrial and aquatic plants possess remarkable metal-sorption capabilities [77]. Duckweed (DW, *Lemna*), an aquatic member of the Lemnaceae family, is enriched with trace minerals, K, and P, and vital sources of vitamins A and B, proteins, fats, amino acids, and starch. Infusing soil with duckweed biomass increases the uptake of nutrients like N, K, Ca, Mg, Fe, and Zn, subsequently boosting crop production. Duckweed extracts have been employed as biostimulants for olive plant growth [78]. Notably, duckweed can withstand pollutants such as ammonia and HMs, marking its potential as a purifier for agricultural and industrial wastewater [79]. However, some research indicates that DW efficacy in HM (Ni, Cd) pollutant removal diminishes under salt stress [80]. Contrarily, others have demonstrated DW's capability to accumulate boron in environments with salinity under 100 mM, significantly improving osmotic stress resistance [66]. Water hyacinth, a rapidly proliferating aquatic plant, owes its growth to nutrient content. Activated C derived from water hyacinth has applications in salinity reduction through mineral absorption [81]. Both *Eichhornia crassipes* and *Lemna minor* effectively remove HM ions, such as As, from water [82].

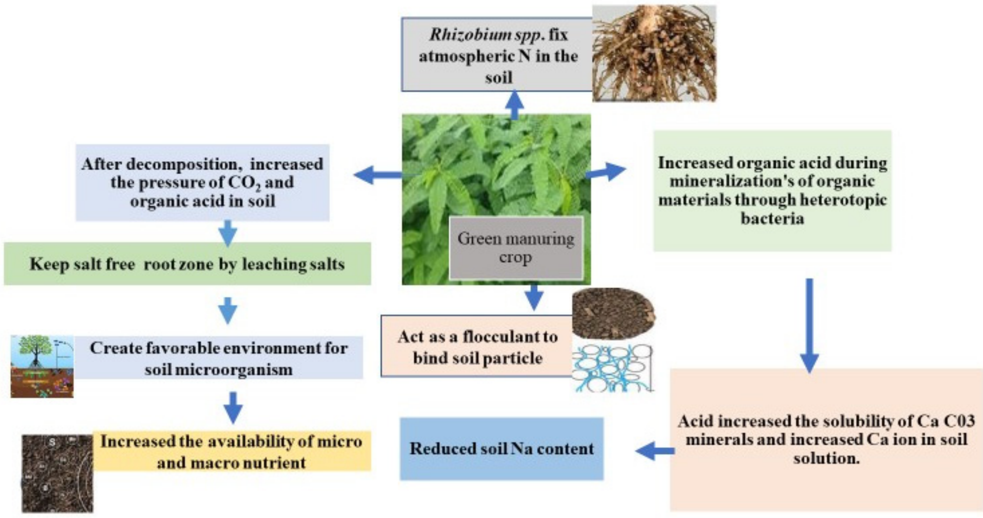

Figure 6. Effect of green manuring crops on soil and crops under salinity.

3.6. Poultry Manure

Poultry manure serves as an organic material for enhancing soil fertility because it is rich in both macro- and micronutrients. Organic N-rich poultry manure (PM) is commonly utilized to amend and enhance fertility in saline soil. As found by numerous researchers, such as Leithy et al. [13], PM ameliorates the physical, chemical, and biological properties of soils and mitigates the toxic impacts of salinity across various plant species. Additionally, PM has been shown to decrease certain trace metal concentrations in soil.

3.7. Farmyard Manure

Farmyard manure (FYM) is a composted blend of cow dung, cow urine, litter, and other dairy byproducts. It is a reservoir of nutrients, including N, P, and trace elements, all of which enhance soil fertility and soil quality, along with the stable humic substance [83]. As an integral source of soil C, it bolsters the activities of soil flora and fauna and effectively reduces EC and pH in saline-sodic soils. Singh and Agrawal [84] emphasize that FYM is invaluable for elevating soil fertility and diminishing soil metal contamination. Its solo use or in conjunction with N, P, and K (inorganic fertilizers) can mitigate the phytoavailability of HMs in the soil. This results in maintaining plant vitality and bolstering growth and yield, especially at contaminated agricultural sites. Chicken and cow manures, when added to polluted soil, drastically cut down the phytoavailability of Cd while amplifying the growth and yield of sweet basil [9]. Rani et al. [85] underscored that FYM, in combination with cow dung and pig manure, can alleviate soil metal stress and markedly reduce Ni by forming resilient metal complexes with organic manure. Among the modifications to reduce chromium toxicity, FYM has been the most effective.

3.8. Press Mud

Press mud, a byproduct of the sugar industry, is esteemed for augmenting SOM, cultivating a conducive environment for microbial communities, and, ultimately, boosting soil fertility and crop yield [86–88]. Beyond being a vital nutrient source, press mud also magnifies plant nutrient uptake through roots, fortifies membrane integrity, and enhances osmoprotectant processes [89]. Additionally, press mud is rich in hydroxyl ions, pivotal for metal adsorption and the diminishment of toxic metal bioavailability [88,90]. The manifold benefits of press mud on soil and crops, especially under salinity conditions, are illustrated in Figure 7.

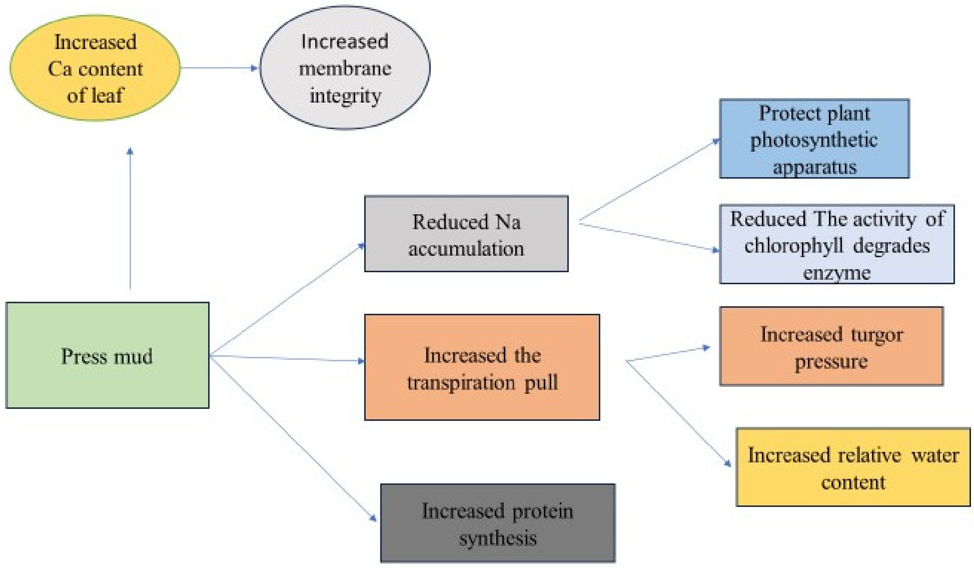

Figure 7. Effect of press mud on soil and crops under salinity.

3.9. Others

The lion's share of humic compounds, notably humic acid, represent the most biologically vivacious components of soil and compost [91]. Incorporating humic substances leads to an elevation in soil pH, cation exchange capacity, and OC content, released P, controlled N loss, reduced metal mobility, and improved crop growth [92]. Sewage sludge is embraced as an OA due to its ample concentrations of N, P, and K. Typically, urban sludge is benign relative to its industrial counterpart. Steel slag, an industrial residue rich in Ca, Si, Fe, and P [93], holds promise for remediating HM pollution. Historically, steel slag, along with BC application, significantly improved growth performances, reduced the oxidative stresses of okra, and mitigated the adverse effects of As stress [94]. Its inclusion diminished the accessible amount of Cd in tainted soils [95], consequently cutting down soil Cd concentration from root to shoot and enhancing rice growth and the soluble protein concentration of black gram [61,86].

4. Biochemical and Physiological Adaptations to Stresses in Crops and Soil through Different Organic Amendments

In recent decades, integrating organic resources into salt-affected soils has become a common practice. Before applying to the soil, OAs should be processed to mitigate potential risks to plants and achieve the desired transformation and stabilization of complex molecules into OM. Decomposed organic residues often result in more stable organic matter compared to fresh materials. These decomposed residues mineralize more slowly and benefit the soil over longer periods, especially in soils with low OM content [26]. The introduction of OAs improves the physicochemical and biological properties of soils, consequently enhancing plant growth.

4.1. Organic Amendments and Improved Soil Quality under Salinity

L'opez-Valdez et al. [96] found that OAs ameliorate soil properties by leaching Na^+ and other salts and by reducing the exchangeable sodium percentage. Additionally, these amendments stimulate the biological and enzymatic activities in the soil, increasing the population of beneficial organisms and thereby enhancing soil fertility. In saline soils, both VC and compost additions have been shown to boost soil cation exchange capacity by

20–70% [57,84,97]. These amendments also enhance microbial biomass and soil respiration compared to unamended soils [55] and increase the salinity tolerance of rice, sugarcane, and fennel by increasing K^+/Na^+ and Ca^{2+}/Na^+ [66,84,98,99] (Table 1). They also improve the availability of soil P, which had previously been tightly bound due to soil pH. This results in effective mitigation of salt stress in plants, like tomatoes [56].

Table 1. Application of compost and vermicomposting for soil and crop salinity reclamation.

Plant Species	Salinity Level	Types and Doses	Effect of Amendments		Reference
			On Soil	On Crop	
Rice (*Oryza sativa*)	Salinity, 2.9 dS m^{-1}	VC with rice husk ash (1000 kg Rai^{-1})	Increased exchangeable K^+, Ca^{2+}, and Mg^{2+} in soil, decreased EC.	Increased plant growth and grain yield.	[99]
Lettuce (*Lactuca sativa*)	Salinity, 8.32 dS m^{-1}	VC 50% and eggshell 12.5%	Reduced soil salinity	Increased germination, growth of seedlings, and yield.	[100]
Rice–wheat	Salinity, 5.02 dS m^{-1}	Hyacinth compost, 10 and 15 t ha^{-1} with gypsum, 50%	Increased water-holding capacity, soil aggregation, and soil CEC.	Rice and wheat yield increased.	[57]
Sugarcane (*S. officinarum* L.)	Salinity, 4.12 dS m^{-1}	VC, 10, 20 t ha^{-1} and N fertilizer, 50, 75, and 100 kg ha^{-1}	Reduced soil EC and Na^+/K^+ ratio and reduced salinity mitigation.	Increased sugarcane growth and production.	[101]
Bean (*Phaseolus vulgaris* L.)	NaCl (20, 40, 60, and 80 mM)	VC and sand mixture (0:100; 10:90; 25:75; 50:50, and 75:25)	Not observed	Increased photosynthetic rate, concentration of K^+ and Ca^{2+} in leaves, and growth of bean improved.	[102]
Potato (*Solanum tuberosum* L.)	NaCl (15, 20, and 25 mM)	VC, 300, 580, and 860 g $plant^{-1}$	Not observed	Increased plant height and stem diameter; potato production.	[103]
Tomato (*S. lycopersicum* L.)	NaCl (150 mM)	VC extract, 6 mL L^{-1}	Increased nutrient availability and reduced soil salinity.	Increased accumulation of proline, total sugars leaf water content, reduced osmotic stress.	[104]
Mustard–pearl millet cropping system	Salinity, 7.2 ds m^{-1}	Rice straw compost 3 to 5 t ha^{-1}	Reduced soil salinity and increased microbial activity	Increased plant growth, grain, and straw yield.	[105]
Rice (*O. sativa*)	EC (7.5 dS m^{-1})	Compost (15 t ha^{-1})	Improved soil nutrient availability and ameliorated salinity.	Increased essential micronutrients in rice grain, increased crop yield.	[106]
Tomato (*S. lycopersicon)*	NaCl (40 and 80 mM)	Compost (25 t ha^{-1})	Increased macro- and micronutrients and reduced salinity	Increased accumulation of osmoprotectants, such as soluble sugars and amino acids. Increased crop yield.	[56]
Fennel (*Foeniculum vulgare*)	NaCl (40, 80, and 120 mM)	VC extract (10%)	Increased Ca^{2+} content, alleviated salinity stress of plants.	Increased root Ca^{2+} content, reduced Na content, enhanced germination and growth of fennel.	[107]
Maize (*Zea mays*)	Salinity (10.6 dS m^{-1})	VC (72 g pot^{-1}) + cow dung (33 g pot^{-1})	Soil physical and chemical properties improved	Increased germination percentage, plant height, root length, and crop yield.	[54]
Tomato (*S. lycopersicon)*	50 (100 mM of NaCl)	Compost (55 g kg^{-1})	-	Increased enzymatic activities, reduced oxidative stress, promoted plant growth and productivity.	[108]

The combined application of compost with BC in saline soil provides both micro- and macronutrients to the rhizosphere, boosting soluble sugars and amino acid levels. This enhances nutrient (N, P, and K) assimilation in the soil [46,51]. Incorporating VC with eggshells and rice husk improves nutrient availability, particularly Ca^{2+} and K^+, by fostering a more diverse soil microbial community in rice and wheat crops under salinity [98,99].

