Pre-registration Economic and Pest Management Analysis for use of Sulfoxaflor in California Crops

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Background

Sulfoxaflor is a sulfoximine insecticide registered federally for control of a range of sucking pests in agricultural production. Department of Pesticide Regulation (DPR) is proposing the registration of two products containing sulfoxaflor: Transform CA™ for use in field/row crops and Sequoia CA™ for use in orchard and fruiting crops. Across crops, registration of sulfoxaflor would provide growers with an additional pesticide option in pest management. Integrated pest management (IPM), practiced by nearly all California growers, uses a combination of cultural, biological, and pesticide tools to reduce damage from pests. If pest populations reach high enough thresholds, farmers may use applications of pesticides to prevent economic losses. The threshold to apply pesticides can be affected by the crops value, quality, and appearance standards from buyers, and how fast acting and effective the pesticide is. Resistance to specific pesticides develops over time, necessitating having multiple options to control each species. While pesticide applications are not always required in all fields or in all years, current production systems depend on their availability.

This report uses recent historical data on insecticide applications for pests targeted by sulfoxaflor in cotton, alfalfa, cherry, tomato, lettuce, and cucurbits. For each commodity, we describe several scenarios of how sulfoxaflor's registration could affect use and calculate how use of existing insecticide options may decrease in response. Due to previous use exemptions for cotton and lettuce, available data differs. We also note what non-pesticide control options are available and describe their role in pest management. For cotton, we calculate how sulfoxaflor registration could prevent substantial yield loss using data from recent outbreaks.

The report is meant to provide general estimates on what pest management could look like in these commodities after sulfoxaflor registration based on historical data.

Methods

This report uses data from the CA Department of Pesticide Regulation's Pesticide Use Reporting (PUR) database to project how registration of sulfoxaflor could affect insecticide use. For each commodity, we consulted pest management specialists to identify existing insecticide options for control of pests listed on the proposed sulfoxaflor product labels. We then calculated the average annual use of existing insecticide options for each active ingredient in cotton, alfalfa, cucurbits, cherry, tomato, and lettuce. By identifying how much of each insecticide is currently used in these production systems, we can estimate what proportion of that use could be replaced with sulfoxaflor. For each crop, the pest species targeted by sulfoxaflor and the legal conditions for use vary. Therefore, each crop section details adjustments to the analyses aimed at better reflecting the actual use cases for sulfoxaflor products in the specific production system. As the actual use cases of sulfoxaflor in each production system could vary, this analysis thus serves as a projection of possible use scenarios rather than an evaluation of known use patterns.

We also describe what feasible alternatives are available to insecticide use in each crop system. The California Code of Regulations defines "Feasible alternative" as "other chemical or non-chemical procedures which can reasonably accomplish the same pest control function with comparable effectiveness and reliability, taking into account economic, environmental, social, and technological factors and timeliness of control" (3 CCR 6000).

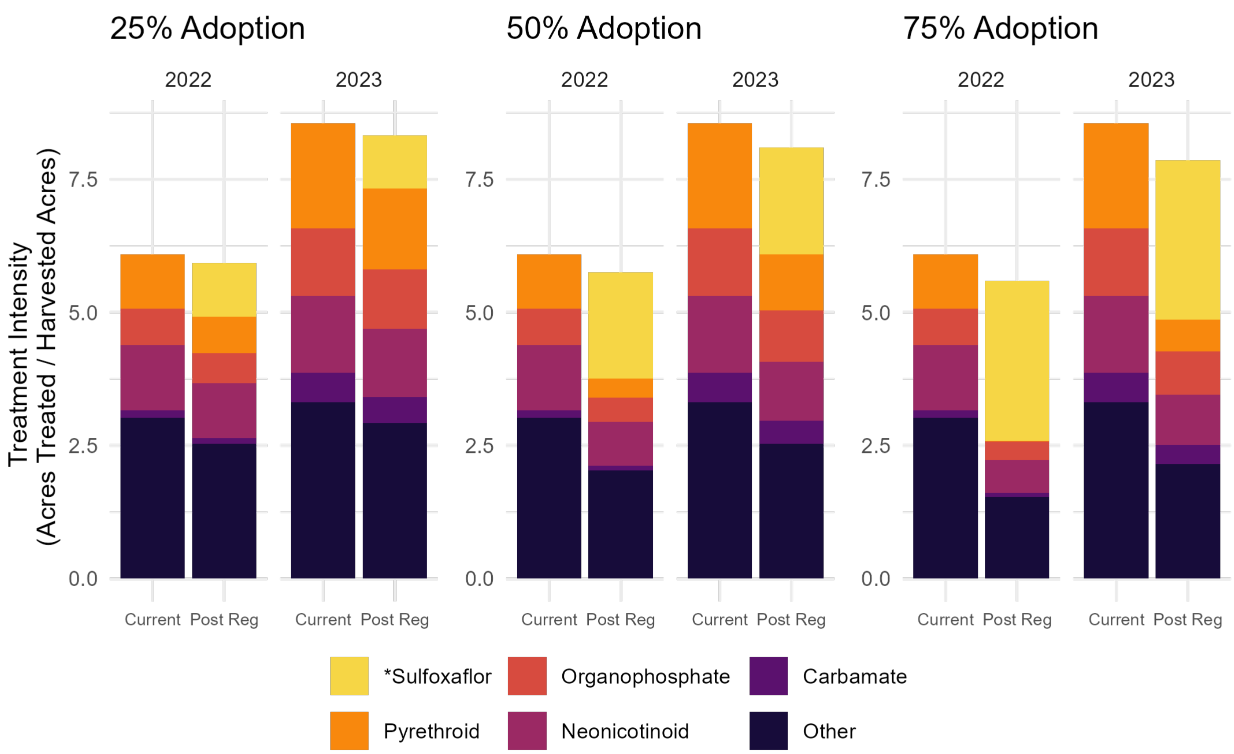
Finally, in cotton a documented Lygus outbreak in 2023 is believed by the cotton industry and researchers to have caused significant yield loss, particularly of the high-quality Pima variety. Given sulfoxaflor's high efficacy against Lygus and evidence that it prevented yield loss in a 2017 Lygus outbreak, we calculate the possible value of unrealized yield that sulfoxaflor registration could have provided during the 2023 outbreak. By comparing Pima cotton yields from 2022 (no Lygus outbreak) and 2023 (severe Lygus outbreak), we report the value of Pima cotton that farmers theoretically could have obtained in the absence of Lygus damage. We use the peak 2023 price for Pima cotton, making this an upper-level estimate of value.

