**Sulfoxaflor Use in Arizona Cotton**

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*Introduction*

To enable contemporaneous evaluation of our systems so that we can constantly and progressively adjust and adapt our research and Extension approach, we maintain two major databases: Cotton Pest Losses & Impact Assessment database (CPL) and the Arizona Pest Management Center Pesticide Use Database (APMC-PUD). The CPL engages stakeholders directly in an annual series of workshops and intensive surveys of user behaviors and practices related to insect and weed management, pest losses, and pest management costs. The APMC-PUD information resource is harvested from Arizona Department of Agriculture through cooperative agreements with that agency. These data are ingested in a raw form by our database and then extensively vetted, corrected and improved by our staff. Without such processing, these data would be of very limited value because they are prone to errors that impact their accuracy and utility. We invest and leverage many resources to produce these databases so that they are usable for queries of interest and value to Arizona's cotton producers.

We endeavor to produce robust systems of assessment that detail economic, environmental and human health hazards and risks of pests and pest management tactics. We maintain two critical resources, the APMC Pesticide Use Database (APMC-PUD) and the Cotton Pest Losses and Impact Assessment database (CPL), both extending information on pests and pest control practices back > 30 years. Each depends on the contemporaneous collection, vetting and correction of incoming data funded under this project. In addition to the PIs, we invest two full-time staff in data acquisition, correction and maintenance functions.

***Cotton Pest Losses and Impact Assessment Database (CPL)***

In 2022, we had 31 Arizona participants (plus additional California pest managers and guests) in four virtual workshops, each 4.5 h in duration. Over 71,000 acres of upland cotton were reported into our database or 61.5% of Bt cotton planted in 2021. Of the 839 acres of non-Bt upland cotton acreage grown in 2021 zero acres were surveyed. Based on participants and not acres, our response rates are also high. We estimate that there may be as many as 63 pest control advisors in Arizona that check cotton, though this is likely an over-estimate. Therefore about 49% of all pest control advisors participated in this annual workshop and survey process, representing >60% of acres.

In our survey, we are estimating behaviors and outcomes for the entire cotton acreage in Arizona. With acreage response rates well over 40% each year (>60% in 2021), we obtain a robust set of information that guides our inferences. However, we endeavor to protect against sample bias but enforcing leverages by survey to shape our final estimates of Arizona cotton data. We do this by first considering the acreages represented in each survey as a proportion of the acreage in the County or Counties on which they are reporting. In past years, our sample was very representative of the distribution of acres across the state. For 2021, the sample was skewed, and the leverages were important to adjusting for those imbalances.

Lygus and whiteflies were targeted in 2021 by 82% of the total sprays made against arthropods in Arizona cotton (83%, 2015–2020). Whiteflies are the number one quality-limiting pest. Lygus bugs are the number one yield-limiting pest. Together, they were responsible for 89% of the arthropod related yield loss in 2021, which stood at 5%. A statewide average of 1.87 sprays were required to control arthropods. The 16-year statewide average is 2.06 ± 0.2 sprays for all arthropod pests. Over 22% of the state's upland cotton acreage did not receive a foliar spray for arthropod pests in 2021. Pest Control Advisors cited slightly lower to similar insect pressure than the previous year.

***Arizona Pest Management Center Pesticide Use Database (APMC-PUD)***

The APMC Pesticide Use Database, developed in partnership with the Arizona Department of Agriculture, now contains 31 years of agricultural pesticide use reports along with data from other sources. The database currently stores information from well over 1 million pesticide applications and over 2,100 products. It has become a vital tool in the assessment of IPM, enhancing our capacity to track changes in pesticide usage over time and adoption of new technologies. Along with CPL information, this database is used to conduct IPM assessment research, develop data for Extension presentations and publications, and to support pesticide registrations needs in Arizona, including registration review.

Arizona does not require 100% use-reporting like California. As such, the PUD is also a sample of pesticide use behaviors. However, prior studies have shown it to be very representative of overall industry trends, especially for cotton insecticide use. The opportunities to support the cotton industry with this information are many.

***Successes in Cotton IPM***

Through the data resources and understanding developed under this project, we have helped achieve and/or document success in the Arizona's cotton arthropod IPM system.

