Assessment of Phytotoxicity of Atrazine Loaded Hydrogels in Maize (*Zea mays* L.)

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Abstract

The sustainable enhancement of agricultural productivity relies on the prudent use of herbicides to control weed competition. However, widespread use of atrazine, a common herbicide, has raised concerns due to its potential environmental contamination and non-target plant phytotoxicity. In this study, we explored the potential of hydrogel-based delivery systems to mitigate atrazine's adverse effects on maize (*Zea mays* L.) plants. We prepared atrazine-loaded hydrogel composites and evaluated their phytotoxicity in comparison to a commercial atrazine formulation. A pot culture experiment with nine treatments and three replications was conducted under a completely randomized design. Phytotoxicity readings were taken at 7 and 15 days after initial irrigation using a scale ranging from 0 to 10. Surprisingly, all treatments, including encapsulated formulations and the commercial atrazine, displayed a phytotoxicity rating of 0, indicating the absence of harmful consequences on maize plants. Visual observations confirmed that the plants remained healthy and green without any injuries. These findings offer promising insights into the potential of hydrogel-based delivery systems as eco-friendly alternatives for atrazine application in sustainable agriculture. Further validation through field trials is warranted to consolidate these promising results.

***Keywords*:** Atrazine loaded hydrogels, Phytotoxicity, Maize

Introduction

Agricultural productivity is a cornerstone of global food security and sustenance of the ever-growing human population. To achieve optimal crop yields, farmers often rely on the use of agrochemicals, including herbicides, to control weeds that compete with crops for resources such as water, nutrients, and light. Atrazine, a widely used herbicide, has been instrumental in enhancing crop productivity by effectively suppressing weed growth. However, its excessive and indiscriminate use had raised concerns due to its potential to cause environmental contamination (Dias *et al*., 2018) and adverse effects on non-target plants, including crops like maize (*Zea mays* L.).

Phytotoxicity refers to the harmful effects of chemicals on plant growth, development, and overall health. In the context of herbicides, it specifically addresses their potential to adversely affect non-target plants. One promising approach to mitigate the environmental impact of herbicides is by incorporating them into eco-friendly and controlled release delivery systems. Hydrogels, three-dimensional networks of hydrophilic polymers (Ho *et al*., 2022), have shown great promise in the controlled release of agrochemicals. Atrazine incorporation into hydrogels can potentially provide a controlled release mechanism for atrazine, reducing its direct contact with the environment and minimizing phytotoxicity.

While the concept of using hydrogel-based composites for controlled release of herbicides holds promise, there is limited research exploring the specific application of atrazine-loaded hydrogel composites in maize cultivation. Addressing this research gap is critical to understanding the potential of this eco-friendly approach in sustainable agriculture. Hence, this research paper aims to contribute to the advancement of sustainable agriculture practices by exploring the potential of hydrogel-based delivery systems for reducing the phytotoxic effects of atrazine on maize plants. The findings of this study can provide valuable insights into the efficacy and safety of using guar gum and cellulose nanoparticles hydrogel composites as carriers for atrazine. By assessing the phytotoxicity of this novel delivery system, we can gain a deeper understanding of its environmental implications and its potential as an eco-friendly alternative to conventional herbicide application methods.

As global concerns about environmental sustainability and food security continue to grow, innovative approaches like hydrogel-based delivery systems offer a promising pathway towards efficient and environmentally responsible agriculture. Understanding the impacts of such novel technologies is crucial for making informed decisions that align with the principles of sustainable development.

Methodology

A pot culture experiment was carried out at Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, India to evaluate the phytotoxicity of encapsulated and commercial atrazine in maize plants. The experiment included nine treatments with three replications laid out on completely randomized design (CRD). The treatments included were three atrazine loaded hydrogel formulations A, B and C, each at the rate of 1.5 and 1.2 kilograms of active ingredient per hectare, commercial atrazine formulation, weed free check and absolute control.

Five maize seeds were sown in each pot and the treatment imposition was done on the same the day while the initial watering of pots was carried out after four days of sowing and treatment imposition. Phytotoxicity readings were taken at 7 and 15 days after initial irrigation (DAI) using a scale ranging from 0 to 10, as described by (Rao, 2000).

Results and Discussion

The results revealed that neither the encapsulated nor the commercial formulation of atrazine caused any observable phytotoxic effects on maize crop. The phytotoxicity ratings obtained from the study are summarized in Table 01, indicating the absence of any harmful consequences on the plants.

Table 01: Effect of atrazine loaded guar gum and cellulose nanoparticles hydrogel composite on the phytotoxicity ranking against 0 to 10 score in maize

Treatments	Phytotoxicity rating	
	7 DAI	15 DAI
T_1: Pre-emergence application of atrazine formulation (A) @ 1.5 kg a.i.ha^{-1}	0	0
T_2: Pre-emergence application of atrazine formulation (A) @ 1.2 kg a.i.ha^{-1}	0	0
T_3: Pre-emergence application of atrazine formulation (B) @ 1.5 kg a.i.ha^{-1}	0	0
T_4: Pre-emergence application of atrazine formulation (B) @ 1.2 kg a.i.ha^{-1}	0	0
T_5: Pre-emergence application of atrazine formulation (C) @ 1.5 kg a.i.ha^{-1}	0	0
T_6: Pre-emergence application of atrazine formulation (C) @ 1.2 kg a.i.ha^{-1}	0	0
T_7: Pre-emergence application of commercial atrazine @ 1.5 kg a.i.ha^{-1}	0	0
T_8: Weed free check	-	-
T_9: Absolute control	-	-

It can be observed from the data provided and Plate 01, that no phytotoxic symptoms were reported with the application of encapsulated formulations and commercial atrazine. The plants were found to be green and healthy without any injury. This might be due to differential metabolism of maize for atrazine herbicide, where it was noticed that lesser translocation of atrazine in maize crop. Maize plants comprises of detoxification or sequestration of herbicide within the plant, preventing it from causing damage to sensitive plant tissues. Atrazine primarily acts by inhibiting photosynthesis in susceptible plants. Maize has a different target site for atrazine compared to the susceptible weed species, making it less affected by the herbicide's mode of action. Maize can metabolize atrazine faster than many weed species, reducing its negative effects. The herbicide might be broken down into less toxic compounds there by showing no symptoms of phytotoxicity (Hatti *et al*., 2014; Moinuddin *et al*., 2018;).

Plate 01: Pot culture experiment carried out showing no phytotoxicity symptoms on maize

Conclusion:

To conclude, the use of atrazine loaded guar gum and cellulose nanoparticles-hydrogel composite formulations, as well as the conventional commercial atrazine, did not result in any detrimental effects on maize plants in this pot culture experiment. These findings highlight the potential of hydrogel-based delivery systems in mitigating the phytotoxicity associated with atrazine application. Further studies and field trials should be conducted to validate these results under real-world agricultural conditions.

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