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The Effects of Vermicompost, Farm Manure, and DAP+Urea Fertilizers on Safflower (*Carthamus tinctorius* L.) Growth and Soil Enzyme Activity in Saline and Non-Saline Soils

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Abstract
Safflower (*Carthamus tinctorius* L.) is one of the oldest cultivated crops, known for its adaptability to extreme environmental conditions such as high temperatures, drought, and salinity. This study investigates the influence of vermicompost, farm manure, and DAP+Urea fertilizers on safflower growth and soil enzyme activity under saline and non-saline soil conditions. The findings reveal that vermicompost application significantly enhanced plant growth, whereas farm manure application contributed to more significant soil enzyme activity. Across both soil types, plant growth indicators—including plant height, root length, leaf count, leaf area, fresh and dry biomass, root fresh weight, and SPAD values exhibited notable improvements with these treatments. Soil enzyme activities increased by 68.37%, 41.07%, and 25.52% (urease, DHG, and CAT, respectively) in non-saline soil, while saline soil exhibited corresponding increases of 34.0%, 33.62%, and 25.71%. The study underscores the importance of farm manure in mitigating salinity stress and improving soil quality.

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1. Introduction

Soil salinity is a critical environmental constraint that affects agricultural productivity by disrupting soil quality and plant health (Liang et al., 2005). High salt concentrations deteriorate soil properties, reduce microbial diversity, and hinder plant development. Elevated electrical conductivity compromises soil structure by increasing bulk density and reducing permeability (Tejada and Gonzalez, 2005). Furthermore, excessive soil salinity suppresses enzymatic processes such as benzoyl arginineamide hydrolysis, alkaline phosphatase function, and microbial respiration (Garcia and Hernandez, 1996). Research has also demonstrated that salinity negatively influences microbial biomass carbon and enzymatic activity (Rietz and Haynes, 2003). Organic amendments such as farm manure, compost, and vermicompost have been widely studied for their role in improving soil structure and alleviating salinity stress. The addition of organic matter facilitates sodium leaching, reduces exchangeable sodium levels, enhances water permeability, and stabilizes soil structure (El-Shakweer et al., 1998). Moreover, organic inputs enhance microbial biomass and enzymatic functions, including urease, alkaline phosphatase, and β-glucosidase activities (Blagodatsky and Richter, 1998; Liang et al., 2003). With its deep root system, safflower is well-suited for cultivation in saline-prone environments (Gholami et al., 2018). Several factors-including environmental conditions, agronomic practices, and genotype selection-affect safflower yield and quality (Pasandi et al., 2018; Beyyavas et al., 2024). Research has shown that optimal fertilization strategies significantly enhance safflower production (Baljani et al., 2015). However, salinity remains a significant challenge that negatively impacts plant growth and metabolism (Ahmad et al., 2012). This study uniquely evaluates the effects of organic and inorganic fertilizers on safflower growth and soil enzyme activity under saline and non-saline conditions. In safflower farming, various environmental challenges, particularly soil salinity, have emerged as significant concerns on a global scale, exerting substantial effects on plant development and overall productivity (Ahmad et al., 2012). These adverse conditions significantly limit crop yields, preventing them from reaching their optimal levels (Warraich et al., 2011; Abbas et al., 2013). Salinity hinders the germination phase, ultimately leading to stunted plant growth and lower agricultural output (Azzedine et al., 2011; Basiri et al., 2013). This study presents a novel approach to examine safflower plant growth and soil enzyme activities under salt stress conditions, comparing the effects of organic and inorganic fertilizers and analysing comprehensive plant physiological and morphological parameters. These features are the main factors that distinguishing this study from previous similar studies.

The objective of this study was to evaluate the effects of vermicompost, farmyard manure and DAP+Urea fertilizers on (i) growth parameters (plant height, root length, number of leaves, leaf area, plant wet weight, plant dry weight, root wet weight and plant SPAD value) and (ii) soil urease, DHG and CAT enzyme activity of safflower under both saline and non-saline conditions. The study evaluates how different fertilization strategies affect plant growth and soil health, providing insights into the most effective methods to improve safflower production and soil enzyme activity.

2. Material and Methods

2.1. Material

2.1.1. Experiment design

This study was conducted between January 21, 2024, and March 15, 2024, in a semi-open greenhouse at Harran University Faculty of Agriculture. Safflower was used as the experimental plant material, while saline and non-saline soil samples were collected from Bozyazı village (Harran, Şanlıurfa) and Osmanbey Campus, respectively. The soils were obtained from a 0–30 cm depth and analysed for their characteristics (Table 1).