Cotton

In cotton, the sulfoxaflor product Transform CA would target aphids, fleahoppers, Lygus bug, and whiteflies. Many insecticide products are available to control these pests, including pyrethroids, neonicotinoids, and organophosphates. However, farmers have been unable to control recent outbreaks of Lygus with available chemicals or non-chemical options. Additionally, cotton suffers from late season outbreaks of aphids and whiteflies, which can generate significant economic losses by producing unmarketable "sticky cotton" with their sugary droppings. "Sticky cotton" can damage cotton processing equipment and lead to entire regions losing access to markets. Insecticides used to control Lygus may reach the legal maximum of applications annually, leaving no insecticides available for late season aphid and whitefly control. Additional insecticide options could significantly improve management by allowing for flexibility in product choice and timing of applications.

If registered, we predict that sulfoxaflor would be widely adopted and used to control Lygus and several other primary pests in cotton production. For this reason, our scenarios included 25%, 50% and 75% of harvested acreage receiving full annual rates of Transform CA (four applications or 0.266 lb ai/acre). In these scenarios, sulfoxaflor applications would replace two pyrethroid applications, further reducing pyrethroid use. This is informed by significant increases in pyrethroid use during the 2023 Lygus outbreak. However, pyrethroid use did not decline between 2016 and 2017 when sulfoxaflor became available through a Section 18 exemption, making this a lower-bounds estimate of pyrethroid use. Sulfoxaflor registration is projected to potentially replace use of existing insecticide options by an average of 14.1%, 28.1%, or 42.2% in the 25%, 50%, and 75% harvested acreage use scenarios, respectively (Figure 1, Table 1). Notably, pyrethroid use would decline by 27% (4,148 lbs), 54.1% (8,298 lbs), or 81.1% (12,447 lbs) in the 25%, 50%, and 75% scenarios, respectively. Pyrethroids are also used to control pest species that would not be affected by sulfoxaflor, including beet armyworm, darkling beetles, and false chinch bugs, meaning a baseline level of pyrethroid use will likely exist. It is possible that pyrethroid use on other pest species would be greater than the amount of use described in the 50% or 75% adoption scenarios, resulting in our analysis underestimating continued pyrethroid use.

Figure 1. Changes in Treatment Intensity of insecticides in California cotton in 2022 and 2023 based on 25%, 50%, and 75% sulfoxaflor adoptions scenarios.



Despite increased use of broad-spectrum insecticides in 2023, average Pima cotton yields decreased 13.6% from 1558 lb/acre in 2022 to 1346 lb/acre in 2023, representing a 13.6% yield reduction and demonstrating the current management strategies do not control Lygus in an outbreak year. Assuming that the registration of sulfoxaflor would have fully prevented this yield loss from occurring and that prices for Pima cotton were at their peak of $2.35/lb, the value of Pima cotton production in 2023 would have increased from $259.3 million to $300.2 million, a gain of $40.9 million. There are many caveats to this assumption as no product is perfectly effective in controlling outbreaks and several factors may have contributed to average cotton yield in 2023, including high winter precipitation and flooding in the Tulare Lake basin.

Table 1. Changes in average annual use of alternative insecticides in response to different scenarios of sulfoxaflor adoption in 2022-2023 California cotton production

Active Ingredient	Use Scenario	Current Acres Treated	Current Lbs Applied	Post-Reg. Acres Treated	Post-Reg. Lbs Applied	Acres Reduced	Lbs Reduced	% reduction
Afidopyropen	25%	73,402	3,188	63,251	2,747	10,151	441	13.8
Afidopyropen	50%	73,402	3,188	53,100	2,306	20,302	882	27.7
Afidopyropen	75%	73,402	3,188	42,948	1,864	30,454	1,324	41.5
Carbamate	25%	45,119	44,973	39,346	39,218	5,773	5,755	12.8
Carbamate	50%	45,119	44,973	33,574	33,462	11,545	11,511	25.6
Carbamate	75%	45,119	44,973	27,800	27,706	17,319	17,267	38.4
Flonicamid	25%	163,106	14,076	140,161	12,092	22,945	1,984	14.1
Flonicamid	50%	163,106	14,076	117,216	10,110	45,890	3,966	28.1
Flonicamid	75%	163,106	14,076	94,272	8,126	68,834	5,950	42.2
Flupyradifurone	25%	36,658	6,478	31,366	5,542	5,292	936	14.4
Flupyradifurone	50%	36,658	6,478	26,076	4,605	10,582	1,873	28.9
Flupyradifurone	75%	36,658	6,478	20,784	3,668	15,874	2,810	43.3
Indoxacarb	25%	25,311	3,259	21,752	2,797	3,559	462	14.1
Indoxacarb	50%	25,311	3,259	18,192	2,336	7,119	923	28.1
Indoxacarb	75%	25,311	3,259	14,631	1,874	10,680	1,385	42.2
Neonicotinoid	25%	183,070	17,112	157,260	14,680	25,810	2,432	14.1
Neonicotinoid	50%	183,070	17,112	131,450	12,248	51,620	4,864	28.2
Neonicotinoid	75%	183,070	17,112	105,642	9,818	77,428	7,294	42.3
Novaluron	25%	99,207	7,224	85,210	6,206	13,997	1,018	14.1
Novaluron	50%	99,207	7,224	71,214	5,186	27,993	2,038	28.2
Novaluron	75%	99,207	7,224	57,218	4,168	41,989	3,056	42.3
Organophosphate	25%	130,388	106,752	112,700	92,258	17,688	14,494	13.6
Organophosphate	50%	130,388	106,752	95,011	77,764	35,377	28,988	27.1
Organophosphate	75%	130,388	106,752	77,323	63,270	53,065	43,482	40.7
Pyrethroid*	25%	201,124	15,006	146,722	10,858	54,402	4,148	27.0
Pyrethroid*	50%	201,124	15,006	92,320	6,708	108,804	8,298	54.1
Pyrethroid*	75%	201,124	15,006	37,918	2,559	163,206	12,447	81.1
Pyriproxyfen	25%	32,606	2,184	27,548	1,844	5,058	340	15.5
Pyriproxyfen	50%	32,606	2,184	22,489	1,506	10,117	678	31.0
Pyriproxyfen	75%	32,606	2,184	17,432	1,166	15,174	1,018	46.5
Spiromesifen	25%	5,721	1,411	4,868	1,200	853	211	14.9
Spiromesifen	50%	5,721	1,411	4,016	990	1,705	421	29.8
Spiromesifen	75%	5,721	1,411	3,163	778	2,558	633	44.7
Sulfoxaflor	25%	-	-	138,326	9,199	-138,326	-9,199	-
Sulfoxaflor	50%	-	-	276,652	18,397	-276,652	-18,397	-
Sulfoxaflor	75%	-	-	414,978	27,596	-414,978	-27,596	-

