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Review

Crop Physiological, Growth, and Yield Responses to Organic Fertilizers under Abiotic Stress Conditions:

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Abstract: Abiotic stresses such as salinity, drought, heat, and heavy metal contamination represent escalating threats to global food insecurity, decreasing crop productivity and soil health. Sustainable strategies that enhance crop resilience to those stressors are urgently required, and organic fertilizers have emerged as promising inputs to enhance crop response to various forms of stresses. This review synthesizes current knowledge on the physiological, growth, and yield responses of crops to key organic amendments, including compost, farmyard manure, vermicompost, and biochar, under major abiotic stress conditions. Evidence indicates that organic fertilizers improve soil structure, nutrient availability, and microbial activity, thereby supporting ion balance under salinity, water retention during drought, photosynthetic stability under heat stress, and reduced heavy metal uptake. While these benefits of organic amendments are well-documented, significant gaps remain: comparative studies across stress types are scarce, and long-term field validations-based evidences under diverse agro ecological settings are limited. Addressing these knowledge gaps is essential to optimize application strategies and integrate organic fertilizers into resilient food systems. This review highlights the dual role of organic fertilizers in mitigating abiotic stress and advancing sustainable agriculture, while underscoring research priorities for future innovations in crop and soil management towards sustainable agriculture development.

Keywords: abiotic stress, crop productivity, organic fertilizers, soil fertility

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1. Introduction

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Organic fertilizers have significant potential to enhance plant growth and promote environmental sustainability (Zhou et al., 2022). They are typically produced by composting materials such as animal manure, household waste, municipal waste, agricultural residues, and plant components (Chew et al., 2019). Application of organic fertilizers improves soil organic matter (SOM), enhances microbial activity, and increases nutrient availability, leading to higher crop yields (Maltas et al., 2018). Additionally, they influence soil cation exchange capacity (CEC), improve moisture retention, and positively affect soil fauna communities, particularly in acidic soils (Abbott & Murphy, 2007). Organic fertilizers can reduce reliance on chemical fertilizers, lowering production costs while maintaining or improving soil fertility and crop yields (Tao et al., 2016). They supply essential micro- and macronutrients, including nitrogen, which is vital for crop growth (Gao et al., 2020). Studies have shown that compost, slurry, and farmyard manure (FYM) enhance both yield and quality of crops by improving soil physicochemical and biological properties and increasing plant access to nutrients (Niyungeko et al., 2020). The increasing intensity of abiotic stresses such as heat, salinity, drought, and heavy metals poses a significant threat to global food security. Rapid population growth necessitates effective strategies to boost crop productivity under these challenging conditions (Devi et al., 2024). Despite these well-established benefits, major uncertainties remain regarding the role of organic fertilizers under abiotic stress conditions, such as heat, salinity, drought, and heavy metal contamination. While some evidence suggests that organic amendments can enhance crop resilience and productivity under stress (Akef et al., 2022). There is limited systematic understanding of how different types of organic fertilizers affect crop performance, nutrient use efficiency, and soil properties under specific stress scenarios. For instance, it is unclear which organic materials are most effective for particular stress conditions, or how application rates and soil types influence stress mitigation. This review aims to address these knowledge gaps by synthesizing current research on the impacts of organic fertilizers on crop growth and yield under abiotic stress. It highlights the mechanisms through which organic amendments improve soil quality and plant resilience and identifies areas where further research is needed to optimize their use in stress-prone agricultural systems. By clarifying both what is known and what remains uncertain, this review provides a foundation for future studies focused on sustainable crop production under challenging environmental conditions.

2. Materials and Methods

This review is a narrative synthesis of the literature, based on targeted searches of Web of Science, Scopus, and Google Scholar. Keywords included terms such as “organic fertilizers,” “organic manures,” “soil fertility,” “crop productivity,” and combinations related to abiotic stress (e.g., salinity, drought, heat, heavy metals). Only peer-reviewed studies published in English were considered. No formal systematic review methodology (e.g., PRISMA) was applied.

