Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.31766

Plasticulture and microplastics: Long-term environmental impact and co-contaminant interactions

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The growing reliance on plasticulture in modern agriculture has raised significant environmental concerns due to improper disposal and the persistent accumulation of plastic residues in soil ecosystems. Farmers extensively utilize various plastic-based agricultural inputs, including mulch films, plastic threads, germination trays, polyhouses, drip irrigation pipes, and fruit protection bags, primarily composed of polymers such as LLDPE, polystyrene (PS), polypropylene (PP), and polyethylene (PE). While these materials provide multiple agronomic benefits, such as enhanced crop yield and water retention, their degradation generates microplastics (MPs; <5 mm), contributing to soil contamination. However, knowledge gaps remain regarding the long-term impacts of plasticulture and the specific polymer types that contribute most to MPs accumulation.

To address this, we comprehensively assessed MPs abundance in agricultural soils across 40 sites spanning seven districts in Maharashtra, India, stratified by duration of plasticulture implementation. Results indicate a progressive increase in MP concentrations in soils with extended plasticulture use, with sites exceeding 20 years of plastic application exhibiting the highest contamination levels (5806±2834 p Kg^{-1}). Morphological and chemical analysis showed a shift in polymer composition, with film-type microplastics increasing from 2.1% (PE 29.2%) in non-plasticulture sites to 29.5% (PE 45.9%) in fields with over 20 years of plastic use, highlighting long-term mulch use impact. Notably, fields involving both plastic threads and mulch films exhibited nearly a 1.7-fold increase in MP concentrations (2587±1022 p Kg^{-1} soil) compared to those utilizing mulch films alone (1489±517 p Kg^{-1} soil) for the same application period (1-5 years). To validate these observations, laboratory weathering tests on agroplastics confirmed that PP threads and PS germination trays degraded faster than LLDPE-based mulch films.

Beyond terrestrial impacts, MPs are transported via runoff, affecting aquatic systems. Interaction studies were conducted with UV-aged and unaged MPs with nano zinc oxide (nZnO), a nano-agricultural product recently promoted for agricultural applications in India, to assess their role as contaminant vectors. Results revealed significantly higher retention of nZnO onto MPs in river water than in deionised water. These findings highlight the need for sustainable plastic management to prevent soil and water contamination.