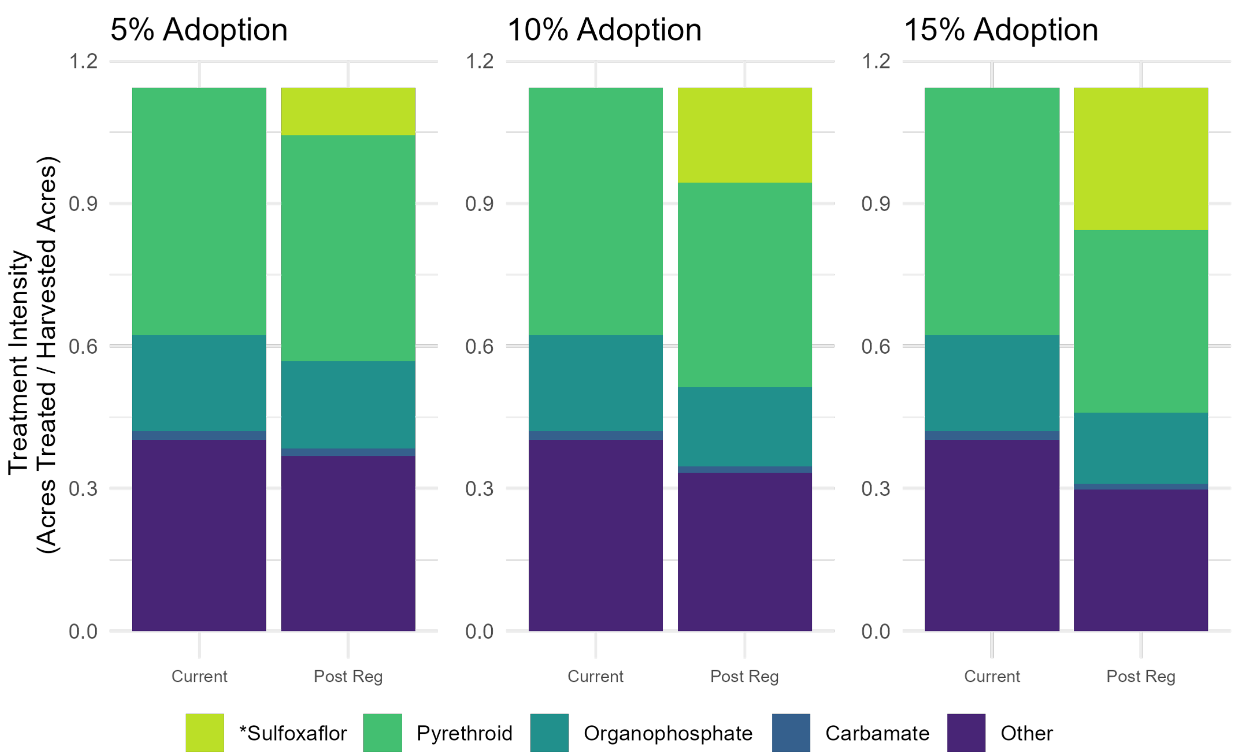
* For each sulfoxaflor application, 2 Pyrethroid applications are replaced.

In cotton, feasible non-chemical alternatives have not proven effective for control of Lygus bugs. Vacuum systems used for Lygus control in strawberries are currently incompatible with the cotton production system, and biological control options are not effective during outbreaks. Alfalfa is more attractive to Lygus bugs than cotton and has potential use as a trap crop to reduce migration of Lygus bugs into cotton fields, though this practice has never been widely implemented.

Alfalfa

In alfalfa, the sulfoxaflor product Transform CA would target aphids and Lygus bugs. Several effective insecticide products are available for use against aphids in alfalfa, and it is likely that sulfoxaflor would be included in rotation with these products. Unlike in cotton, Lygus bugs are not a primary pest of alfalfa and are more destructive to seed alfalfa than forage alfalfa. However, use of Transform CA on seed alfalfa production is not allowed on the proposed label given concerns over bloom and pollinator risk. Our scenarios include 5%, 10% and 15% of harvested forage alfalfa acreage receiving two annual applications of Transform CA or 0.133 lb active ingredient/acre. Sulfoxaflor registration is projected to potentially replace use of existing insecticide options by an average of 8.5%, 17.0%, or 25.5% in the 5%, 10%, and 15% scenarios respectively (Figure 2, Table 2).

Figure 2. Changes in Average Treatment Intensity of insecticides in California alfalfa in 2022 and 2023 based on 5%, 10%, and 15% sulfoxaflor adoptions scenarios.