3. Crop responses to organic fertilizers

3.1. Types of organic fertilizers

Fertilizers are substances that contain one or more nutrients in the form of both organic and inorganic chemical components. Fertilizers can be classified into two categories: inorganic and organic fertilizers. Organic fertilizers, which are natural substances derived from plants and animals affect the physiochemical and biological properties of soil both directly and indirectly (N. S. et al., 2024). Another type of organic fertilizer is called a "bio-fertilizer," which consists of beneficial microorganisms (bacteria, fungi, and algae) that promote plant growth by mobilizing soil nutrients through their biological activity (Naeem et al., 2020). The world's largest source of organic manure is animal excrement, followed by pig and poultry manures (Meena et al., 2023). The rising demand for milk and beef has led to a 5% increase in cattle production in recent years (Meena et al., 2023). As a result, more cattle dung is being produced, which can be applied to agricultural soils to enhance soil fertility and environmental quality. The total amount of nitrogen excreted in animal manure worldwide making it a valuable and sustainable source of NPK (nitrogen, phosphorus, and potassium) (Liu et al., 2017). It is important to note, however, that there are significant differences in the type and quantity of nitrogen found in animal manure (Kitamura et al., 2021).

The amount of nitrogen in organic fertilizers is influenced by factors such as the animal species, diet, livestock bedding, animal bedding, and the methods used to handle and process the manures (Ouatahar et al., 2024). For instance, compared to pig and cattle manures, chicken manure has a much higher nitrogen concentration. However, liquid manures have lower organic nitrogen content and a higher ammonium (NH_4^+) concentration than solid manures (Jinxia Huang, 2024). Furthermore, the type and quantity of nutrients found in manure are also greatly influenced by the bedding material, as well as the processing and storage techniques (Moradi et al., 2024). For example, compared to solid manures, manures handled through aerobic composting and vermicomposting contain higher amounts of organic nitrogen and nitrate (NO_3^-). In contrast, anaerobically digested manures have higher nitrogen contents, with ammonium (NH_4^+) pools of nitrogen predominating (Haddad et al., 2024). However, it is important to note that there are significant variations in the type and quantity of nitrogen found in animal manure.

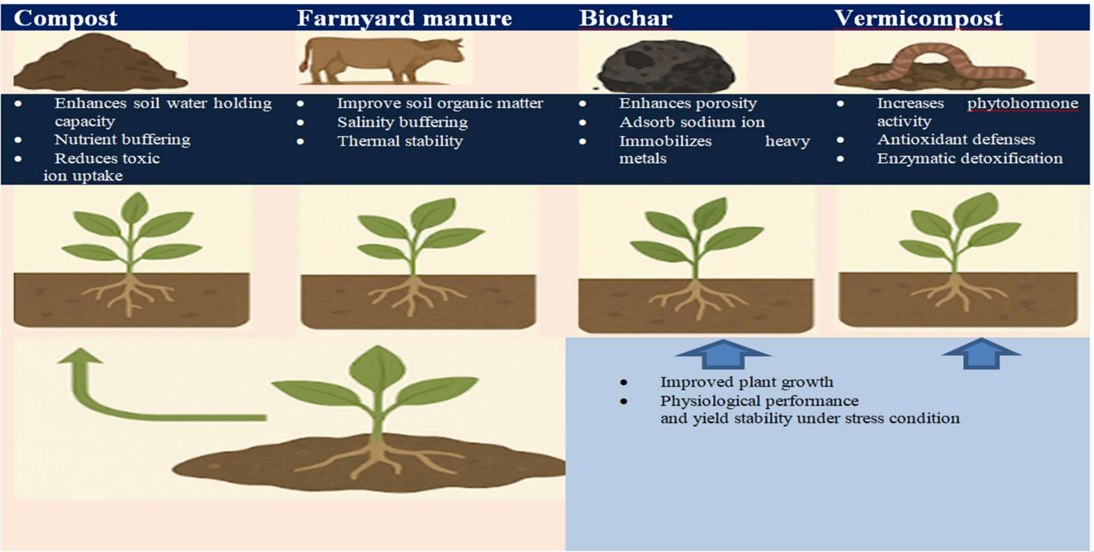

Figure 1: Comparative overview of major organic fertilizers (compost, farmyard manure, biochar, vermicompost) and their roles in mitigating specific abiotic stresses.