Using legume green manuring, especially *Sesbania*, raises SOC, improves nutrient availability, and enhances the soil's physical, chemical, and biological characteristics. It also bolsters the yield of crops like rice and wheat [109–112] (Table 2). Sunnhemp green manuring has shown promise in saline soils by improving soil fertility and nutrient status [72]. Once decomposed, GM crops release organic acids, fostering a favorable environment for soil microbes. This promotes the release of various nutrients, thus improving soil quality.

Table 2. Application of green manuring crops and duckweed for salinity reclamation of crops and soil.

GM Crops as OA	Crop	Salinity	Effect of Amendments		Reference
			On Soil	On Crops	
Green manure + FYM (1:1 *w*/*w*) at 12.5 kg m^{-2}	*Oryza sativa*	1–2% salt	Soil fertility improved and alleviated the problem of salinity.	Increased total chl, photosynthesis abilities, crop growth, and grain yield.	[109]
Sesbania + Compost+ FYM, 5% volume	*O. sativa* and *T. aestivum*	Total soluble salts = 25.3 mg L^{-1}	Increased soil fertility.	Increased rice–wheat production in saline-affected area.	[110]
(*Sesbania* + Gypsum), 12.5 to 20 Mg ha^{-1}	Rice–Wheat (*T. aestivum*)	Salinity (2.7–4.5 dS m^{-1})	Alleviated soil salinity	Increased crop growth and grain (rice and wheat) yield.	[111]
Water hyacinth (*E. crassipes*) and Duckweed (*Lemna minor*)	Industrial wastewater	45 mM NaCl	Decrease in pH, EC, oxidation redox potential (ORP), and salinity.	-	[112]

Furthermore, BC possesses a high adsorption capacity, aiding in the retention of negative ions and enhancing cation exchange capacity by introducing Ca^{2+} into the soil solution [98] (Table 3). This replaces and releases essential mineral nutrients to the soil and boosts its OM content [113,114]. Biochar applications also mitigate soil compaction, encourage evaporation, and reduce salinization, making it a potent remedy for reducing soil ESP [114]. The addition of cow dung, PM, also reduced soil ESP and EC and notably increased soil Ca^{2+} status and improved soil salinity [115,116] (Table 4). Again, press mud application in soil improved soil OM and nutrient availability and reduced salinity.

Table 3. Application of biochar for soil and crop salinity reclamation.

Plant Species	Salinity Level	Type and Dose of Amendment	Effect of Amendments		Reference
			On Soil	On Crops	
Rice (*Oryza sativa*)	50 mM and 75 mM of NaCl	BC + Trico compost + Phospogypsum	Increased soil N, P, K^+/Na^+, Ca^{2+}/Mg^{2+}, enhanced SO_4^{2-}, NO_3^-, Mn^{4+}, Fe content in rice rhizosphere, and reduced CH_4 emission.	Increased plant height, shoot biomass, and crop yield.	[98]
	Salinity, 1 and 3 dS m^{-1}	Rice straw BC (0.3%)	Reduced Na^+ and Cl^- contents of soil and improved physiochemical properties of soil.	Granum lamellae in mesophyll cells' structure is improved, improved rice productivity.	[117]
	Salinity (2, 4, 6, and 8 dS m^{-1})	BC (2 kg m^{-2})	Increased soil moisture content and physicochemical properties	Increased chl content, relative water content, stomatal conductance, reduced proline content, increased plant growth and productivity.	[118]

Table 3. *Cont.*

Plant Species	Salinity Level	Type and Dose of Amendment	Effect of Amendments		Reference
			On Soil	On Crops	
Wheat (*Triticum aestivum* L.)	NaCl, 3000 ppm	Soybean straw BC (5%) (*w*/*v*) + selenium (0.15%)	Not observed	Increased biomass assimilation, mineral uptake, chl synthesis, photosynthesis rate. Reduced EL, improved salinity tolerance.	[119]
	Saline water irrigation (10 dS m^{-1})	Wheat straw BC (10 and 20 t ha^{-1})	Reduced soil bulk density, increased permeability and nutrient status of soil	Improved growth, photosynthesis and reduced aging of leaves.	[120]
	150 mM NaCl	BC (5%) and jasmonic acid (5 µM)	Reduced accumulation of Na^+	Reduced oxidative stress and boosted antioxidant activity.	[121]
	EC = 7.17 dS m^{-1}	BC (2% *w*/*w*) + Lysin (1.0 and 2.0 mM)	Reduced soil salinity and increased nutrient availability.	Increased chl a, chl b, total chl, and carotenoid, photosynthesis, reduced MDA, H_2O_2, and EC, increased growth, biomass, and grain yield.	[122]
Maize (*Zea mays*)	100 mM NaCl	Wheat straw BC + Arbuscular mycorrhizal fungi	Soil nutrient status improved, and mitigated salinity.	Improved photosynthetic performance, reduced oxidative damage, enhancement maize production.	[123]
	EC = 0.01955 dS cm^{-1}	Mixture of cotton straw, peanut shell, and sawdust (90:5:5, *w*/*w*/*w*) 30, 50 and 75 t ha^{-1}	Increased soil bulk density, soil pore space, macroaggregates, CEC, total carbon, N, P, K and decreased exchangeable Na^+ and decreased salinity.	Reduced oxidative stress. improved palmitoleic acid, oleic acid, and linolenic acid contents, increased crop yield.	[124]
Soyabean (*Glycine max)*	Salinity (5 and 10 dSm^{-1})	BC (50 and 100 g kg^{-1} soil)	Enhanced nutrient availability and lower Na^+ content.	Improved leaf chl (*a*, *b*, *c*) content	[113]
Mungbean (*Vigna radiata* L.)	Salinity, 5 and 10 dS m^{-1}	BC (50 and 100 g kg^{-1})	SOM status improved and salinity stress mitigated.	Improved xylem structure, decreased ABA and ACC, increased root/shoot ratio, total root area, and plant growth.	[125]
Sorghum (*Sorghum bicolor* L.)	Salinity, 0.8, 4.1, and 7.7 dS m^{-1}	BC, 2.5, 5, and 10% (*w*/*w*)	Decreased soil degradation and reduced salinity.	Increased plant height, DM RWC, crop yield, and mineral availability, decreased osmotic stress.	[114]
Quinoa (*Chenopodium quinoa* L.)	Saline water irrigation (400 mM)	BC, 5% (*w*/*w*)	Increased soil water content, nutrient availability and reduced Na^+	Increased plant height, shoot biomass, and grain yield, increased leaf photosynthetic rate and stomatal conductance, maintained ionic balance.	[126]
	Salinity (20 dS m^{-1})	BC (1%) *w*/*w* and Endophytic bacteria	Reduced soil salinity and increased nutrient availability	Reduced antioxidant activities, increased plant growth, grain yield and grain nutrient content.	[127]
	Salinity, 11.5 dS m^{-1}	Cotton shell BC 1 and 2% (*w*/*w*)	Reduced soil salinity.	Reduced Na^+ induced phytotoxicity and increased yield. Increased plant growth, water contents, stomatal conductance, and chl contents.	[128]

Table 3. *Cont.*

Plant Species	Salinity Level	Type and Dose of Amendment	Effect of Amendments		Reference
			On Soil	On Crops	
Potato (*S. tuberosum*)	25 and 50 mM of NaCl	BC, 5% (*w*/*w*)	Reduced soil salinity.	Increased photosynthetic rate, stomatal conductance, relative water content, increased shoot biomass, root length, and tuber yield.	[129]
Tomato (*Solanum lycopersicum*)	Salinity level 0.3% and 0.6% of soil dry weight salts	BC, 1% of soil dry weight	Not observed	Increased total soluble solids and vitamin C in tomato.	[130]
	Salinity (1, 3 dS m^{-1})	BC (2, 4, 8%)	Released mineral ion K^+, Ca^{2+}, and Mg^{2+} in soil solution, increased organic matter.	Increased vegetative growth and production.	[131]
Cabbage (*Brassica oleracea* var. *Capitata*)	150 mM NaCl	BC doses (weighed at the rate of 2.5%, and 5% by soil weight)	Reduced salinity stress.	Reduced oxidative stress, ABA content, Na^+ content and increased growth of cabbage seedling.	[132]
Jute (*Corchorus capsularis*)	50, 100, and 150 mM NaCl	BC (2.0 g kg^{-1} soil) + Chitosan (100 mg L^{-1})	-	Improved enzymatic and non-enzymatic antioxidant systems, enhanced glyoxalase enzyme activities, increased Na^+/K^+ ratio, reduced oxidative stress, plant growth improved.	[133]

Table 4. Salinity reclamation through PM, press mud, sewage sludge, cow dung, and FYM.

Plant Species	Stress Level	OA Doses and Application Method	Effect of Amendments		Reference
			On Soil	On Crops	
Rice (*Oryza sativa)*	Salinity, 6.4 dS m^{-1}	FYM (5 to10 t ha^{-1}) + PM (4 to 8 t ha^{-1} + proline	Reduced soil salinity.	Increased nutrient uptake, plant height, panicle length, grain yield, and straw yield of rice, decreased K^+/Na^+ in both grain and straw.	[134]
Wheat-Maize	Salinity, 5.4 dS m^{-1}	PM + FYM + GM (12 t ha^{-1})	Increased CEC, total N, soil carbon, reduced soil EC, pH, and SAR, improved soil structure.	Increased crop growth, biomass, and grain yield.	[135]
Rice–wheat	Salinity, 3.6 dS m^{-1}	Sugarcane press mud (10 t ha^{-1})	Reductions in soil pH, ESP, reduced soil salinity.	Enhanced leaf water potential, membrane, reduced membrane injury stability, Na^+/K^+ accumulation, increased photosynthetic efficiency, plant growth, and yield.	[136]
Wheat (*Triticum aestivum*)	Salinity, 11.72 dS m^{-1}	Sugarcane press mud 10–15 g kg^{-1}	Increased SOM, improved microbial activity, enhanced nutrient availability, reduced soil salinity.	Increased nutrient availability in rhizosphere, fertile tiller, plant biomass production, and plant growth, grain yield.	[137]
Wheat (*T. aestivum*)	Salinity (6, 12 dS m^{-1})	Sugarcane press mud (3, 6, and 9%)	Improved soil properties, increased Ca^{2+} and K^+ in soil, leaching of Na^+, improved salt induced toxic effect.	Increased chl content (a, b, and total chl), soluble sugar, proteins, free amino acids, leaf water content, proline, K^+, and activity of antioxidant enzymes; APX), CAT, and POD, rice growth and yield reduced EL, H_2O_2, MDA.	[138]

Table 4. *Cont.*

Plant Species	Stress Level	OA Doses and Application Method	Effect of Amendments		Reference
			On Soil	On Crops	
Pepper (*Capsicum annuum*)	Salinity (6 dS m^{-1})	PM (10% and 30%) with exogenous gibberellins (0, 250 mg L^{-1})	Decreased EC and osmotic stress in soil solution, increased nutrient availability.	Increased photo synthetic rates, stomatal conductance, total chl, total biomass, leaf N, P, and K, reduced proline and Na content, increased fruit set.	[139]
Potato (*S. tuberosum*)	Salinity, 0.9 to 5.9 dS m^{-1}	PM (20, 30, 40, 50, 60 mt ha^{-1})	Decreased nutrient losses and soil salinity.	Increased K, N in leaves and roots, growth, yield, and nutritional status of tuber.	[140]
CherryTomato (*Lycopersicon esculentum*)	Salinity, 0.44 mS cm^{-1}	Poultry manure (0. 25, 31, 38, and 44%)	Improved soil properties, soil available nutrients and reduced salinity.	Increased plant height, root length, fresh and dry weight, number of flowers and shoot K concentration.	[116]
Saline soil	Salinity, 4 dS m^{-1}	Cow dung (2%)	Improved soil aggregation, Ca^{2+}, reduced ESP and EC, soil pH, Na^{+}	Not observed	[115]

In conclusion, organic additions can significantly improve the mineral nutrient status and growth of plants in saline soils, mainly through the reduced translocation of harmful salts [116].

