Economic and pest management evaluation of proposed regulation of nitroguanidine-substituted neonicotinoid insecticides: eight major California commodities

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Executive Summary

In 2018 the California Department of Pesticide Regulation (DPR) released its risk determination for four nitroguanidine-substituted neonicotinoid (NGN) insecticides: clothianidin, dinotefuran, imidacloprid, and thiamethoxam (Troiano et al. 2018). The estimated potential economic impact of fully removing what were deemed high risk uses by Troiano et al., 2018 were analyzed, and the estimated annual costs ranged from $165.6 million to $205.1 million per year using data from 2015-2017 (Goodhue et al., 2019). In 2020, DPR released a draft proposed regulation detailing mitigation measures to protect managed pollinators. The estimated potential impact of those regulations were analyzed, and the estimated annual costs ranged from $11.8 million to $13.6 million using data from 2015 to 2017 (Goodhue et al., 2020). Following public outreach events and a public comment period, DPR updated the proposed regulation in spring of 2021.

This report uses economic data and pesticide use data from 2017-2019 to estimate the economic and pest management implications of the 2021 draft proposed regulation for eight focal crops: almond, cherry, citrus, cotton, grape, strawberry, tomato, and walnut. From 2017-2019, these crops accounted for approximately 90% of total acres treated with NGN and 89% of NGN use by pounds of active ingredient (AI) applied in treatments that would have been affected by the draft proposed regulation (not all crops would be affected). They also accounted for 59% of the value of California's field crop, fruit, nut, vegetable, and melon production and about half of its agricultural exports in 2019 (CDFA 2020a; CDFA 2020b). The draft proposed regulation includes three key features: timing restrictions on applications, allowing regular use in a season within allowed times provided only one NGN is used, and cumulative per-season use rate restrictions when multiple NGNs are used. The applicable restrictions are crop-specific.

Overall, estimated annual net return losses for the eight crops considered would have totaled $13.334 million in 2017, $13.175 million in 2018, and $12.155 million in 2019 if the draft proposed regulation had been in effect (Table ES-1). Net return losses occur if gross revenues decline as a result of decreased yield or if costs increase. The net return loss in this study is due entirely to cost increases because no yield losses are anticipated for these eight crops due to the proposed restrictions. The costs considered are the treatment costs of replacing NGNs with alternative AIs during times in which they are restricted or prohibited by this regulation, including material and application costs. We calculate the total annual loss for each of the three years by comparing the cost of an alternative treatment to that of each application of an NGN actually made that would have been prohibited under the draft proposed regulation. We report the counterfactual annual losses as a way of reflecting how losses would vary depending on differences in pest pressure, acreage, and other considerations across years. Any single year would not be representative and reporting a three-year average alone would obscure year-to-year variations.

Loss estimates do not include losses owing to the more rapid development of resistance to remaining active ingredients by pests for which NGNs are part of the current management program. Chlorpyrifos would have been considered an alternative for multiple crop/pest combinations in this report based on its use in 2017-2019, but, due to the withdrawal of all non-granular chlorpyrifos products in 2019, it was omitted here. Note that restrictions that came into effect in 2019 were associated with much lower use than in previous years.

Table ES-1. Estimated Changes in Costs by Crop and Year ($M)

Crop	2017	2018	2019
Almond	0.012	0.001	0.006
Cherry	0.013	0.024	0.015
Citrus	2.917	3.063	2.968
Cotton	1.811	1.155	1.653
Grape			
Raisin and table	0.692	0.488	0.223
Wine	1.499	1.446	1.634
Strawberry	0.200	0.208	0.209
Tomato			
Fresh market	1.240	1.133	1.091
Processing	4.945	5.650	4.353
Walnut	0.005	0.007	0.003
Estimated total*	**13.334**	**13.175**	**12.155**

*From unrounded estimated costs

Almond. Almond is California's second largest agricultural commodity in terms of value of production, ranked behind milk and cream. Gross revenues totaled $6.1 billion in 2019 and exports were $4.9 billion (CDFA 2020a; CDFA 2020b). Clothianidin is the only NGN currently registered in almond. Imidacloprid was registered until 2015 and growers are allowed to exhaust inventory, so some use was reported during 2017-2019. Neither NGN is applied to a substantial share of almond acreage. The insects most commonly targeted with these NGNs are leaffooted bugs, stink bugs, and San Jose scale. There are effective alternative AIs for each pest. Under the draft proposed regulation, roughly 89% to 94% of the pounds of AI applied and 94% to 96% of the acres treated would be permitted per year. Switching to alternatives for treatments that would have been prohibited would lead to a 68.2% increase in cost on acres using imidacloprid and a 1.5% increase in cost on acres using clothianidin. The total increase in annual costs to almond from the restrictions on NGNs was estimated to be $0.012 million or less. This was due to the small acreage treated with NGNs. Costs due to the regulation would decline once existing imidacloprid product is exhausted.

Cherry. In 2019, gross revenues were $191 million for sweet cherry and exports were $85 million (CDFA 2020a; CDFA 2020b). All four NGNs are registered in cherry; however, only imidacloprid and thiamethoxam are regularly used. Under the draft proposed regulation only 3.6% to 5.5% of acres treated and 3.2% to 12.4% of pounds of AI applied would have been allowed per year. Imidacloprid and thiamethoxam are mainly used against black cherry aphid, cherry leafhopper, and mountain leafhopper. If the target NGNs were restricted in cherry, the percent change in total annual treatment cost on all acres that would have used alternatives instead would have ranged from 2.6% to 5.8%. These percentages correspond to a total estimated cost increase of

$0.013 million to $0.024 million, respectively. The net effect was small because switching to imidacloprid alternatives increases costs while switching to the thiamethoxam alternatives decreases costs.

Citrus. Citrus—specifically grapefruit, lemon, orange, mandarin, and their hybrids—constitute one of California's top ten most economically important commodities by value, with $2.1 billion in gross revenues and $840 million in exports in 2019 (CDFA 2020a; CDFA 2020b). NGNs are used to manage glassy-winged sharpshooter (GWSS), citricola scale, citrus leafminer, Fuller rose beetle, and Asian citrus psyllid (ACP). They are also used to treat harvested citrus before it is shipped to combat the spread of insect pests. Controlling GWSS, which vectors Pierce's disease, in citrus is essential to keep it from invading vineyards, where the disease is devasting. In addition, NGNs are part of the area-wide programs for managing GWSS in citrus. Two NGNs are registered for California citrus, imidacloprid and thiamethoxam; both would be restricted to some extent. Under the proposed regulation, only 30.3% to 36.5% of treated acres and 11.2% to 13.0% of lbs applied would have been allowed per year. The substantial difference between the acreage and volume shares was due to the prohibited treatments having relatively high application rates. Switching to alternatives for applications that would have been prohibited would lead to a cost increase of 61.6% to 66.6% for those applications. The cost increase was small in dollar terms, however, leading to a total estimated cost increase ranging from $2.917 million to $3.063 million on acreage treated with imidacloprid or thiamethoxam.