In alfalfa, selecting resistant varieties is the primary non-chemical control of aphids. Aphid-resistance has been bred into many varieties of alfalfa, but variety choice is affected by agronomic traits like yield, quality, and dormancy in addition to pest management. While resistance is valuable in preventing pest damage and reducing the need for insecticide applications, it can be variable by plant and by environmental conditions even within varieties. Alfalfa varieties are not clonal so resistance can vary substantially between individual plants in a field; varieties that are classified as highly resistant (HR) to a given pest or disease have a greater than 50% of plants resistant, while resistant (R) varieties have 35-50% of plants resistant. The UC ANR Irrigated Alfalfa Management section on variety selection states, “Resistance to pests is not absolute. Due to the nature of alfalfa varieties as populations, some plants will remain susceptible even within a highly resistant line. Resistance to pests should be considered an insurance policy that is an important benefit of improved varieties. Additionally, resistance to cowpea aphid (*Aphis craccivora)*, one of the most damaging pest species, has not yet been developed. In summary, resistant varieties are a key part of aphid control but are not currently sufficient on their own.

Table 2. Changes in average annual use of alternative insecticides in response to different scenarios of sulfoxaflor adoption in 2021-2023 California alfalfa production

Active Ingredient	Use Scenario	Current Acres Treated	Current Lbs Applied	Post-Reg. Acres Treated	Post-Reg. Lbs Applied	Acres Reduced	Lbs Reduced	% Reduction
Afidopyropen	5%	71,066	1,628	64,915	1,487	6,151	141	8.7
Afidopyropen	10%	71,066	1,628	58,763	1,346	12,303	282	17.3
Afidopyropen	15%	71,066	1,628	52,611	1,206	18,455	422	26.0
Carbamate	5%	11,106	8,660	10,125	7,896	981	764	8.8
Carbamate	10%	11,106	8,660	9,145	7,131	1,961	1,529	17.7
Carbamate	15%	11,106	8,660	8,164	6,367	2,942	2,293	26.5
Flonicamid	5%	38,339	3,316	34,966	3,024	3,373	292	8.8
Flonicamid	10%	38,339	3,316	31,594	2,733	6,745	583	17.6
Flonicamid	15%	38,339	3,316	28,221	2,441	10,118	875	26.4
Flupyradifurone	5%	145,578	15,531	132,857	14,174	12,721	1,357	8.7
Flupyradifurone	10%	145,578	15,531	120,135	12,817	25,443	2,714	17.5
Flupyradifurone	15%	145,578	15,531	107,414	11,459	38,164	4,072	26.2
Organophosphate	5%	129,154	65,091	117,758	59,365	11,396	5,726	8.8
Organophosphate	10%	129,154	65,091	106,362	53,641	22,792	11,450	17.6
Organophosphate	15%	129,154	65,091	94,967	47,916	34,187	17,175	26.5
Pyrethroid	5%	330,748	9,668	301,819	8,822	28,929	846	8.7
Pyrethroid	10%	330,748	9,668	272,891	7,976	57,857	1,692	17.5
Pyrethroid	15%	330,748	9,668	243,962	7,131	86,786	2,537	26.2
Sulfoxaflor	5%	-	-	63,551	4,226	-	-	-
Sulfoxaflor	10%	-	-	127,101	8,452	-	-	-
Sulfoxaflor	15%	-	-	190,652	12,678	-	-	-

While biological control of aphids exists, the highly damaging blue alfalfa aphid (*Acyrthosiphon kondoi*) develops well before the presence of natural enemies. Additionally, pyrethroid and organophosphate use in alfalfa can disrupt natural enemy populations; any reduction in their use could potentially benefit biological control. Pyrethroids are used extensively for other pests in alfalfa, including the alfalfa weevil for which limited host plant resistance exists.

Cucurbits

California grows a variety of cucurbit crops, including melons, cucumbers, squash, and others. The proposed Sequoia CA label would register it for use on aphids and whiteflies, which are persistent pests of many cucurbit varieties. UC IPM lists a variety of insecticide options for control of aphids and whiteflies in cucurbits, including bifenthrin, dinotefuran, imidacloprid, thiamethoxam, pymetrozine, methomyl, cyantraniliprole, spiromesifen, buprofezin, and pyriproxyfen. Of these insecticides, the pyrethroid bifenthrin is used most commonly for control of aphids and whiteflies, as well as other secondary pests, with use peaking in June-August (UC ANR, Personal Communication). As mentioned in previous sections, pyrethroid use is unlikely to be wholly replaced by sulfoxaflor, which is more expensive and less broad spectrum. However, given that summer pyrethroid use is primarily targeted towards aphids and whiteflies, sulfoxaflor is likely to be included as a component of control programs as it is softer on natural enemies. New restrictions on neonicotinoid (imidacloprid, clothianidin, thiamethoxam, and dinotefuran) use in cucurbits that started in 2024 make it likely that sulfoxaflor would replace their use during bloom and for crops using managed pollinators. Bloom periods in cucurbits can vary significantly by variety, region, and whether plants were seeded or transplanted. Most cucurbits bloom continuously, eliminating the use of neonicotinoids for the season once bloom starts, which can be as early as one to two weeks post-transplant. If sulfoxaflor use is permitted during bloom it would provide a replacement for that neonicotinoid use. Managed pollinators are sometimes used for some cucurbits, such as melons, further restricting neonicotinoid use. For those crops, Sequoia CA could be an important replacement for neonicotinoid use pre-bloom as neonicotinoid use was restricted pre-bloom when managed pollinators are used.

For this analysis, we assume that sulfoxaflor will replace 10% of insecticides use given its effectiveness against aphids and whiteflies in summer periods. We also assume it will replace 50% of neonicotinoid use to replace uses during bloom periods and pre-bloom use for fields using managed pollinators. Due to differing planting times and time to bloom, it is not possible to tell from PUR data which neonicotinoid applications were done post bloom. Soil applications of the neonicotinoid dinotefuran are exempt from the regulations and were removed from the analysis. With exempted applications removed, dinotefuran use is projected to be reduced by 38.4% (Table 3, Figure 3). We estimate a total of 17,480 acres will use sulfoxaflor instead of neonicotinoids (Table 3, Figure 3). We estimate a total of 4,173 acres will use sulfoxaflor instead of pyrethroids (Table 3, Figure 3). A caveat to this analysis is that the crops analyzed, which include all cucurbits, vary in their pest pressure, bloom period, and regions grown. Additionally, it is not yet clear how strongly the 2024 neonicotinoid regulations will affect their use, as data from the post-regulation period is not yet available. This analysis thus serves as a rough generalization of potential changes to insecticide use with sulfoxaflor registration.