Table 1. Characteristics of soil used in the experiment

	EC [ds m^{-1}]	pH	Lime [%]	Organic carbon [%]
Saline soil	3.40	8.0	26.62	0.50
Non-saline soil	0.88	7.62	10.96	0.60

2.2. Methods

2.2.1. Setting up the experiment

The study utilized five-kilogram pots (20 cm height, 10 cm bottom diameter, 20 cm top diameter) for plant cultivation. Fertilizers were homogeneously mixed into the soil before planting. Five safflower seeds were sown in each pot, and only one plant was retained after germination. The experimental layout followed a randomized complete block design with three replications.
Non-saline soil control:0
Saline soil control:0
Vermicomposting: 50 g^{-1} pot (Sharifi et al., 2019)
Farmyard manure 45 g^{-1} pot (Hutchison et al., 2005)
Dap+ Urea 180 g^{-1} pot (Beyyavas et al., 2024)

2.2.2. Plant and soil parameters analysed

- **Growth parameters:** Root and plant height were measured in cm and fresh and dry weights were weighed and expressed in g. Measurement and weighing procedures were performed in duplicate. After the wet weights were taken, dry weights were found by keeping them in an oven at 70°C for 72 hours until they reached constant weight (Acar et al., 2011).
- **SPAD values:** Were measured in each replicate (leaf below the youngest leaf) using a Minolta SPAD 502 instrument (Johnson and Sounders, 2003). For the leaf area, three leaves were taken from the middle part of the plant and not from the tip and lower parts of the plant. The Image-J program determined the surface area of the leaf.
- **Catalase enzyme activity:** Catalase activity in the soils was determined volumetrically following the method by (Beck, 1971). Air-dried soils sieved to 2 mm were used. The enzyme catalase breaks down hydrogen peroxide (H_2O_2) into water and oxygen. The amount of oxygen released during this reaction was measured, indicating of catalase activity in the soil.
- **Urease enzyme activity:** Soil samples are incubated at 37°C with a 10% urea and sodium phenolate solution, and the filtrate is evaluated based on color intensity (Hoffman and Teicher, 1961).
- **Dehydrogenase enzyme activity:** The dehydrogenase enzyme activity of soils will be determined by the spectrophotometric measurement of the color intensity of TPF (triphenyl formazan) at 485 nm after the incubation of soil samples treated with TTC (triphenyl tetrazolium chloride) solution for 24 hours at 25 ºC (Tabatabai, 1982).

3. Results

3.1. Plant height (cm)

As a result of the analysis of variance, there was no significant difference ($p<0.01$) between fertilizer treatments in terms of plant height (cm) between saline and non-saline soils. In the experiment, the lowest plant height of safflower was observed in the soil*DAP+Urea fertilizer (68.2.0 cm) interaction and the highest plant height was observed in the soil*non-saline soil*farmyard manure (80.7 cm) interaction compared to the control group (64.4 cm non-saline soil*control) in non-saline soil. In saline soil, compared to the control group (44.5 cm; saline soil*control), the lowest was observed in the saline soil*vermicompost (47.0 cm) interaction, while the highest was measured in the saline soil*farmyard manure (60.1 cm) application (Figure 1).

3.2. Root length (cm)

Based on the variance analysis, a notable distinction ($p<0.01$) was detected among different fertilizer applications concerning root length (cm) under saline and non-saline conditions. During the study, the shortest root length of safflower in non-saline soil was recorded in the saline soil vermicomposting

(44.4 cm) combination, in contrast the most extended root length was observed in the treatment of the non-saline soil farmyard manure (50.8 cm) compared to the control group (40.8 cm, non-saline soil control). Under saline conditions, in comparison to the control group (35.6 cm; saline soil control), the shortest root length was noted in the saline soil DAP+Urea (28.8 cm) combination, whereas the most extended root length was detected in the saline soil farmyard manure (42.1 cm) application (Figure 1).

