# Is Atrazine Impacting Fish in Lake Champlain: An Assessment

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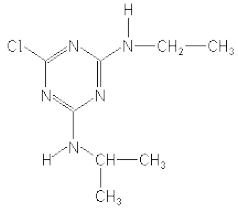
# Overview

- Atrazine is a widely used herbicide in corn
- Corn is grown in Lake Champlain watershed
- Concern has been raised that atrazine in Lake Champlain watershed may be impacting fish populations
- Two potential mechanisms by which fish impacts could occur
  - Direct toxicological effects to fish
  - Indirect effects to the environment on which fish depend, i.e., effects on habitat and food
- In this presentation
  - Safe level for fish
  - Safe level for algae and plants
  - Compare safe levels to available monitoring data in L. Champlain to determine if there is a potential concern
  - Benefits of atrazine to farmers


ATRAZINE

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# Toxicity to Fish

- According to EPA's preliminary assessment
  - Not toxic to fish during short-term exposures, i.e., most sensitive study: 4-day LC50 = 5,300 μg/L (parts per billion) for rainbow trout
  - Levels are orders of magnitude higher than observed in ponds in high use areas
  - Long-term exposures: EPA contends that most sensitive no observed effects level (NOEL) is 5 μg/L based on Japanese medaka study by Papoulias et al. (2014)
  - Study however is deeply flawed, i.e., did not follow accepted test protocol, high mortality and poor reproduction in no exposure treatments, unorthodox sex ratio
  - EPA's own reviewers gave the study a poor rating
  - New medaka study conducted according to accepted OECD test protocol and good laboratory practice (Schneider et al., 2015) found no effects at highest test concentration of 53 μg/L
  - EPA determined that the Schneider et al. (2015) study is scientifically sound
- Safe level for fish reproduction during long-term exposures is >53 μg/L
- Van der Kraak et al. (2014) published weight of evidence assessment that concluded, "atrazine does not adversely affect fish, amphibians, and reptiles at concentrations that are present in surface waters"

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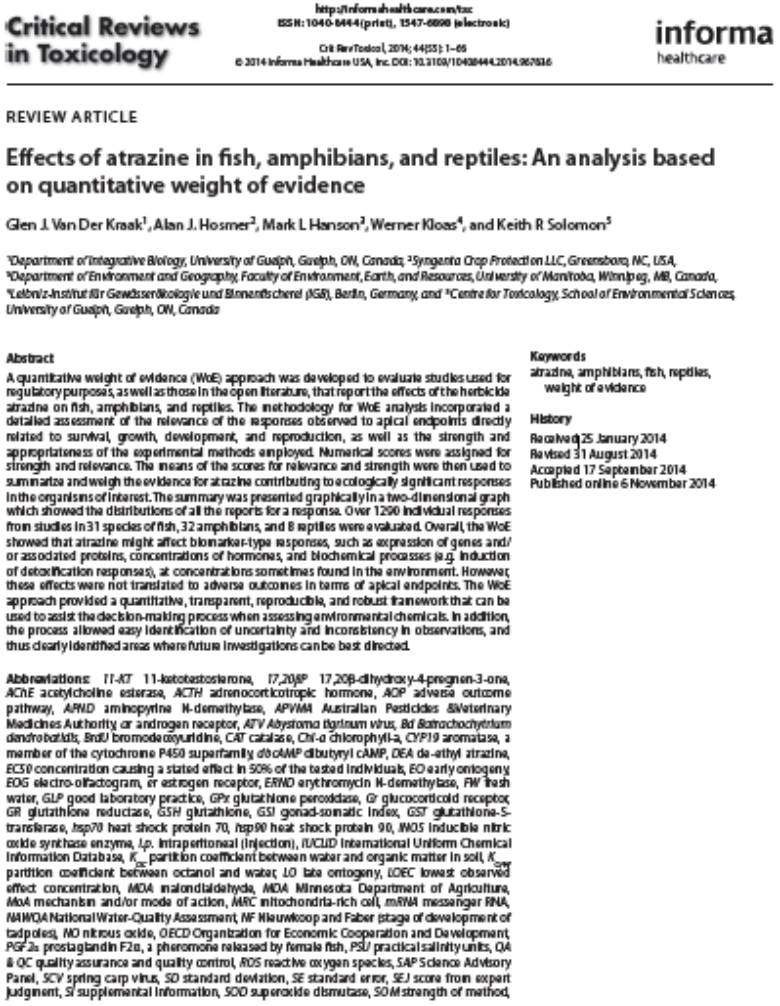
# Endocrine Disruption