Applications for a quarantine pest are exempt from the proposed regulation. This is particularly important for citrus because it faces significant potential losses due to a specific invasive, Asian citrus psyllid (ACP). Imidacloprid is a vital component of ACP control programs for commercial and residential citrus. Without the use of imidacloprid, the deadly bacterial disease vectored by ACP, huanglongbing (HLB, or citrus greening disease), would spread at a faster rate in the state, jeopardizing the entire industry. Economic losses from widespread HLB would be significant and are not included in this report because imidacloprid use for ACP, a quarantine pest, would be exempt.

Cotton. Cotton generated $425 million in gross revenues and $438 million in exports in 2019 (CDFA 2020a; CDFA 2020b). Acreage had been decreasing gradually until it recently expanded from its ten-year low of 164,000 acres planted in 2015 to 304,000 planted acres in 2017. It then decreased gradually and reached 258,000 acres in 2019. All four NGNs evaluated in this study are registered and used in cotton. Restrictions would limit growers to choosing one of the four to use on a given field each year. Applications would only be allowed prior to bloom. Lygus, aphids, whiteflies, mites, and thrips are targeted by the NGNs. Preventing secondary pest outbreaks and rotating AIs to reduce the risk of resistance are both important concerns with restrictions on NGNs. Under the draft proposed regulation, only 34.9% to 41.4% of acres treated, and 32.4% to 37.5% of pounds applied would have been allowed per year. The percent change in costs from replacing the NGN applications that would have been prohibited with alternatives ranged from 28.8% in 2018 to 36.6% in 2019, with associated estimated annual losses ranging from $1.155 million to $1.811 million annually depending on the year. The magnitude of these changes was driven by treated cotton acreage, which was a substantial share of harvested acreage, and the large insecticide material cost differences between NGN and alternatives.

Grape. Grape is California's third largest agricultural commodity by value of production, with gross revenues of $5.4 billion and exports totaling $2.3 billion in 2019 (CDFA 2020a; CDFA 2020b). There are three categories of grape produced in California: wine, raisin, and table. In grape, growers use NGN products against vine mealybug, leafhoppers, sharpshooters, and grape phylloxera. Vine mealybug is a problem in all grape-growing areas and can be especially severe in warmer areas, such as the southern San Joaquin Valley. Raisin and table grape are concentrated in warmer growing areas than wine grape, and, as a result, tend to have more problems with vine mealybug. Controlling sharpshooters is vital because they vector Pierce's disease, which is untreatable and devasting to vineyards. CDFA has a Pierce's disease program, with USDA funding, that addresses GWSS. There are alternatives to the NGNs for sharpshooters, leafhoppers and mealybugs, but they are more expensive. Phylloxera management does not have good alternatives for NGNs. Restrictions would limit growers to choosing one of the four NGNs to use on a given field each year. PUR data separate grape into two categories, grape, including table and raisin, and wine. Under the draft proposed regulation, 79.5% to 85.0% of acres treated, and 83.6-84.6% of pounds applied would have been allowed on table and raisin grape, and 82.9% to 88.5% of acres treated, and 86.8% to 87.7% of pounds applied would have been allowed on wine grape. For table and raisin grape, the percent change in costs on affected acreage ranged from 57.4% in 2019 to 71.4% in 2018. The associated annual total cost increase on affected acres summing over all NGNs was estimated to be $0.223 to $0.692 million. For wine grape, the percent change in costs ranged from 72.0% in 2019 to 73.8% in 2017. The associated annual total cost increase was estimated to be $1.446 million to $1.634 million. The changes were driven mainly by the use rate restrictions on fields using more than one NGN or application method and the greater cost of alternatives.

Strawberry. In 2019, strawberry was California's fourth largest agricultural commodity by value of production, with gross revenues of over $2 billion (CDFA 2020a). Exports in 2019 were $402 million (CDFA 2020b). Two NGNs are used to control sucking insect pests in California strawberry: imidacloprid and thiamethoxam. Target insect pests include aphids, leafhoppers, lygus bug, root weevils and grubs, and whiteflies. The importance of these insects may vary by region and year. Provided a grower is not using managed pollinators, applications are restricted to before bloom has begun. If using more than one NGN or application method for one or more NGNs, growers would face new, lower cumulative maximum use rates for total NGN use. In practice, it is likely that only thiamethoxam use would be restricted as it is only used after bloom. Under the proposed regulation, 36.7% to 39.0% of acres treated, and 80.3% to 82.7% of pounds applied, consisting entirely of imidacloprid applications, would have been allowed per year. This would have resulted in an estimated $0.2-0.209 million increase in total costs annually, which was a 29.2% increase in costs on acres treated with thiamethoxam. Although imidacloprid is not nearly as widely used as thiamethoxam for strawberry, it is vital for control of disease vectors; its use would be largely unchanged by the proposed regulation because it occurs before bloom.

Tomato. Tomato was California's eighth largest commodity by value of production in 2019, with gross revenues of $1.2 billion (CDFA 2020a). Exports were $735 million (CDFA 2020b). Tomatoes in California are grown for two markets: fresh and processed. California is the largest producer of processing tomato in the U.S. and the second largest producer of fresh tomato, behind only Florida. Provided a grower is not using managed pollinators, applications would be restricted to before bloom has begun. If using more than one NGN or application method for one or more NGNs, growers would face new, lower cumulative maximum use rates for total NGN use. NGNs are used for aphids, flea beetles, leafhoppers, leafminers, Lygus, potato psyllid, stink bugs, thrips, and whiteflies. The importance of these insects varies by region, year, and market. In addition to the direct efficacy and cost considerations of using alternatives to NGNs, secondary pest outbreaks and resistance management are key considerations in tomato. Owing to the systemic nature of the NGNs, they can be applied once at planting and provide effective control for an extended period of time. Without them, growers would likely apply multiple applications of alternative active ingredients, greatly increasing the treatment cost on affected acres. Under the proposed regulation, 24.8-31.2% of acres treated and 30.6-38.8% of pounds applied would have been allowed. The result would be a 150.5% to 186.6% increase in treatment costs for fresh tomato and a 133.5% to 163.5% increase for processing tomato. In absolute terms, the estimated total annual cost increase ranged from $1.091 million to $1.240 million for fresh market and $4.353 million to $5.650 million for processing.