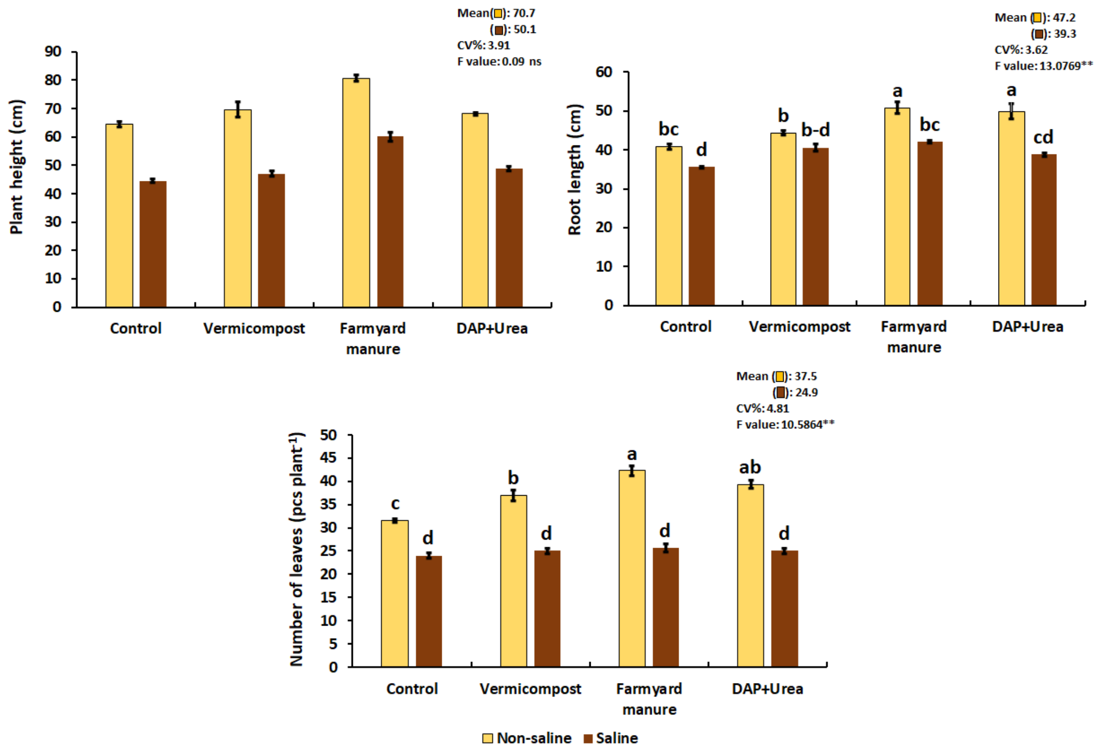

Figure 1. Effects of different fertilizer applications on plant height, root length and number of leaves in saline and non-saline soil conditions

3.3. Number of leaves (pcs^{-1} plant)

As a result of the analysis of variance, a significant difference (p<0.01) was found between the fertilizer treatments in terms of leaf number in saline and non-saline soils. In the experiment, the lowest number of safflower leaves was observed in the saline soil*vermicomposting (37.0 pieces cm) interaction and the highest number was observed in the non-saline soil*farmyard manure (42.3 pieces cm) application compared to the control group (31.6 pieces in non-saline soil*control). In saline soil, compared to the control group (24.0 pieces cm; saline soil*control), the lowest was observed in the saline soil*vermicomposting (25.0 cm) interaction, while the highest was measured in the saline soil*farmyard manure (25.6 pieces cm) treatment (Figure 1).

3.4. Leaf area (cm^2)

According to the variance analysis, no notable differences (p<0.01) were detected among fertilizer applications regarding leaf area under saline and non-saline conditions. Throughout the study, the smallest leaf area of safflower in non-saline soil, relative to the control group (35.2 cm², non-saline soil control), was recorded in the non-saline soil DAP+Urea fertilizer (40.1 cm²) combination in contrast, the largest leaf area was identified in the non-saline soil farmyard manure (48.0 cm²) application. Under saline conditions, in comparison to the control group (34.7 cm²; saline soil control), the minimum leaf area was noted in the saline soil vermicompost (39.0 cm²) combination, while the maximum leaf area was determined in the saline soil farmyard manure (45.9 cm²) treatment (Figure 2).

