Global Greenchem
Innovation & Network Program

Commercializing an Alternative Pest Control Technology

Key Concepts- Greener Synthetic Pathways, Greener Reaction Conditions, Design of Less Hazardous Chemicals, Systems Thinking, Source Reduction

Instead of designing a pesticide that kills insects, they shrank the problem at its source.

Central Problem

The fall armyworm (*Spodoptera frugiperda*) is an invasive pest that feeds on more than 80 plant species such as rice, sugarcane, cotton and corn. Corn is a critical food source for a substantial portion of the world's population, particularly in Mexico, Africa, and Asia. These pests can significantly reduce corn crop yields which can threaten food security.

The fall armyworm lifecycle averages 31 days. This cycle timeline allows for a number of generations of the pest during the growing seasons. For this reason and due to insecticide misuse, this pest has become resistant to many insecticides.

In addition to insecticide resistance, there have been many pesticides whose use result in damage to non-targeted species and/or negative impacts to human health and the environment.

There are alternative pest control technologies but they are frequently cost prohibitive.

Scaling of an innovative solution by improving efficiencies

The use of insect pheromones to control certain phases of the lives of pest species is an alternative method of pest management that has been used to protect high-value crops such as fruits, vegetables and nuts. Sex pheromones are relatively species specific and elicit behavioral or physiological reactions. They can be used to control insect populations by confusing the insects resulting in missed mating opportunities resulting in a decrease or elimination of the next generation of larvae pests. Using this method reduces reliance on conventional pesticides while improving the populations of beneficial insects, including pollinators.

A challenge to the adoption of this alternative pest control technology, especially among lower-value row crops such as corn, cotton and soybeans, is the high cost of the conventional synthesis of the pheromones. Conventional pheromone syntheses have traditionally used technologies such as Wittig olefination or Grignard Kumada cross-coupling reactions requiring dilute reaction conditions to control reagent solubilities or to control excessive heat generated in these reactions.

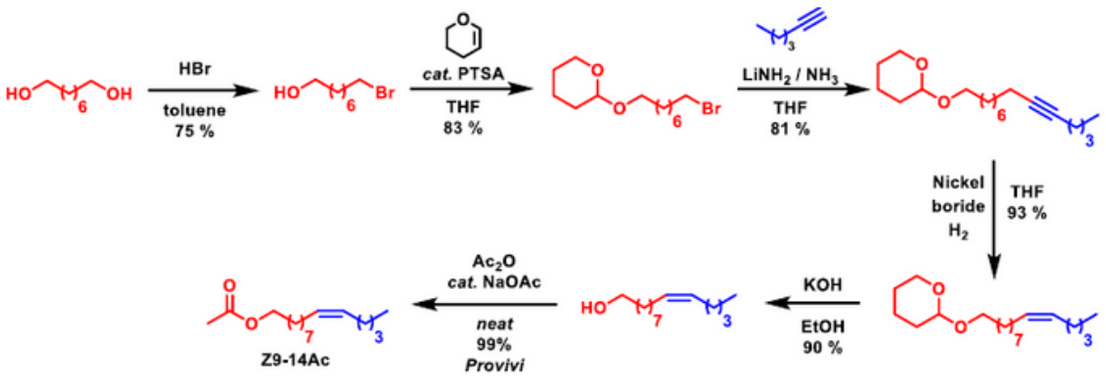

Figure 1: A representative conventional synthesis of Z9-14Ac. (from the EPA Green Chemistry Award application)

To address this cost/efficiency challenge, several bio-based methods of pheromone production have been researched. One of the organizations that has researched and commercialized their technology is Provivi, a company headquartered in the United States.

Provivi's technology uses low cost renewable plant oils to produce pheromones and synthesize the pheromones using optimized biocatalysts (via fermentation and olefin metathesis). Their synthesis of Z9-14Ac is depicted in Figure 2.

