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The Effects of the Herbicide Atrazine on *Ruppia maritima* L. Growing in Autotrophic versus Heterotrophic Cultures

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Bioassay experiments were performed to determine the effects of atrazine on *Ruppia maritima* L. (Potamogetonaceae) cultures grown in an inorganic seawater medium where bicarbonate provided the sole carbon source and in a sucrose augmented seawater medium. The bioassays were run for 35 days and growth (measured as the development of new nodes) was monitored on a weekly basis. The calculated EC_{50} value for growth of cultures augmented with sucrose was 44.7 mg L^{-1}, compared to 2.5 mg L^{-1} where bicarbonate was the only carbon source. Photosynthetic experiments were also run to compare rates of photosynthesis among cultures exposed to various atrazine concentrations in bicarbonate versus sucrose-based media. Results from the bioassays and the photosynthesis study showed that atrazine decreased growth of *R. maritima*, but that those cultures grown in sucrose-based media were not as strongly affected as those cultures growing on a totally inorganic carbon source. These results suggest that the availability of an alternative carbon source may help *R. maritima* to withstand the inhibitory effects of atrazine.

Introduction

Atrazine (2-chloro-4-ethylamino-6-isopropyl-amino-s-triazine) is one of the most heavily used herbicides in the United States (DeNoyelles 1982). Since its introduction in 1958, atrazine has experienced widespread application as an herbicide for corn (*Zea mays* L.) and *Sorghum bicolor* (L.) Moench (Jones and Winchell 1984). As an inhibitor acting on photosystem II light reactions, it inhibits electron flow (Cobb 1992).

Atrazine loss into the environment due to agricultural run-off may reach up to 18% of the total volume applied; however the average loss is less than 3% (Huber 1993). Atrazine concentrations between 0 and 0.087 mg L^{-1} have been found in the United States, with the majority falling below 0.010 mg L^{-1} (Huber 1993). Photosynthesis in various submerged macrophyte species has been significantly reduced by concentrations as low as 0.005–0.010 mg L^{-1} (Jones and Winchell 1984). It is therefore important to be concerned about the effects of herbicides like atrazine on aquatic environments such as estuaries. Estuaries are among the most important ecosystems, acting as sources, sinks and transformers for several chemical and biological materials, and also functioning to provide habitats for many species of flora (Mitsch and Gosselink 1986).

Seagrasses are important inhabitants of estuaries (Cunningham *et al.* 1984). Inhibitory effects of atrazine have been found on several seagrass species common to estuaries. Photosynthesis of *Zostera marina* L. has been shown to be severely inhibited at concentrations exceeding 0.65 mg L^{-1} (Correll and Wu 1982). During whole plant exposure to 1.9 mg L^{-1} and above, no new plant growth was observed in *Z. marina* (Schwarzschild *et al.* 1994).

Ruppia maritima L. is a seagrass that inhabits brackish waters of bays, rivers and estuaries (Koch and Dawes 1991). This species occurs along the east coast from Newfoundland to Florida, as well as along the west coast, and can also be commonly found throughout North America in inland saline habitats (Verhoeven 1979). Its occurrence in the brackish areas where river run-off occurs make it a vulnerable target for herbicide run-off into estuaries.

Atrazine's effects on *R. maritima* could be mitigated by several factors. First, active benthic and epiphytic microbial flora could contribute to atrazine degradation. Second, recent research indicates that *R. maritima* can grow heterotrophically under *in vitro* culture conditions (Koch and Durako 1991, Bird *et al.* 1993). This raises the question as to whether this species could use organic carbon as an energy source during brief exposures to atrazine.

The null hypothesis of this research was that there would be no differences in atrazine effects on growth of axenic *R. maritima* cultures in a sucrose versus bicarbonate-based medium. Other experiments were conducted to examine the effects of varying sucrose concentrations on growth of atrazine treated plants. The effects of atrazine on photosynthetic rates of plants growing in the two different types of media was also examined.