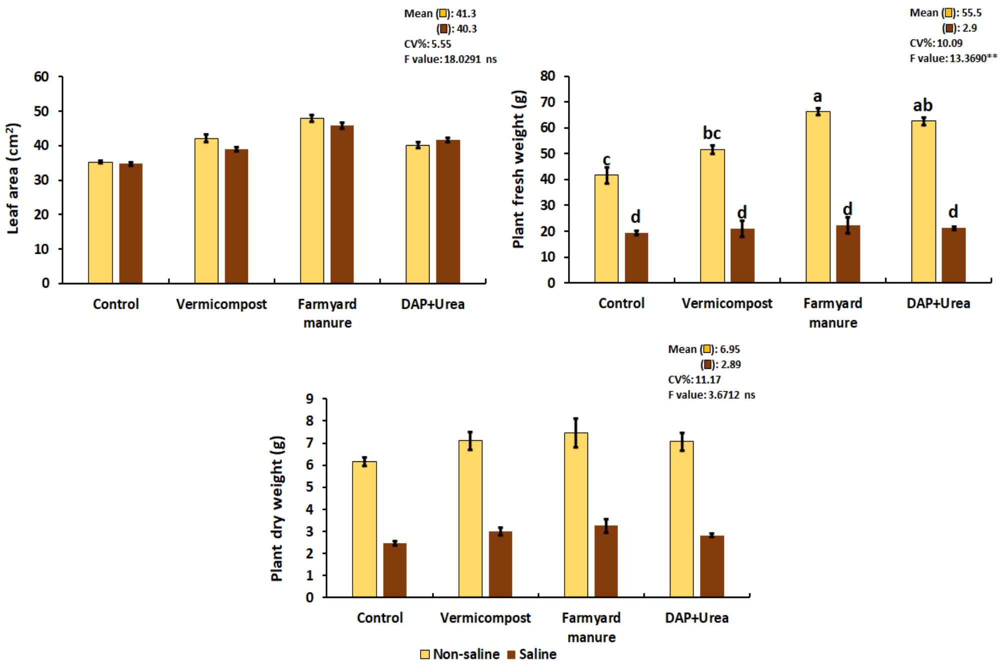

Figure 2. Effects of different fertilizer applications on plant leaf area, plant fresh weight and plant dry weight in saline and non-saline soil conditions

3.5. Plant fresh weight (g)

According to the findings obtained, a significant difference (p<0.01) was found between the fertilizer treatments in terms of safflower plant wet weight between saline and non-saline soils. In the experiment, in the non-saline soil, the lowest plant wet weight was observed in the non-saline soil*vermicomposting (51 g) interaction and the highest was in the non-saline soil*farmyard manure (66.2 g) application compared to the control group (41.6 g non-saline soil*control). In saline soil, compared to the control group (19.2 g; saline soil*control), the lowest was observed in the saline soil*vermicomposting (20.9 g) interaction, while the highest was measured in the saline soil*farmyard manure (22.3 g) application (Figure 2).

3.6. Plant dry weight (g)

According to the data obtained from the study, a notable disparity (p<0.01) among the fertilizer applications regarding plant dry weight in saline and non-saline soils. Within the study, the minimum plant root weight was recorded in the non-saline soil treated with DAP+Urea fertilizer (7.06 g) in contrast, the maximum plant root weight was observed in the non-saline soil amended with farmyard manure (7.46 g), surpassing the control group (6.16 g in the non-saline soil control setup). In the saline soil conditions, when compared to the control group (2.46 g; saline soil control), the least plant root weight was found in the saline soil treated with DAP+Urea fertilizer (2.86 g), whereas the highest root weight was documented in the saline soil treated with farmyard manure (3.26 g) (Figure 2).

3.7. Root fresh weight (g)

The variance analysis detected a statistically significant variation (p<0.01) among the fertilizer applications regarding root wet weight across saline and non-saline soils. Within the study, the minimum root wet weight was recorded in the non-saline soil treated with vermicomposting (23.07 g) in contrast, the maximum root wet weight was identified in the non-saline soil supplemented with farmyard manure (29.62 g), surpassing the control group (16.79 g in the non-saline soil control setup). Under saline soil conditions, compared to the control group (9.09 g; saline soil control), the least root wet weight was found in the saline soil treated with vermicomposting (15.41 g), whereas the maximum was documented in the saline soil amended with farmyard manure (19.48 g) (Figure 3).

3.8. Root dry weight (g)

The variance analysis identified a noteworthy difference ($p<0.05$) among fertilizer applications regarding root dry weight under saline and non-saline conditions. minimum root dry weight was recorded throughout the study in the non-saline soil vermicomposting (2.7 g) combination in contrast, the maximum root dry weight was determined in the non-saline soil farmyard manure (2.53 g) treatment, relative to the control group (1.76 g, non-saline soil control). Under saline conditions, in comparison to the control group (0.86 g; saline soil control), the lowest root dry weight among the treatments was noted in the saline soil vermicomposting (1.10 g) combination, whereas the highest was identified in the saline soil farmyard manure (1.26 g) application (Figure 3).

