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# Phytotoxic effects and mode of action of the alkaloid norharman on *Arabidopsis* seedlings

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## Abstract

The secondary metabolite norharman is an indol alkaloid that can be found in land plants of the families Gramineae, Sapotaceae and Zygophyllaceae and in marine organisms such as the dinoflagellates *Nocticula miliaris* or in cyanobacteria of the Nostocaceae family. Although the algicidal, antibacterial and pharmacological activities of this secondary metabolite have been widely demonstrated, its herbicidal activity has been poorly investigated.

Therefore, in this work the phytotoxic activity of different concentrations of the compound (12.5, 25, 50, 75, 100, 200 and 400  $\mu\text{M}$ ) was analyzed on *A. thaliana* (L). Col-0 seedlings, selected as model species.

Seedlings showed a strong decrease in growth with an IC50 value (concentration that causes 50% inhibition) of 62  $\mu\text{M}$ , and showed an altered morphology of the roots with a left-handed torsion and symptoms of necrosis. Electron microscopy showed important differences between treated and control seedlings, both at structural and cellular levels. Roots treated with IC50 norharman showed tissue disorganization, altered division planes with incomplete cell walls and multinucleated cells. The alteration of the microtubules was confirmed by immunofluorescence and increased cell death was detected by Trypan Blue staining. As well, norharman treatment caused the rupture and enlargement of many vacuoles at the cellular level.

The seedlings treated with the compound showed an altered morphology characterized by a decrease in the length of the main root, accompanied by an increase in the formation of lateral and adventitious roots and an increase in the production of root hairs. These alterations suggested the possibility of an alteration on the production or transport of auxins, which were measured by GC-MS.

Due to its strong phytotoxic potential, norharman appears as a promising molecule for studies of weed control.

**Keywords:** norharman, mode of action, phytotoxicity, cell death, microtubules

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