Walnut. By value of production, walnut was the seventh largest agricultural commodity in California with gross revenues totaling $1.29 billion in 2019 (CDFA 2020a). Two NGN insecticides are registered for use on walnut: clothianidin and imidacloprid. Applications are restricted to post bloom. If using more than one NGN or application method for one or more NGNs, growers will face new, lower cumulative maximum use rates for total NGN use. They are used mostly against aphids and walnut husk fly with minor use against scale insects. Under the draft proposed regulation, 99% of acres treated and 99% of pounds applied would have been allowed per year. Insecticide material and application costs for applications using alternative active ingredients compared to applications using NGNs would increase by 75.9% under the policy. The increase in annual cost was estimated to be $0.003 million - $0.007 million annually.

Caveats. There are a number of caveats regarding the estimates in this report. Here we mention the most significant general ones, while crop-specific ones are included in the individual crop analyses. First, the net revenue loss estimates are not comprehensive estimates for California agriculture; the crops examined account for 59% of California's field crop, fruit, nut, vegetable and melon production and 90% of NGN use that could be affected by the regulation. Second, the analysis uses data from 2017-2019, the three most recent years of data available. Although the data are the most recent available at the time of writing, nonetheless there may have been notable changes in pesticide use since then that could affect the number of impacted acres and/or change the cost of using target NGNs versus alternative AIs. Third, growers' land allocation decisions across crops could change the use of specific AIs. Fourth, new regulations may change the availability of alternative AIs due to cancellations of uses or new restrictions on use, such as approved application methods. One change that has already occurred is the cancellation of chlorpyrifos, effective January 1, 2020. There is also the possibility that new AIs or new uses of existing AIs could be registered. Fifth, invasive species may increase the cost of the restriction of the target NGNs. Finally, the development of pest resistance to AIs can increase the cost of restriction by reducing the number of modes of action available. Even if there are efficacious alternatives for a target NGN for the management of specific pests, using alternatives may limit their availability for controlling other pests and ultimately increase pest management costs and/or reduce yields.

Contents

Executive Summary 2
  Almond. 3
  Cherry 3
  Citrus 4
  Cotton 4
  Grape 5
  Strawberry. 5
  Tomato 6
  Walnut 6
  Caveats 6
Table of Tables 13
Table of Figures 16
Introduction 18
  Considerations across All Crops 21
    Withdrawal of chlorpyrifos. 21
    Resistance management. 21
    Secondary outbreaks. 22
  Cucurbits 22
  Caveats 23
Methods 25
  Crop Selection 25
  Pesticide Use Data 27
    Regions. 27
  IPM Overview 27
  Maps 28
  Determining allowed and prohibited applications 28
  Economic Analysis 29
    Acres treated and pounds applied 30
    Selecting representative products 30
    Representative product prices 30
    Material costs 30
    Application cost 30
    Net returns scenarios 31

Crop-specific considerations. 33

Almond 35

IPM Overview 36

Target Pests 37

Leaffooted bugs. 37

Stink bugs 37

San Jose scale (*Diaspidiotus perniciosus*) 37

Nematodes 37

Target NGN Use: 2017-2019 37

Proposed Restrictions 39

Economic Analysis 40

Conclusions and Critical Uses 43

Cherry 44

IPM Overview 45

Target Pests 45

Black cherry aphid (*Myzus cerasi*). 45

Leafhoppers 45

Other Considerations: Resistance Management 46

Target NGN Use: 2017-2019 46

Proposed Restrictions 47

Economic Analysis 48

Conclusions and Critical Uses 51

Citrus 52

IPM Overview 55

Target Pests 56

Glassy-winged sharpshooter (*Homalodisca vitripennis*). 56

Citricola scale (*Coccus pseudomagnolarium).* 56

Citrus leafminer (*Phyllocnistis citrella*) 57

Fuller rose beetle (*Naupactus godmani*). 57

Asian citrus psyllid (*Diaphorina citri*). 58

Target NGN Use: 2017-2019 58

Timing of imidacloprid applications 59

San Joaquin Valley. 60

Coastal region. 62

        Desert region. 63
        Inland southern California. 64
    Proposed Restrictions 66
    Economic Analysis 68
    Conclusions and Critical Uses 71
Cotton 73
    IPM Overview 74
    Target Pests 76
        Lygus bug (*Lygus hesperus).* 76
        Cotton aphid (*Aphis gossypii*). 78
        Silverleaf whitefly (*Bemesia tabaci* biotype B). 79
        Stink bugs 80
    Target NGN Use: 2017-2019 80
        Other considerations 82
    Proposed Restrictions 83
    Economic Analysis 84
    Conclusions and Critical Uses 88
Grape 89
    IPM Overview 91
    Target Pests 91
        Mealybugs. 91
        Sharpshooters 92
        Leafhoppers 93
        Grape phylloxera (*Daktulosphaira vitifoliae*) 93
    Target NGN Use: 2017-2019 94
    Proposed Restrictions 97
    Economic Analysis 98
    Conclusions and Critical Uses 103
Strawberry 104
    Strawberry Production Systems 105
    IPM Overview 107
    Target Pests 107
        Aphids. 107
        Lygus bug (*Lygus hesperus).* 108

- Root weevils and grubs. 109
- Whiteflies. 110
- Target NGN Use: 2017-2019 110
- Other Considerations 113
  - Resistance management. 113
- Proposed Restrictions 114
- Economic Analysis 115
- Conclusions and Critical Uses 118

Tomato 119
- IPM Overview 121
- Target Pests 122
  - Aphids 122
  - Beet leafhopper (*Circulifer tenellus*). 122
  - Flea beetles 123
  - Lygus bug (*Lygus hesperus)*. 123
  - Stink bugs 124
  - Thrips 124
  - Tomato psyllid 125
  - Whiteflies 125
- Other Considerations 126
  - Secondary pest outbreaks 126
  - Resistance management. 126
- Target NGN Use: 2017-2019 127
- Proposed Restrictions 129
- Economic Analysis 131
- Conclusions and Critical Uses 137

Walnut 139
- IPM Overview 140
- Target Pests 141
  - Aphids. 141
  - Walnut husk fly (*Rhagoletis completa*). 141
- Target NGN Use: 2017-2019 141
- Proposed Restrictions 142
- Economic Analysis 143

  Conclusions and Critical Uses 145
Literature cited 146
Appendix A: Draft Text of Proposed Regulation 150