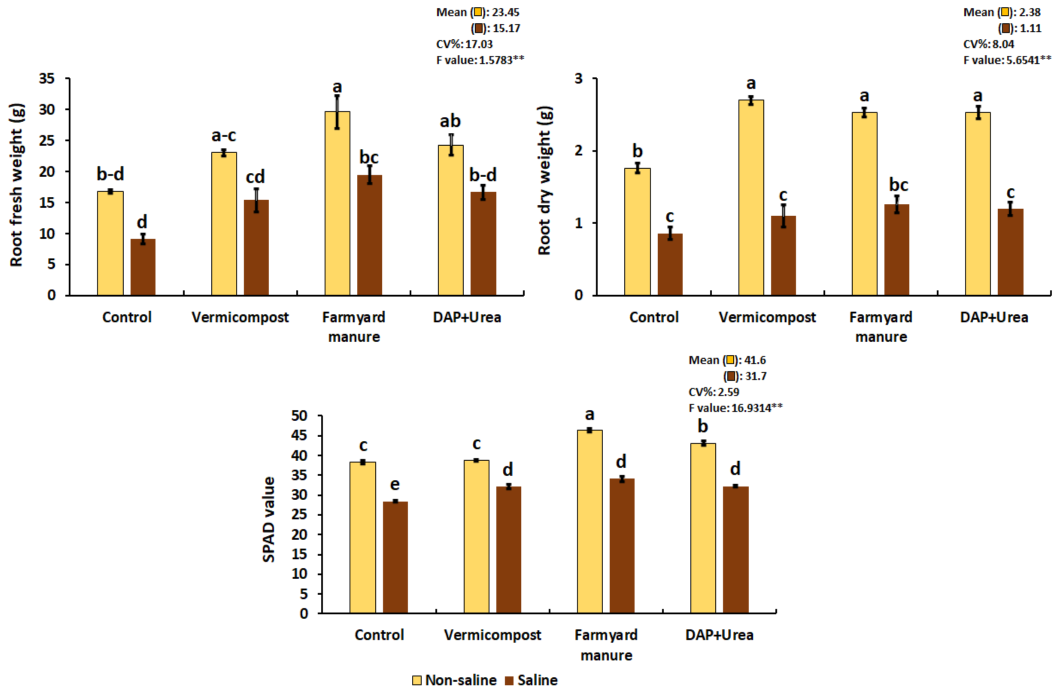

Figure 3. Effects of different fertilizer applications on plant root fresh weight, root dry weight and SPAD value in saline and non-saline soil conditions

3.9. SPAD value

The variance analysis identified a statistically significant variation ($p<0.01$) among the fertilizer applications regarding plant SPAD values in saline and non-saline soils. Within the study, the minimum SPAD value was recorded in the non-saline soil treated with vermicompost (38.70), whereas the maximum SPAD value was determined in the non-saline soil amended with farmyard manure (46.30), surpassing the control group (38.30; non-saline soil control). Under saline soil conditions, relative to the control group (28.40; saline soil control), the least SPAD value among the treatments was documented in the saline soil supplemented with vermicompost (32.10), whereas the highest was observed in the saline soil enriched with farmyard manure (34.10) (Figure 3).

3.10. Urease enzyme activity

As a result of the analysis of variance, a significant difference (p<0.01) was found between the fertilizer treatments in terms of urease enzyme activity value between saline and non-saline soils. In the experiment, the lowest activity was observed in the non-saline soil*DAP+urea (32.97) interaction, while the highest activity was measured in the normal soil*vermicompost (41.81) application compared to the control group (21.28; non-saline soil*control). In saline soil, the lowest activity was observed in the saline soil*DAP+Urea (18.46) interaction, while the highest activity was measured in the normal soil*vermicompost (23.44) treatment compared to the control group (15.03; saline soil*control) (Figure 4).

3.11. Dehydrogenase enzyme activity

As a result of the analysis of variance, a significant difference (p<0.01) was found between the fertilizer treatments in terms of dehydrogenase value between saline and non-saline soils. In the experiment, DHG activity in the non-saline soil was lower in the non-saline soil*DAP+urea (16.01) interaction compared to the control group (13.61; non-saline soil*control), while the highest activity was measured in the normal soil*vermicompost (23.45) application. In saline soil, the lowest activity was observed in the saline soil*DAP+urea (18.46) interaction, while the highest activity was measured in the normal soil*vermicompost (15.43) treatment compared to the control group (8.68; saline soil*control) (Figure 4).