Figure 3. Changes in average annual use of alternative insecticides where sulfoxaflor replaces use in California cucurbit production, 2021-2023

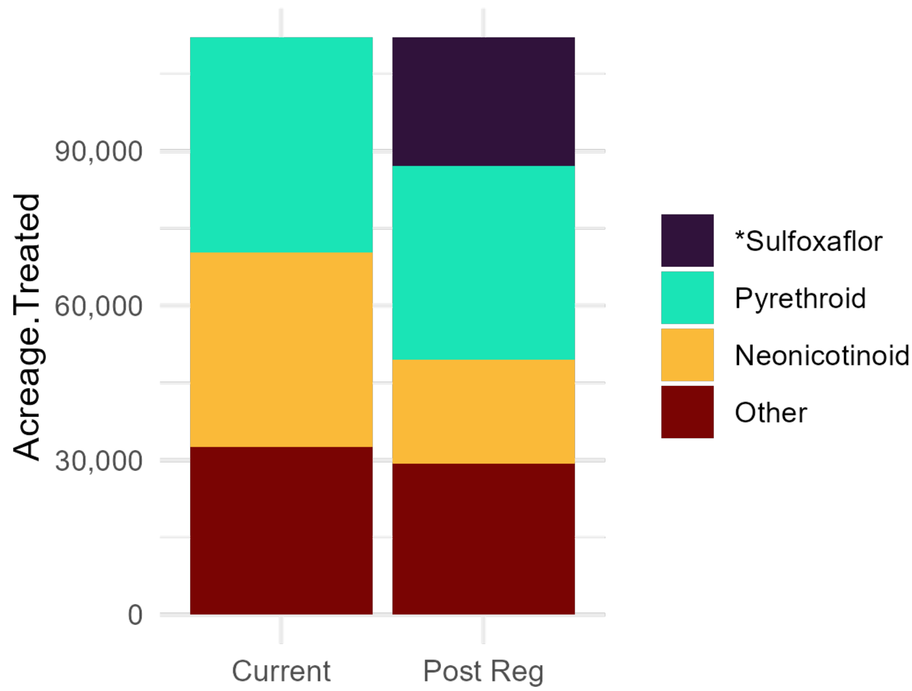


Table 3. Changes in average annual use of select insecticides in response to sulfoxaflor adoption in California cucurbit production, 2021-2023

Active Ingredient	Current Acres Treated	Current Lbs Applied	Post-Reg. Acres Treated	Post-Reg. Lbs Applied	Acres Reduced	Lbs Reduced	% reduction
Neonicotinoid							
dinotefuran	11,868	1,997	7,307	1,296	4,562	701	38.4
imidacloprid	15,102	5,083	7,551	2,541	7,551	2,541	50
thiamethoxam	10,734	735	5,367	368	5,367	368	50
Pyrethroid							
bifenthrin	41,733	3,873	37,560	3,485	4,173	387	10
Other							
buprofezin	8,009	3,000	7,208	2,700	801	300	10
cyantraniliprole	7,492	718	6,743	646	749	72	10
methomyl	2,590	1,811	2,331	1,630	259	181	10
pymetrozine	3,257	278	2,931	251	326	28	10
pyriproxyfen	3,908	253	3,517	228	391	25	10
spiromesifen	7,354	896	6,618	807	735	90	10
*Sulfoxaflor			24,914	1,769			

In cucurbit production, biological control assists in the control of aphids and whiteflies but does not generally keep pest populations below damage thresholds (UC IPM). Reflective silver mulches can help reduce whitefly populations, and in desert regions row covers can be used to reduce whitefly colonization. However, whitefly populations often originate in other crop fields and rapidly colonize cucurbits, resulting in the need for insecticide applications. Systemic insecticides like neonicotinoids are often required to eliminate colonizing adults before they oviposit on the underside of leaves where nymphs are more difficult to control. Additionally, the rapid control provided by systemic insecticides can reduce transmission of aphid-borne viruses to cucurbits, including Cucumber mosaic, Watermelon mosaic, and Zucchini yellow viruses. Viruses are a major driver of yield loss, and virus vectors are treated aggressively to mitigate transmission. If viruses are present, it is unlikely that pest populations could be kept below damaging levels without chemical control.

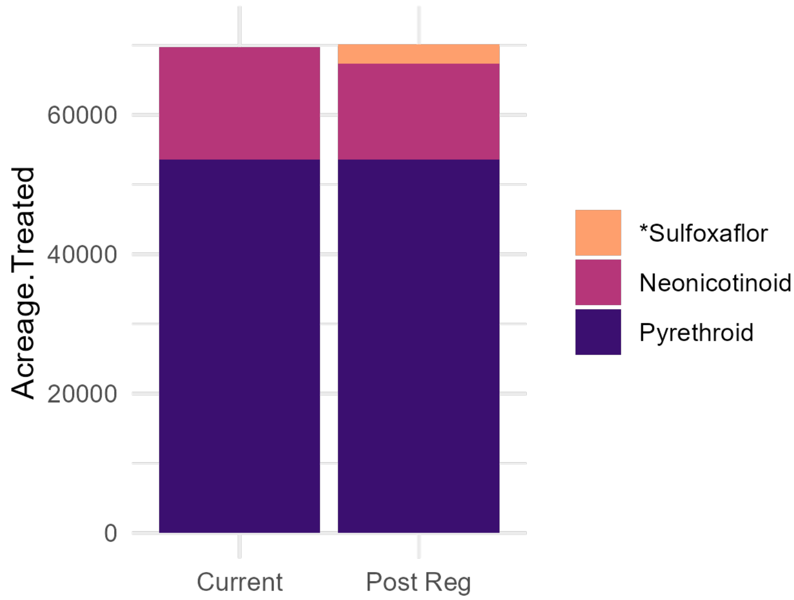
Cherry

In cherry Sequoia CA would be used against aphids, primarily the black cherry aphid (*Myzus cerasi)*. Historically, aphids have been primarily controlled by applications of pyrethroids and neonicotinoids from February through May. However, regulations effective in 2024 have restricted the use of the neonicotinoids imidacloprid and thiamethoxam in cherry, with use allowed only between post-bloom and harvest (roughly the month of May in most years). Similarly, Sequoia CA applications would not be allowed between seven days prior to bloom and after petal fall.