1. A historic achievement in 2021, Arizona cotton growers sprayed whiteflies fewer times than at any other time in the history of this invasive pest (32 years). Growers averaged 1.87 sprays for all arthropod pests, of which ca. 0.33 directed against whiteflies and 1.2 directed against Lygus on a statewide basis. More than 22% of the state's upland cotton acreage did not receive a foliar spray for arthropod pests in 2021.
2. Natural enemy populations were at extraordinarily high levels in our study sites and elsewhere in 2021. Usage of fully selective insecticides that are safe to non-target arthropods, and subject of our research and teaching, is at an all-time high percentage of sprays made (85% over the last two years).
3. Insecticides in use to control our two key pests are dominated by fully selective options. 95% and 94% of all sprays made for whiteflies and Lygus, respectively, are fully selective and safe to the beneficials in the system. These insecticide use practices better support conservation biological control and greatly reduce grower's costs while reducing risks of pest damage and costly secondary pest problems.
4. While a formal comprehensive analysis has not been performed since 2017 (Ellsworth et al. 2017), we know that cotton growers in Arizona have cumulatively prevented more than 35,000,000 lbs of insecticide active ingredient from entering the environment while saving more than $600,000,000 since 1996. Broad spectrum and broadly toxic insecticides in use in cotton are down more than 96.9% since the early 1990s; all insecticide use is down more than 80%. Over the last 16 years (the 'post-selective' period), we have exceptionally low insecticide use in cotton, spraying less than 2.06 ± 0.2 times all season long (1.87 times in 2021), mainly with very targeted and selective compounds that are safe to beneficials. In 2021, growers sprayed for whiteflies fewer times than any other time in history since this invasive pest entered Arizona (32 years; 0.33 sprays per acre). More than 22% of Arizona's cotton acreage is never sprayed foliarly for insects, and pink bollworm and boll weevil have been eradicated from Arizona. The economic benefits continue to grow, with historic lows in the costs of foliar insecticide investment by Arizona growers in cotton. Pest managers and growers of cotton in this state have accomplished a great thing, stability in the cotton agroecosystem that is almost unparalleled around the world.

***Questions from Don Parker of the National Cotton Council***

A series of questions about sulfoxaflor use in cotton were posed by Don Parker (6/23/22, Pers. Comm.):

1. **What is the Maximum single use rate actually used in your state?**

The maximum single use rate in Arizona cotton is stipulated by label at 2.25 oz per acre of Transform. On rare occasions of exceptional pest pressure, growers have used this maximum rate, 2.25 oz per acre.

2. **What is the minimum single use rate actually used in your state?**

With Lygus bugs as the target, the lowest use rates hover around 1.5 oz per acre of Transform.

3. **How many applications are typically made in your state?**

**Max number:** 3

**Min number:** 1

**Average:** Approximately 0.6–0.9

**Explanatory comments:** While it is rare, we have seen as many as three applications of Transform made usually under extraordinarily high pest conditions. Again in rare instances, an additional spray to reach 3 total is made due to a "miss". These misses are due either to rainfall immediately after a spray or due to some other unspecified applicator error that results in sub-par performance. Up to 4 applications are permitted on the label, but we are unaware of anyone deploying 4 applications of Transform. With 2021 data as an example, 1 and 2 sprays are major modalities where Transform is used (see Figure 8).

For average number, we know that in general growers have sprayed Lygus 1.2 to 1.6 times per season over the last several years (for 2021, see Figure 1 and for all years see Figure 2). In general, growers rotate their sprays between Transform and Carbine, the two accounting for >95% of all Lygus-targeted sprays. In our sampling, these two products about split the market with half of the sprays being Transform and half being Carbine (see Figure 7). Thus, on average, 0.6–0.9 sprays are deployed against Lygus, noting that this includes all acres such as those that are not sprayed for Lygus at all.

4. **What is the target pest in your State?**

*Lygus hesperus*, secondarily *Lygus lineolaris* and *Pseudatomoscelis seriatus* (cotton fleahopper).

5. **What percent of the applications are made:**

a. **By aerial applications**

About 80%

b. **By ground equipment**

About 20%

**Explanatory comments:** Because our data are not complete and 100% use reporting is not required in Arizona, application modalities are estimates based on user interviews and cotton pest losses data. However, most of our cotton acreage is furrow irrigated. Once canopies close, most acreages are inaccessible by ground. Aerial application is required in our system.