4.2. Organic Amendments Improve Crop Growth under Salinity

Salinity impedes nutrient availability due to osmotic stress. Organic amendments directly contribute by adding C, promoting microbial cells that counteract osmotic stress through osmoprotectants under various stresses [141,142] (Figure 8). A high Na^{+} buildup inhibits N absorption, thereby reducing protein levels in grains [143]. Organic amendments, on the other hand, enhance SOM content. They provide a substrate for decomposing organisms, resulting in better nutrient assimilation and, consequently, higher grain yields in rice and lettuce [100–102,104,106]. The negative effects of salinity were mitigated, and rice root and shoot growth was amplified by the FYM + PM treatment [89].

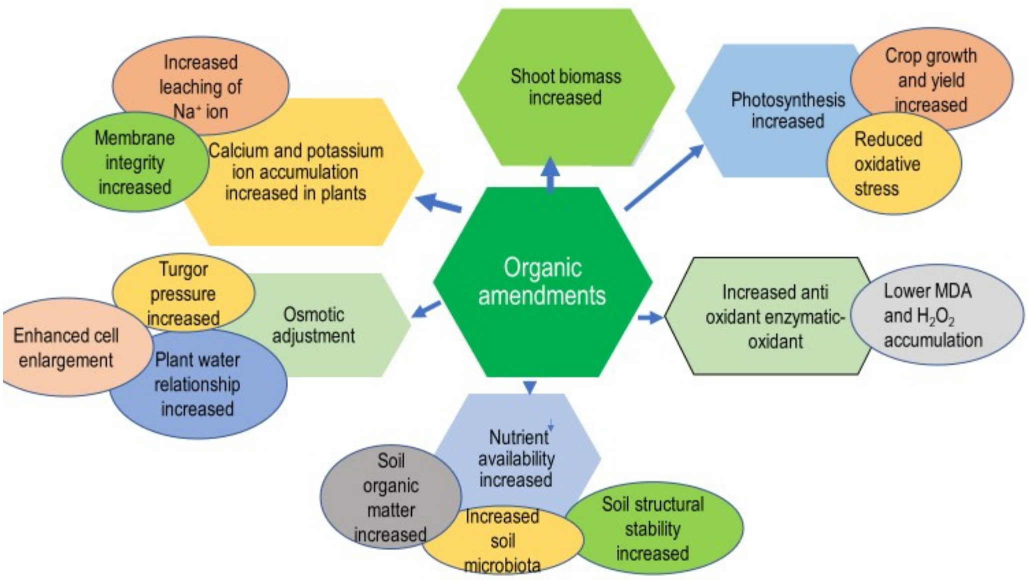

Figure 8. Effect of organic amendments on crop physiology.

According to Ahmed et al. [57], incorporating FYM into the soil boosted its OM content and decreased SAR. This replaced Na^{+} in the soil with Ca^{2+}, promoting growth, increasing biomass output, and reducing the negative impacts of salt stress on crop growth. The combined application of FYM and PM augmented maize growth [7], while combining FYM with GM crops increased essential soil nutrients, thus improving soil quality and crop yield [135].

Biochar application in saline soil creates a conducive environment for rice seedlings by augmenting nutrient availability and enhancing soil physical properties [117] while also maintaining leaf water potential [125]. Additionally, BC has been shown to boost the shoot biomass of mung bean [125], quinoa [126], and tuber yield of potatoes, as well as elevate total soluble solids and vitamin C in tomato plants in saline soil [3,130]. Again, VC addition in soil increased the growth of sugarcane, bean, potato, fennel, and tomato [101–104,107].

4.3. Organic Amendments Enhance Relative Water Content, Photosynthetic Pigments, and Reduce EL under Salinity

Salinity markedly decreases crop photosynthesis by increasing the activity of the enzyme chlorophyllase, which breaks down chl. Moreover, chl synthesis in plants is suppressed due to the accumulation of MDA and hydrogen peroxide (H_2O_2), resulting in diminished Mg uptake under salinity stress. However, the use of OAs reduces the accumulation of MDA and H_2O_2 in plants, thereby increasing Mg uptake and, consequently, chl levels [127,143].

Organic amendments enhance SOM content, fostering a favorable soil environment that notably increases relative water content and reduces EL in plants, bolstering their growth [106,136,144]. Press mud, for instance, plays a crucial role in minimizing EL by reducing reactive oxygen species production [89]. Furthermore, a combined application of FYM and PM resulted in increased concentrations of chl a and b, total chl, and carotenoids, higher relative water content, and decreased EL compared to controls.

The introduction of BC to soil has been observed to amplify photosynthetic rates, enhance chl synthesis, and reduce EL in crops like wheat, maize, tomato, and soybean [113,118,122–131]. Alharbi and Alaklabi [121] have pointed out that wheat benefits from the combined use of BC and jasmonic acid in terms of growth, photosynthesis, and salt stress tolerance. As per Cha-um and Kirdmanee [109], applying GM in conjunction with FYM to RD6 rice grown in saline soil leads to an increase in chl a concentration, overall chl pigments, and photosynthetic capabilities.

4.4. Organic Amendments Improve Antioxidant Activities

Salt stress triggers an excessive generation of ROS, which negatively impacts proteins, lipids, and carbohydrates [145]. Organic amendments help manage these issues by maintaining reduced Na^+ concentrations and lowering MDA and H_2O_2 accumulations. Applying VC, either through foliar or edaphic methods, bolsters the activity of antioxidant enzymes, namely SOD, POD, and CAT [108]. This leads to a decrease in EL and oxidative stress and benefits maize seedling growth [146]. Furthermore, applications of FYM + PM under salinity stress notably enhance antioxidant activities, elevating CAT and APX levels by 59.9% and 68.8%, respectively. This also boosts grain protein and Fe and Zn contents in rice [89]. Separate studies showed that PM can decrease CAT activity while augmenting nutrient availability in saline soils [139]. Lastly, BC has proven beneficial for plant growth under salinity. It achieves this by diminishing oxidative stress, moderating phytohormone production, enhancing stomatal attributes, and promoting seed germination. It also bolsters microbial activities, which, in turn, boosts maize growth [124].

4.5. Organic Amendments Maintain Ionic Homeostasis under Salinity

Research indicates a pronounced accumulation of Na^+ and a reduction in K^+ around plant roots under salinity stress. This elevates the osmotic pressure in the soil solution. However, using OA facilitates a higher K^+ buildup and curtails Na^+ accumulation in rice plants. This notably decreases the Na^+/K^+ ratio; Ca^{2+} plays a vital role in enhancing membrane integrity [147]. The application of press mud has been found beneficial in improving Ca^{2+} accumulation, reducing Na^+ accumulation, and mitigating salinity stress [89]. Vermicompost and regular compost applications aid in nutrient assimilation and ion balance [108]. This offers relief to plants from the severe damage inflicted by salinity. In BC-treated soils, there is a notable improvement in the K^+/Na^+ ratio, a reduction in Na^+ and Cl^- contents, and an augmentation of abscisic acid and plant nutrient contents, as observed in cabbage seedlings [132].

4.6. Organic Amendments Increased the Yield under Salinity

Organic amendments boost crop yields by an average of 27% compared to mineral fertilization [148]. Biochar, due to its high adsorption potential, can mitigate EL, even in situations with high salt concentrations. This is achieved by decreasing Na^+ absorption [113,118,120,122–131]. This results in increased plant height, total biomass, and overall productivity of sorghum, rice, and wheat [98,114,117–120]. According to She et al. [131], BC, through its adsorption of Na^+ ions, releases other essential minerals like K, Ca, and Mg into the soil solution. This helps reduce salt stress and augment tomato production. Hafez et al. [118] observed that BC treatments markedly reduced Cd and Na^+ uptake in plants, subsequently enhancing the growth and photosynthesis of rice. Moreover, a combination of BC and selenium–chitosan nanoparticles have shown promise in protecting wheat plants from salt damage and increasing plant growth and production by restoring nutrient balance, ionic homeostasis, and C assimilation [119].

Naveed et al. [127] found that the combined application of BC with endophytic bacteria significantly boosted the grain yield and grain quality of quinoa. On the other hand, when used on its own, BC improved Na^+-induced oxidative stress and increased quinoa's grain yield [128]. Using FYM alongside PM application noticeably improved the yield traits of the rice crop by 9.83% and 15.58% [89,134]. Moreover, PM application was found to enhance wheat production and P absorption [135]. The highest concentration of vital macronutrients in rice grain, wheat, and pearl grain was consistently associated with compost treatment [105,106]. Olive yield, when considering pomological character, also saw an uptick with compost application [56,149]. Savy et al. [56] reported that applying compost effectively countered salt stress in tomato plants, favoring metabolite accumulation compared to mineral fertilization. In addition, the introduction of *Sesbania* GM and sunhemp notably elevated cotton production in salt-affected soils [72]. Ghafoor et al. [111] opined that *Sesbania* green manuring yielded better results for wheat compared to rice under saline conditions. *Sesbania* GM notably enhanced the dry matter in aerial parts and the grain yield of wheat in saline soils [20]. The combined application of PM with BC lowered salinity and increased the total dry matter and yield of pulse crops [89]. In contrast, applying only PM boosted rice and tuber growth and yield in semi-arid regions [134,140]. Furthermore, the application of gibberellic acid (GA) combined with PM invigorated growth and increased pepper's resilience against salinity stress [139]. An emerging and promising aquatic extract, DW, functions as a biostimulant. This extract has been found to augment leaf chl content, enhance the essential nutrient composition of olive plants [78], and decrease salinity in industrial wastewater [112]. Another substance, water hyacinth, is showing potential for the desalinization of seawater [81].

4.7. Alleviating Metal Stress through OA

Organic amendments contain humic acid, which binds metal particles, including Cd, Cr, Cu, and Pb, rendering them immobile [9]. According to Ho et al. [150], carboxyl and oxygen groups are responsible for lessening HMs through the ion exchange process. Consequently, these HMs transition from being highly accessible to being less bioavailable through organic OA (Figure 9). These amendments, such as compost, BC, cow and pig dung, and FYM, reduce the mobility and uptake of HMs in soils. This has resulted in significant reductions in metals like Pb, Co, and Cr, which subsequently benefitted the growth of cabbage, bean, wheat, *Spinacia oleracea*, Brassica, and lettuce [79,86,141,151–154] (Table 5). Compost application not only elevated soil pH but also bound metal particles with SOM and caused them to co-precipitate with soil P [155]. Additionally, compost application cut down Cd accumulation by 97.8% in wheat grain and up to 50% in *Brassica* fields [155,156] and promoted the growth and quality of *Brassica napus,* simultaneously reducing the stress ability of MDA and antioxidant enzymes to HMs [157]. Ahmed et al. [3] found that compost and biogas slurry could neutralize and stabilize Cd, thus mitigating its adverse effects on the growth and dry biomass production of wheat and maize. Furthermore, amended compost applications have been observed to bolster the growth of rye grass by removing metals like Cd and Pb from its stem [154].