3.2. Impact of organic fertilizers on enzymatic and microbial activity in soils

The breakdown and nutrient release from organic materials are significantly influenced by soil microorganisms. The application of organic fertilizers increases soil enzymatic activity and leads to a significant rise in soil organic carbon (SOC). For example, it has been observed that applying vermicompost raised the activity of catalase, alkaline phosphatase, and sucrase to varying degrees; however, applying vermicompost reduced the activity of urease (Tian et al., 2024). Organic manure alters the bacterial structure of the soil and increases the abundance of beneficial bacteria, such as Bacilli and Flavobacteriales. Furthermore, organic fertilizers accelerate carbon-related functional group activities, including chitinolysis and aromatic hydrocarbon degradation (Liu et al., 2023). The use of organic manures also enhances the activity of enzymes such as β-glucosidase and dehydrogenases, thereby promoting microbial activity (Ikoyi et al., 2020). According to research by Cui et al., (2018), the long-term use of organic materials increased the abundance of Proteobacteria and Chloroflexi. However, the combination of organic materials and chemical fertilizers was found to increase the abundance of Firmicutes**,** Actinobacteria, and Planctomycetes. Additionally, Ikoyi Wang et al., (2023) reported that bacterial genera associated with nutrient cycling and plant growth, such as Burkholderia**,** Allorhizobium, Terrimonas**,** Chryseolinea, and Ohtaekwangia, were significantly more abundant in grasslands treated with organic fertilizers compared to those treated with mineral fertilizers.

Organic fertilizers also alter soil characteristics, creating an environment conducive to the growth of microbial populations (Li et al., 2023). However, several researchers have reported that the combined application of organic and inorganic fertilizers had no significant effect on the abundance of fungi and bacteria (Yang et al., 2016). The impact of organic fertilizers on soil microbial communities is well-documented, with fertilizer schedules and application timing shown to significantly influence the composition of bacterial populations (Poshvina et al., 2024). Additionally, the composition of microbial communities is affected by crop species and climatic factors, such as temperature and soil moisture (Maitra et al., 2024). Organic fertilizer substitution significantly reduced soil alkalization (by 3.05%), improved soil nutrients, enhanced soil enzyme activities, and increased sorghum yield (Nie et al., 2024). While Organic fertilizer substitution significantly reduced soil alkalization (by 3.05%), improved soil nutrients, enhanced soil enzyme activities, and increased sorghum yield (Zha et al., 2024). Carbon substrates have the potential to promote microbial growth, and the addition of organic manures enhances microbial activity, significantly improving plant performance (Verma et al., 2024). Crop growth and yield were significantly increased due to the mediation of organic fertilizers, which boosted soil organic matter, as well as microbial and enzymatic activity (Zhang et al., 2020).

Figure 2: organic fertilizers influence soil microbial activity, nutrient cycling, and plant physiological processes under stress.

3.3. Responses of Crops to Organic Fertilizers under Abiotic Stressors

As the world's population continues to grow, crop output must increase significantly. However, declining soil fertility and intensifying abiotic stress pose a significant threat to global food security and crop productivity (Bello et al., 2021). Therefore, modern, efficient, and environmentally sustainable methods to enhance soil fertility and improve tolerance to abiotic stresses are essential to feed the growing population while preserving soil health. According to the literature, the use of organic materials can alter the molecular and biochemical mechanisms in plants, thereby enhancing their resistance to abiotic stressors (Terán et al., 2024). Additionally, organic manures significantly improve soil fertility, which promotes crop growth and yield under both normal and stressful conditions(Mohanty et al., 2024) .

3.3.1. Responses of crops to organic fertilizers under salinity stress

Soil salinity, a severe abiotic stress, poses a significant threat to crop productivity. Under alkaline soil conditions, the use of organic resources greatly improves plant performance (Abdelhameed et al., 2024). For instance, the application of vermicompost has been shown to enhance the morphological and biochemical characteristics of plants in saline environments (Toor et al., 2024). Vermicompost also promotes the accumulation of K^+ and the exclusion of Na^+, which improves stomatal function, chlorophyll production, and antioxidant activities, protecting plants from the adverse effects of salinity (Acharya et al., 2024). Furthermore, organic manures increase the levels of carotenoids and chlorophyll, thereby enhancing photosynthetic efficiency and, in turn, assimilate production (Mthiyane et al., 2024). By boosting the activities of catalase (CAT), peroxidase (POD), and superoxide dismutase (SOD), they also reduce hydrogen peroxide (H_2O_2) and malondialdehyde (MDA), resulting in improved growth and yield (Mthiyane et al., 2024).

