ABSTRACT

Recently, nanomaterial synthesis and application have entered a new realm of green synthesis and agricultural—environmental applications. The widespread problem of soil health, micronutrient deficiency and “low use efficiency” of conventional (bulk-regime) agrochemicals appears daunting in the face of increasing demand for food production in a climate-resilient and sustainable manner. Additionally, the global micronutrient deficiency in soil plant-continuum is translating into human population as “hidden hunger”, which has drawn the public attention for its immediate solution.

This thesis, titled “Green synthesis of nano metal oxides for agricultural and environmental application”, is centered around the utilization of sugar press mud (agro-industrial solid waste) for the green synthesis of nano metal oxides and extending its application toward the efficient and sustainable plant nutrition, as well as soil remediation.

The study starts by exploring the use of sugar press mud water extract in synthesizing wurtzite ZnO (P63mc), α-Fe2O3 and monoclinic CuO nanoparticles using base hydrolysis and in aqueous sol-gel process. The study evolves further into the screening of suitable metal precursor salts and comparison of PM water extract-based ligands with commercially available analytical grade surfactants. The study also attempted to identify the probable active chemical agent (capping agent) in PM extract.

Furthermore, the study about extending its application to agriculture and the environment includes experiments designed to study the interface of nano metal oxide with the biotic and abiotic components of the environment. First, the role of nano metal (Zn, Fe and Cu) oxides (MxOy) for sustainable and efficient crop nutrition was studied with randomized control block design (RCBD)

pot trials using a soil matrix amended with 1.4% w/w dry sugar press mud and reinforced further with metal oxide NPs in the dose range of 10-100 mg/kg. Second, the nano metal oxides were evaluated for their heterogenous photocatalytic potential in degrading the soil organic pollutant, i.e., RhB dye in aqueous medium using direct sunlight. Thirdly, these (M_xO_y) nanoparticles were also evaluated for their compatibility with agriculturally important fungi in a PDA-based food poison assay.

In summary, the green nano synthesis experiments confirmed the capping ability of the PM-based ligands and their anisotropic control by offering the nanoparticle of the smallest size of ~14 nm (ZnO) with the consistent morphology. The application of metal oxides (M_xO_y) as nano fertilizer has shown statistically significant ($p<0.05$) correlations with soil organic carbon (SOC) and various other agronomic parameters, as evidenced by the (~30-60%) increase in grain and biomass yield vis-a-vis significant mineral fortification. Also, the photocatalytic degradation of soil organic pollutant (RhB) by these nanoparticles has shown a rate constant (pseudo-first-order kinetics) of 0.03 to 0.7 min^{-1}. The interface studies of nanometal oxides (M_xO_y) with environmental biotic components targeted at the compatibility of nanomaterials with the fungi indicated no toxicity at the agriculturally operational dose (~0.2 mg/ml). However, findings suggested the possible exploration of ZnO and CuO NPs for their pesticidal value at (2.0 mg/ml) dose. Thus, this study offers a new pathway for the green synthesis of nanometal oxides (M_xO_y) by expanding the green nano synthesis to agri-waste utilization. In addition, this also provides crucial insights into the nano-regime agrochemicals with their environmental interface for sustainable crop nutrition and climate-resilient crop production.