We assume that Sequoia CA will likely replace pre-petal fall use of the neonicotinoids given the new 2024 restrictions on use, while pyrethroid use will not be affected. While Sequoia CA applications will not be permitted during bloom, cherry bloom usually lasts only one-two weeks, and we expect growers to be flexible in applying Sequoia CA outside of the restricted periods. For this reason, we project that Sequoia CA will replace restricted neonicotinoid use from February to April, while neonicotinoids use during the permitted period of May will be unaffected. On average, pyrethroids are broader spectrum and significantly less expensive than Sequoia CA or neonicotinoids, making them unlikely to be replaced. We also included 2021 data in averages to account for variation between insecticide use in 2022 and 2023.

Sulfoxaflor registration is projected to potentially replace use of neonicotinoids in cherry by an average of 14.5% annually, primarily through reductions in imidacloprid use, while pyrethroid use will remain unchanged (Figure 4, Table 4). A caveat to this analysis is that the years included do not yet reflect pesticide use under the 2024 regulations. While this allows us to project what portion of previously allowed neonicotinoid use could be substituted with sulfoxaflor, it is possible that patterns of pesticide use have changed under new regulations which are not captured in this analysis. Additionally, we assume that the bloom restrictions on Sequoia CA use will not restrict average use during this period; bloom periods are short and unpredictable in cherry, and growers will likely be able to apply sulfoxaflor earlier or later depending on these conditions. The majority of restricted neonicotinoid use remaining post regulation (Figure 4, Table 4), which is primarily for leafhopper control and outside of the permitted post-bloom window, will need to be replaced with other insecticides.

Figure 4. Changes in average annual use of alternative insecticides where sulfoxaflor replaces restricted neonicotinoid use in 2021-2023 California cherry production



In cherry, non-chemical alternatives for control of aphids are not actively used. Biological control of aphids by natural enemies occurs at background levels that may keep aphids below damaging levels, however insecticide applications are still required when outbreaks occur.

Table 4. Changes in average annual use of select insecticides in response to different scenarios of sulfoxaflor adoption in California cherry production

Active Ingredient	Use Scenario	Current Acres Treated	Current Lbs Applied	Post-Reg. Acres Treated	Post-Reg. Lbs Applied	Acres Reduced	Lbs Reduced	% Reduction
Neonicotinoid								
Acetamiprid		248	26	248	26	0	0	0.0
Imidacloprid*	Feb-April Use Replaced	11,689	1,284	9,393	1,075	2,296	209	19.6
Thiamethoxam*	Feb-April Use Replaced	4,131	269	4,096	266	35	3	0.8
Pyrethroid		17,878	2,438	17,878	2,438	0	0	0.0
Sulfoxaflor				1,166	78			

* Restricted use Neonicotinoids

Tomato

Tomatoes in California are grown for two markets: fresh and processed. Fresh market tomatoes are grown as bushes or on poles. Bush tomatoes tend to be determinate and are picked once during the season. Pole tomatoes are primarily indeterminate varieties that are harvested over a long period of time during the production season. Since fresh market tomatoes are sold whole, their appearance is crucial. Consumers expect blemish-free fruit, so growers often use insecticides to maintain the quality and appearance of the tomatoes, in addition to protecting yields. Processing tomatoes are primarily determinate varieties grown for a single mechanical harvest. Tomatoes intended for processing are inspected for worm damage and mold, which must be below specific limits. While some pest damage can be tolerated in tomatoes used for juice or paste, canners may reject blemished fruit intended for diced or whole pack products.

In both productions, tomatoes are grown using transplants, which are custom grown by commercial greenhouse operations and are delivered to the field as plug plants seeded in trays to be planted mechanically into field. Transplants can bloom within weeks of being transplanted and plants will then continue blooming throughout the season.

Applications of the sulfoxaflor product Sequoia CA in tomato would not be allowed seven days prior to bloom and until after petal fall. Sequoia CA would primarily target aphids, plant bugs, and whiteflies although it could potentially control beet leafhoppers, potato psyllids, and thrips. Many insecticide products are available to control these pests in both processing and fresh market tomato, including pyrethroids, neonicotinoids, carbamates, organophosphates, and some newer insecticide classes such as diamides.