The addition of organic fertilizers, such as vermicompost and biogas slurry, significantly increases plant height, dry matter, and overall productivity. These fertilizers also enhance nutrient availability while reducing the accumulation of toxic ions (Bhatia & Sindhu, 2024). Additionally, other researchers found that organic fertilizers mitigated the harmful effects of salinity on plants by improving relative water content (RWC), stomatal conductance, chlorophyll synthesis, and antioxidant activity (APX, CAT, and SOD) under saline conditions. This led to reduced malondialdehyde (MDA) production and electrolyte leakage (Kamal et al., 2024). When applied in saline environments, biochar another important organic material enhances root growth, dry matter production, leaf area, and yield compared to control conditions.

The growth and yield of wheat, sorghum, and maize were improved by BC application, which also increased the uptake of NPK, Cu, Fe, Mn, and Zn, reduced the uptake of Cl and Na, and enhanced the photosynthetic rate, stomatal conductance, and transpiration rate (Hafez et al., 2021). When organic manures are exposed to saline environments, their primary function is to trap excess sodium and release nutrients and minerals that alleviate ionic and osmotic stress (Ibrahim et al., 2021). Studies indicate that organic fertilizers mitigate the harmful effects of salinity on plants by reducing Na levels and the Na^+/K^+ ratio (Malal et al., 2024). Additionally, organic fertilizers enhance the water-holding capacity and CO2 absorption, which improves osmotic balance under saline conditions. This, in turn, leads to an increased photosynthetic rate, improved stomatal conductance, and higher transpiration rates (Malal et al., 2024). In addition, organic fertilizers promote the accumulation of indole acetic acid (IAA) while reducing ABA and ACC levels, thereby counteracting the adverse effects of salinity(Liu et al., 2024a). Similarly, Nikpour-Rashidabad et al., (2019) found that organic fertilizers enhanced the development of the vascular cylinder and parenchyma, as well as improved the IAA/ABA and IAA/ACC ratios, to mitigate the harmful impacts of salinity. Additionally, saline environments increase the activity of various antioxidants, including nitrate reductase (NR), glutamate dehydrogenase (GDH), and RuBisCO, which help protect plants from the adverse effects of salinity (Farhangi-Abriz & Torabian, 2018). The improvement of soil organic amounts could make the soil more self-resistant to the coastal salinization. (Li et al., 2024).

The application of organic manures improves plant performance under salt stress by enhancing the hydraulic conductivity, aggregate stability, and porosity of saline soils (Gonçalo Filho et al., 2019). Reports indicate that organic fertilizers function as chelating agents for cations such as Ca^{2+} and Mg^{2+} in the soil solution, promoting their uptake while reducing Na uptake. This helps maintain a lower sodium absorption ratio in saline soils. Organic manures also increase the availability of NPK in the soil and improve its absorption by tomato plants (Nan et al., 2016). In addition, the applications of PGPR as a useful tool since this approach exhibits promising potentials in improving seed vigor, rapid seed germination, and seedling growth uniformity under saline soil (Ha-Tran et al., 2021). Similarly, El-Shazly and Ghieth, (2019) reported that the application of organic manure to papaya and olive plants enhanced their biomass productivity and growth. It also improved osmotic adjustments between the soil and roots, as well as soil microbial activity, helping to mitigate the adverse effects of salt stress.

Similarly, several scientists have found that the application of organic manure enhances antioxidant activity and chlorophyll concentrations while reducing oxidative damage in various plants (Alamer et al., 2022a). Furthermore, the use of organic fertilizers in saline environments increases microbial populations and gene expression, leading to improved plant biomass yield and enhanced salt tolerance (Alexander et al., 2020). By boosting antioxidant activity and secondary metabolite production while reducing ROS generation, organic manures also help to mitigate oxidative damage in plants (Kerbab et al., 2021).