Table of Tables

Table 1. Target Nitroguanidine-substituted Neonicotinoid Proposed Regulations by Focal Crop 19
Table 2. Crop Selection Decision Information 26
Table 3. Growing Regions in California as Defined by the Pesticide Use Report Database 27
Table 4. Application Method Costs per Acre 31
Table 5. Summary of Methodological Refinements by Crop 34
Table 6. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Almond, 2017-2019 38
Table 7. Representative Products and Costs Per Acre: Almond, 2017-2019 41
Table 8. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Almond, 2017-2019 41
Table 9. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Almond, 2017-2019 42
Table 10. Change in Treatment Cost due to the Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Almond, 2017-2019 42
Table 11. Annual Use of Target Nitroguanidine Substituted Neonicotinoids and Alternative Active Ingredients: Cherry, 2017-2019 47
Table 12. Representative Products and Costs Per Acre: Cherry, 2017-2019 49
Table 13. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Cherry, 2017-2019.. 49
Table 14. Costs Per Acre for Target Nitroguanidine-substituted Neonicotinoids and Composite Alternative: Cherry, 2017-2019 50
Table 15. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Cherry, 2017-2019 50
Table 16. California Citrus Production Acreage and Value: 2018-2019 Crop Year 52
Table 17. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Citrus, 2017-2019 59
Table 18. Representative Product Cost per Acre: Citrus 69
Table 19. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Citrus, 2017-2019 ... 70
Table 20. Costs Per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative 71
Table 21. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Citrus, 2017-2019 71
Table 22. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Cotton, 2017-2019 81
Table 23. Representative Products and Costs Per Acre: Cotton 85
Table 24. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Cotton, 2017-2019 . 86
Table 25. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Cotton 87
Table 26. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids (NGNs): Cotton, 2017-2019 87

Table 27. Annual Use of Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Raisin and Table Grape, 2017-2019 96
Table 28. Annual Use of Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Wine Grape, 2017-2019 96
Table 29. Representative Products and Costs Per Acre: Raisin and Table Grape 99
Table 30. Representative Products and Costs Per Acre: Wine Grape 100
Table 31. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Raisin and Table Grape, 2017-2019 101
Table 32. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Wine Grape, 2017-2019 101
Table 33. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and Composite Alternative: Raisin and Table Grape 102
Table 34. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and Composite Alternative: Wine Grape 102
Table 35. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids (NGNs): Raisin and Table Grape, 2017-2019 103
Table 36. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids: Wine Grape, 2017-2019 103
Table 37. California Strawberry Acreage and Yield: 2018 106
Table 38. Flowering and Harvest Periods by Production Region: Strawberry 106
Table 39. Strawberry Growing Regions 107
Table 40. Use Trends for Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Strawberry Thiamethoxam, 2017-2019 113
Table 41. Representative Products and Costs per Acre: Strawberry, 2017-2019 116
Table 42. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Strawberry, 2017-2019 117
Table 43. Average Cost per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Strawberry. 2017-2019 117
Table 44. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Strawberry, 2017-2019 118
Table 45. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Fresh Market Tomato, 2017-2019 128
Table 46. Annual Use of Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Processing Tomato, 2017-2019 129
Table 47. Representative Products and Costs Per Acre: Fresh Tomato 132
Table 48. Representative Products and Costs Per Acre: Processing Tomato 133
Table 49. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Fresh Market Tomato, 2017-2019 134

Table 50. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Processing Tomato, 2017-2019 135
Table 51. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Fresh Tomato 136
Table 52. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Processing Tomato 136
Table 53. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Fresh Market Tomato, 2017-2019 137
Table 54. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Processing Tomato, 2017-2019 137
Table 55. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Walnut, 2017-2019 142
Table 56. Representative Products Cost per Acre in 2018: Walnut 144
Table 57. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids (NGNs): Walnut Pre-Bloom, 2017-2019 144

Table of Figures

Figure 1. Total acres treated with nitroguanidine-substituted neonicotinoids by focal crop: 2017-2019 20
Figure 2. Stepwise process for labeling applications as allowed 28
Figure 3: Reallocation of acres treated with prohibited NGN applications to alternatives 32
Figure 4. California almond production: 2019 36
Figure 5. Monthly use of target nitroguanidine-substituted neonicotinoids: Almond, 2017-2019 39
Figure 6: Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Almond, 2017-2019 40
Figure 7. California cherry production: 2019 44
Figure 8. Monthly use of target nitroguanidine-substituted neonicotinoids: Cherry, 2017-201946
Figure 9. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Cherry, 2017-2019 48
Figure 10. California citrus production and growing regions: 2017 53
Figure 11. Acres planted to orange, mandarin, lemon and grapefruit by region, 2006-2017 54
Figure 12. Top export markets: Orange, 2017 54
Figure 13. Top export markets: Lemon, 2017 55
Figure 14. Imidacloprid use by month, region, and crop: Citrus acres treated, 2010, 2013, 2016, and 2019 60
Figure 15 Pounds of imidacloprid used (bars) and acres treated (line): San Joaquin Valley region, 2006-2019 62
Figure 16. Pounds of imidacloprid used (bars) and acres treated (line): Coastal region, 2006-2019 63
Figure 17: Pounds of imidacloprid used (bars) and acres treated (line): Desert region, 2006-2019 64
Figure 18: Pounds of imidacloprid used (bars) and acres treated (line): Southern California region, 2006-2019 65
Figure 19: Monthly use of target nitroguanidine-substituted neonicotinoids: Citrus, 2017-2019 66
Figure 20. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Citrus, 2017-2019 68
Figure 21. California cotton production: 2019 74
Figure 22. Monthly use of target nitroguanidine-substituted neonicotinoids: Cotton, 2017-2019 82
Figure 23. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Cotton, 2017-2019 84
Figure 24. California raisin and table grape production: 2019 90
Figure 25. California wine grape production: 2019 91
Figure 26. Monthly use of target nitroguanidine-substituted neonicotinoid use: Raisin and table grape and wine grape, 2017-2019. 95
Figure 27. NGN use in grape that would have been allowed with the proposed restrictions: 2017-2019 98
Figure 28. California strawberry production: 2019 105

Figure 29. Nitroguanidine-substituted neonicotinoid use trends: Strawberry, 2017-2019....... 112
Figure 30: Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Strawberry, 2017-2019 115
Figure 31. California fresh market tomato production: 2019 120
Figure 32. California processing tomato production: 2019.. 121
Figure 33. Monthly use of target nitroguanidine-substituted neonicotinoids: Fresh market and processing tomato, 2017-2019 127
Figure 34: NGN use in tomato that would have been allowed with the proposed restrictions: 2017-2019 131
Figure 35. California walnut production: 2019 140
Figure 36. Monthly use of target nitroguanidine-substituted neonicotinoids: Walnut, 2017-2019 142
Figure 37. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed under the proposed restrictions: Walnut, 2017-2019 143

Introduction

Neonicotinoids are a class of systemic insecticides that attack insects' central nervous system, blocking nicotinic acetylcholine receptors (Le Goff and Giraudo 2019). They are effective against many sucking and some chewing insects and have become widely used since their introduction in the mid-1990s as alternatives to organophosphates and carbamates (Jeschke and Nauen 2008; Cimino et al. 2016; Le Goff and Giraudo 2019). They have comparatively low toxicity to mammals but are toxic to many insects, including bees. Nitroguanidine-substituted neonicotinoid (NGN) insecticides are a subset of the neonicotinoid insecticide class that have been determined to be most harmful to bees (Troiano et al. 2018). There are four NGN active ingredients (AIs): clothianidin, dinotefuran, imidacloprid, and thiamethoxam. They are registered on a wide variety of crops in California.