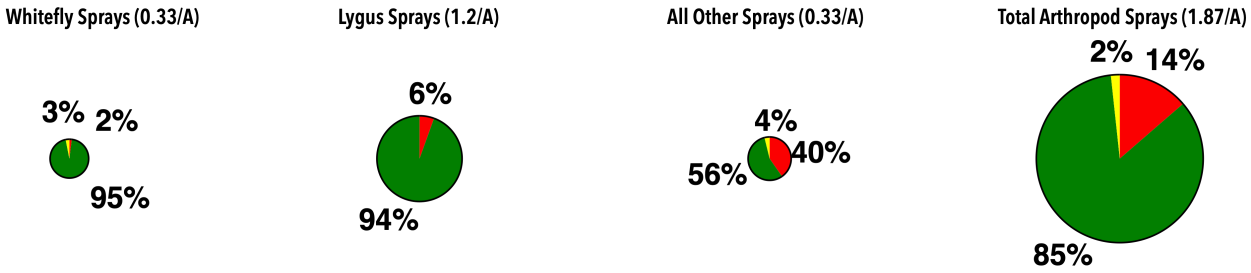


**Figure 1.** Percentage of sprays made in 2021 that are fully, partially, or non-selective (green, yellow, red, respectively) by pest and overall insecticide sprays. Pies are scaled to the number of sprays made. This is the lowest number of sprays made against whiteflies in history (0.33/A). The percentage adoption of fully selective insecticides is at a high-water mark in 2020–2021, reflecting advances in industrial development as well as in the conduct of this project. Source: *Cotton Pest Losses Database*

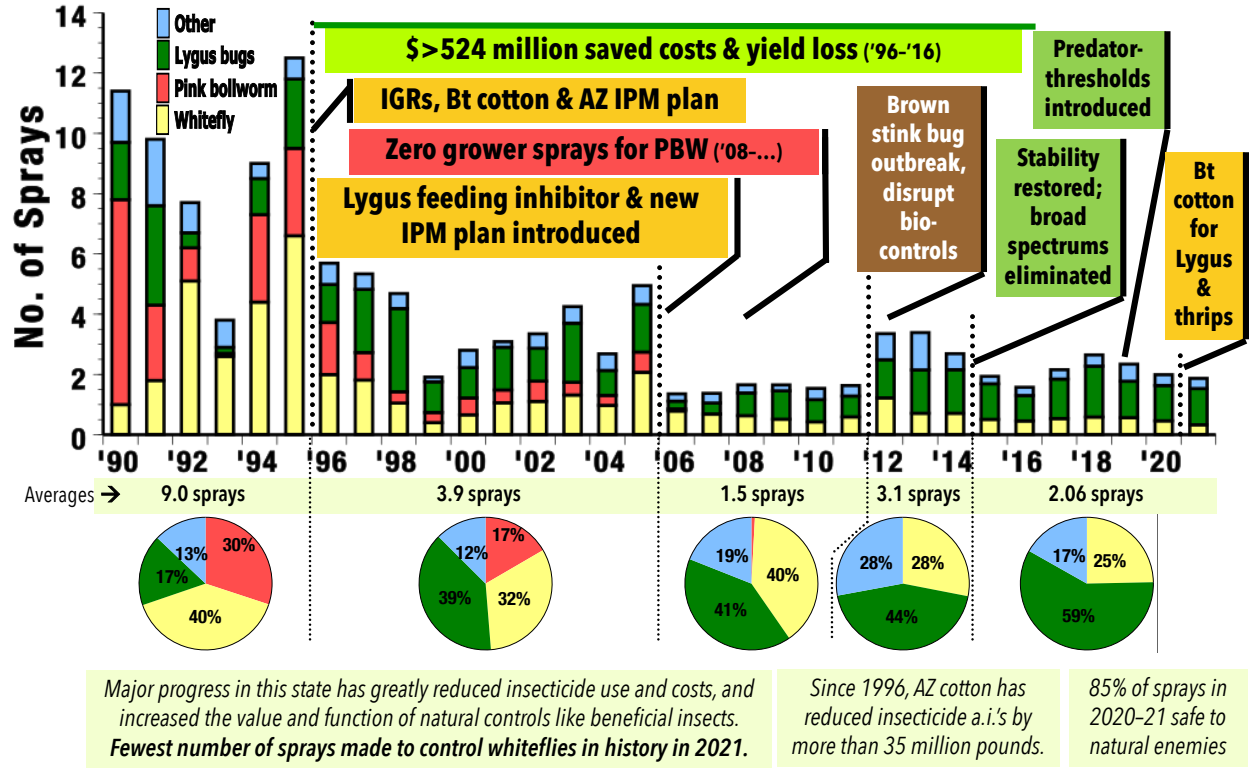


**Figure 2.** Average number of sprays made statewide by Arizona cotton growers to control insect and other arthropod pests. Lygus and whiteflies are targeted by 84% of the total sprays made against arthropods in Arizona cotton (2015–2021). Whiteflies are the number one quality-limiting pest. Lygus bugs are the number one yield-limiting pest. 2021 continues a trend towards fewer sprays to control arthropods. The 16-year statewide average is 2.06 ± 0.2 sprays for all arthropod pests. Source: *Cotton Pest Losses Database*, Ellsworth, unpubl. A new era of biological control was introduced in 2019 with the teaching of eight new predator thresholds for whitefly management. By capturing these data contemporaneously, we can examine the impact of new insect control technologies like new Bt cottons that target Lygus and thrips (2021).

