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Differential Response of Liverwort (*Marchantia polymorpha*) Tissue to POST-Applied Quinoclamine

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Quinoclamine is used in Europe, and was under evaluation in the Unites States for the control of liverwort in nursery crops. Liverwort is a nonvascular, chlorophyll-containing plant that can be problematic in greenhouse and nursery crops. POST-applied quinoclamine controls liverwort. However, liverwort structures vary in their sensitivity to POST-applied quinoclamine. Specifically, archegonial receptacles (female) are much more tolerant of quinoclamine than either antheridial receptacles (male) or thalli (leaflike structures). A series of studies were conducted to, first, document the degree of differential sensitivity between tissues to quinoclamine, and second, to determine the basis of this differential sensitivity. The dose that results in 50% of the population being controlled (I_{50}) of antheridial receptacles and juvenile thalli were estimated to be 1.60 and 1.27 kg·ha^{-1}, respectively. The I_{50} of archegonial receptacles could not be estimated, but exceeded 10.45 kg·ha^{-1}. Chlorophyll content varied between liverwort tissues, but the content did not correlate to quinoclamine sensitivity. Absorption of ^{14}C after application of radiolabeled quinoclamine was less in archegonial receptacles than in either antheridial receptacles or thalli. Scanning electron microscopy of the surface of the liverwort tissues revealed that archegonial receptacles had smaller pores (equivalent to stomata in higher plants) than either antheridial receptacles or thalli. The tolerance of archegonial receptacles to quinoclamine can be partially, but not exclusively, attributed to reduced absorption. This reduced absorption may be attributed to the limited pore size and less total pore area of the archegonial receptacles.
Nomenclature: Liverwort, *Marchantia polymorpha* L.; quinoclamine.
Key words: Chlorophyll, Bryophyta, herbicide absorption, nursery crops, ultrastructure.

La quinoclamina es usada en Europa y se estuvo evaluando en los Estados Unidos para el control de *Marchantia polymorpha* en cultivos en viveros. *M. polymorpha* es una planta no vascular, que contiene clorofila y que puede ser problemática en invernaderos y viveros. Las aplicaciones POST de quinoclamina controlan *M. polymorpha.* Sin embargo, las estructuras de esta planta varían en su sensibilidad a quinoclamina aplicada POST. Específicamente, los arquegonios (órgano reproductor femenino) son mucho más tolerantes a la quinoclamina que los anteridios (órgano reproductor masculino) o los talos (estructura compuesta con semejanza de hoja). Se realizaron una serie de estudios para poder primero, documentar el grado de sensibilidad diferencial entre tejidos al quinoclamina y segundo, para determinar las bases de esta sensibilidad diferencial. El I_{50} de los anteridios y talos jóvenes se estimaron en 1.60 y 1.27 kg ha^{-1} respectivamente. El I_{50} de los arquegonios no pudo ser estimado, pero excedió 10.45 kg ha^{-1}. El contenido de clorofila varió entre los tejidos de *M. polymorpha,* pero el contenido no tuvo correlación con la sensibilidad a la quinoclamina. La absorción de ^{14}C después de la aplicación de quinoclamina radioetiquetada fue menor en los arquegonios que en los anteridios o talos. El escaneo de la superficie de los tejidos de *M. polymorpha* con microscopio electrónico reveló que los arquegonios tuvieron poros (equivalentes a estomas en plantas superiores) más pequeños que los anteridios o talos. La tolerancia de los arquegonios a la quinoclamina, puede atribuirse parcial más no exclusivamente a una absorción reducida. Esta reducción en la absorción puede atribuirse al tamaño limitado de los poros y a una menor área total de poros en los arquegonios.

Liverwort is a nonvascular, chlorophyll-containing plant that is problematic in greenhouse and nursery crops. Liverworts are characterized by thalli, which are leaflike structures that grow prostrate over the soil or substrate surface. Liverwort can reproduce by sexual and asexual means. The sexual cycle results in airborne spores, which can also be disseminated by splashing of irrigation or rain (Svenson 1997). The sexual cycle utilizes archegonial and antheridial receptacles, which are two distinctly different structures borne on stalks that extend above thalli. The antheridial receptacle is male and produces sperm. Sperm are transferred by water to female archegonial receptacles. Upon fertilization and subsequent meiosis, spores are produced and released from the archegonia. Asexual propagation is by either asexually produced diaspores termed gemmae, or by thallus fragmentation.

Liverwort thrives in the low-light, high-humidity, and high-fertility conditions associated with plant nurseries (Svenson 1998). The herbicide quinoclamine is labeled for POST liverwort control as a broadcast application to nursery crops in some European countries. Excellent liverwort control combined with minimal phytotoxicity to a broad spectrum of ornamental species has been documented (Vea and Palmer 2006). Early research indicated that very high spray volumes (e.g., $>$ 100 gallons per acre) were required for quinoclamine to be effective (Vea and Palmer 2006). However, Altland et al. (2007) established that control was influenced only by quinoclamine application rate; neither spray volume nor spray pressure influenced quinoclamine efficacy. This research also established that ^{14}C absorption followed by ^{14}C-quinoclamine application into liverwort thalli approached 61% of the amount

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