Food and Agricultural Code (FAC) section 12838 required the California Department of Pesticide Regulation (DPR) to issue a risk determination on its reevaluation of the NGNs, which it completed in July 2018 (Troiano et al. 2018). The risk determination report provides detailed designations of whether uses of the four NGNs at full label rates on different crops are high risk or low risk to bees. Among the risks considered were those to the colony as a whole from sub-lethal exposure (Troiano et al. 2018). Following public outreach events and a public comment period, DPR updated the proposed regulation in spring of 2021. The new draft proposed regulation is meant to mitigate the risks to managed pollinators (honeybees) that were identified in the 2018 risk determination while allowing growers to use NGNs in lower-risk ways. This report estimates the economic effects of the 2021 draft proposed regulation on eight major California crops: almond, cherry, citrus, cotton, grape, strawberry, tomato and walnut. These crops accounted for 59% of the value of California's field crop, fruit, nut, vegetable and melon production and about half of its agricultural exports in 2019 (CDFA 2020a; CDFA 2020b).[1]

The draft proposed regulation (presented in Appendix A: Draft Text of Proposed Regulation) will be referred to as the "proposed regulation" throughout the remainder of this report. The proposed regulation includes general and crop group-specific restrictions. In all crop groups, applications are prohibited during bloom. For crops deemed highly attractive to bees that routinely use managed pollinators, including citrus, stone fruit, and almond, there are restrictions on the cumulative pounds per acre both for individual NGNs and cumulative applications of all NGNs annually, and restrictions on the times of the year the NGNs can be applied in addition to the prohibition during bloom. In other crops, including fruiting vegetables, walnut, and berries, one NGN applied with one application method (soil versus foliar) may be used up to the label limit on cumulative application rates. However, if a grower decides to use more than one NGN or more than one application method, there are restrictions on the cumulative use rates for

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[1] Grape juice included in raisin and table grape exports.

individual and all NGN use that are lower than current labels allow.[2] Combined, these restrictions can significantly impact when and how NGN products can be used. The extent of timing and use rate restrictions are in Table 1 and detailed in each crop section. There is an exemption for use of NGNs for a quarantine pest, which is particularly important for citrus and will be addressed in the citrus section.

Table 1. Target Nitroguanidine-substituted Neonicotinoid Proposed Regulations by Focal Crop

	Multiple NGNs or application methods	**Imidacloprid**	**Thiamethoxam**	**Clothianidin**	**Dinotefuran**
Almond	Cumulative use max 0.2 lb AI/ac/yr	No current products registered. Use of existing stock allowed from end of bloom to harvest up to 0.2 lb AI/ac/yr	No current products registered.	No soil application. Foliar application allowed from end of bloom to harvest up to 0.2 lb AI/ac/yr	No current products registered.
Cherry	Cumulative use max soil - 0.38 lb AI/ac/yr, foliar - 0.54 lb AI/ac/yr	Allowed end of bloom to harvest (max soil - 0.38 lb AI/ac/yr, foliar - 0.5 lb AI/ac/yr)	Allowed end of bloom to harvest (max soil - 0.38lb AI/ac/yr, foliar - 0.172 lb AI/ac/yr)	No current products registered.	No current products registered.
Citrus	Cumulative use max soil - 0.25 lb AI/ac/yr, foliar - 0.172 lb AI/ac/yr	Allowed: soil - petal fall to November 10 (max - 0.25 lb AI/ac/yr); foliar - petal fall to December 1 (max - 172 lb AI/ac/yr)	Allowed: soil - petal fall to January 31 (max - 0.172 lb AI/ac/yr); foliar - petal fall to December 1 (max - 172 lb AI/ac/yr)	Allowed: soil - petal fall to September 13 (max - 0.2 lb AI/ac/yr); foliar - petal fall to December 1 (max - 172 lb AI/ac/yr)	Allowed: soil - petal fall to January 31 (max - 0.172 lb AI/ac/yr); foliar - petal fall to December 1 (max - 172 lb AI/ac/yr)
Cotton*	Cumulative use by any method max 0.3 lb AI/ac/yr	No use during bloom	No use during bloom	No use during bloom	No use during bloom
Grape*	Cumulative use max soil - 0.2 lb AI/ac/yr, foliar - 0.1 lb AI/ac/yr	No use during bloom	No use during bloom	No use during bloom	No use during bloom
Strawberry*	Cumulative use max soil - 0.2 lb AI/ac/yr, foliar - 0.1 lb AI/ac/yr	No use during bloom	No use during bloom	No use during bloom	No use during bloom
Tomato*	Cumulative use by any method max 0.172 lb AI/ac/yr	No use during bloom	No use during bloom	No use during bloom	No use during bloom
Walnut*	Cumulative use by any method max 0.2 lb AI/ac/yr	No use during bloom	No use during bloom	No use during bloom	No use during bloom

*While there are use rate restrictions with managed pollinators for these crops, they rarely use managed pollinators.

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[2] Foliar applications refer to ground and aerial applications in which the product is applied to the leaves or stems of a plant. Soil applications refer to applications of product directly to the soil by chemigation, side dressing, or other methods.

In 2014, Assembly Bill 1789 (which added section 12838(b)(1) to the California Food and Agriculture Code), required DPR to issue a determination with respect to its reevaluation of neonicotinoids by July 1, 2018. After making this determination, the bill gave the department two years to identify and adopt measures necessary to protect pollinator health. After the risk determination was released, the Office of Pesticide Consultation and Analysis (OPCA) in the California Department of Food and Agriculture (CDFA) began working with DPR to assess the economic and pest management effects of potential changes in the availability of NGNs. Additional information regarding mitigation measures was provided by DPR in January, February, and March 2020 and March 2021. This report evaluates the potential estimated economic impacts on eight major California crops of a specific possible change driven by DPR's 2021 proposed regulation to mitigate risk. There are two previous reports available. One was completed immediately after the 2018 risk determination and examined the potential impact of fully removing what were deemed high risk uses by Troiano et al. (2018) (Goodhue et al., 2019). The second report, Goodhue et al., (2020), examined the potential economic impact of the 2020 draft proposed regulation released by DPR. This report includes updated mitigation options and uses PUR data from 2017-2019 instead of 2015-2017. All three reports are part of the interagency consultation between DPR and OPCA. Accordingly, the analyses are limited to evaluations of the economic effects on California agriculture of regulations regarding pesticides under consideration by DPR, which is OPCA's mandate as specified in FAC Section 11454.2.

