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Short-Term Response of the Soil Microbial Community to the Addition of Polystyrene Nanoplastics (PS-NPs)

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Globally, plastics now represent a ubiquitous contaminant in soils. The potential accumulation of plastic in soils has been shown to have a negative impact on soil health and agricultural output in many regions of the world. Notably, nanoplastic (NPs), with enhanced adsorption affinity and pollutant-carrying capabilities, exert more harmful effects, given their higher surface area-to-volume ratio and colloidal mobility. They can enter the cells more readily than microplastics causing direct harm to organisms. Polystyrene (PS) is a commonly used polymer which can enter soil via organic inputs and atmospheric deposition where it can then undergo fragmentation into nano-sized particles. Although PS is considered to be non-toxic, polystyrene nanoplastics (PS-NPs) have been demonstrated to have potentially harmful effects. Therefore, this study investigated the short-term impact of PS-NPs on soil biological properties, particularly focusing on the effects of prior soil exposure to plastic film mulch (PFM). Two Reddish Brown Earth soils (RBE, Typic Rhodustalfs) from two farms in the dry zone Sri Lanka, one previously exposed to PFM and the other without such exposure were chosen for incubation, with three replicates per each soil type. Fabrication of PS-NPs was undertaken using micro-emulsion polymerization and modified non-solvent induced phase separation. Synthesized PS and PS-NPs were characterized via scanning electron microscope imaging and fourier-transform infrared spectroscopy. Optimization of these methods were carried out to obtain higher yield of NPs. NIPS method produced better quality PS-NPs according to SEM analysis and particle size distribution data. After 2 weeks of pre-incubation of soils, PS-NPs were homogenously mixed at 0.004% (w/w) ratio based on dry weight. The soils were subsequently incubated in darkness for 9 weeks, maintaining a consistent moisture level equivalent to 60% of the field capacity at 25 °C. Periodic measurements of soil microbial respiration, catalase and urease enzyme activities, soil pH and electrical conductivity (EC) were conducted. Soil pH was affected by NP treatments, decreasing slightly ($p < 0.05$) with time. The NP treated soil showed a slightly higher pH values than the control for both soil types. A significant interaction ($p < 0.05$) was observed in soil×treatment×time for pH indicating that the effect of pH varied depending on the soil type and incubation time. Soil EC increased significantly ($p < 0.05$) with incubation time. EC was significantly higher in both soil types in the 5th week in control and NP treatments. Microbial respiration slightly but significantly ($p < 0.05$) increased with NP addition compared to the control in both soil types. Cumulative CO_2 emission of control for soil with PFM history showed the highest value than others. Both urease and catalase activities were not significantly affected by NP treatment. An alteration of soil biological activity by NPs is evidenced by changes in microbial respiration and the response of microbial community for NP addition differed based on their previous exposure to PFM. Soil pH and EC have altered with the time suggesting that NPs engage in the buffering activity in soil. Therefore, the input of PS-NPs has influenced microbial activity with a low concentration over a short period.

Keywords: PS-NPs, Soil microbial activity, Incubation

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