Organic fertilizers also increase the concentration of vitamins, hormones, enzymes, micro and macronutrients, and other substances that help mitigate the negative effects of salt stress on plants (Alamer et al., 2022b). Additionally, the microbial activity in organic manures enhances the environment by fixing atmospheric N, P, and K, producing antibiotics, and decomposing organic matter, all of which contribute to improved salinity tolerance a key strategy for reducing the impacts of salt stress is the application of arbuscular mycorrhizal fungi (AMF). Reports indicate that AMF promotes root growth and nutrient availability, enhancing soil nutrient uptake and improving salt tolerance (Ndiate et al., 2021). Organic fertilizers also reduce the uptake of harmful Cl^- and Na^+ ions, boost physiological and antioxidant activities, and promote plant growth and enhance gene expression, antioxidant activity, and soil bacterial abundance, all of which support plant development in saline soils (He et al., 2022). Ultimately, by improving nutrient uptake, physiological processes, and antioxidant activity, while reducing the uptake of Cl^- and Na^+, organic fertilizers significantly increase salt tolerance in plants.

Table 1: Growth, physiology, and biochemistry responses of crop to organic fertilizers under salinity stress

Plant Species	Organic Fertilizer	Effect on Growth	Effect on Physiology	Effect on Biochemistry	Citation
Foeniculum vulgare (fennel)	Vermicompost	Increased shoot length, dry weight, leaf area, root dry weight	Enhanced relative water content, membrane stability index, photosynthetic pigments (chlorophylls, carotenoids)	increased soluble sugar, soluble protein, proline, total phenol, anthocyanin, mineral elements (phosphate, nitrate, zinc, molybdenum, magnesium, iron)	(Beyk-Khormizi et al., 2023)
Triticum aestivum L. Wheat	Organic acids (humic and ascorbic acids), PGPR (*Rhizobium leguminosarum*, *Paenibacillus polymyxa*)	Increased biological yield, grain yield, 1000-grain weight	Enhanced antioxidant activity, phenolic components, NPK uptake	Improved tolerance to salt stress, increased production of HCN and siderophores	(Nawaz et al., 2020)
Phaseolus vulgaris (common bean)	Organo-mineral fertilizer (OMF) compost	Improved soil chemical and physical properties, similar growth and yield to control	Enhanced physio-biochemical attributes	Decreased Cd2+ and NO3− concentrations in plant leaves, pods, and seeds	(Rady et al., 2016)
Medicago sativa (alfalfa)	Fulvic acid potassium, Fulvic acid potassium + wood vinegar, Fulvic acid potassium + Bacillus	Increased alfalfa yield	Enhanced soil bacterial diversity, improved relative water content, membrane stability index	Increased soluble sugar, soluble protein, proline, total phenol, anthocyanin, mineral elements (phosphate, nitrate, zinc, molybdenum, magnesium, iron)	(Cao et al., 2023a)
Triticum aestivum L. Wheat	Combined manure and mineral fertilizers (NPKO)	Increased grain yield, wheat equivalent yield	Enhanced soil organic matter, nutrient supply	Improved phosphorus harvest, economic income	(Zhao et al., 2024)
Hordeum vulgare L. Barley	Farm yard manure, animal manure, poultry manure,	Increased number of tillers per plant, spike length, straw, biomass, grain weight, grain yield	Enhanced soil fertility, nutrient availability	Improved yield components, grain quality	(Yimer, 2021a)

	vermi compost				
Various cereals	Compost, farm yard manure, green manure, crop residue, biogas slurry	increased crop productivity	Enhanced soil chemical and physical properties	Improved nutrient content and soil health	(Workineh, 2024)
Sorghum bicolor (L.) Sorghum	Organic manure (decomposed cow dung)	Increased grain yield, above-ground weight	Enhanced soil water content, available nitrogen	Reduced N2O emissions, improved nitrogen use efficiency	(Yang et al., 2025)