- Van der Kraak et al. (2014) found very limited evidence that atrazine is an endocrine disruptor in fish
- Effects on reproductive hormones did not translate to effects on survival, growth, development and reproduction
- Although intersex observed in bass in Lake Champlain watershed (Iwanowicz et al. 2015), causes unknown (possibly effluents from paper mill, WWTP and/or animal operations; agrochemicals, etc)



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REVIEW ARTICLE

## Effects of atrazine in fish, amphibians, and reptiles: An analysis based on quantitative weight of evidence

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**Abstract**

A quantitative weight of evidence (WoE) approach was developed to evaluate studies used for regulatory purposes, as well as those in the open literature, that report the effects of the herbicide atrazine on fish, amphibians, and reptiles. The methodology for WoE analysis incorporated a detailed assessment of the relevance of the responses observed to apical endpoints directly related to survival, growth, development, and reproduction, as well as the strength and appropriateness of the experimental methods employed. Numerical scores were assigned for strength and relevance. The means of the scores for relevance and strength were then used to summarize and weigh the evidence for atrazine contributing to ecologically significant responses in the organisms of interest. The summary was presented graphically in a two-dimensional graph which showed the distributions of all the reports for a response. Over 1290 individual responses from studies in 31 species of fish, 32 amphibians, and 8 reptiles were evaluated. Overall, the WoE showed that atrazine might affect biomarker-type responses, such as expression of genes and/or associated proteins, concentrations of hormones, and biochemical processes (e.g. induction of detoxification responses), at concentrations sometimes found in the environment. However, these effects were not translated to adverse outcomes in terms of apical endpoints. The WoE approach provided a quantitative, transparent, reproducible, and robust framework that can be used to assist the decision-making process when assessing environmental chemicals. In addition, the process allowed easy identification of uncertainty and inconsistency in observations, and thus clearly identified areas where future investigations can be best directed.

**Keywords**
atrazine, amphibians, fish, reptiles, weight of evidence

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**Abbreviations:** *11-KT* 11-ketotestosterone, *17,20βP* 17,20β-dihydroxy-4-pregnen-3-one, *AChE* acetylcholine esterase, *ACTH* adrenocorticotropic hormone, *AOP* adverse outcome pathway, *APND* aminopyrine N-demethylase, *APVMA* Australian Pesticides &Veterinary Medicines Authority, *ar* androgen receptor, *ATV Abystoma tigrinum virus*, *Bd Batrachochytrium dendrobatidis*, *BrdU* bromodeoxyuridine, *CAT* catalase, *Chl-a* chlorophyll-a, *CYP19* aromatase, a member of the cytochrome P450 superfamily, *dbcAMP* dibutyryl cAMP, *DEA* de-ethyl atrazine, *EC50* concentration causing a stated effect in 50% of the tested individuals, *EO* early ontogeny, *EOG* electro-olfactogram, *er* estrogen receptor, *ERND* erythromycin N-demethylase, *FW* fresh water, *GLP* good laboratory practice, *GPx* glutathione peroxidase, *Gr* glucocorticoid receptor, *GR* glutathione reductase, *GSH* glutathione, *GSI* gonad-somatic index, *GST* glutathione-S-transferase, *hsp70* heat shock protein 70, *hsp90* heat shock protein 90, *iNOS* inducible nitric oxide synthase enzyme, *i.p.* intraperitoneal (injection), *IUCLID* International Uniform Chemical Information Database, $K_{oc}$ partition coefficient between water and organic matter in soil, $K_{ow}$ partition coefficient between octanol and water, *LO* late ontogeny, *LOEC* lowest observed effect concentration, *MDA* malondialdehyde, *MDA* Minnesota Department of Agriculture, *MoA* mechanism and/or mode of action, *MRC* mitochondria-rich cell, *mRNA* messenger RNA, *NAWQA* National Water-Quality Assessment, *NF* Nieuwkoop and Faber (stage of development of tadpoles), *NO* nitrous oxide, *OECD* Organization for Economic Cooperation and Development, *PGF2α* prostaglandin F2α, a pheromone released by female fish, *PSU* practical salinity units, *QA & QC* quality assurance and quality control, *ROS* reactive oxygen species, *SAP* Science Advisory Panel, *SCV* spring carp virus, *SD* standard deviation, *SE* standard error, *SEJ* score from expert judgment, *SI* supplemental information, *SOD* superoxide dismutase, *SOM* strength of method,