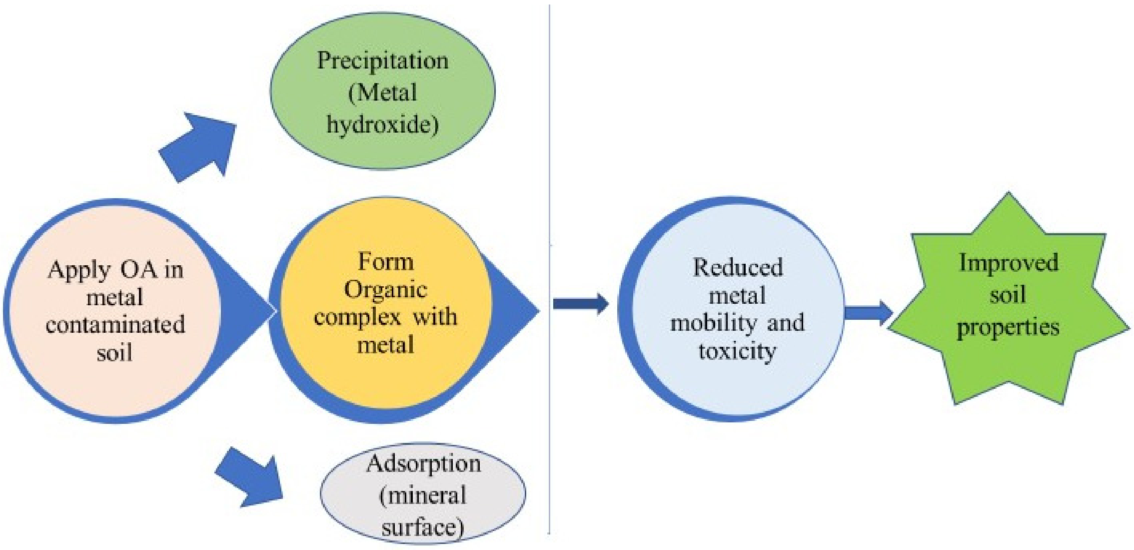

Figure 9. Effect of organic amendments (OAs) on metal-contaminated soil.

Table 5. Metal mobility on soil through different organic amendments.

Crops	Heavy Metal	Organic Amendment Used	Effect on Soil and Crops	Reference
Rice (*Oryza sativa)*	Cd (5 mg kg^{-1})	Steel slag (3 gm kg^{-1})	Increased soil pH, Si, Ca concentration I roots, decreased Cd content, improved crop growth and grain yield.	[61]
Black gram (*Vigna mungo*)	Cd contaminated soil (10 and 20 mg kg^{-1})	Cow manure (5%), sugarcane press mud (5%), and (cow dung + PM)	Improved photosynthetic pigments, leaf water status, reduced hydrogen peroxide production, EL, MDA accumulation, and increased accumulation of soluble protein and free amino acids	[86]
	Cd (0.2 mg kg^{-1}) and Cr (2.75 mg kg^{-1})	BC, 1.5% (*w*/*w*)	Reduced soil Cr, Cd concentration, increased available carbon, microbial activity, plant growth.	[151]
Maize (*Zea may*)	Cd (2.5, 5) mg kg^{-1}	Compost with BC (0.50, 0.75, and 1.00%)	Improvement in soil organic matter, plant height, root length, number of leaves, leaf fresh and dry weight, plant fresh and dry weight, chlorophyll a, b, and total, and carotenoids.	[53]

Table 5. *Cont.*

Crops	Heavy Metal	Organic Amendment Used	Effect on Soil and Crops	Reference
Rice (*O. sativa*) and Wheat (*T. aestivum)*	Pb (54.39 mg kg^{-1}) Cd (0.83 mg kg^{-1})	BC and green stabilizing agent Poultry manure (34% and 25%)	Reduced Pb concentration accumulation in wheat and rice roots, shoots, and leaves. Increased biomass and yield.	[152]
Cacao (*Theobroma cacao* L.) beans	Cd (5 mg kg^{-1})	Compost + zeolite (0.5, or 2%)	Increased soil pH and reduced soil Cd concentration.	[65]
Brassica chinensis	Cd (1 mg kg^{-1})	Cow dung + cow dung derived Biochar (3.0 and 6.0% w/w)	Decreased cd availability, increased trace elements and biomass production	[141]
Mustard (*B. juncea*)	Cd, Cu, and Pb (5, 160, and 1000 mg kg^{-1})	Wood BC (1%)	Reduced toxicity of metals and increased nutrient availability.	[158]
	Ni (50 mg kg^{-1} and 100 mg kg^{-1})	BC with muscle cell (1 g 250 mL^{-1} volumetric glass)	Reduced Ni bioavailability, increased plant biomass, chl content.	[49]
	Cd (1 mg kg^{-1}), Pb (74.4 mg ha^{-1})	Rice husk BC (0.5, 1, and 2% w/w)	Reduced phytoability of metals.	[159]
Wheat and Maize *T. aestivum* *Z. mays*	Cd (5, 20, 50 mg kg^{-1} soil)	Compost and Biogas slurry, 15 t ha^{-1}	Total dry biomass increased; Cd concentration reduced.	[3]
Pakchoi (*Brassica chinensis* L.)	Cd (50 mg kg^{-1} soil)	Poultry manure compost (120 g kg^{-1})	Increased soil pH, reduced Cd concentration in soil, favored antioxidant capacity dissolved OM.	[156]
Duckweed Extract	Cr (1.2 µg L^{-1}) Ni (0.9 µg L^{-1}), and Co (0.5 µg L^{-1}) concentrations	*Lemna gibba* and *L. minor*	Cr, Co, and Ni concentration reduced.	[160]

Mining soils laden with a plethora of HMs adversely impact radish growth and yield. However, organic fertilizers, including VC and C, by forming stable metal complexes, not only enhance radish growth but also minimize risks to human health [48]. Biochar applications form stable metal complexes, drastically cutting down Cd concentrations in various crops such as rice, wheat, maize, and *Brassica* [58,140,159,161].

Biochar has been found to augment plant biomass production and diminish the concentration of HMs in plant tissues. Additionally, it reduces copper uptake in soils polluted by Cu mines [162]. The use of soybean and rice straw BC significantly decreased Cd content in various parts of the rice plant, including the roots, shoots, husks, and grains [163]. The combined application of BC and compost considerably enhanced SOM as well as the content of leaf chl *a* and *b* and carotenoids [153]. Conversely, pairing BC with chicken manure boosted the height, biomass, and enzyme activity (SOD, POD, and CAT) of maize plants while reducing MDA content [153]. Sewage sludge, due to its OM, acted as a metal chelator, lowered metal concentrations in the *Sorghum bicolor* crop, and significantly promoted crop growth and soil quality [164].

Cow manure has proven effective in cutting down on metal concentrations, elevating soil pH, and boosting soil nutrients [116]. As per the researcher, FYM substantially curtails Cd and Pb contents in both the shoots and roots of amaranth cultivated in sandy soil. Green manure crops also reduced Cd content in the aerial parts and Cu concentrations in the roots of Indian mustard [165].

Certain aquatic plants have shown a significant ability to decrease metal concentrations [160]. Water hyacinth (*Eichhornia crassipes*), DW (*Lemna minor, Spirodela intermedia*), and water lettuce (*Pistia stratoites*) are used for the phytoremidation of HMs (As, Ca, Pb, and Hg) from wastewater through their extensive root systems [166]. Again, industrial hemp (*Cannabis sativa* L.) can accumulate soil metal and metaloid in its shoot through the root system and form a stable complex, thus reducing soil metal pollution [167]. Due to their influence on adsorption, complexation, reduction, and volatilization processes, these OAs can serve as a means to reduce the bioavailability of metal(loid)s in polluted soils and sediments [158]. The ways in which OAs improve metal-contaminated soils are illustrated in Figure 9.

5. Conclusions

The significance of OAs in reducing the bioavailability of HMs and alleviating salinity stress in soils, along with their impact on soil quality, is highlighted in this review. Salinity and HM contamination are primary abiotic stresses that diminish crop productivity and can render soil infertile for extended periods. Such conditions adversely affect the overall GDP. Organic amendments are rich in OM, which is readily soluble and available for soil microbial activity. Increased microbial activity results in the production of more carbon dioxide, which can displace sodium ions from the soil solution, thus aiding in saline soil reclamation and diminishing metal stress. The application of VC, BC, and FYM has been observed to mitigate the detrimental effects of salinity and metal concentrations. This review reveals that VC, BC, and FYM boost antioxidant enzyme activities, stabilize ionic balance, alleviate osmotic and oxidative stresses, and modulate gene expression, collectively supporting enhanced plant growth and productivity. In summary, the incorporation of the aforementioned OAs is a promising strategy to bolster soil fertility and productivity for field crops cultivated in salt-affected terrains. Agriculturists and farmers in regions with salt-impacted soils can adopt this method to increase crop yield and decrease crop failure due to soil salinity and metal contamination.

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References

1. Wang, M.; Zhao, S.; Wang, L.; Chen, S.; Li, S.; Lei, X.; Sun, X.; Qin, L. Salt stress-induced changes in microbial community structures and metabolic processes result in increased soil cadmium availability. *Sci. Total Environ.* **2021**, *782*, 147125. [CrossRef]
2. Nosek, M.; Kaczmarczyk, A.; Jędrzejczyk, R.J.; Supel, P.; Kaszycki, P.; Miszalski, Z. Expression of Genes Involved in Heavy Metal Trafficking in Plants Exposed to Salinity Stress and Elevated Cd Concentrations. *Plants* **2020**, *9*, 475. [CrossRef] [PubMed]
3. Ahmad, I.; Akhtar, M.J.; Zahir, Z.A.; Mitter, B. Organic amendments: Effects on cereals growth and cadmium remediation. *Int. J. Sci. Technol.* **2014**, *12*, 2919–2928. [CrossRef]
4. Alvarez, A.; Saez, J.M.; Davila Costa, J.S.; Colin, V.L.; Fuentes, M.S.; Cuozzo, S.A.; Benimeli, C.S.; Polti, M.A.; Amoroso, M.J. Actinobacteria: Current research and perspectives for bioremediation of pesticides and heavy metals. *Chemosphere* **2017**, *166*, 41–62. [CrossRef] [PubMed]
5. Askari, M.S.; Alamdari, P.; Chahardoli, S.; Afshari, A. Quantification of heavy metal pollution for environmental assessment of soil condition. *Environ. Monit Assess* **2020**, *192*, 162. [CrossRef] [PubMed]
6. Ali, I.; Yuan, P.; Ullah, S.; Iqbal, A.; Zhao, Q.; Liang, H.; Khan, A.; Zhang, H.; Wu, X.; Ei, S.; et al. Biochar amendment and nitrogen fertilizer contribute to the changes in soil properties and microbial communities in a paddy field. *Front. Microbiol.* **2022**, *13*, 834751. [CrossRef] [PubMed]
7. Mulugeta, A.; Getahun, G. Effect of organic amendments on soil fertility and environmental quality. *J. Plant Sci.* **2020**, *8*, 112–119.