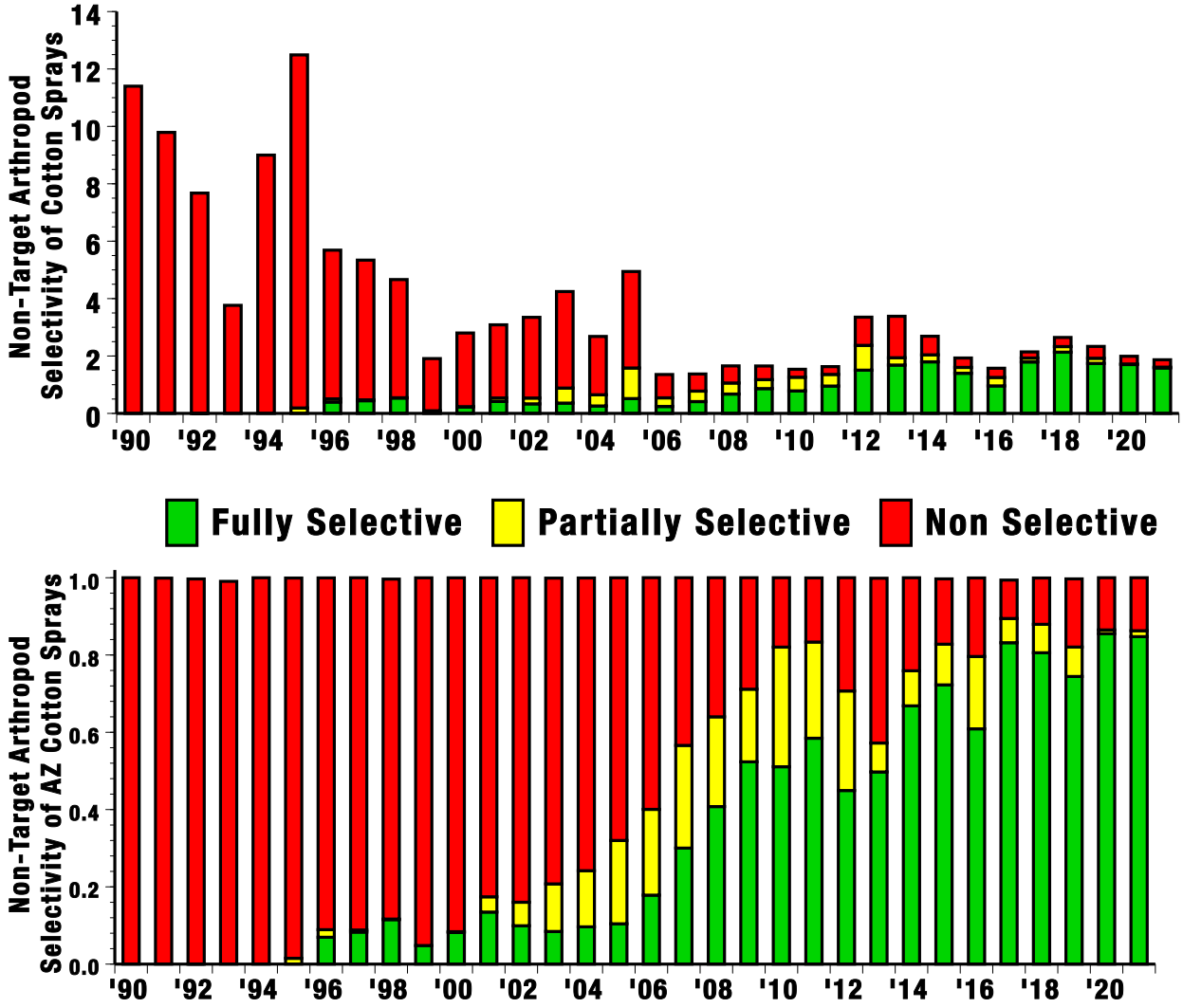


**Figure 3.** Longitudinal analysis of cotton insecticide use (actual spray frequency, above, and proportional use, below), as in Figure 2 but with each bar depicting proportion of sprays made that are fully (green), partially (yellow) or non-selective (red). The putative selectivity shows a dramatic shift toward higher selectivity to non-target arthropods in Arizona in recent years. There are concomitant reductions in spray frequencies, increases in safety towards predators that support conservation biological control, and large savings to growers (Ellsworth et al. 2017). However, when growers use non-selective insecticides, increased spraying results in significant losses. For example, in 2012–2014, as rates of non-selective insecticide use increased in Arizona to cope with a brown stink bug outbreak, the frequency of spraying doubled because of lost biological control of whiteflies, mites, and aphids. Source: *APMC Pesticide Use Database*, Ellsworth & Fournier, unpubl.

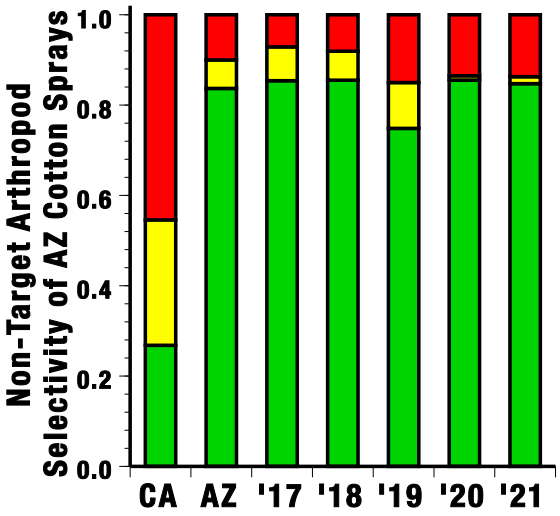