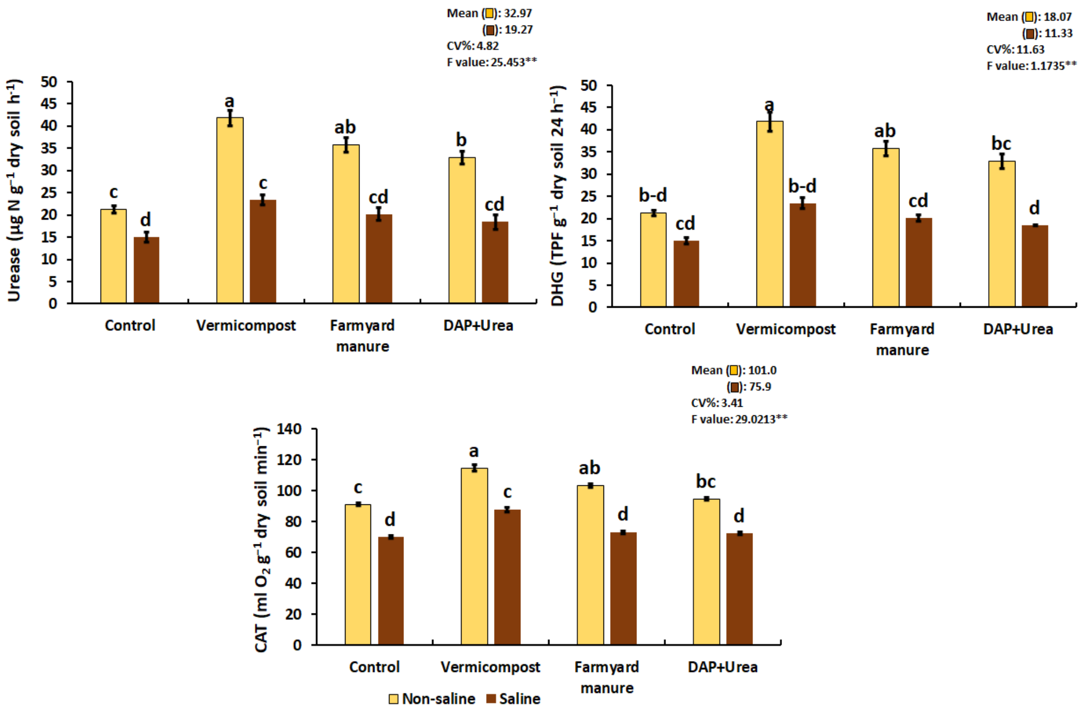

Figure 4. Effects of different fertilizer applications on urease, DHG and CAT enzyme activity in saline and non-saline soil conditions

3.12. Catalase enzyme activity

As a result of the analysis of variance, a significant difference (p<0.01) was found between the fertilizer treatments in terms of catalase enzyme activity value between saline and non-saline soils. In the experiment, CAT activity in the non-saline soil was lower in the non-saline soil*DAP+urea (94.60) interaction compared to the control group (91.30; non-saline soil*control), while the highest activity was measured in the normal soil*vermicompost (114.6) application. In saline soil, the lowest activity was observed in the saline soil*DAP+urea (72.3) interaction, while the highest activity was measured in the normal soil*vermicompost (88.0) treatment compared to the control group (70.0; saline soil*control) (Figure 4).

4. Discussions

The application of earthworm, farm-based, and DAP+Urea fertilizers to both saline and non-saline soils led to a notable rise in plant height, root elongation, leaf count, leaf surface area, fresh biomass, dry biomass, root fresh weight, root dry weight, and SPAD values of safflower across different soil conditions. Among the three treatment types, the most substantial enhancement was detected in farmyard manure applications.

The buildup of salts within the soil diminishes the water availability within the soil matrix. It negatively impacts the movement of water through plant tissues and their overall moisture retention capacity (Munns, 2002). Excessive salt levels in saline soils further lower the water availability in the soil matrix, creating challenges for plant roots in absorbing moisture from the substrate, ultimately leading to "osmotic stress" (Akram et al., 2002). Salinity restricts plant development by reducing water intake and disrupting nutrient absorption. Nonetheless, incorporating farmyard manure, which is abundant in organic material, enhances soil composition (Cevheri et al., 2021), boosts water-holding capacity, and mitigates the adverse impacts of salinity by fostering microbial activity, thereby contributing positively to plant growth.

