



## **Nano-fungicides against plant pathogens: Copper, silver and zinc NPs**

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Nanofungicides are expected to play an important role in future plant disease management as eco-friendly alternatives of conventional synthetic fungicides. The suppressive properties of metal nanoparticles containing copper (Cu-NPs, CuO-NPs), silver (Ag-NPs) and zinc (ZnO-NPs) were assessed in vitro against seven causal agents of economically important foliar and soil-borne plant diseases. Cu-NPs were proven to be most successful in inhibiting mycelial growth (EC50 values ranging between 162 and 310  $\mu\text{g/mL}$ ) followed by ZnO-NPs exhibiting mean inhibition rates ranging between 235 and 848  $\mu\text{g/mL}$ . All fungal species were practically insensitive to CuO-NPs while Ag-NPs exhibited significant inhibitory effect only against *B. cinerea*. Comparative mycelial growth fungitoxicity experiments between the nanoparticles tested and their bulk sized counterparts revealed that ZnO-NPs were more toxic to all fungal species tested than ZnSO<sub>4</sub> whereas CuNPs were more fungitoxic to CuSO<sub>4</sub> in all cases except for *B. cinerea*, *A. alternata* and *M. fructicola*. A positive correlation between Cu-NPs and CuO-NPs toxicity and the absence of any correlation between NPs and their respective bulk metal counterparts is indicative of potential differences in the mode of action between bulk and nanosized metals. Although there was considerable variation between fungal species, fungitoxicity of all nanoparticles dramatically increased when applied to spores rather than fungal hyphae indicating a great potential of these compounds to be used as protective antifungal agents.