**Figure 4.** Comparison of measurement systems, here depicting proportional use of fully (green), partially (yellow) or non-selective (red) insecticides through time and location. CA, 2017 use pattern in California cotton based on a census of all insecticides used there. AZ, 2017 use pattern in Arizona cotton based on a survey sample of all insecticides reported to the State. '17–'21, Use patterns for Arizona cotton based on chemical use surveys performed as part of the Cotton Pest Losses and Impact Program workshops. Note how similar AZ and '17 are for estimating the same behaviors in 2017. This gives us confidence that the two reporting methods are reflecting accurate behaviors of our Arizona cotton growers. Sources: *CAL-DPR Pesticide Use Database*; *APMC Pesticide Use Database*; and *Cotton Pest Losses Database,* Ellsworth & Fournier, unpubl.

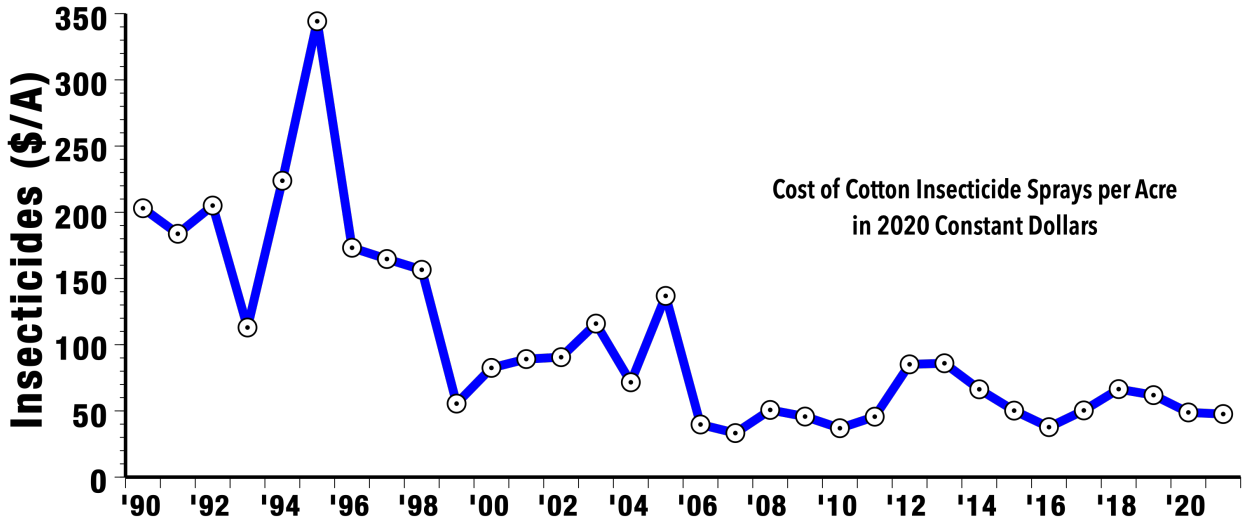


**Figure 5.** Growers have saved more in the last 16 years in insecticide costs than at any other time in history. Foliar insecticide costs inclusive of cost of applications in Arizona cotton since 1990. Eleven of the last 16 years are among the lowest costs in more than 40 years. Source: *Cotton Pest Losses Database*, Ellsworth, unpubl.