8. Hoque, M.N.; Imran, S.; Hannan, A.; Paul, N.C.; Mahamud, M.A.; Chakrobortty, J.; Sarker, P.; Irin, I.J.; Brestic, M.; Rhaman, M.S. Organic Amendments for Mitigation of Salinity Stress in Plants: A Review. *Life* **2022**, *12*, 1632. [CrossRef]
9. Saleem, A.; Ur Rahim, H.; Khan, U.; Irfan, M.; Akbar, W.A.; Akbar, Z.; Alatalo, J.M. Organic materials amendments can improve NPK availability and maize growth by reducing heavy metals stress in calcareous soil. *Int. J. Environ. Sci. Technol.* **2024**, *21*, 2533–2546. [CrossRef]
10. Ali, K.; Arif, M.; Shah, F.; Shehzad, A.; Munsif, F.; Mian, I.A.; Mian, A.A. Improvement in maize (*Zea mays* L.) growth and quality through integrated use of biochar. *Pak. J. Bot.* **2017**, *49*, 85–94.
11. Shirale, A.O.; Kharche, V.K.; Wakode, R.R.; Meena, B.P.; Das, H.; Gore, R.P. Influence of gypsum and organic amendments on soil properties and crop productivity in degraded black soils of central India. *Commun. Soil Sci. Plant. Anal.* **2018**, *49*, 2418–2428. [CrossRef]
12. Agbede, T.M.; Oyewumi, A. Benefits of biochar, poultry manure and biochar–poultry manure for improvement of soil properties and sweet potato productivity in degraded tropical agricultural soils. *Resour. Environ. Sustain.* **2022**, *27*, 100051. [CrossRef]
13. Celestina, C.; Hunt, J.R.; Sale, P.W.; Franks, A.E. Attribution of crop yield responses to application of organic amendments: A critical review. *Soil Till. Res.* **2019**, *186*, 135–145. [CrossRef]
14. Jaiswal, B.; Singh, S.; Agrawal, S.B. Improvements in Soil Physical, Chemical and Biological Properties at Natural Saline and Non-Saline Sites Under Different Management Practices. *Environ. Manag.* **2022**, *69*, 1005–1019. [CrossRef] [PubMed]
15. Chahal, S.S.; Choudhary, O.P.; Mavi, M.S. Organic amendments decomposability influences microbial activity in saline soils. *Arch. Agron. Soil Sci.* **2017**, *63*, 1875–1888. [CrossRef]
16. Leogrande, R.; Vitti, C. Use of organic amendments to reclaim saline and sodic soils: A review. *Arid. Land Res. Manag.* **2019**, *33*, 1–21. [CrossRef]
17. Meers, E.; Ruttens, A.; Hopgood, M.; Lesage, E.; Tack, F.M. Potential of *Brassic rapa*, *Cannabis sativa*, *Helianthus annuus* and *Zea mays* for phytoextraction of heavy metals from calcareous dredged sediment derived soils. *Chemosphere* **2005**, *61*, 561–572. [CrossRef] [PubMed]
18. Nephali, L.; Piater, L.A.; Dubery, I.A.; Patterson, V.; Huyser, J.; Burgess, K.; Tugizimana, F. Biostimulants for Plant Growth and Mitigation of Abiotic Stresses: A Metabolomics Perspective. *Metabolites* **2020**, *10*, 505. [CrossRef] [PubMed]
19. Liu, D.; She, D. Can rock fragment cover maintain soil and water for saline-sodic soil slopes under coastal reclamation? *Catena* **2017**, *151*, 213–224. [CrossRef]
20. Bai, J.; Gao, H.; Xiao, R.; Wang, J.; Huang, C. A review of soil nitrogen mineralization as affected by water and salt in coastal wetlands: Issues and methods. *Clean–Soil Air Water.* **2012**, *40*, 1099–1105. [CrossRef]
21. Sritongon, N.; Sarin, P.; Theerakulpisut, P.; Riddech, N. The effect of salinity on soil chemical characteristics, enzyme activity and bacterial community composition in rice rhizospheres in Northeastern Thailand. *Sci. Rep.* **2022**, *12*, 20360. [CrossRef]
22. Hasnine, M.T.; Huda, M.E.; Khatun, R.; Saadat, A.H.M.; Ahasan, M.; Akter, S.; Uddin, M.F.; Monika, A.N.; Rahman, M.A.; Ohiduzzaman, M. Heavy Metal Contamination in Agricultural Soil at DEPZA, Bangladesh. *Environ. Ecol. Res.* **2017**, *5*, 510–516. [CrossRef]
23. Obinnaa, I.B.; Ebere, E.C. Water pollution by heavy metal and organic pollutants: Brief review of sources, effects, and progress on remediation with aquatic plants. *Anal. Meth. Environ. Chem. J.* **2019**, *2*, 5–38. [CrossRef]
24. Narayanan, M.; Ma, Y. Mitigation of heavy metal stress in the soil through optimized interaction between plants and microbes. *J. Environ. Manag.* **2023**, *335*, 118732. [CrossRef]
25. Zhao, X.; Huang, J.; Lu, J.; Sun, Y. Study on the influence of soil microbial community on the long-term heavy metal pollution of different land use types and depth layers in mine. *Ecotoxicol. Environ. Saf.* **2019**, *170*, 218–226. [CrossRef]
26. Kumar, S.; Prasad, S.; Yadav, K.K.; Shrivastava, M.; Gupta, N.; Nagar, S.; Bach, Q.; Kamyab, H. Hazardous heavy metals contamination of vegetables and food chain: Role of sustainable remediation approaches—A Review. *Environ. Res.* **2019**, *179*, 108792. [CrossRef] [PubMed]
27. Paul, G.; Lade, H. Plant-growth-promoting rhizobacteria to improve crop growth in saline soils: A Review. *Agron. Sustain. Dev.* **2014**, *34*, 737–752. [CrossRef]
28. Keisham, M.; Mukherjee, S.; Bhatla, S.C. Mechanisms of sodium transport in plants-progresses and challenges. *Int. J. Mol. Sci.* **2018**, *19*, 647. [CrossRef]
29. Hedrich, R.; Shabala, S. Stomata in a saline world. *Curr. Opini. Plant Biol.* **2018**, *46*, 87–95. [CrossRef] [PubMed]
30. Sade, N.; Del Mar Rubio-Wilhelmi, M.; Umnajkitikorn, K.; Blumwald, E. Stress-induced senescence and plant tolerance to abiotic stress. *J. Exp. Bot.* **2018**, *69*, 845–853. [CrossRef] [PubMed]
31. Al-Shareef, N.O.; Tester, M. Plant Salinity Tolerance. In *eLS*; John Wiley and Sons, Ltd.: Chichester, UK, 2019; pp. 1–6.
32. Krishnamurthy, L.; Upadhyaya, H.D.; Gowda, C.L.L.X.; Kashiwagi, J.; Purushothaman, R.; Singh, S.; Vadez, V. Large variation for salinity tolerance in the core collection of foxtail millet (*Setaria italica* (L.) P. Beauv.) germplasm. *Crop Pasture Sci.* **2014**, *65*, 353–361. [CrossRef]
33. Seleiman, M.F.; Semida, W.M.; Rady, M.M.; Mohamed, G.F.; Hemida, K.A.; Alhammad, B.A.; Hassan, M.M.; Shami, A. Sequential application of antioxidants rectifies ion imbalance and strengthens antioxidant systems in salt-stressed cucumber. *Plants* **2020**, *9*, 1783. [CrossRef]

34. Siddiqui, M.N.; Mostofa, M.G.; Akter, M.M.; Sivastava, A.K.; Sayed, M.A.; Hasan, M.S.; Tran, L.S.P. Impact of salt induced toxicity on growth and yield-potential of local wheat cultivars: Oxidative stress and ion toxicity are among the major determinants of salt-tolerant capacity. *Chemosphere* **2017**, *187*, 385–389. [CrossRef]
35. Ghori, N.H.; Ghori, T.; Hayat, M.; Imadi, S.R.; Gul, A.; Atey, V.; Osturk, M. Heavy metal stress and responses in plants. *Int. J. Environ. Sci. Technol.* **2019**, *16*, 1807–1828. [CrossRef]
36. Aizaz, M.; Khan, I.; Lubna; Asaf, S.; Bilal, S.; Jan, R.; Khan, A.L.; Kim, K.-M.; AL-Harrasi, A. Enhanced Physiological and Biochemical Performance of Mung Bean and Maize under Saline and Heavy Metal Stress through Application of Endophytic Fungal Strain SL3 and Exogenous IAA. *Cells* **2023**, *12*, 1960. [CrossRef]
37. Haider, F.U.; Liqun, C.; Coulter, J.A.; Cheema, S.A.; Wu, J.; Zhang, R.; Wenjun, M.; Farooq, M. Cadmium toxicity in plants: Impacts and remediation strategies. *Ecotoxicol. Environ. Safe* **2021**, *211*, 111887. [CrossRef]
38. Major, J.; Rondon, M.; Molina, D.; Riha, S.J.; Lehmann, J. Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. *Plant Soil.* **2010**, *333*, 117–128. [CrossRef]
39. Bouqbis, L.; Daoud, S.; Koyro, H.W.; Kammann, C.I.; Ainlhout, L.F.Z.; Harrouni, M.C. Biochar from argan shells: Production and characterization. *Int. J. Recyc. Org. Waste Agric.* **2016**, *5*, 361–365. [CrossRef]
40. Rasa, K.; Heikkinen, J.; Hannula, M.; Arstila, K.; Kulju, S.; Hyväluoma, J. How and why does willow biochar increase a clay soil water retention capacity. *Biomas. Bioener.* **2018**, *119*, 346–353. [CrossRef]
41. Isimikalu, T.O.; Olaniyan, J.O.; Affinnih, K.O.; Abdulmumin, O.; Adede, A.C.; Jibril, A.H.; Atteh, E.; Yusuf, S. Rice husk biochar and inorganic fertilizer amendment combination improved the yield of upland rice in typical soils of Southern Guinea Savannah of Nigeria. *Int. J. Recycl. Org. Waste Agric.* **2022**, *12*, 412–456.
42. Majumder, S.; Neogi, S.; Dutta, T.; Powel, M.A.; Banik, P. Th impact of biochar on soil carbon sequestration: Meta- analytical approach to evaluating environmental and economic advantages. *J. Environ. Manag.* **2019**, *250*, 109466. [CrossRef]
43. Mandal, S.; Pu, S.; Adhikari, S.; Ma, H.; Kim, D.H.; Bai, Y.; Hou, D. Progress and future prospects in biochar composites: Application and reflection in the soil environment. *Crit. Rev. Environ. Sci. Technol.* **2021**, *51*, 219–271. [CrossRef]
44. Yadav, V.; Karak, T.; Singh, S.; Singh, A.K.; Khare, P. Benefits of biochar over other organic amendments: Responses for plant productivity (*Pelargonium graveolens* L.) and nitrogen and phosphorus losses. *Ind. Crops Prod.* **2019**, *131*, 96–105. [CrossRef]
45. Dahlawi, S.; Naeem, A.; Rengel, Z.; Naidu, R. Biochar application for the remediation of salt-affected soils: Challenges and opportunities. *Sci. Total Environ.* **2018**, *625*, 320–335.
46. Kocsis, T.; Kotroczó, Z.; Kardos, L.; Biró, B. Optimization of increasing biochar doses with soil–plant–microbial functioning and nutrient uptake of maize. *Environ. Technol. Innov.* **2020**, *20*, 101191. [CrossRef]
47. Alam, M.; Zawar, H.; Anwarzeb, K.; Muhammad, A.K.; Abdur, R.; Muhammad, A.; Muhammad, A.S.; Asim, M. The effects of organic amendments on heavy metals bioavailability in mine impacted soil and associated human health risk. *Sci. Hort.* **2020**, *262*, 109067. [CrossRef]
48. Gul, S.; Naz, A.; Fareed, I.; Irshad, M. Reducing Heavy Metals Extraction from Contaminated Soils Using Organic and Inorganic Amendments—A Review. *Pol. J. Environ. Stud.* **2015**, *24*, 1423–1426.
49. Hannan, F.; Islam, F.; Huang, Q.; Farooq, M.A.; Ayyaz, A.; Fang, R.; Ali, B.; Xie, X.; Zhou, W. Interactive effects of biochar and mussel shell activated concoctions on immobilization of nickel and their amelioration on the growth of rapeseed in contaminated aged soil. *Chemosphere* **2021**, *282*, 130897. [CrossRef]
50. Lwin, C.S.; Seo, B.H.; Kim, H.U.; Owens, G.; Kim, K.R. Application of soil amendments to contaminated soils for heavy metal immobilization and improved soil quality—A critical review. *Soil Sci. Plant Nutr.* **2018**, *64*, 156–167. [CrossRef]
51. Elbagory, M. Reducing the Adverse Effects of Salt Stress by Utilizing Compost Tea and Effective Microorganisms to Enhance the Growth and Yield of Wheat (*Triticum aestivum* L.) Plants. *Agronomy* **2023**, *13*, 823. [CrossRef]
52. Guo, X.-X.; Liu, H.-T.; Zhang, J. The role of biochar in organic waste composting and soil improvement: A review. *Waste Manag.* **2020**, *102*, 884–899. [CrossRef]
53. Manirakiza, N.; Şeker, C. Effects of compost and biochar amendments on soil fertility and crop growth in a calcareous soil. *J. Plant Nutr.* **2020**, *43*, 3002–3019. [CrossRef]
54. Khatun, M.; Shuvo, M.A.R.; Salam, M.T.B.; Rahman, S.M.H. Effect of organic amendments on soil salinity and the growth of maize (*Zea mays* L.). *Plant Sci. Today* **2019**, *6*, 106–111. [CrossRef]
55. 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 and without earthworms. *Land Degrad. Dev.* **2015**, *26*, 300–310. [CrossRef]
56. Savy, D.; Cozzolino, V.; Vinci, G.; Verrillo, M.; Aliberti, A.; Maggio, A.; Barone, A.; Piccolo, A. Fertilization with compost mitigates salt stress in tomato by affecting plant metabolomics and nutritional profiles. *Chem. Biol. Technol. Agric.* **2022**, *9*, 104. [CrossRef]
57. Ahmed, K.; Sajib, A.I.; Naseem, A.R.; Qadir, G.; Nawaz, M.Q.; Khalid, M.; Warraich, I.A.; Arif, M. Use of hyacinth compost in salt-affected soils. *Pak. J. Agric. Res.* **2021**, *33*, 720–728. [CrossRef]
58. Cui, H.; Ou, Y.; Wang, L.; Yan, B.; Li, Y.; Bao, M. Critical passivation mechanisms on heavy metals during aerobic composting with different grain-size zeolite. *J. Hazard. Mater.* **2021**, *406*, 124313. [CrossRef]
59. Wang, W.; Man, Z.; Li, X.; Chen, R.; You, Z.; Pan, T.; Dai, X.; Xiao, H.; Liu, F. Response mechanism and rapid detection of phenotypic information in rice root under heavy metal stress. *J. Hazard. Mater.* **2023**, *449*, 131010. [CrossRef]