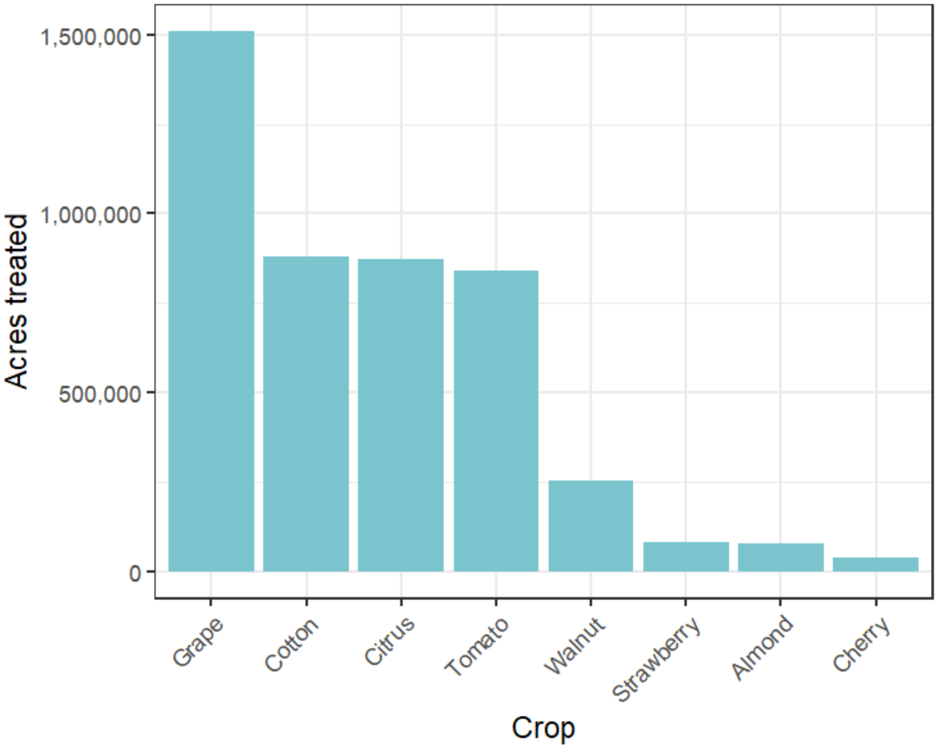

Figure 1. Total acres treated with nitroguanidine-substituted neonicotinoids by focal crop: 2017-2019

For the eight focal crops, we discuss the importance of NGN insecticides for pest management, identify situations where NGNs are of key importance, i.e., alternative AIs are not economically viable or efficacious, and analyze the economic impact of the proposed regulation of NGNs.

Total acres treated with target NGNs for each focal crop over the three-year period 2017-2019 are plotted in Figure 1 using DPR's Pesticide Use Report (PUR) database. Crops were chosen based on four criteria: their acreage treated with the AIs relative to their total acreage, their use of the AIs relative to the total use of that AI across crops, the potential impact of the regulations on their pest management practices and costs, and their economic importance to California agriculture (see page 25). Each crop section includes basic economic information, the pests targeted by NGNs, the monthly and annual use of the target NGNs, and an economic analysis of the impact of restricting specific uses of the NGNs.

Considerations across All Crops

There are several issues that are common across crops: the cancellation of chlorpyrifos, resistance management, secondary pest infestations, and regional differences that lead to differences in the relative efficacy of the NGNs and available alternatives. The crop analyses identify instances in which one or more of these are particularly important; however, none are entirely absent for any crop.

Withdrawal of chlorpyrifos. Chlorpyrifos was listed as a toxic air contaminant by the California Department of Pesticide Regulation in 2018, which led to an agreement between Dow AgroSciences and DPR to discontinue the use of all chlorpyrifos, except granular products, within two years. Apart from granular formulations, chlorpyrifos products were no longer sold in California as of January 2020 and all use ended by December 31, 2020.[3] Chlorpyrifos could have served as a substitute for NGNs in some cases. This report restricts attention to evaluating the economic impacts of restricting NGNs for specific uses based on acres treated with NGNs. Economic impacts of canceling chlorpyrifos essentially concurrently are not considered directly.[4]

Resistance management. Resistance is when insects become less susceptible to a specific insecticide through a change that is heritable. Resistance is a major problem facing growers. It decreases the effectiveness of the insecticide, thereby increasing the cost of insect management and/or reducing yield due to more insect damage.

How insecticides kill insects – their modes-of-action (MoA) – is important because insects can quickly evolve resistance to one MoA if it is heavily used (Le Goff and Giraudo 2019). Insecticides are classified based on MoA by the Insecticide Resistance Action Committee (IRAC).[5] These classifications are routinely used by growers and pest control advisors (PCAs). One of the best ways to slow the development of resistance is to limit the exposure of insect populations to

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[3] https://www.cdpr.ca.gov/docs/chlorpyrifos/index.htm

[4] See https://www.cdfa.ca.gov/files/pdf/ChlorpyrifosReport.pdf for an assessment of the cost to California agriculture of the cancellation of chlorpyrifos.

[5] https://www.irac-online.org/

specific MoAs by rotating what is applied in a given location. Guidelines are available to growers and PCAs about how to rotate insecticides to reduce the risk of resistance.

Neonicotinoids, including the four NGNs addressed here, are often used in rotation with insecticides with other MoAs, particularly for pests that are known to develop or have already developed resistances to some AIs. Even if a variety of AIs are effective against a pest, it is likely that resistance would develop more quickly if NGNs are removed from the rotation. We do not address the economic impact of resistance to other insecticides developing faster than it would have otherwise.

Secondary outbreaks. Virtually all crops have primary and secondary pests. Primary, or key, pests generally attack a crop on a perennial basis, requiring regular management. Secondary pests cause infrequent damage, needing only occasional control measures. Secondary pests can quickly become damaging if an insecticide applied for a key pest eliminates natural enemies that were keeping the secondary pest in check. This is a common situation with spider mites, which are often well-controlled by natural enemies. Broad spectrum insecticides, like pyrethroids, destroy natural enemies, allowing mite populations to explode. This is called a ‘secondary pest outbreak.’

As a result, pest managers take into account how an application targeting one pest will affect populations of other pests when selecting insecticides for use. NGNs play an important role in preventing secondary pest outbreaks because they are less harmful to natural enemies than alternatives including organophosphates, carbamates, and pyrethroids. Restricting use of NGNs could increase the use of insecticides beyond direct replacement of the NGN if secondary pest outbreaks necessitate more treatments. This cost is not captured in the economic analyses but could be substantial. Additionally, it could worsen the problem of resistance development.