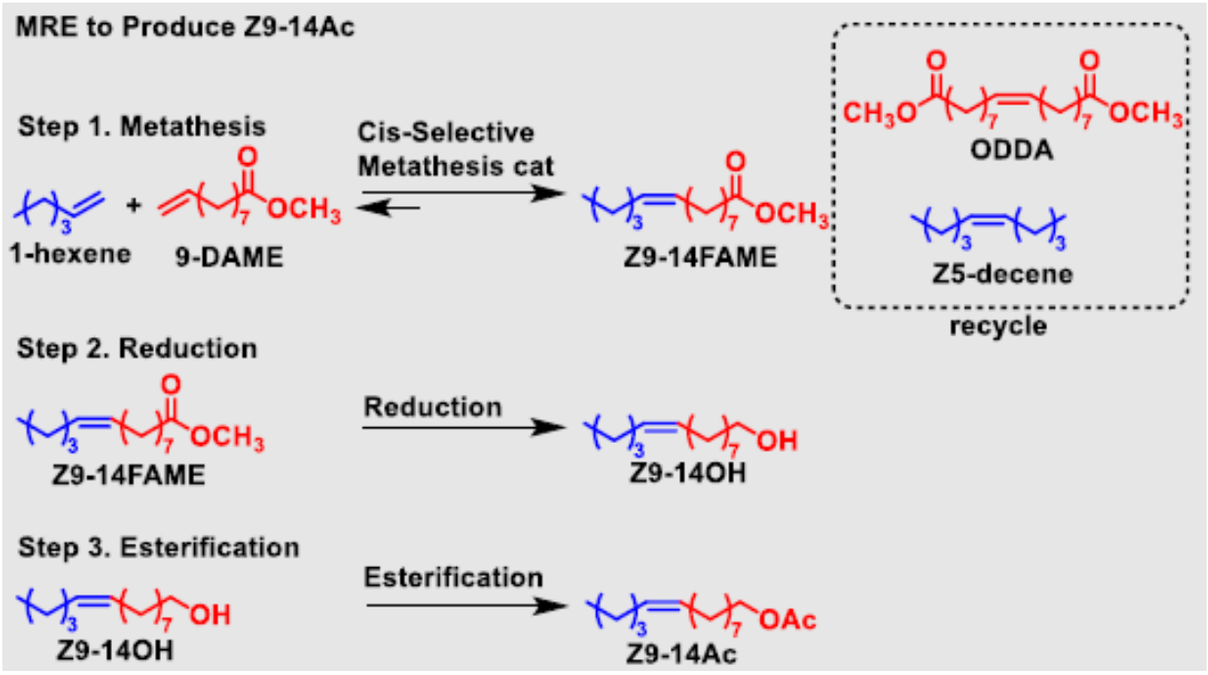

Figure 2: Provivi's synthesis of Z9-14Ac by cis-selective metathesis. (from the EPA Green Chemistry Award application)

The improvements to the synthesis result in many-fold decreases in aqueous, solid and organic waste generation and the number of reaction steps, raw materials and organic solvents needed. A comparison of the reduced waste and reaction steps for their processes compared to convention synthetic processes is in Table 1.

Synthesis Waste Streams and Steps	*Conventional*		*Metathesis*	*Fermentation*	Conventional Avg.	Met & Ferm Avg.
	Z9-14Ac	Z11-16Ac	Z9-14Ac	Z11-16Ac		
Aqueous waste (L)	55	57	2	38	56	14
Organic waste (L)	69	36	2	2	58	2
Solid waste (Kg)	6	3	0	0	5	0
No. of Rxn Steps	6	6	3	4	6	3
No. of Raw Materials	20	20	7	9	20	8
No. of Organic Solvents	6	6	0	2	6	1

Table 1: A comparison of the reduced waste and reaction steps for the Provivi processes compared to convention synthetic processes (Table is from the EPA application).

Provivi produced 100 metric tons of insect pheromones in 2021, representing approximately 25% of the world's production of pheromones and received product registrations for its fall armyworm-controlling pheromone products in the United States, Mexico, Brazil, and Kenya. They continue to collaborate with other companies to scale the availability of their products around the world.

This technology was an EPA Green Chemistry award winner in 2022.

Supplemental Information

Video:
https://www.youtube.com/watch?v=bOou_xL0LQU

Additional Materials:

- Brazil - https://www.provivi.com/br
- Mexico - https://www.provivi.com/mx
- United States - https://www.provivi.com/en
- Green Chemistry Challenge: 2022 Small Business Award
- Wang, HL., Ding, BJ., Dai, JQ. et al. Insect pest management with sex pheromone precursors from engineered oilseed plants. Nat Sustain 5, 981–990 (2022).
- Did you know that the lack of cost-effective, large-scale methods to synthesize insect pheromones is limiting the growth of pheromone market?