60. Tammam, A.D.; Shehata, M.R.A.M.; Pessarakli, M.; El-Aggan, W.H. Vermicompost and its role in alleviation of salt stress in plants—I. Impact of vermicompost on growth and nutrient uptake of salt-stressed plants. *J. Plant. Nutr.* **2023**, *46*, 1446–1457. [CrossRef]
61. He, H.; Tam, N.F.Y.; Yao, A.; Qiu, R.; Li, W.C.; Ye, Z. Growth and Cd uptake by rice (*Oryza sativa*) in acidic and Cd-contaminated paddy soils amended with steel slag. *Chemosphere* **2017**, *9*, 69. [CrossRef]
62. Wang, X.X.; Zhao, F.; Zhang, G.; Zhang, Y.; Yang, L. Vermicompost improves tomato yield and quality and the biochemical properties of soils with different tomato planting history in a greenhouse study. *Front. Plant Sci.* **2017**, *8*, 1978. [CrossRef] [PubMed]
63. Hafez, E.M.; Omara, A.E.; Alhumaydhi, F.A.; El-Esawi, M.A. Minimizing hazard impacts of soil salinity and water stress on wheat plants by soil application of vermicompost and biochar. *Physiol. Plant.* **2020**, *172*, 587–602. [CrossRef] [PubMed]
64. Liu, M.; Wang, C.; Wang, F.; Xie, Y. Vermicompost and humic fertilizer improve coastal saline soil by regulating soil aggregates and the bacterial community. *Arch. Agron. Soil Sci.* **2019**, *65*, 281–293. [CrossRef]
65. Chavez, E.; He, Z.L.; Stoffella, P.J.; Mylavarapu, R.; Li, Y.; Baligar, V.C. Evaluation of soil amendments as a remediation alternative for cadmium-contaminated soils under cacao plantations. *Environ. Sci. Pollut. Res.* **2016**, *23*, 17571–17580. [CrossRef]
66. Ciura, J.; Kruk, J. Phytohormones as targets for improving plant productivity and stress tolerance. *J. Plant Physiol.* **2018**, *229*, 32–40. [CrossRef]
67. Irin, I.J.; Biswas, P.K. Residual Effect of Green Manure on Soil Properties in Green Manure-Transplant Aman-Mustard Cropping Pattern. *Indian J. Agric. Res.* **2023**, *57*, 67–72. [CrossRef]
68. Irin, I.J.; Hoque, M.N.; Hannan, A.; Alam, M.M. Green manure for soil salinity reclamation—A comprehensive review. *J. Agric. Food Envirn.* **2022**, *3*, 5–14.
69. Mubarak, A.R.; Nortclif, S. Calcium carbonate solubilization through H-proton release from some legumes grownin calcareous saline sodic soils. *Land Degrad. Dev.* **2010**, *21*, 24–31. [CrossRef]
70. Yazdanpanah, N. CO_2 emission and structural characteristics of two calcareous soils amended with municipalsolid waste and plant residue. *Solid Earth.* **2016**, *7*, 105–114. [CrossRef]
71. Choudhary, O.P.; Ghuman, B.S.; Thuy, N.; Buresh, R.J. Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice–wheat cropping system in a calcareous soil. *Field Crops Res.* **2011**, *121*, 363–372. [CrossRef]
72. Parwar, S.K.; Kumbhar, G.A.; Dighe, P.K. Comparative study of crop residue, green manuring and gypsum on chemical properties and yield of cotton in salt affected oils of purna valley. *J. Pharmacogn. Phytochem.* **2020**, *9*, 442–445.
73. Irin, I.J.; Biswas, P.K.; Ullah, M.J.; Roy, T.S. Effect of in situ green manuring crops and chemical fertilizer on yield of T. Aman rice and mustard. *Asian J. Crop Soil Sci. Plant Nutr.* **2020**, *2*, 68–79. [CrossRef]
74. Kim, K.R.; Owens, G.; Kwon, S.I. Influence of Indian mustard *(Brassica juncea)* on rhizosphere soil solution chemistry in long-term contaminated soils: A rhizobox study. *J. Environ. Sci.* **2010**, *22*, 98–105. [CrossRef] [PubMed]
75. Foucault, Y.; Lévêque, T.; Xiong, T.; Schreck, E.; Austruy, A.; Shahid, F.; Dumat, C. Green manure plants for remediation of soils polluted by metals and metalloids: Ecotoxicity and human bioavailability assessment. *Chemosphere* **2013**, *93*, 1430–1435. [CrossRef] [PubMed]
76. Bruning, B.; Van, L.R.; Broekman, R.; Vos, A.D.; González, A.P.; Rozema, Z. Growth and nitrogen fixation of legumes at increased salinity under field conditions: Implications for the use of green manures in saline environments. *AoB Plants* **2015**, *7*, 10. [CrossRef]
77. Dhir, B. Use of aquatic plants in removing heavy metals from wastewater. *Int. J. Environ. Eng.* **2010**, *2*, 185–201. [CrossRef]
78. Regni, L.; Del Buono, D.; Miras-Moreno, B.; Senizza, B.; Lucini, L.; Trevisan, M.; Morelli Venturi, D.; Costantino, F.; Proietti, P. Bio stimulant Effects of an Aqueous Extract of Duckweed (*Lemna minor* L.) on Physiological and Biochemical Traits in the Olive Tree. *Agriculture* **2021**, *11*, 1299. [CrossRef]
79. Zhou, Y.; Stepanenko, A.; Kishchenko, O.; Xu, J.; Borisjuk, N. Duckweeds for Phytoremediation of Polluted Water. *Plants* **2023**, *12*, 589. [CrossRef]
80. Leblebici, Z.; Aksoy, A.; Duman, F. Influence of salinity on the growth and heavy metal accumulation capacity of *Spirodela polyrrhiza* (Lemnaceae). *Turk. J. Biol.* **2011**, *35*, 215–220. [CrossRef]
81. TU, S.; Subash, A. Desalination of sea water using water hyacinth activated carbon. *Int. Res. J. Eng. Technol.* **2022**, *9*, 309–313.
82. Guzmán, E.T.R.; Gutiérrez, L.R.R.; Allende, M.J.M.; Acevedo, Z.I.G.; Gutiérrez, M.T.O. Physicochemical properties of non-living water hyacinth (*Eichhornia crassipes*) and lesser duckweed (*Lemna minor*) and their influence on the As (V) adsorption processes. *Chem. Ecol.* **2013**, *29*, 459–475. [CrossRef]
83. Mockeviciene, I.; Repsiene, R.; Amaleviciute-Volunge, K.; Karcauskiene, D.; Slepetiene, A.; Lepane, V. Effect of long-term application of organic fertilizers on improving organic matter quality in acid soil. *Arch. Agron. Soil Sci.* **2022**, *68*, 1192–1204. [CrossRef]
84. Singh, A.; Agrawal, M. Management of heavy metal contaminated soil by using organic and inorganic fertilizers: Effect on plant performance. *IIOAB J.* **2011**, *2*, 22–30.
85. Rani, N.; Singh, D.; Sikka, R. Effect of applied chromium and amendments on dry matter yield and uptake in maize-Indian mustard rotation in soils irrigated with sewage and tubewell waters. *Agric. Res. J.* **2018**, *55*, 677. [CrossRef]