Cucurbits

Cucurbits were not included in the focal crops (see methods section for crop selection), and no economic impacts were estimated for them. Owing to specific pest management constraints, however, it is possible that cucurbits would be significantly affected by the proposed regulation. Like strawberry and tomato, in cucurbit crops – melon, cucumber, squash – NGNs are used to manage insects that vector diseases, specifically aphids. Unlike strawberry and tomato, cucurbit crops do use managed pollinators. For fields using managed pollinators, there are proposed restrictions on cumulative use rate. For imidacloprid these would be no more than 0.2 lbs AI/acre/year of soil applied and 0.172 lbs AI/acre/year of foliar applied. Imidacloprid is a critical tools for managing vectors. If the cumulative use rate restrictions proposed in the regulation render these AIs ineffective against aphids, it is likely that multiple sprays of alternatives would be needed to control aphids, and it is possible that even with multiple applications of alternatives these crops would nonetheless sustain yield loses. These potential economic impacts are not included in this report.

Caveats

There are a number of caveats regarding the estimates in this report. Here we mention the most significant ones. In addition, the individual crop analyses include crop-specific considerations. The first set of caveats regards methodology, starting with the selection of crops we analyzed. While they are economically important crops that apply the target NGNs to a substantial amount of acreage, they account for only slightly more than 60% of the value of California's field crop, fruit, nut, vegetable and melon production and 90% of acres treated with NGNs that could be subject to restrictions each year. The loss estimates presented here are not comprehensive estimates for the entire production agriculture sector. A second caveat regards the use of historical data. 2017-2019 were the three most recent years of data available at the time of analysis. There may have been notable changes in pesticide use since then that are not reflected in this analysis. Such changes could affect the number of impacted acres if there was a significant increase or decrease in the use of the target NGNs relative to the use of alternative AIs. Any redistribution of use across AIs could increase or decrease the cost of using target NGNs versus alternative AIs. Steggall et al. (2018) provide a more complete discussion of the development of the methodology and addresses the logic behind each major modeling decision.

Another methodological caveat is that the proposed restrictions are complicated and sometimes related to crop development (e.g., allowed after bloom or between petal fall and December 1). These phenological phases do not always occur at the same time each year, and may vary by growing region. We used estimates of when those events would likely occur to conduct these analyses. It is possible that our estimates are either too broad, thereby allowing applications that should not be allowed, or too narrow, thereby disallowing applications that should be allowed. Similarly, in order to analyze the restriction to only one NGN per field per year, we had to select which one growers would be most likely to choose based on use during the base years and the role(s) each plays in an integrated pest management program for the crop in question.

A second set of caveats regards external factors that could substantially alter the results presented here. First, growers' land allocation decisions could change. Changes in crop acreage may change the number of individual AIs applied in total. Second, new regulations may change the availability of alternative AIs. We were able to control for one regulatory action in this report; chlorpyrifos was excluded as an alternative due to its cancellation. There is the potential for other regulatory actions, even in the near term; for example, beta-cyfluthrin is under review by DPR (https://www.cdpr.ca.gov/docs/registration/canot/2018/ca2018-04.pdf). Given the stage of the review process, beta-cyfluthrin is included as an alternative, though it may not be available in the future. In general, the availability of existing alternative AIs may change due to cancellations of uses or new restrictions on use, such as approved application methods. There is also the possibility that new AIs or new uses of existing AIs could be registered in California. Third, growers could reduce their cumulative use rate to comply the new limits with only moderate changes to their use patterns in some cases. For this analysis, we assumed that growers were using the minimum amount they considered effective. As such, we assumed that no one would change their use to adjust to the regulations. This is likely overly conservative. Growers near the cumulative use rate would likely be able to adjust downward with no loss of efficacy. Even so, the cumulative use rate was not usually the most restrictive part of the proposed regulation in terms of eliminating applications from the set that would remain feasible. Often timing restrictions and full prohibitions eliminated more applications.

A third set of caveats is that biological changes may occur. Invasive species may increase the cost of the restriction of the target NGNs. For example, the development of pest resistance to AIs can also increase the cost of regulation. Rotating AIs with different modes of action is a key tool for managing the development of resistance, as noted above. Even if there are efficacious alternatives for a target NGN for the management of a specific pests, using these alternatives may limit their availability for controlling other pests and ultimately increase pest management costs and/or reduce yields.

Methods

This section details the methods used for each crop in the following analysis, which are based on Steggall et al. (2018). The criteria used for crop selection are discussed first, followed by the data regarding pesticide use, the integrated pest management (IPM) methods, and finally the components of the economic analysis.

Crop Selection

DPR used the federal Environmental Protection Agency's crop group categories in the proposed regulations. Accordingly, we utilized those categories to select crops for analysis. For each crop group, Table 2 reports the crop that treated the most acres with all NGNs from 2017-2019 along with its total acres treated for that three-year period, and whether the crop is included in this analysis. If it is not, the reason is provided in the rightmost column. In some groups, additional crops were analyzed due to their substantial use of NGNs and/or their economic importance to California agriculture. In the berry crop group, grape (wine, table, and raisin) was the top user. Strawberry was also included owing to the potential large impact of prohibiting imidacloprid use and its economic importance as a crop. Pistachio was the heaviest user in the tree nut group but would not be subject to any restrictions unlike almond and walnut, which would be. Lettuce and cole crops (Brussels sprout, cabbage, collard green, and kale) were heavy users by acres treated but would not be restricted unless the crops are allowed to flower.[6] Potato would not be restricted. Artichoke, carrot, sugarbeet, turnip, parsnip, radish, rutabaga, and skirret would not be restricted unless they are being grown for seed. In total, eight crops were selected for analysis based on NGN use and economic importance. These crops represented 63-66% by acres treated and 54-68% by pounds applied of total NGN use annually during the study period. They represented approximately 89% or 90% of use, for pounds and acres respectively, for crops that would be affected by the regulation.[7]

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[6] If these crops are allowed to flower, all use of NGNs would be prohibited. This would only happen in crops grown for seed.

[7] Crops that would be affected only if being grown for seed are excluded from this calculation because the acreage dedicated to seed production is small.