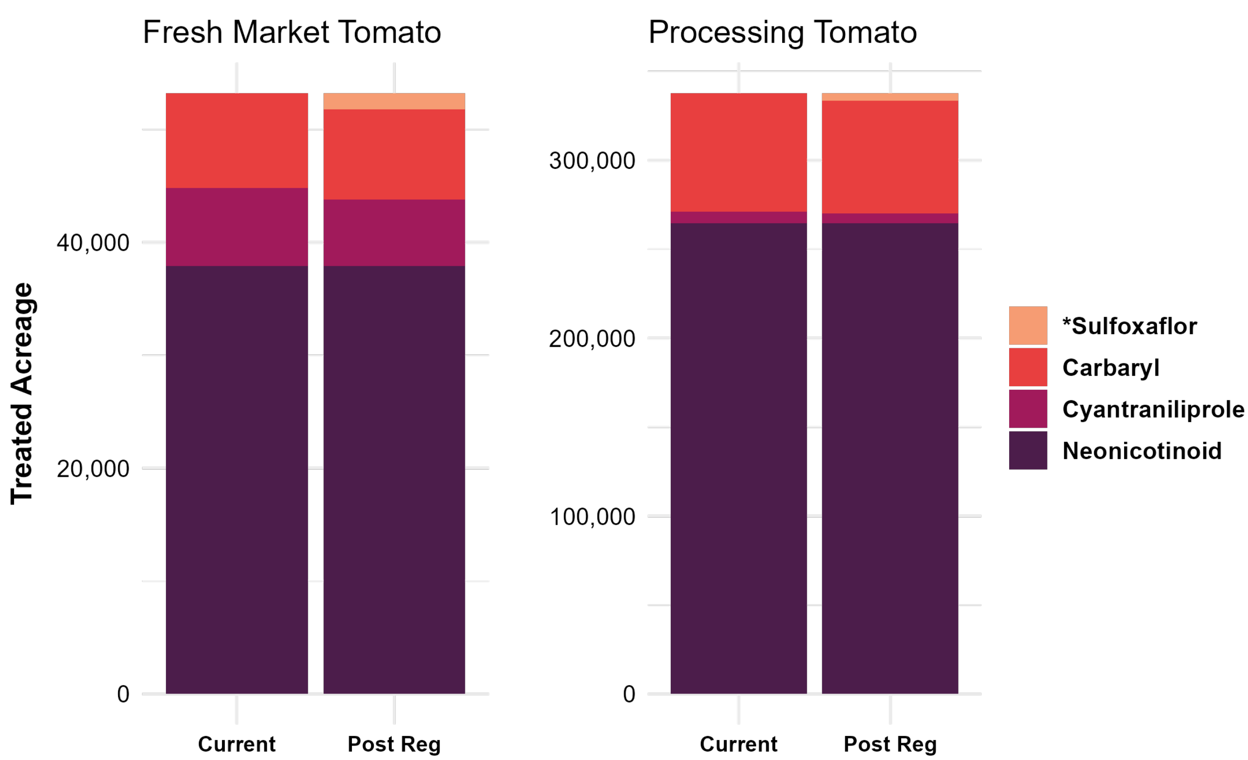
Pre-bloom control of aphids, whiteflies, and beet leafhoppers is essential to prevent transmission of viral pathogens. Insect-transmitted viral diseases can cause substantial yield loss when the plants are infected early. The neonicotinoid insecticides containing the active ingredients imidacloprid, dinotefuran, and thiamethoxam are the most used pre-bloom insecticides for these pests. Pre-bloom use of sulfoxaflor and substitution of neonicotinoids would largely be dependent on the relative cost of the Sequoia CA product. The replacement by sulfoxaflor could only occur if the product will be less expensive than neonicotinoid products, which is unlikely. The diamide insecticide cyantraniliprole can also be used for pre-bloom control of aphids and whiteflies, and we assume some cyantraniliprole use could be reduced by sulfoxaflor use.

Carbaryl is an alternative to neonicotinoids for early-season control of beet leafhopper and even though beet leafhopper is not on the Sequoia CA label, we assume a small amount of carbaryl use would also be reduced with growers using sulfoxaflor instead. Since other products registered on tomatoes are applied after bloom, the effect of sulfoxaflor availability on their use would be negligible and was excluded from this analysis. Although most applications for tomato psyllid control are made during the season when they are typically first seen on tomatoes, there is some pre-bloom or early post-bloom preventative use of insecticides for this purpose as well. All the current pre-bloom applications for tomato psyllid rely on imidacloprid, and although sulfoxaflor would be a direct substitute for imidacloprid, we anticipate no change in its use. There is some early post-bloom use of spirotetramat, spinetoram, abamectin, and spiromesefen for tomato psyllid control, but these post-bloom applications are not likely to change to pre-bloom use of sulfoxaflor. Thrips are effectively controlled by the spinosyns spinetoram and spinosad. However, the propensity of thrips to develop resistance to spinosyns may limit their long-term efficacy for controlling these pests. This could lead to the increased use of sulfoxaflor as an alternative.

Methomyl, dimethoate, and flonicamid are also used in season for thrips control or suppression, and the availability of sulfoxaflor pre-bloom is unlikely to change the amount of these products used. Dinotefuron can also be used pre-bloom for thrips control and is more effective than sulfoxaflor.

For this analysis, we assumed that 15% of cyantraniliprole and 5% of carbaryl use would be replaced by sulfoxaflor, while neonicotinoid use will remain unchanged. A caveat to this analysis is that the years included (2021-2023) do not reflect pesticide use under the 2024 neonicotinoid regulations, and patterns of pesticide use have changed under new regulations which are not captured in this analysis. In fresh market tomato production, the acreage treated with carbaryl would be reduced from 8,408 acres to 7,988 acres, and the acreage treated with cyantraniliprole would be reduced from 6,929 acres to 5,890 acres. Therefore, we anticipate a total of 1,460 acres will use sulfoxaflor instead of these two active ingredients (Figure 5, Table 5). In processing tomato production, the acreage treated with carbaryl would be reduced from 66,866 acres to 63,523 acres, and the acreage treated with cyantraniliprole would be reduced from 6,438 acres to 5,472 acres. Therefore, sulfoxaflor will be used in 4,309 acres instead of carbaryl and cyantraniliprole (Figure 5, Table 5).

Figure 5. Changes in average annual use of alternative insecticides where sulfoxaflor replaces cyantraniliprole and carbaryl use in California tomato production, 2021-2023



The use of neonicotinoids shown in Table 5 reflect use in 2021-2023, prior to the 2024 regulations restricting their use significantly in tomato. OPCA's economic and pest management impact report for those regulations estimated that only 24.8-31.2% of acres and 30.6-38.8% of pounds applied would continue to be allowed annually on fresh market tomato, and 22.0-35.8% of acres and 29.9-54.6% of pounds applied would continue to be allowed annually on processing tomato (https://www.cdfa.ca.gov/oars/opca/docs/NGN_Mitigation_Economic_Impact_Report_7_2_21.pdf). The remainder of historical neonicotinoid use would need to use other alternatives. Sulfoxaflor is not an alternative for this use because of the bloom time restrictions.

