Precision Management of Fluoride-Contaminated Soils Using Organic and Inorganic Amendments for Enhanced Maize Productivity

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Abstract:

Fluoride contamination in agricultural soils has emerged as a significant constraint to crop productivity and soil health in several semi-arid regions. Excess fluoride adversely affects plant growth, physiological functions, nutrient uptake, and yield, necessitating the development of effective site-specific soil management strategies. This study evaluated the effectiveness of organic and inorganic soil amendments in mitigating fluoride toxicity and enhancing maize (Zea mays L.) productivity under fluoride-contaminated soil conditions. A field experiment was conducted during the rabi season of 2020 in a fluoride-affected Typic Haplustalf at Tiruppur district, Tamil Nadu, India. The experiment was laid out in a randomized block design with six treatments comprising control, recommended dose of fertilizers (RDF), RDF + farmyard manure (FYM @ 12.5 t ha^{-1}), RDF + vermicompost (5 t ha^{-1}), RDF + lime (2 t ha^{-1}), and RDF + gypsum (2 t ha^{-1}). Growth parameters, chlorophyll content, fluoride accumulation in plant tissues, yield attributes, and soil fluoride status were assessed at critical growth stages and harvest.

Application of soil amendments significantly improved plant growth, physiological performance, and yield compared to the untreated control. Among the treatments, RDF combined with FYM recorded the highest plant height (187 cm), root length (24.1 cm), chlorophyll content (2.50 mg g^{-1}), biomass production (9425 kg ha^{-1}), and grain yield (8810 kg ha^{-1}). Fluoride accumulation was consistently higher in roots than shoots, indicating restricted translocation within the plant system. The lowest fluoride concentrations in plant tissues were observed under FYM application, demonstrating the role of organic matter in reducing fluoride bioavailability and uptake. Inorganic amendments were particularly effective in reducing soil fluoride concentrations. Gypsum application reduced soil fluoride to 0.50 ppm, followed by lime (0.55 ppm), owing to the precipitation of fluoride as stable calcium fluoride complexes. Organic amendments also contributed to fluoride immobilization through adsorption and complexation mechanisms while improving soil biological activity and nutrient availability. The findings demonstrate that integrated amendment-based management can effectively alleviate fluoride toxicity, improve soil quality, and enhance maize productivity. Farmyard manure proved most effective for crop performance, whereas gypsum and lime were superior in reducing soil fluoride availability. The study highlights the potential of precision soil management

approaches for identifying and ameliorating fluoride-affected areas, thereby supporting sustainable crop production and soil health management in vulnerable agroecosystems.

Keywords:
Precision agriculture, Fluoride-contaminated soil, Soil amendments, Maize, Soil health, Site-specific management, Sustainable productivity.