3.3.2. Responses of crops to organic fertilizers under drought stress

Drought, defined as prolonged dryness that impairs plant growth and development, is increasingly threatening global food security due to climate change (Carvalho et al., 2021). Drought stress negatively affects plant growth and productivity through various physiological and biochemical disruptions. Organic fertilizers have emerged as a promising strategy to enhance crop resilience under water-limited conditions (Ullah et al., 2021). They improve soil water holding capacity, and water use efficiency, while increasing soil organic matter, organic carbon, and nutrient availability, all of which facilitate plant water and nutrient uptake during drought (Adejumo et al., 2020). By supporting microbial activity and maintaining a balanced fungi-to-bacteria ratio, organic amendments further enhance soil fertility and promote plant drought tolerance (Lin et al., 2019). organic fertilizers improve relative water content, photosynthesis, transpiration, and stomatal conductance, while also enhancing antioxidant defenses through increased activities of catalase, peroxidase, superoxide dismutase, and ascorbate peroxidase, under drought conditions (Hussain & Nadeem Shah, 2023). The combination of organic fertilizers with arbuscular mycorrhizal fungi further strengthens drought tolerance by promoting chlorophyll synthesis, nutrient uptake, osmolyte accumulation, and antioxidant activity (Begum et al., 2019). Different organic amendments provide distinct benefits: poultry manure primarily improves water holding capacity and soil nutrient status (Murtaza et al., 2021). Farmyard manure enhances nutrient uptake and supports plant physiological and biochemical processes (Rizwan et al., 2021). While compost, vermicompost, and biochar improve soil porosity, microbial activity, and water retention, and boosting yield and resilience (Ait-El-Mokhtar et al., 2022). All organic fertilizers enhance drought tolerance, but their effectiveness varies by type and composition.

Table 2: Growth, physiology, and biochemistry responses of crop to organic fertilizers under drought stress

Plant Species	Organic Fertilizer	Effect on Growth	Effect on Physiology	Effect on Biochemistry	Citation
Brassica juncea Mustard	Chitosan, Ultra Green, Home-grown Natural Vegetable Foods	Improved plant height, leaf area	Increased relative water content, membrane stability index, chlorophyll content	Enhanced macronutrient (Ca, K, P, N, C, S, Na, Mg) and micronutrient (Fe, Zn) content	(Geremew et al., 2021a)
Various crops	Various organic fertilizers	Improved soil health, nutrient uptake, water-holding capacity	Enhanced synthesis of chlorophyll, osmolytes, hormones, secondary metabolites, antioxidant activitie	Improved tolerance against drought, salinity, heat, and heavy metals	(Liu et al., 2024b)
Brassica chinensis Chinese cabbage	Plant- and animal-derived organic fertilizers	Increased weight of leaves and roots	Enhanced carbon and nitrogen cycle pathway	Reduced antibiotic resistance genes and viruses	(Yu et al., 2024)
Various cereal crops	Various organic fertilizers	Improved plant height, biomass, root development	Enhanced water-use efficiency, nutrient uptake, phytohormone levels	Increased antioxidant enzyme activities, osmolyte accumulation	(Jeyasri et al., 2021)
Wheat, Soybean, Pulses	Vermicompost, Green Manure, Seaweed, Wood Ash	Improved plant height, biomass, root development	Enhanced water-use efficiency, nutrient uptake, phytohormone levels	increased antioxidant enzyme activities, osmolyte accumulation	(Morris et al., 2024)

