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Multifactorial Stressors: Linking *Fusarium* Infection, Heavy Metals, and Salinity to Physiological Dysfunction in Tomato *Solanum lycopersicum* L.

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Abstract

Tomato (*Solanum lycopersicum* L.) is a globally strategic crop, vital for food security and agricultural economies, yet its productivity is increasingly threatened by biotic and abiotic stresses. This study investigates the combined effects of *Fusarium oxysporum* f. sp. *lycopersici* (FOL), heavy metals (cadmium, cobalt, chromium and lead), and salinity on biochemical and growth parameters of the Yassamen tomato variety. Results revealed that FOL infection alone significantly reduced chlorophyll content (3.68 to 2.96 mg.g^{-1}) and total soluble carbohydrates (2.51 to 1.95 mg.g^{-1}), while elevating oxidative stress markers: hydrogen peroxide (H_2O_2, 0.18 to 0.58 µmol.g^{-1}) and malondialdehyde (MDA, 0.13 to 0.44 nmol.g^{-1}). Synergistic interactions exacerbated stress responses, with lead and high salinity (12 dS.m^{-1}) causing the most severe declines in chlorophyll (1.61 and 1.41 mg.g^{-1}, respectively) and carbohydrates (1.40 and 1.32 mg.g^{-1}). Proline accumulation peaked under combined stresses (2.20 µmol.g^{-1} with FOL + 12 dS.m^{-1}), suggesting a partial compensatory mechanism. Growth parameters were severely inhibited: plant height decreased by 36.8% under FOL, plummeting further to 68% with FOL + 12 dS.m^{-1}, while root dry weight dropped by 63% under FOL + chromium. These findings underscore the compounded damage caused by FOL, heavy metals, and salinity, linked to oxidative membrane damage, photosynthetic impairment, and resource diversion to stress mitigation. To safeguard tomato productivity in stress-prone regions, integrated strategies such as developing stress-tolerant cultivars, optimizing soil remediation, and managing pathogen load are urgently recommended.

Keywords: *Fusarium oxysporum* f. sp. *lycopersici*¸ Oxidative stress, Heavy metal, Salinity stress, Tomato

I. Introduction

Tomato plants *Solanum lycopersicum* L., belonging to the Solanaceae family, are a strategic crop of global and Iraqi importance, playing a pivotal role in enhancing food and economic security through their contribution to nutrition and the agricultural value chain (Natali et al., 2025). According to FAO statistics (FAOSTAT, 2025), the global cultivated area of tomatoes is approximately 5 million hectares, with an annual production of 186.8 million tons, contributing around $1.4 billion to the global economy. In Iraq, the total cultivated area of tomatoes reached 86,942 dunams, with a total production of 534,821 tons in 2023, as reported by the Central Statistical Organization (https://www.cosit.gov.iq/ar/).

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