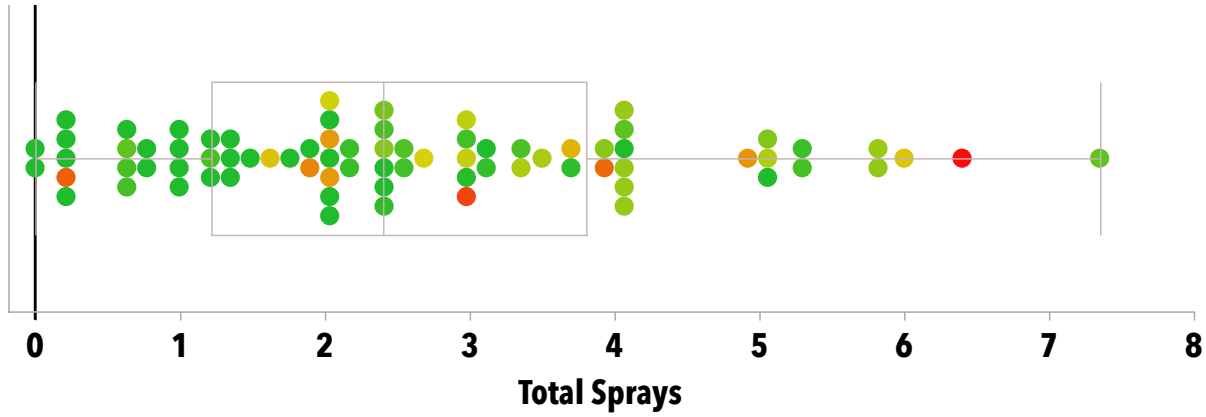


**Figure 6.** Growers spray insecticides only a few times each season; however, there remains a broad range of practice (2019–2021). Distribution of spray frequencies reported by PCA respondents for Arizona cotton (N=89). Average frequency of sprays = 2.34 in 2019, 1.99 in 2020, and 1.87 in 2021. In 2021, 60.9% of acres responding; point color indicates proportion of sprays made by each PCA that are fully selective from red to yellow to green to represent lower use (22%) to higher use (100%). Source: *Cotton Pest Losses Database*, Ellsworth, unpubl.