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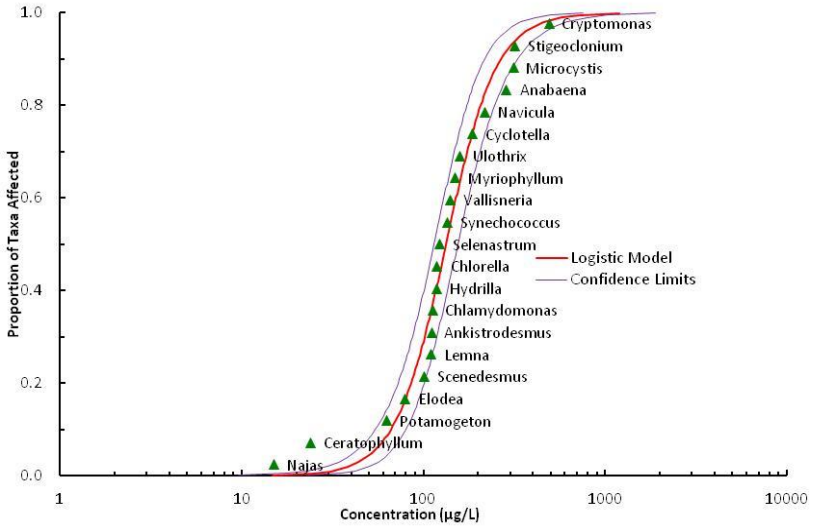
# Toxicity to Aquatic Plants

- Considerable toxicity data exist for aquatic plant communities exposed to atrazine
  - >100 treatments in plant community studies (i.e., mesocosm studies)
  - New mesocosm study from Baylor Experimental Aquatic Research (BEAR) Facility recently completed and published (King et al. 2016)
- Large number of single species studies also available
  - At least 21 genera of algae and aquatic macrophytes have been tested
- US Environmental Protection Agency (EPA) recently proposed that a 60-day average Level of Concern (LOC) of 3.4 μg/L is protective of plant communities
- EPA's LOC, however, is overly conservative
  - Relied on studies declared as unacceptable by EPA's own Scientific Advisory Panels
  - Did not account for rapid recovery of plant communities

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# Weight of Evidence Approach to Derive Aquatic Plants LOC

| Method | LOC (µg/L) | Weight of Evidence Score (/15) |
|---|---|---|
| EPA Approach (Revised Dataset) | 25 | 9 |
| Community Model | 18 | 11 |
| Mesocosm Data | 25 | 6 |
| Single Species Toxicity Tests | 26 | 9.67 |

*Weighted LOC of 23 µg/L supported by results from recent Baylor mesocosm study*

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Health & Ecological Risk Assessment

## A Weight-of-Evidence Approach for Deriving a Level of Concern for Atrazine that Is Protective of Aquatic Plant Communities

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ABSTRACT

Atrazine is a selective triazine herbicide widely used in the United States primarily for control of broadleaf weeds in corn and sorghum. In 2003, the US Environmental Protection Agency (USEPA) concluded that atrazine poses potential risks to sensitive aquatic species. Consequently, a surface water monitoring program was developed to assess whether measured levels of atrazine could impact aquatic plants in vulnerable watersheds. To facilitate evaluation of the monitoring data, the Agency needed to establish a level of concern (LOC) below which atrazine would not cause unacceptable adverse effects to aquatic plant communities. Several attempts at developing a community-level LOC have followed from USEPA but none have been formally accepted or endorsed by independent Scientific Advisory Panels. As part of registration review, the USEPA needs to revisit development of a community-level LOC for atrazine that will be protective of aquatic plant communities. This article reviews 4 methods that can or have been used for this purpose. Collectively, the methods take advantage of the large number of single species and mesocosm studies that have been conducted for aquatic plants exposed to atrazine. The Plant Assemblage Toxicity Index (PATI) and the Comprehensive Aquatic Systems Model for atrazine ($CASM_{ATZ}$) incorporate single-species toxicity data but are calibrated with micro- and mesocosm study results to calculate community-level LOCs. The Brock et al. scoring system relies exclusively on mesocosm studies. Single-species toxicity data were used in a modified version of the USEPA's Water Quality Criteria (WQC) method. The 60-day LOCs calculated using the 4 methods ranged from 19.6 to 26 µg/L. A weight-of-evidence assessment indicated that the $CASM_{ATZ}$ method was the most environmentally relevant and statistically reliable method. Using all 4 methods with weights based on method reliability, the weighted 60-day LOC was 23.6 µg/L. *Integr Environ Assess Manag* 2017;00:000–000. © 2016 SETAC