In saline conditions, root growth is restricted due to osmotic stress. Farmyard manure promotes root elongation by increasing soil fertility and water availability so that plants access water and nutrients more efficiently (Ullah et al., 2021). Fertilizer increases nutrient availability by providing nutrients necessary for leaf development and increases the number of leaves despite salt stress. Salinity negatively affects leaf area due to osmotic stress and limited water uptake. However, farmyard manure reduces the effects of salinity and increases leaf area by improving soil structure and microbial activity (Irin and Hasanuzzaman, 2024). Saline soils reduce water uptake and biomass production. Fertilizer enhances soil fertility, alleviating the stress caused by salinity and improving wet weight. The dry weight of plants in saline soils is reduced due to limited nutrient uptake and osmotic stress (Ouni et al., 2014). Farmyard manure alleviated this situation by increasing nutrient availability and improving soil structure. In saline conditions, roots experience stress due to it's osmotic effects and their limited growth.

Salt stress negatively impacts leaf water dynamics, including relative leaf moisture levels, hydraulic potential, osmotic balance, and turgor pressure, leading to diminished growth characteristics and developmental stagnation in safflower (Jabeen and Ahmad, 2012). Farmyard manure enhanced the plant’s ability to withstand salinity stress, promoting improved development. A decline in growth can be interpreted as a potential mechanism for sustaining long-term energy reserves, facilitated by incorporating farmyard manure and preserving carbohydrates, contributing to enhanced post-stress recovery. Under such conditions, exposure to high salinity may induce continued root elongation, despite its potential to suppress leaf and stem expansion (Spollen et al., 1993). This phenomenon could be associated with ion toxicity.

Farmyard manure increases root biomass by improving soil structure and water retention. In saline soils, plant growth is stunted due to reduced nutrient uptake and water stress. Manure alleviates this stress by increasing nutrient availability, improving soil porosity and increasing dry weight (Hussain et al., 2019; Bello et al., 2021). SPAD value is a parameter that measures photosynthetic capacity by chlorophyll content (Zhang et al., 2022). In saline soils, chlorophyll production is reduced due to osmotic stress and nutrient imbalances (Shah et al., 2017). On the other hand, farmyard manure reduces chlorophyll loss by increasing soil fertility, which leads to an increase in SPAD value.

The excessive uptake of specific ions is a primary factor leading to toxicity-related stress, significantly contributing to growth restriction under saline stress conditions (Chinnusamy et al., 2005). An overabundance of sodium ions (Na+) triggers toxicity and disrupts plant metabolic functions, whereas potassium ions (K+) play a crucial role in counteracting Na+ toxicity by modulating osmotic balance and preserving ionic stability. Research has demonstrated that elevated Na+ levels harm foliage more than roots (Munns, 2005), with leaf scorching being a distinctive symptom (Zhu, 2003). In this study, the incorporation of farmyard manure enhanced plant growth in saline environments, presumably due to its potassium-rich composition.

Under saline soil conditions, an excessive accumulation of Na^+ and Cl^- ions in the root zone disturbs the nutrient equilibrium in safflower, primarily as a result of their strong interactions with essential minerals, including potassium (K), calcium (Ca), nitrogen (N), phosphorus (P), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn). Sodium (Na^+) functions as the dominant toxic ion in safflower, limiting potassium uptake, disrupting stomatal function, and triggering dehydration along with tissue necrosis (Siddiqi et al., 2011).

Researchers have increasingly focused on alternative biological fertilizers such as organic manure (Aira et al., 2002). Beyond converting nutrients into plant-available forms, biological fertilizers have improved seed germination, growth and development. Taleshi et al. (2012) found that organic fertilizer application increased seed yield and yield components under water stress. Applying of farmyard manure to both saline and non-saline soils positively affected the growth parameters of safflower. The effects are more pronounced in non-saline soils, but fertilizer can reduce stress and improve plant growth even in saline conditions.

The application of fertilizers of organic origin to the soil is very important for the effects of organic management on soil health, which is determined by soil physical, chemical and especially biological parameters (van Diepeningen et al., 2006; Kılınçoğlu et al., 2024). Farmyard manure increases plant height in non-saline soils by improving soil structure and fertility. Increased nutrient availability leads to better growth. The organic matter in manure increases soil porosity by stimulating microbial activity, which leads to longer and healthier roots. Nutrient richness stimulates leaf growth, so plants produce more leaves.