86. Chattha, M.U.; Arif, W.; Khan, I.; Soufan, W.; Bilal Chattha, M.; Hassan, M.U.; Ullah, N.; Sabagh, A.E.; Qari, S.H. Mitigation of Cadmium Induced Oxidative Stress by Using Organic Amendments to Improve the Growth and Yield of Mash Beans [*Vigna mungo* (L.)]. *Agronomy* **2021**, *11*, 2152. [CrossRef]
87. Kumar, S.; Meena, R.; Jinger, D.; Jatav, H.S.; Banjara, T. Use of press mud compost for improving crop productivity and soil health. *Int. J. Chem. Stud.* **2017**, *5*, 384–389.
88. Nawaz, M.; Chattha, M.; Ahmad, R.; Munir, H.; Usman, M. Assessment of compost as nutrient supplement for spring planted sugarcane (*Saccharum officinarum* L.). *J. Anim. Plant. Sci.* **2017**, *27*, 283–293.
89. Khan, I.; Muhammad, A.; Chattha, M.U.; Skalicky, M.; Bilal, C.M.; Ahsin, A.M. Mitigation of salinity induced oxidative damage, growth and yield reduction in fine rice by sugarcane press-mud application. *Front. Plant Sci.* **2022**, *13*, 865. [CrossRef]
90. Mahmood, T. Phytoextraction of heavy metals-the process and scope for remediation of contaminated soils. *Soil Environ.* **2010**, *29*, 91–109.
91. Eissa, M.A. Impact of compost on metals Phyto stabilization potential of two halophytes species. *Int. J. Phytoremediation* **2015**, *17*, 662–668. [CrossRef]
92. Liu, M.; Tan, X.; Zheng, M.; Yu, D.; Lin, A.; Liu, J.; Wang, C.; Gao, Z.; Cui, J. Modified biochar/humic substance/fertiliser compound soil conditioner for highly efficient improvement of soil fertility and heavy metals remediation in acidic soils. *J. Environ. Manag.* **2023**, *325*, 116614. [CrossRef]
93. Navarro, C.; Díaz, M.; Villa-García, M.A. Physico-chemical characterization of steel slag. Study of its behavior under simulated environmental conditions. *Environ. Sci. Technol.* **2010**, *44*, 5383–5388. [CrossRef]
94. Kapoor, R.T.; Hasanuzzaman, M. Unlocking the potential of co-application of steel slag and biochar in mitigation of arsenic-induced oxidative stress by modulating antioxidant and glyoxalase system in *Abelmoschus esculentus* L. *Chemosphere* **2024**, *17*, 141232. [CrossRef]
95. Saki, P.; Mafigholami, R.; Takdastan, A. Removal of cadmium from industrial. wastewater by steel slag. *Jundishapur J. Health Sci.* **2013**, *5*, 23–34.
96. López-Valdez, F.; Fernández-Luqueño, F.; Luna-Guido, M.L.; Marsch, R.; Olalde-Portugal, V.; Dendooven, L. Microorganisms in sewage sludge added to an extreme alkaline saline soil affect carbon and nitrogen dynamics. *Appl. Soil Ecol.* **2010**, *45*, 2225–2231. [CrossRef]
97. Cicek, N.; Erdogan, M.; Yucedag, C.; Cetin, M. Improving the detrimental aspects of salinity in salinized soils of arid and semi-arid areas for effects of vermicompost leachate on salt stress in seedlings. *Water Air Soil Pollut.* **2022**, *233*, 197. [CrossRef]
98. Khatun, L.; Ali, M.A.; Sumon, M.H.; Islam, M.B.; Khatun, F. Mitigation Rice Yield Scaled Methane Emission and Soil Salinity Stress with Feasible Soil Amendments. *J. Agric. Chem. Environ.* **2021**, *9*, 16–36. [CrossRef]
99. Penkam, C.; Iwal, C.B.; Kume, T. Effects of Vermicompost and Rice Husk Ash on the Change of Soil Chemical Properties and the Growth of Rice in Salt Affected Area. *Int. J. Environ. Rural Develop.* **2019**, *10*, 129–132.
100. Zurbano, L.Y. Response of lettuce (*Lactuca sativa)* on saline soil amended with vermicompost and pulverized eggshell. *Indian J. Sci. Technol.* **2018**, *11*, 1–8. [CrossRef]
101. Djajadi, D.; Syaputra, R.; Hidayati, S.N.; Khairiyah, Y. Effect of vermicompost and nitrogen on N, K, Na uptakes and growth of sugarcane in saline soil. *Agrivita. J. Agric. Sci.* **2020**, *42*, 110–119. [CrossRef]
102. Beykkhormizi, A.; Abrishamchi, P.; Ganjeali, A.; Parsa, M. Effect of vermicompost on some morphological, physiological and biochemical traits of bean (*Phaseolus vulgaris* L.) under salinity stress. *J. Plant Nutr.* **2016**, *39*, 883–893. [CrossRef]
103. Pérez-Gómez, J.D.; Abud-Archila, M.; Villalobos-Maldonado, J.J.; Enciso-Saenz, S.; de Hernández, L.H.; Ruiz-Valdiviezo, V.M.; Gutiérrez-Miceli, F.A. Vermicompost and vermiwash minimized the influence of salinity stress on growth parameters in potato Plants. *Compost Sci. Util.* **2017**, *25*, 282–287. [CrossRef]
104. Benazzouk, S.; Lutts, S.; Djazouli, Z.E. Alleviation of salinity stress by Vermicompost extract in *Solanum lycopersicum* L. by mobilizing salt tolerance mechanisms. *AgroBiologia* **2018**, *8*, 1136–1144.
105. Meena, M.D.; Joshi, P.K.; Narjary, B.; Sheoran, P.; Jat, H.S.; Chinchmalatpure, A.R.; Yadav, R.K.; Sharma, D.K. Effects of municipal solid waste compost, rice-straw compost and mineral fertilizers on biological and chemical properties of a saline soil and yields in a mustard–pearl millet cropping system. *Soil Res.* **2016**, *54*, 958–969. [CrossRef]
106. Litardo, R.C.M.; Bendezú, S.J.G.; Zenteno, M.D.C.; Pérez-Almeida, I.B.; Parismoreno, L.L.; García, E.D.L. Effect of mineral and organic amendments on rice growth and yield in saline soils. *J. Saudi Soc. Agric. Sci.* **2022**, *21*, 29–37.
107. Beykkhormizi, A.; Hosseini, S.; Sarafraz, A.M.; Moshtaghioun, S.; Mousavi, K.; Seyed, M. Alleviation of Salinity Stress by Vermicompost Extract: A Comparative Study on Five Fennel Landraces. *Commun. Soil Sci. Plant Anal.* **2018**, *49*, 2123–2130. [CrossRef]
108. Tartoura, K.A.; Youssef, S.A.; Tartoura, E.S.A. Compost alleviates the negative effects of salinity via up-regulation of antioxidants in L. plants. *Plant Growth Regul.* **2014**, *74*, 299–310. [CrossRef]
109. Cha-um, S.; Kirdmanee, C. Remediation of salt-affected soil by the addition of organic matter: An investigation into improving glutinous rice productivity. *Sci. Agirc.* **2011**, *68*, 406–410. [CrossRef]
110. Sarwar, G.; Malik, M.A.; Sabah, N.-S.; Tahir, M.A.; Aftab, M.; Manzoor, M.Z.; Zafar, A. Comparative efficiency of compost, farmyard manure and sesbania green manure to produce rice-wheat crops under salt stressed environmental conditions. *J. Pure Appl. Agric.* **2020**, *5*, 33–42.

111. Ghafoor, A.; Murtaza, G.; Maann, A.A.; Qadir, M.; Ahmad, B. Treatments and economic aspects of growing rice and wheat crops during reclamation of tile drained saline-sodic soils using brackish waters. *Irrig. Drain.* **2011**, *60*, 418–426. [CrossRef]
112. Bhutiani, R.; Rai, N.; Kumar, N.; Rausa, M.; Ahamad, F. Treatment of industrial waste water using Water hyacinth (Eichornia crassipus) and Duckweed (*Lemna minor*): A Comparative study. *Environ. Conserv. J.* **2019**, *20*, 15–25. [CrossRef]
113. Farhangi-Abriz, S.; Torabian, S. Biochar improved nodulation and nitrogen metabolism of soybean under salt stress. *Symbiosis* **2018**, *74*, 215–223. [CrossRef]
114. Ibrahim, M.E.H.; Ali, A.Y.A.; Elsiddig, A.M.I.; Zhou, G.; Nimir, N.E.A.; Agbna, G.H.; Zhu, G. Mitigation effect of biochar on sorghum seedling growth under salinity stress. *Pak. J. Bot.* **2021**, *53*, 387–392. [CrossRef]
115. Foronda, D.A. Reclamation of a Saline-Sodic Soil with Organic Amendments and Leaching. *Environ. Sci. Proc.* **2020**, *16*, 56.
116. Eglous, N.M.; Alhdad, G.M.; Al-Qant, H.I.; Alar, S.M. The effects of poultry manure on growth and yield of tomato(*L.esculentum* mill) cultivated salt marsh soil. *Sci. J. Fac. Sci.-Sirte Univ.* **2023**, *3*, 59–67.
117. Zhang, J.; Bai, Z.; Huang, J.; Hussain, S.; Zhao, F.; Zhu, C.; Zhu, L.; Cao, X.; Jin, Q. Biochar alleviated the salt stress of induced saline paddy soil and improved the biochemical characteristics of rice seedlings differing in salt tolerance. *Soil Till. Res.* **2019**, *195*, 104372. [CrossRef]
118. Hafez, E.M.; Alsohim, A.S.; Farig, M.; Omara, A.E.-D.; Rashwan, E.; Kamara, M.M. Synergistic Effect of Biochar and Plant Growth Promoting Rhizobacteria on Alleviation of Water Deficit in Rice Plants under Salt-Affected Soil. *Agronomy* **2019**, *9*, 847. [CrossRef]
119. Soliman, M.H.; Alnusairi, G.S.; Khan, A.A.; Alnusaire, T.S.; Fakhr, M.A.; Abdulmajeed, A.M.; Aldesuquy, H.S.; Yahya, M.; Najeeb, U. Biochar and Selenium Nanoparticles Induce Water Transporter Genes for Sustaining Carbon Assimilation and Grain Production in Salt-Stressed Wheat. *J. Plant Growth Regul.* **2022**, *42*, 1522–1543. [CrossRef]
120. Huang, M.; Zhang, Z.; Zhai, Y.; Lu, P.; Zhu, C. Effect of straw biochar on soil properties and wheat production under saline water irrigation. *Agronomy* **2019**, *9*, 457. [CrossRef]
121. Alharbi, K.; Alaklabi, K. Alleviation of salinity induced growth and photosynthetic decline in wheat due to biochar and jasmonic acid application involves up-regulation of ascorbate-glutathione pathway, glyoxylase system and secondary metabolite accumulation. *Rhizosphere* **2022**, *24*, 100603. [CrossRef]
122. Aibdin, Z.; Nafees, M.; Rizwan, M.; Ahmad, S.; Ali, S.; Obaid, W.A.; Alsubeie, M.S.; Darwish, D.B.E.; Abeed, A.H.A. Combined effect of Zinc lysine and biochar on growth and physiology o wheat (*Triticum aestivum* L.) to alleviate salinity stress. *Front. Plant Sci.* **2023**, *13*, 1017282. [CrossRef]
123. Ndiate, N.I.; Saeed, Q.; Haider, F.U.; Liqun, C.; Nkoh, J.N.; Mustafa, A. Co-Application of Biochar and *Arbuscular mycorrhizal* Fungi Improves Salinity Tolerance, Growth and Lipid Metabolism of Maize (*Zea mays* L.) in an Alkaline Soil. *Plants* **2021**, *10*, 2490. [CrossRef]
124. Yue, Y.; Lin, Q.; Li, G.; Zhao, X.; Chen, H. Biochar Amends Saline Soil and Enhances Maize Growth: Three-Year Field Experiment Findings. *Agronomy* **2023**, *13*, 1111. [CrossRef]
125. Nikpour-Rashidabad, N.; Tavasolee, A.; Torabian, S.; Farhangi-Abriz, S. The effect of biochar on the physiological, morphological and anatomical characteristics of mung bean roots after exposure to salt stress. *Arch. Biol. Sci.* **2019**, *71*, 321–327. [CrossRef]
126. Yang, A.; Akhtar, S.S.; Li, L.; Fu, Q.; Li, Q.; Naeem, M.A.; He, X.; Zhang, Z.; Jacobsen, S.E. Biochar mitigates combined effects of drought and salinity stress in quinoa. *J. Agron.* **2020**, *10*, 912. [CrossRef]
127. Naveed, M.; Ramzan, N.; Mustafa, A.; Samad, A.; Niamat, B.; Yaseen, M.; Ahmad, Z.; Hasanuzzaman, M.; Sun, N.; Shi, W. Alleviation of Salinity Induced Oxidative Stress in Chenopodium quinoa by Fe Biofortification and Biochar—Endophyte Interaction. *Agronomy* **2020**, *10*, 168. [CrossRef]
128. Abbas, G.; Abrar, M.M.; Naeem, M.A.; Siddiqui, M.H.; Ali, H.M.; Li, Y.; Ahmed, K.; Sun, N.; Xu, M. Biochar increases salt tolerance and grain yield of quinoa on saline-sodic soil: Multivariate comparison of physiological and oxidative stress attributes. *J. Soils Sediments.* **2022**, *22*, 1446–1459. [CrossRef]
129. Akhtar, S.S.; Andersen, M.N.; Liu, F. Biochar mitigates salinity stress in potato. *J. Agron. Crop Sci.* **2015**, *201*, 368–378. [CrossRef]
130. Wu, Z.; Fan, Y.; Qiu, Y.; Hao, X.; Li, S.; Kang, S. Response of yield and quality of greenhouse tomatoes to water and salt stresses and biochar addition in Northwest China. *Agric. Water Manag.* **2022**, *270*, 107736. [CrossRef]
131. She, D.; Sun, X.; Gamareldawla, A.H.; Nazar, E.A.; Hu, W.; Edith, K.; Yu, S.E. Benefits of soil biochar amendments to tomato growth under saline water irrigation. *Sci. Rep.* **2018**, *8*, 14743. [CrossRef]
132. Ekinci, M.; Turan, M.; Yildirim, E. Biochar mitigates salt stress by regulating nutrient uptake and antioxidant activity, alleviating the oxidative stress and abscisic acid content in cabbage seedling. *Turk. J. Agric. For.* **2022**, *46*, 28–37.
133. Hasanuzzaman, M.; Raihan, M.R.H.; Khojah, E.; Samra, B.N.; Fujita, M.; Nahar, K. Biochar and Chitosan Regulate Antioxidant Defense and Methylglyoxal Detoxification Systems and Enhance Salt Tolerance in Jute (*Corchorus olitorius* L.). *Antioxidants* **2021**, *10*, 2017. [CrossRef]
134. Dhar, S.; Kibria, M.G.; Rahman, M.M.; Hoque, M.A. Mitigation of the adverse effects of soil salinity in rice using exogenous proline and organic manure. *Asian J. Med. Biol. Res.* **2016**, *1*, 478. [CrossRef]
135. Farooqi, Z.U.R.; Sabir, M.; Ahmad, H.R.; Shahbaz, M.; Smith, J. Reclaimed Salt-Affected Soils Can Effectively Contribute to Carbon Sequestration and Food Grain Production: Evidence from Pakistan. *Appl. Sci.* **2023**, *13*, 1436. [CrossRef]
136. Sheoran, P.; Kumar, A.; Singh, A.; Kumar, A.; Parjapat, K.; Sharma, R. Press mud alleviates soil sodicity stress in a rice–wheat rotation: Effects on soil properties, physiological adaptation and yield-related traits. *Land Degrad. Dev.* **2021**, *32*, 2735–2748. [CrossRef]