Keywords: Atrazine Level of concern Mesocosm Aquatic plants

INTRODUCTION

Atrazine is a selective triazine herbicide widely used in the United States for pre- and early postemergent control of many broadleaf and grass weeds in corn, sorghum, sugarcane, and other row and field crops. All pesticides sold or distributed in the United States must be registered by the US Environmental Protection Agency (USEPA). The registration process is governed by the Federal, Insecticide, Fungicide, and Rodenticide Act (FIFRA). The Food Quality Protection Act (FQPA) further requires that registered pesticides undergo reregistration to account for changes in science, policy, and pesticide use practices. Thus, the USEPA is required to re-evaluate previously registered pesticides every 15 years. During reregistration in 2003, the USEPA concluded that atrazine poses potential risks to sensitive aquatic plant species, which are defined to include all types of algal and macrophyte species. The USEPA further concluded that such effects from atrazine use could occur at the population and community levels of organization.

As a condition of reregistration, the USEPA required registrants (i.e., atrazine producers) to develop a monitoring program to determine exposure profiles for atrazine in intensive corn and sorghum production areas. The monitoring program was designed to generate atrazine exposure profiles over time (i.e., chemographs) for several small and highly vulnerable Midwestern watersheds (typically 23–104 $km^2$). The watersheds reflected the upper 20th centile of potential atrazine runoff vulnerability (Brain et al. 2012a). To facilitate evaluation of the monitoring data, the USEPA needed to determine a level of concern (LOC) below which

This article includes online-only Supplemental Data.

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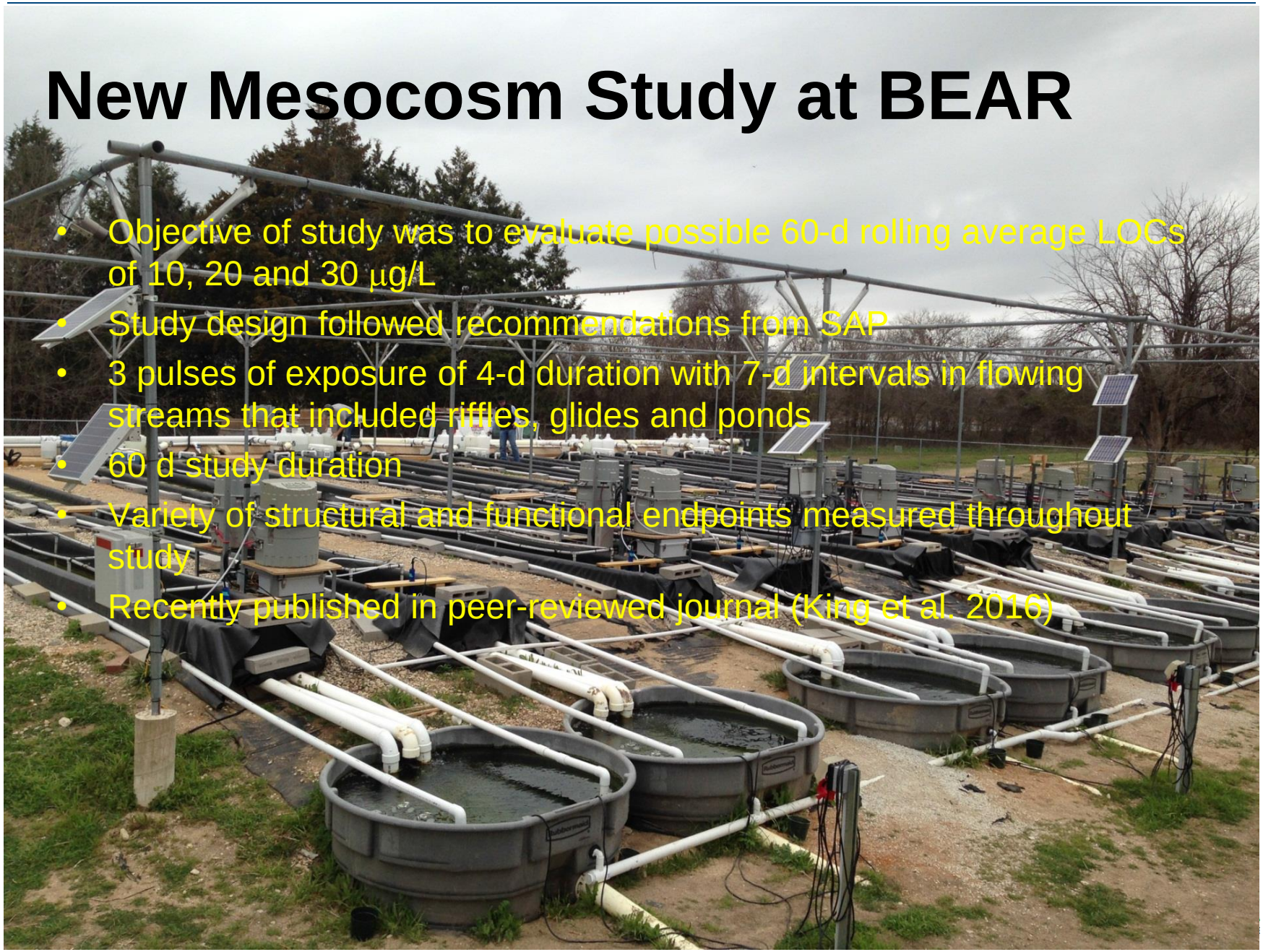
# New Mesocosm Study at BEAR