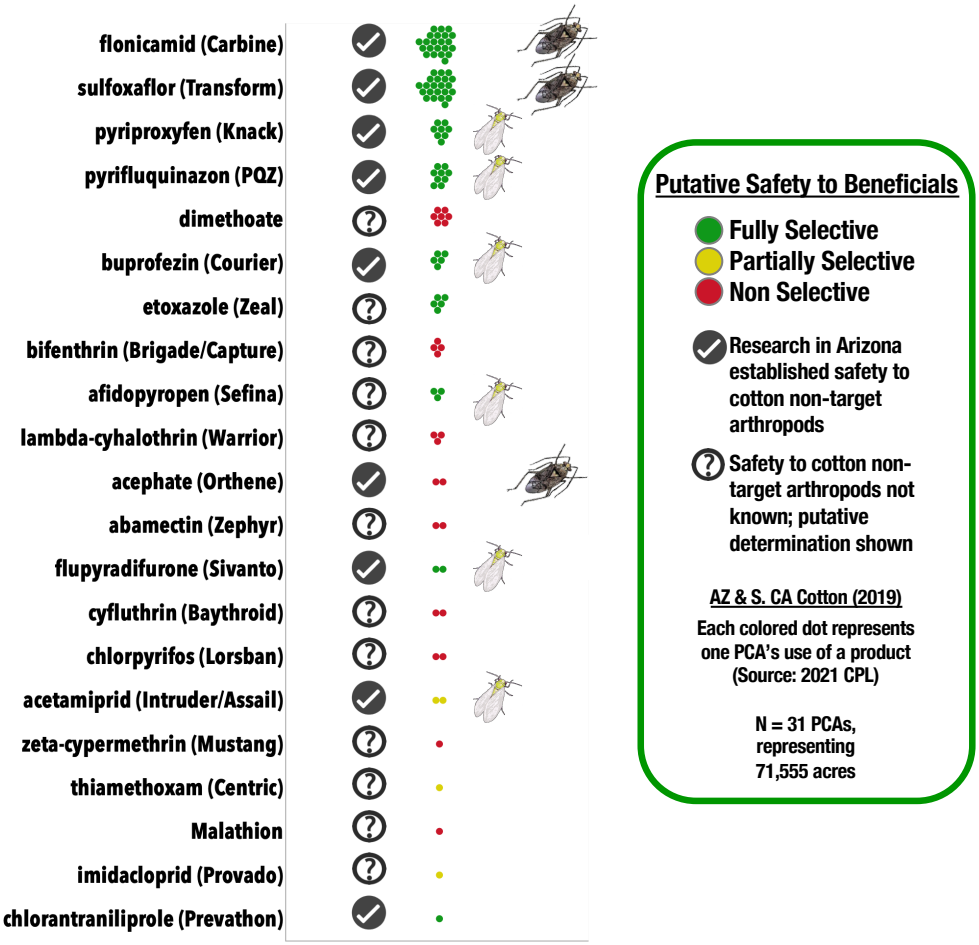


**Figure 7.** PCAs in Arizona generally make use of fully selective insecticides when possible. However, some non-selective and partially selective materials are still in regular use. Furthermore, uncertainty about the risk attributes for some active ingredients remains because the place-based research has not been carried out in these western cotton agroecosystems. We classified each product used by PCAs as either putatively fully selective, partially selective, or non-selective (i.e., broad spectrum). Because only 12 of these 21 products have system-specific research available on their safety towards non-target arthropods in cotton, the remainder are only putative estimates. About half of the products used by PCAs were to address needs to control one of the two key pests of cotton, Lygus bugs or the silverleaf / sweetpotato whitefly (SWF). Source: *Cotton Pest Losses Database*, Ellsworth, unpubl.

