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Weed to wonder: antioxidant and antibacterial investigation of *Parthenium hysterophorus* L.

Heena Choudhary[1], Aman Saket[2], Parshant[1], Shivani Singh[2], T. Srinivasan[3] & Ravindra Shukla[1]*

[1]Bioresource Technology Laboratory, Department of Botany, Indira Gandhi National Tribal University, Amarkantak 484887, Madhya Pradesh, India

[2]Microbiology Laboratory, Department of Botany, Indira Gandhi National Tribal University, Amarkantak 484887, Madhya Pradesh, India

[3]Department of Botany, Central Tribal University of Andhra Pradesh, Vizianagaram 535003, Andhra Pradesh, India

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The overuse of modern synthetic pesticides for controlling insect-pest and plant diseases has led to environmental pollution, health risks, and the development of resistant bacterial strains, creating an urgent need for sustainable and eco-friendly alternatives. *Parthenium hysterophorus*, a widely distributed invasive weed, is known for its harmful effects but also contains bioactive compounds such as phenolics, flavonoids, tannins, and alkaloids. This study explores its potential as a natural source of antioxidant and antibacterial agents to address crop protection challenges. Aqueous leaf and flower extracts were analyzed for phytochemicals and bioactivity. Qualitative and quantitative profiling confirmed a high level of phenolics (13.5±9.49 mg GAE/g), flavonoids (22.60±0.52 mg QE/g), tannins (11.26±1.70 mg TAE/g), and alkaloids (717.27±211mg/g) in leaf extracts. Antioxidant evaluation revealed strong radical scavenging activity, with leaf extracts exhibiting lower IC_{50} values in DPPH (604.88 µg/mL) and ABTS (644.9 µg/mL) assays compared to flower (1,028.74 µg/mL and 900 µg/mL, respectively). Reducing power was higher in leaves (256.92 mg AAE/g) than flowers (210.30 mg AAE/g). Fourier transform infrared spectroscopy (FTIR) revealed a strong broad peak at 4000–400 cm^{-1}, corresponding to O–H stretching, which is characteristic of phenolic and alcoholic compounds, and Gas chromatography mass spectroscopy (GC-MS) exhibited the Dimethyl sulfone as a major bioactive compound in both leaf (24.31%) and flower (32.83%) extracts. Antibacterial activity assessed by agar well diffusion demonstrated significant inhibition against *Pectobacterium carotovorum* (18 mm at 60 mg/mL) and *Ralstonia solanacearum* (11mm at 60 mg/mL), outperforming flower extracts. These findings highlight *P. hysterophorus* as a rich source of bioactive compounds with potent antioxidant and antibacterial properties, supporting its transformation from an invasive weed into a sustainable biocontrol agent for eco-friendly crop protection.

Keywords: crop protection, free radical scavenging, Gram-negative pathogens, *Parthenium hysterophorus*, phytochemicals, plant-derived metabolites