- Objective of study was to evaluate possible 60-d rolling average LOCs of 10, 20 and 30 μg/L
- Study design followed recommendations from SAP
- 3 pulses of exposure of 4-d duration with 7-d intervals in flowing streams that included riffles, glides and ponds
- 60 d study duration
- Variety of structural and functional endpoints measured throughout study
- Recently published in peer-reviewed journal (King et al. 2016)

# Baylor Mesocosm Study Results

- Minor effects at highest treatment level (60-day average = 30 μg/L)
  - Only minor impacts on function
  - Rapid recovery following cessation of exposure
  - No significant impacts on community structure
  - No effects at next highest treatment level (60-day average = 20 μg/L)
- Supports aquatic plants LOC of 23 μg/L derived by Moore et al. (2017)

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# Atrazine Does Not Pose a Significant Risk to Fish in Lake Champlain Area

- Targeted monitoring results in surface waters of Lake Champlain and major tributaries (2001-16)
  - # sites = 36, # samples = 950
  - 920 samples (97%) < 1 μg/L (ppb)
  - 940 samples (99%) < 3 μg/L
  - Only 10 samples (1%) > 3 μg/L
  - 60-day averages would be much lower than above results
- Direct effects to fish
  - No concern for short-term effects
  - Observed levels well below most sensitive chronic NOEC of >53 μg/L from a scientifically defensible study
  - Nearly all samples also below EPA's most sensitive NOEC of 5 μg/L which was based on a poor quality study
- Indirect effects to fish
  - No exceedances of Weight of Evidence LOC of 23 μg/L
  - Only 1% exceedance of EPA's hyperconservative LOC of 3.4 μg/L

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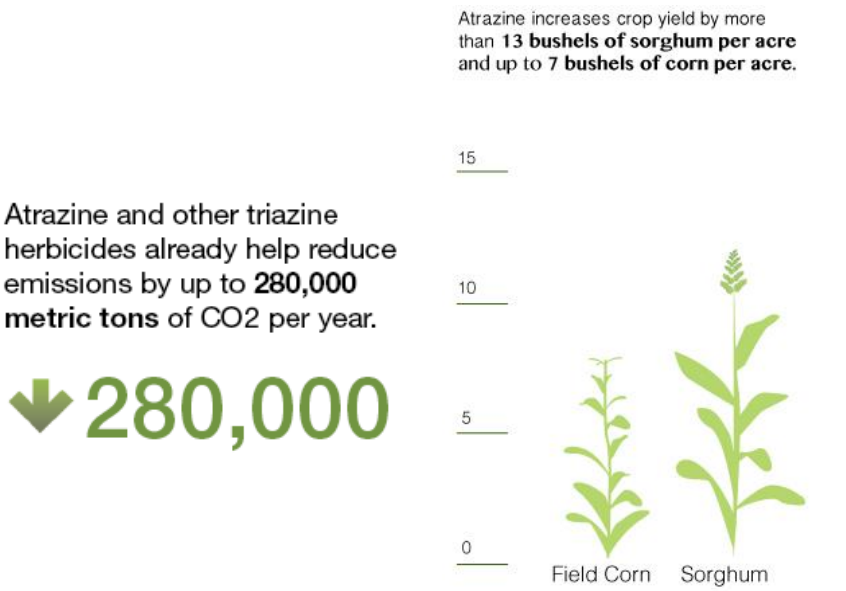
# Atrazine is Important to Farmers and Consumers

- More than 400,000 U.S. corn, sorghum and sugar cane growers depend on atrazine
- Atrazine is used for weed control on over half of US corn acres
- Atrazine saves U.S. farmers up to $3.3 billion and consumers up to $4.8 billion each year
- Farming without atrazine would cost corn growers up to $30 to $59 per acre
- Atrazine increases crop yields and reduces soil erosion
- Atrazine is an important tool for weed resistance management





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