3.3.4. Responses of crops to organic fertilizers under heavy metal stress

Heavy metals (HMs) pose a serious threat to both human health and agricultural production, with their environmental concentrations rising due to anthropogenic activities. Organic fertilizers have been widely reported to mitigate HM stress by reducing metal bioavailability, immobilizing HMs in soils, and limiting plant uptake, thereby promoting safer food production (Palansooriya et al., 2020). Materials such as cow manure, compost, chicken manure, sheep manure, biochar, and humic acids can form complexes with HMs through adsorption, precipitation, or chelation, stabilizing metals like cadmium (Cd), lead (Pb), arsenic (As), zinc (Zn), and copper (Cu) (Li et al., 2021) . Biochar, in particular, due to its porous structure and alkaline nature, persists in soils for extended periods and effectively reduces HM bioavailability (Khan et al., 2020).These amendments enhance plant growth by improving nutrient uptake, photosynthetic efficiency, water use efficiency (WUE), and antioxidant activities (APX, CAT, POD, SOD), while reducing oxidative stress and HM toxicity (Yu et al., 2021). However, the effects of organic fertilizers on HM accumulation are not entirely consistent. While many studies report reduced uptake of metals such as Cd, Pb, and Zn in crops like tobacco, wheat, and pakchoi (Li et al., 2021). While others show increased accumulation under certain conditions for instances application of poultry manure to garlic enhanced the accumulation of Cd, Cr, Fe, and Pb, though it reduced Cu and Zn uptake (Akhter et al., 2022). These discrepancies appear to depend on multiple factors, including the type and composition of the organic amendment, the specific crop species, soil characteristics, metal type, and environmental conditions. Such variability underscores the need for critical evaluation when selecting organic fertilizers for HM-contaminated soils. Organic fertilizers can improve plant performance under HM stress by enhancing physiological and biochemical processes, reducing oxidative damage, and modulating HM availability. Nevertheless, careful consideration of amendment type, application rate, and crop soil interactions is essential, as some organic materials may inadvertently increase metal accumulation in certain crops. Future research should focus on identifying optimal combinations of organic amendments and crop types to maximize HM immobilization while ensuring food safety and plant productivity.

Table 3: Growth, physiology, and biochemistry responses of crop to organic fertilizers under heavy metals stress

Plant Species	Organic Fertilizer	Effect on Growth	Effect on Physiology	Effect on Biochemistry	Citation
Triticum aestivum L. Wheat	Organic manure (cow manure, pig manure)	Decreased grain yield compared to chemical fertilizer	Enhanced soil organic matter, nutrient supply	No significant increase in heavy metals in soil and wheat	(Chen et al., 2024)
Brassica juncea Mustard	Organic amendments	Increased plant height, biomass, root development	Enhanced nutrient homeostasis, antioxidant enzyme activities	Increased Ni bioconcentration factor, Ni bioaccumulation concentration, Ni translocation factor	(Naveed et al., 2024)
Medicago sativa (alfalfa)	Fulvic acid potassium, Fulvic acid potassium + wood vinegar, Fulvic acid potassium + Bacillus	Increased alfalfa yield	Enhanced soil bacterial diversity, improved relative water content, membrane stability index	Increased soluble sugar, soluble protein, proline, total phenol, anthocyanin, mineral elements (phosphate, nitrate, zinc, molybdenum, magnesium, iron)	(Cao et al., 2023b; Yu et al., 2024)
Chickpea (*Cicer arietinum* L.)	Organic amendments	Increased shoot length, root length	Enhanced photosynthesis, nutrient uptake	Increased antioxidant enzyme activities, reduced metal accumulation	Majhi and Sikdar, 2023)
Pea (*Pisum*	Organic amendments	Improved germination	Enhanced water-use efficiency,	Increased proline, total phenol, anthocyanin	(Majhi and

sativum L.)		rate, plant biomass	chlorophyll content		Sikdar, 2023)
Lentil (*Lens culinaris* Medik.)	Organic amendments	Increased plant height, pod number	Enhanced nutrient assimilation, membrane stability index	Increased soluble sugar, soluble protein, mineral elements (phosphate, nitrate, zinc, molybdenum, magnesium, iron)	(Majhi & Sikdar, 2023)