Table 5. Changes in average annual use of select insecticides in response to sulfoxaflor adoption in California tomato production, 2021-2023

Tomato Production	Active Ingredient	Current Acres Treated	Current Lbs Applied	Post-Reg. Acres Treated	Post-Reg. Lbs Applied	Acres Reduced	Lbs Reduced
Fresh Market	Carbaryl	8,408	4,696	7,988	4,461	420	235
	Cyantraniliprole	6,929	762	5,890	648	1,039	114
	Neonicotinoid	37,890	5,746	37,890	5,746	0	0
	Sulfoxaflor	-	-	1,460	388	-	-
Processing	Carbaryl	66,866	41,789	63,523	39,700	3,343	2,089
	Cyantraniliprole	6,438	767	5,472	652	966	115
	Neonicotinoid	264,536	42,891	264,536	42,891	0	0
	Sulfoxaflor	-	-	4,309	1,146	-	-

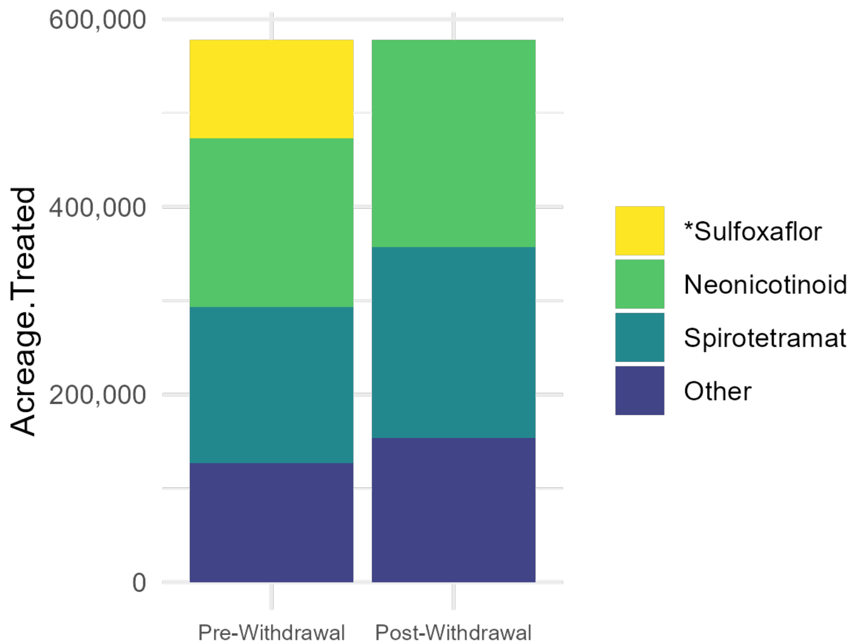
Non-chemical alternatives for control of aphids and whiteflies in tomato production are limited. Silver or aluminum-colored mulches can repel winged aphids and adult whiteflies, reducing their colonization and delaying the buildup of both winged and wingless populations. This can help prevent the spread of viral diseases transmitted by these insects. However, this method is most effective in the early stages of plant growth, specifically during the first few weeks after seeding or transplanting, before the mulch is obscured by foliage. Biological control agents can help reduce aphid and whitefly populations. However, insecticide applications are often necessary to manage outbreaks, and many insecticides, especially pyrethroids and organophosphates, are highly disruptive of these natural enemies. Covering tomato plants with nets for most of the growing season, especially early in the season, can protect plants from larger pests like beet leafhopper; this method is not effective against smaller pests such as aphids and whiteflies and requires a significant amount of plastic.

Lettuce

California is the nation's leading producer of lettuce, primarily in the Salinas Valley. Federally, Sequoia is currently registered for use, but Sequoia CA was also registered for use in California from May 2020 until April 2024. During this time period, sulfoxaflor represented a significant portion of the use of insecticides targeting aphids and whiteflies, which also includes spirotetramat, imidacloprid, flupyradifurone, dinotefuron, malathion, flonicamid, pymetrozine, pyrethrin, and thiamethoxam. Of these, spirotetramat (product name Movento) is used most in lettuce to control aphids and whiteflies, with suppressive effects on diamondback moth, leafminers, and larval thrips. As lettuce crops are always harvested prior to bloom, the 2024 neonicotinoid regulations will not affect pest management.

Compared to the other analyses in this report, lettuce represents the reverse scenario since we have multiple years of sulfoxaflor use that directly shows its use in lettuce pest management programs. Therefore, we compare how use of alternative insecticides may increase in the absence of sulfoxaflor. We assume that use of alternative insecticides would have increased proportionally to the amount of sulfoxaflor used previously; these are 21.9%, 22.7%, and 9.6% for 2021, 2022, and 2023 respectively (Table 6). Previous OPCA reports have provided support for the fact that alternative insecticide use increases proportionate to the use share of a withdrawn material.

Figure 6. Changes in average annual use of alternative insecticides where sulfoxaflor use is replaced in California lettuce production, 2021-2023



Biological control can provide significant control of aphid populations in lettuce production, with several species of natural enemies including parasitoid wasps and syrphid larvae reducing aphid numbers. Some growers plant quick-flowering annuals near lettuce to serve as sources of habitat and food for natural enemies. Results have been mixed so far. Insecticide applications for other pest species can reduce natural enemy populations and biological control alone is often not effective or reliable enough to serve as a feasible alternative to insecticide use. Furthermore, control of aphids by natural enemies may not be fast enough to prevent the transmission of insect-borne viruses in lettuce. While thrips were not included in this analysis since the Sequoia CA label lists them as "suppression only", the thrips-transmitted Impatiens Necrotic Spot Virus (INSV) currently stands as one of the largest economic threats to lettuce production, and additional options to manage thrips vectors would likely benefit growers substantially.

Table 6. Changes in average annual use of select insecticides in response to sulfoxaflor removal in California lettuce production, 2021-2023

Active Ingredient	Current Acres Treated	Current Lbs Applied	Post-Reg. Acres Treated	Post-Reg. Lbs Applied	Acres Increased	Lbs Increased	% Increase
Neonicotinoid							
imidacloprid	112,538	16,238	138,379	19,961	25,841	3,724	22.9
thiamethoxam	67,561	4,320	82,427	5,248	14,866	929	22
Spirotetramat	166,540	12,632	203,624	15,444	37,084	2,813	22.3
Other							
flonicamid	29,257	2,378	35,149	2,857	5,891	479	20.1
flupyradifurone	58,328	9,204	71,035	11,206	12,707	2,002	21.8
malathion	18,445	29,957	22,584	36,717	4,140	6,760	22.4
pymetrozine	8,151	699	9,733	834	1,582	135	19.4
pyrethrins	12,451	480	15,446	596	2,995	116	24.1
*Sulfoxaflor	105,106	4,163					