Cu-NPs combating fungicide resistance: effectiveness and synergy against B. cinerea

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The potential of copper nanoparticles (Cu-NPs) alone or in combination with conventional fungicides against sensitive and resistant to fungicides Botrytis cinerea isolates was assessed in vitro and in vivo. DNA sequencing revealed the E198A resistance mutation in the β-tubulin gene in three B. cinerea isolates highly resistant to benzimidazoles (BEN-R), thiophanate methyl (TM), and the G143A mutation in the cytb gene in four isolates highly resistant to the QoI pyraclostrobin (PYR-R). Cu-NPs could effectively control sensitive and resistant isolates. A synergistic effect between Cu-NPs and TM both in vitro and in vivo was observed in the case of benzimidazole sensitive isolates while an additive effect was observed in BEN-R isolates. The above observed synergistic action could be attributed to increased TM availability in the target site as indicated by the positive correlation observed between TM and TM+Cu-NPs treatments. A positive cross sensitivity and antagonistic action between Cu-NPs and NaCl suggested that copper ions contribute in the fungitoxic action of Cu-NPs, at least partly, since no correlation between Cu(OH)\textsubscript{2} and Cu-NPs sensitivity was found. The co-application of Cu-NPs with the oxidative phosphorylation inhibitor fluazinam (FM) resulted in a synergistic action in all isolates regardless resistance phenotype, indicating a ATP-dependent mechanism of toxic action of Cu-NPs. Cu-NPs combined with conventional fungicides can aid in the design and implementation of eco friendly, sustainable management strategies by reducing fungicide use and combating resistance against B. cinerea.