3.3.5. Responses of crops to organic fertilizers under temperature stress

Temperature is one of the most crucial environmental factors affecting plant growth and productivity Tesfaye et al., (2017), yet both high and low temperatures can negatively impact these processes (Mangani et al., 2019). A key strategy for improving plant heat tolerance is the use of organic manure. Under heat stress, organic manure increased biomass yield, plant height, stem diameter, leaf area, and chlorophyll concentration by 35%, 36%, 41%, 59%, and 78%, respectively (Chukwudi et al., 2021). In another study, organic fertilizers significantly enhanced the photosynthetic properties and antioxidant activity of maize by lowering canopy temperature and improving the soil's water-holding capacity by 8% (Wang et al., 2021). The increased soil water holding capacity (WHC) after applying organic manure demonstrates its effectiveness in mitigating the negative effects of heat stress (HS) on plants (Wang et al., 2021). Research by Kumar et al., (2014) showed that the combined application of farmyard manure (FYM) and NPK fertilizers enhanced maize's ability to tolerate heat by boosting soil microbial activity, antioxidant activity, and nutrient uptake. Similarly, compost is highly beneficial for the sustainable cultivation of Lunuwila, even in the face of global warming (Attanayake et al., 2024) Furthermore, the use of biofertilizers improved resistance to late-stage heat stress. According to these researchers, fertilizer application increased grain yield, chlorophyll fluorescence parameters, and PS-II quantum yield (Eisvand et al., 2018). A study found that applying compost and biochar significantly improved water use efficiency (WUE) under heat stress (HS), leading to notable improvements in plant growth and productivity (Jin et al., 2021). Additionally, the researchers discovered that applying cow dung enhanced the leaf nutritional status and efficiency of PS-II, while reducing oxidative stress by increasing jasmonic acid and decreasing abscisic acid (ABA). A more recent study showed that combining 50% nitrogen and 50% compost under heat stress conditions improved the grain-filling rate, grain protein, wet gluten content, and grain production (Liu et al., 2024c). In conclusion, organic fertilizers mitigate the negative effects of heat stress by preserving osmolyte accumulation, WUE, antioxidant activity, nutritional homeostasis, and reducing reactive oxygen species (ROS) generation.

Table 4: Growth, physiology, and biochemistry responses of crop to organic fertilizers under temperature stress

Plant Species	**Organic Fertilizer**	**Effect on Growth**	**Effect on Physiology**	**Effect on Biochemistry**	**Citation**
Triticum aestivum L . Wheat	Chitosan, Ultra Green, Home-grown Natural	Improved plant height, leaf area	Enhanced relative water content, membrane stability index,	Increased macronutrients (Ca, K, P, N, C, S, Na, Mg) and	(Geremew et al., 2021b)

	Vegetable Foods		chlorophyll content	micronutrients (Fe, Zn)	
Hordeum vulgare L. Barley	arm yard manure, animal manure, poultry manure, vermi compost	Increased number of tillers per plant, spike length, straw, biomass, grain weight, grain yield	Enhanced soil fertility, nutrient availability	Improved yield components, grain quality	(Yimer, 2021b)
Various cereals	Compost, farm yard manure, green manure, crop residue, biogas slurry	Increased crop productivity	Enhanced soil chemical and physical properties	Improved nutrient content and soil health	(Workineh, 2023)

4. Conclusion

This review demonstrates that organic fertilizers, derived from plant and animal sources, play a critical role in enhancing crop growth, yield, and resilience under a range of abiotic stresses, including salinity, drought, heat, and heavy metal contamination. By improving soil structure, increasing microbial activity, and enhancing nutrient availability, organic amendments such as compost, farmyard manure, and biochar not only boost crop performance but also reduce dependence on chemical fertilizers, supporting more sustainable and environmentally friendly agricultural practices. Evidence indicates that organic fertilizers enhance crop resilience by improving water retention, enzymatic activity, antioxidant defenses, and nutrient uptake, while mitigating oxidative stress and maintaining physiological balance under stress conditions. These multifaceted benefits position organic amendments as a key strategy for promoting agricultural sustainability and long-term soil health. Despite these promising outcomes, significant knowledge gaps remain. In particular, most studies have assessed individual organic amendments in isolation, and very few have provided comparative evaluations across multiple organic fertilizers under the same abiotic stress. This limitation prevents clear recommendations on which amendment is most effective under specific stress conditions. Addressing this gap through systematic, head-to-head comparative studies represents an important priority for future research. There is also an urgent need for long-term field trials and multi-seasonal studies to assess the durability of organic fertilizer effects on soil fertility, crop productivity, and resilience to abiotic stresses. Future research should additionally quantify sustainability outcomes, including carbon sequestration, soil microbial diversity, and contributions to food security. Moreover, integrating organic fertilizers with modern agronomic practices and precision nutrient management strategies can maximize their effectiveness while minimizing environmental impacts. Overall, organic fertilizers offer a strategic pathway toward resilient, productive, and sustainable agro-ecosystems, but realizing their full potential requires coordinated, long-term research efforts. This review provides a foundation and reference point for future investigations aimed at harnessing organic amendments to meet the dual challenges of climate stress and global food security.

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