Furthermore, the fertilizer promotes photosynthetic activity by increasing leaf area. Wet weight increases as soil conditions improve under fertilizer, producing higher biomass. Dry weight also increases with fertilizer application, because the increase in nutrients and organic matter promotes plant growth. Farm fertilizer increases root wet weight by promoting root development. Furthermore, fertilizer increases dry weight by improving nutrients and soil structure. Finally, the SPAD value strengthens photosynthetic capacity by increasing chlorophyll production.

Excessive use of chemical fertilizers reduces the organic matter content of soils, while applying farmyard manure increases this content. Continuous and excessive use of chemicals adversely affects the soil's physical, chemical and biological properties, leading to a decrease in soil quality (Gross and Glaser, 2021). Therefore, soil organic matter is an essential indicator of soil health (Sakin et al., 2024). Appropriate organic matter management strategies must be developed to mitigate growing concerns about the sustainability of soil health. Farmyard manure effectively increases soil organic matter (Angst et al., 2019; Gross and Glaser, 2021; Ramazanoglu et al., 2024).

In non-saline soils, organic matter increases microbial populations producing dehydrogenase, and catalase enzymes. These enzymes help in soil nitrogen cycling, organic matter decomposition (Sakin et al., 2024), and antioxidant defense (Farooqi et al., 2023).

Salinity in saline soils stresses soil microorganisms and plants (Shabaan et al., 2022). The addition of vermicompost helps reduce salinity's effects by improving soil structure and moisture retention and helps soil microorganisms thrive (Tammam et al., 2023; Manzoor et al., 2024). As a result, enzyme activities increase in non-saline soil, while in saline soil, they may be somewhat limited by the severity of salinity (Alharbi et al., 2023). The increase in enzyme activity is the improvement in microbial health and soil structure facilitated by vermicompost.

In non-saline soils, FYM supports an active microbial community capable of degrading organic matter. During the microbial activity, decomposition and fragmentation result in the release of some nutrients (Farooqi et al., 2023) and stimulate enzyme activities, especially urease and DHG, which play an important role in nitrogen and carbon cycling, and catalase, which are indicators of oxidative stress responses (Chettri et al., 2021). In saline soils, microbial populations are low due to high salt concentrations. Still, organic fertilizers applied to the soil help offset salinity's harmful effects by providing organic carbon and buffering pH levels (Yang et al., 2024). This can lead to some improvement in enzyme activities, but the effect is not as strong as in non-saline soils. This is due to adding organic matter and nutrients through FYM, which enhances microbial growth and metabolic activity.

DAP + Urea application enhances plant growth in non-saline soils by providing essential nutrients. However, direct effects on soil microbial enzymes may be limited because the fertilizer lacks organic material to promote long-term microbial activity (Adnan et al., 2017; Chhabra et al., 2021). DAP+urea applied to the soil improves plant growth parameters, resulting in a good below- and above-ground plant biomass (Singh et al., 2023). Increased plant biomass creates energy sources for microorganisms. Enzyme activities may not directly increase significantly with this application, and in some cases an imbalance in nutrient availability may reduce microbial diversity and enzyme production. The combination of nitrogen and phosphorus from DAP and Urea on saline soils can exacerbate salinity stress. The high soluble salt concentrations in the fertilizers can further increase soil salinity. This leads to a decrease in microbial activity, reducing the production of urease, dehydrogenase and catalase enzymes (Rietz and Haynes, 2003).

5. Conclusions

Vermicompost and farmyard manure on non-saline and saline soils generally improve urease, dehydrogenase and catalase activities in soils in both soil environments, with a more pronounced effect in non-saline conditions. On the other hand, DAP and Urea fertilizers impact enzyme activities, especially in saline soils, as they do not meet the organic matter needs of the soil and can contribute to salinity stress. Therefore, using organic amendments to improve soil health and enzyme activities is very important, especially in saline soils where microbial life is often compromised.

This study shows that earthworm, farm and DAP+Urea fertilizers positively affected safflower in non-saline and saline soils. The treatments caused significant increases in growth parameters such as plant height, root length, number of leaves, leaf area, plant wet and dry weight, root wet weight and plant SPAD values. In particular, among these three fertilization methods, farmyard manure application was observed to provide higher yields in both soil environments. These findings emphasize the effects of organic and inorganic fertilizers on safflower plant depending on soil structure. Farmyard manure stands out as a more practical option for promoting plant growth. These results may be helpful in determining fertilization strategies suitable for soil characteristics in safflower cultivation.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the article's final version ready for publication.

Declaration of Conflicts of Interest

All authors declare no conflict of interest related to this article.

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