137. Imran, M.; Ashraf, M.; Awan, A.R. Growth, yield and arsenic accumulation by wheat grown in a press mud amended salt-affected soil irrigated with arsenic contaminated water. *Ecotox. Environ. Saf.* **2021**, *22*, 112692. [CrossRef]
138. Chattha, M.U.; Hassan, M.U.; Barbanti, L.; Chatta, M.B.; Khan, I.; Usman, M.; Ali, A.; Nawaz, M. Composted Sugarcane By-product Press Mud Cake Supports Wheat Growth and Improves Soil Properties. *Int. J. Plant Prod.* **2019**, *13*, 241–249. [CrossRef]
139. AlTaey, D.K.A. Alleviation of Salinity Effects by Poultry Manure and Gibberellin Application on growth and Peroxidase activity in pepper. *Int. J. Environ. Agric. Biotech.* **2017**, *2*, 1851–1862. [CrossRef]
140. Oustani, M.; Halilat, M.T.; Chenchouni, H. Effect of poultry manure on the yield and nutriments uptake of potato under saline conditions of arid regions. *Emir. J. Food Agric.* **2015**, *27*, 106–120. [CrossRef]
141. Kiran, Y.K.; Barkat, A.; Cui, X.Q.; Feng, Y.; Pan, F.; Tang, L.; Yang, X. Cow manure and cow manure derived biochar application as a soil amendment for reducing cadmium availability and accumulation by *Brassica chinensis* L. in acidic red soil. *J. Integr. Agric.* **2017**, *16*, 725–734. [CrossRef]
142. Wichern, F.; Islam, M.R.; Hemkemeyer, M.; Watson, C.; Joergensen, R.G. Organic Amendments Alleviate Salinity Effects on Soil Microorganisms and Mineralization Processes in Aerobic and Anaerobic Paddy Rice Soils. *Front. Sustain. Food Syst.* **2020**, *4*, 30. [CrossRef]
143. Hassan, M.U.; Aamer, M.; Nawaz, M.; Rehman, A.; Aslam, T.; Afzal, U. Agronomic Bio-Fortification of Wheat to Combat Zinc Deficiency in Developing Countries. *Pak. J. Agric.* **2021**, *34*, 201. [CrossRef]
144. Saeed, R.; Mirza, S.; Ahmed, R. Electrolyte leakage and relative water content as affected by organic mulch in okra plant (*Abelmoschus esculentus*) grown under salinity. *Fuuast. J. Biol.* **2014**, *4*, 221–227.
145. Khaliq, A.; Zia, U.l.; Haq, M.; Ali, F.; Aslam, F.; Matloob, A.; Navab, A.; Hussain, S. Salinity tolerance in wheat cultivars is related to enhanced activities of enzymatic antioxidants and reduced lipid peroxidation. *CLEAN–Soil Air Water.* **2015**, *43*, 1248–1258. [CrossRef]
146. Alamer, K.H.; Perveen, S.; Khaliq, A.; Zia, U.l.; Haq, M.; Ibrahim, M.U.; Ijaz, B. Mitigation of Salinity Stress in Maize Seedlings by the Application of Vermicompost and Sorghum Water Extracts. *Plants* **2022**, *11*, 2548. [CrossRef] [PubMed]
147. Talaat, N.B.; Shawky, B.T. Synergistic effects of salicylic acid and melatonin on modulating ion homeostasis in salt-stressed wheat (*Triticum aestivum* L.) plants by enhancing root H+-pump activity. *Plants* **2022**, *11*, 416. [CrossRef]
148. Luo, G.; Li, L.; Friman, V.; Guo, J.; Guo, S.; Shen, Q.; Ling, N. Organic amendments increase crop yields by improving microbe-mediated soil functioning of agroecosystems: A meta-analysis. *Soil Biol. Biochem.* **2018**, *124*, 105–115. [CrossRef]
149. Cheheb, H.; Takaya, M.; Hajlaoi, H.; Abdelhamid, S.; GoChuiaa, M.; Sfina, H.; Chihaoui, B.; Boujnah, D.; Mechari, B. Complementary irrigation with saline water and soil organic amendments modified soil salinity, leaf Na^+, productivity and oil phenols of olive trees (cv. Chemlali) grown under semiarid conditions. *Agric. Water Manag.* **2020**, *237*, 106183. [CrossRef]
150. Ho, S.H.; Zhu, S.; Chang, J.S. Recent advances in nanoscale-metal assisted biochar derived from waste biomass used for heavy metals removal. *Bioresou. Technol.* **2017**, *246*, 123–134. [CrossRef]
151. Bashir, S.; Hussain, Q.; Akmal, M.; Riaz, M.; Hu, H.; Ijaz, S.S.; Iqbal, M.; Abro, S.; Mehmood, S.; Ahmad, M. Sugarcane bagasse-derived biochar reduces the cadmium and chromium bioavailability to mash bean and enhances the microbial activity in contaminated soil. *J. Soils Sediments* **2018**, *18*, 874–886. [CrossRef]
152. Hamid, Y.; Tang, L.; Yaseen, M.; Hussain, B.; Zehra, A.; Aziz, M.Z.; He, Z.L.; Yang, X. Comparative efficacy of organic and inorganic amendments for cadmium and lead immobilization in contaminated soil under rice-wheat cropping system. *Chemosphere* **2019**, *214*, 259–268. [CrossRef]
153. Rahi, A.A.; Hussain, S.; Hussain, S.; Baig, K.S.; Tahir, M.S.; Hussain, G.S.; Zarei, T.; Danish, S.; Akhtar, M.N.; Fahad, S.; et al. Alleviation of Cd stress in maize by compost mixed biochar. *J. King Saud Univ. Sci.* **2022**, *34*, 102014. [CrossRef]
154. Zhang, M.; Gao, B.; Varnoosfaderani, S.; Hebard, A.; Yao, Y.; Inyang, M. Preparation and characterization of a novel magnetic biochar for arsenic removal. *Bioresour. Technol.* **2013**, *130*, 457–462. [CrossRef]
155. Abedi, T.; Mojiri, A. Cadmium Uptake by Wheat (*Triticum aestivum* L.): An Overview. *Plants* **2020**, *9*, 500. [CrossRef]
156. Chen, H.; Huang, Q.; Leu, N.A.; Cai, P. Poultry Manure Compost Alleviates the Phytotoxicity of Soil Cadmium: Influence on Growth of Pakchoi (*Brassica chinensis* L.). *Pedosphere* **2010**, *20*, 63–70. [CrossRef]
157. Sun, Q.; Zhang, Y.; Ming, C.; Wang, J.; Zhang, Y. Amended compost alleviated the stress of heavy metals to pakchoi plants and affected the distribution of heavy metals in soil-plant system. *J. Environ. Manag.* **2023**, *336*, 117674. [CrossRef] [PubMed]
158. Park, J.H.; Lamb, D.; Paneerselvam, P.; Choppala, G.; Bolan, N.; Chung, J.W. Role of organic amendments on enhanced bioremediation of heavy metal(loid) contaminated soils. *J. Hazard. Mater.* **2011**, *185*, 549–574. [CrossRef] [PubMed]
159. Nejad, Z.D.; Jung, M.C. The effects of biochar and inorganic amendments on soil remediation in the presence of hyperaccumulator plant. *Int. J. Energy Environ. Eng.* **2017**, *8*, 317–329. [CrossRef]
160. Sasmaz, A.; Mete, I.; Sasmaz, D.M. Removal of Cr, Ni and Co in the water of chromium mining areas by using *Lemna gibba* L. and *Lemna minor* L. *Water Environ. J.* **2016**, *30*, 235–242. [CrossRef]
161. Namgay, T.; Singh, B.; Singh, B.P. Influence of biochar application to soil on the availability of As, Cd, Cu, Pb, and Zn to maize (*Zea mays* L.). *Aust. J. Soil Res.* **2010**, *48*, 638–647. [CrossRef]
162. Meier, S.; Curaqueo, G.; Khan, N.; Bolan, N.; Cea, M.; Eugenia, G.M.; Cornejo, P.; Ok, Y.S.; Borie, F. Chicken-manure-derived biochar reduced bioavailability of copper in a contaminated soil. *J. Soils Sediments* **2017**, *17*, 741–750. [CrossRef]

163. Zheng, R.L.; Chen, Z.; Cai, C.; Tie, B.Q.; Liu, X.L.; Reid, B.J.; Huang, Q.; Lei, M.; Sun, G.X.; Baltrėnaitė, E. Mitigating heavy metal accumulation into rice (*Oryza sativa* L.) using biochar amendment—A field experiment in Hunan, China. *Environ. Sci. Pollut. Res.* **2015**, *22*, 11097–11108. [CrossRef]
164. Eid, E.M.; Shaltout, K.H.; Alamri, S.A.M.; Alrumman, S.A.; Hussain, M.A.; Sewelam, N.; Ragab, G.A. Monitored Sewage Sludge Application Improves Soil Quality, Enhances Plant Growth, and Provides Evidence for Metal Remediation by Sorghum bicolor L. *J. Soil Sci. Plant Nutr.* **2021**, *21*, 2325–2338. [CrossRef]
165. Bolan, N.S.; Choppala, G.; Kunhikrishnan, A.; Park, J.H.; Naidu, R. Microbial transformation of trace elements in soils in relation to bioavailability and remediation. *Rev. Environ. Contam. Toxicol.* **2013**, *225*, 1–56. [PubMed]
166. Anaokar, G.; Sutar, T.; Mali, A.; Waghchoure, K.; Jadhav, R.; Walunj, S. Low-Cost Municipal Wastewater Treatment Using Water Hyacinth. *J. Water Resour. Pollut. Stud.* **2018**, *3*, 2.
167. Golia, E.E.; Bethanis, J.; Ntinopoulos, N.; Kaffe, G.G.; Komnou, A.A.; Vasilou, C. Investigating the potential of heavy metal accumulation from hemp. The use of industrial hemp (*Cannabis Sativa* L.) for phytoremediation of heavily and moderated polluted soils. *Sustain. Chem. Pharm.* **2023**, *31*, 100961. [CrossRef]