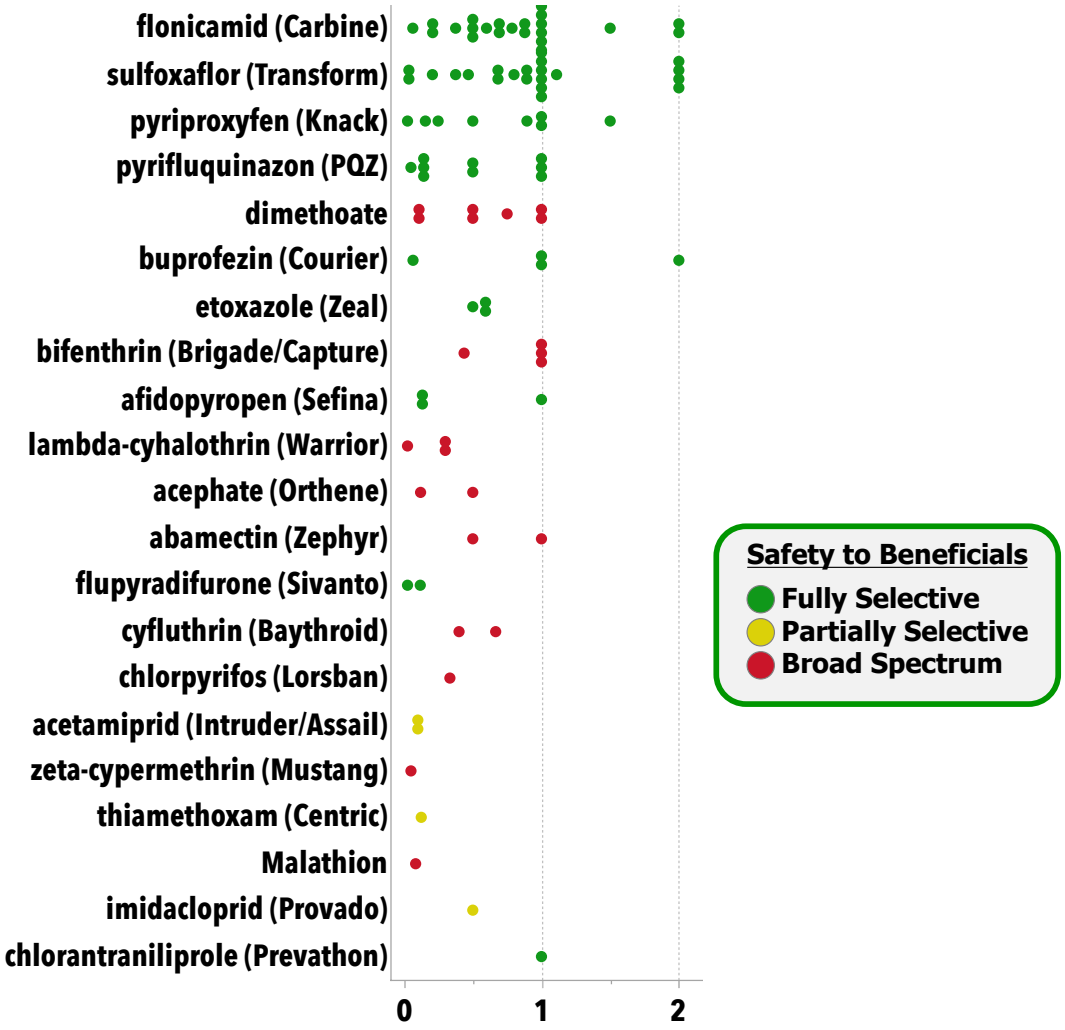


**Figure 8.** Arizona cotton pest managers carefully select and rotate chemistries so as not to overuse any product or modes of action. Most insecticides are sprayed no more than once; however, some acreages (responses > 1) may be sprayed twice with the same product. Number of sprays of foliar insecticide use by respondent (N=31) for Arizona cotton in 2021. Colored dots represent a reported respondent use and number of times used (% acres sprays * number of times), categorized by safety or selectivity for beneficial arthropods. Green = a fully selective insecticide; Yellow = a partially selective insecticide; Red = a non-selective insecticide. Source: *Cotton Pest Losses Database*, Ellsworth, unpubl. *Losses Database*, Ellsworth, unpubl.

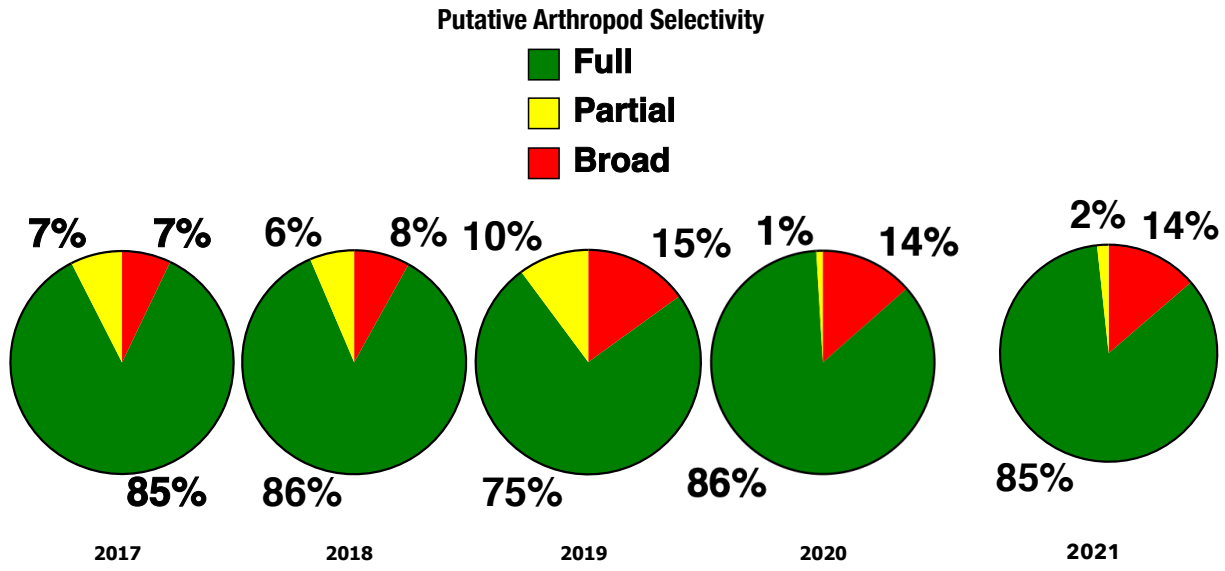


**Figure 9.** Growers return to higher uptake of selective insecticides in 2020–2021 after significant reduction in use of these products in 2019. Non-selective insecticide use remains at elevated but low levels (~15%) over the last two years. Efforts to highlight the benefits of selectivity were made in 2020 and 2021 to help growers understand the comparative risks of continued reliance on broad-spectrum insecticides. Selectivity of insecticides in use by Arizona cotton growers, 2017–2021. Source: *Cotton Pest Losses Database*, Ellsworth, unpubl.

## Relevant Literature

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