

Microwave irradiation and citric acid assisted seed germination and phytoextraction of Nickel (Ni) by *Brassica napus* L.; physiological and biochemical alterations

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The complex bio-geochemistry of soil allows pollutant to persist for a longer period of time which further decreased the fertility and natural composition of land. Ni, an inorganic pollutant, coming from wide range of industrial and manufacturing units possess serious threat to soil degradation and crops productivity around the world. The present study was carried to find out the combined role of microwave irradiation (MR) and citric acid (CA) on the phytoextraction potential of *Brassica napus* under Ni stress. An initial seed germination test was conducted to select effective time scale of MR exposure. Highest seed germination was observed at exposure of 2.45GHz frequency at 650 W for 30s. Healthy seeds of *Brassica napus* L. genotype Faisal Canola (RBN-03060) treated with MR at 2.45GHz, 650 W, for 30s were sown in plastic pots filled with 5 kg of soil. Ni and CA applied exogenously in solution form with different combinations to both treated and non-treated *Brassica napus* plants. The MR treated plants showed higher growth, biomass, photosynthetic pigments (Chl a, b, total and carotenoids) and activities of antioxidant enzymes (SOD, POD, APX, CAT) as compared to non-treated plants showed higher reactive oxygen species (MDA, H₂O₂) and electrolyte leakage concentrations. Increasing Ni concentration significantly decreased the physiological and biochemical attributes of *Brassica napus* both in treated and non-treated plants. The addition of CA alleviated the Ni induced toxic effects in both MR treated and non-treated plants by improving antioxidant defense system. The degree of Ni stress alleviation was higher in MR treated plants. The Ni concentration was higher in root, stem and leaves of MR treated plants under CA application as compared to non-treated plants. The present study concluded that seeds treated with MR before sowing showed higher accumulation and concentration of Ni from soil and this phenomenon boosted with the application of CA. To understand the changes at ultrastructure levels caused by MR and CA application requires more detailed studies in future.

Keywords: Citric acid, Nickel, Microwave, Phytoextraction