

Application of bio-organic amendments improves soil quality and yield of fennel (*Foeniculum vulgare* Mill.) plants in saline calcareous soil

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The impact of bio-organic amendments on crop production is poorly understood in saline calcareous soils. The aim in the present study was to determine the effects of the application of organic manure along with lactic acid bacteria (LAB) on soil quality, and morpho-physio-biochemical responses, seed yield (SY) and essential oil yield (EOY) of fennel plants (*Foeniculum vulgare* Mill.) grown in saline calcareous soils. Eight treatments of farmyard manure (FM) or poultry manure (PM) individually or combined with *Lactobacillus plantarum* (Lp) and/or *Lactococcus lactis* (Ll) were applied to saline calcareous soil in two growing seasons. Either FM or PM combined with LAB had beneficial effects on lowering E_{Ce}, pH and bulk density and increasing total porosity, organic matter, and water and nutrient retention capacities in addition to total bacterial population in the soil. Growth, nutrient uptake, SY and EOY of plants were also enhanced when fennel seeds were inoculated with Lp and/ or Ll and the soil was amended with any of the organic manures under unfavorable conditions. Compared to control (no bio-organic amendments), FM + Lp + Lt or PM + Lp + Lt treatment significantly ($P \leq 0.05$) increased plant height by 86.2 or 65.0%, total chlorophyll by 73 or 50%, proline by 35 or 45%, glutathione by 100 or 138%, SY by 625 or 463% and EOY by 300 or 335%, respectively, in fennel plants. Co-application of the naturally occurring microorganisms (i.e., LAB) and organically-derived, nutrient-rich fertilizer (i.e., FM or PM) is recommended to improve yield of fennel plants in saline calcareous soils.