Table 2. Crop Selection Decision Information

Crop group	Crop with most acres treated 2017-2019	Acres treated 2017-2019	Other crops included	Included in report	Explanation
1: Root and tuber vegetables	Potato	141,638	None	No	Small acreage
3: Bulb vegetables	Artichoke	4,900	None	No	Not restricted
4: Leafy vegetables	Lettuce	884,326	None	No	Not restricted
5: Cole crops	Broccoli	490,913	None	No	Not restricted
6: Legume vegetables	Dried bean	41,019	None	No	Not restricted
8: Fruiting vegetables	Tomato	929,254	None	Yes	
9: Cucurbit vegetables	Cantaloupe	168,762	None	No	Small acreage
10: Citrus fruit	Aggregated	974,006	None	Yes	
11: Pome fruits	Apple	7,48	None	No	Small acreage
12: Stone fruits	Cherry	42,782	None	Yes	
13: Berry	Grape (table, raisin, and wine)	1,600,210	Strawberry	Yes	
14: Tree nuts	Walnut	592,405	, Almond	Yes	
15: Cereal grains	Rice	968	None	No	Small acreage
19: Herbs and spices	Cilantro	13,918	None	No	Not restricted
20: Oilseeds	Cotton	880,274	None	Yes	
24: Tropical and subtropical fruit	Fig	399	None	No	Small acreage

Pesticide Use Data

Pesticide use data from 2017-2019, specifically pounds applied, and acres treated by AI, were obtained from DPR's pesticide use reporting (PUR) database.[8] 2019 is the most recent year of data available when this analysis was conducted. Any shifts in use since then are not captured in our analysis. Use of the target NGNs was examined for various time intervals within a year depending on how the proposed regulations might affect the crop.

Regions. Table 3 presents the standard growing regions for California defined in the PUR.

Table 3. Growing Regions in California as Defined by the Pesticide Use Report Database

Region	**Counties**
Middle Coast	Monterey, San Benito, San Francisco, San Luis Obispo, San Mateo, Santa Clara, Santa Cruz
North Coast	Del Norte, Humboldt, Lake, Marin, Mendocino, Napa, Sonoma, Trinity
North East	Alpine, Amador, Calaveras, El Dorado, Lassen, Mariposa, Modoc, Nevada, Placer, Plumas, Shasta, Sierra, Siskiyou, Tuolumne
Sacramento Valley	Butte, Colusa, Glenn, Sacramento, Solano, Sutter, Tehama, Yolo, Yuba
San Joaquin Valley	Alameda, Contra Costa, Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, Tulare
South Coast	Los Angeles, Orange, San Diego, Santa Barbara, Ventura
South East	Imperial, Inyo, Mono, Riverside, San Bernardino

Citrus, strawberry, and tomato were examined using crop-specific regions, which are presented in the crop sections.

IPM Overview

The PUR does not contain information on the target pest for an application. To determine the appropriate alternatives, it is necessary to know generally what growers are targeting with the NGNs and alternative AIs, as well as a sense of the factors influencing variations in NGN use within and across years. Based on our knowledge of pest management for these crops, coupled with consultations with PCAs, growers, industry members, and other extension personnel, we identify target pests for each NGN and then identify alternative AIs for managing each of those pests.

The IPM overviews for individual crops largely replicate the discussions in Goodhue et al. (2020). While the mitigation measures proposed by DPR have changed, the basics of pest management

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[8] https://www.cdpr.ca.gov/docs/pur/purmain.htm

in these crops have not changed since that report. An exception, noted in the introduction, was the withdrawal of all non-granular chlorpyrifos products from the California market. Chlorpyrifos was not included as an alternative to the target NGNs in the IPM discussions in the prior report for this reason.

Maps

The maps presented in each crop section depict the spatial distribution of production across California. With the exception of citrus, the maps were created using PUR data. PUR data are organized spatially using the Public Land Survey System (PLSS), which divides the country into sections of one square mile. As such, the highest resolution possible with PUR data is one square mile. The maps plot every square mile in which any application of any material was made to the crop in 2019. It is rare for fields to have zero PUR records in a whole year. This method does not capture the acres treated of the crop within a square mile. The map would show the same result if there were one acre or 100 acres treated within the square mile.

Determining allowed and prohibited applications

For each crop, we assessed which applications would have been allowed and which would have been prohibited under the proposed regulations. The economic impacts are based on what would have happened in place of the applications that would have been prohibited (e.g. one or more applications of alternative insecticides) and if yield losses would be expected under that scenario. Due to the complex and layered nature of the restrictions, we defined applications as allowed using a stepwise process to remove prohibited ones. Allowed applications were: 1) within the allowed timeframes; 2) on fields using only one AI and method over the course of the year; or 3) on field using multiple NGNs or application methods but with a total annual use rate of no more than the new cumulative use rate for each NGN. Those applications would have been unaffected by the proposed regulation (Figure 2). We estimate the cost of prohibiting the remaining applications.

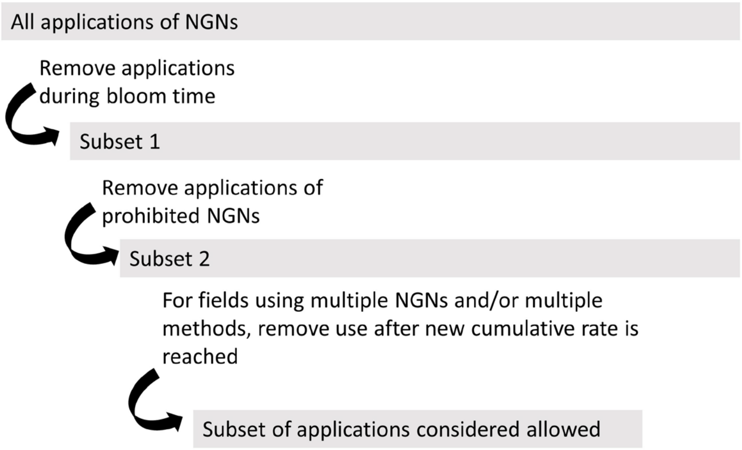

Figure 2. Stepwise process for labeling applications as allowed

The timing restrictions in the proposed regulations are based primarily on crop phenology. When possible, we estimated the approximate annual timing of the relevant crop development stages (i.e., bud burst, bloom, petal fall, berry size, harvest). The estimates of crop development are broad approximations that are unlikely to be exactly right for every year. When the proposed regulation gave dates (e.g., December 1), we used those dates. Applications outside of the allowed times were considered prohibited.

The number of NGNs used and the type and number of application methods (soil and foliar) used determine what the maximum use rate on a field can be. PUR method codes were used to determine if an application was foliar or soil applied. Fields using only one of the four NGNs and only one type of application method NGN use would be allowed to apply up to the current maximum label rate. For fields that used more than one NGN AI and/or both application methods, applications would be allowed up to new (bee safe) cumulative use rates. The cumulative rates are crop specific. Additionally, crops that highly attractive to bees have use rate restrictions and/or use manage pollinators, all applications are subject to new lower cumulative use rates. Which applications would be kept (allowed) and which would be considered prohibited was determined on a crop-by-crop basis based on pest management requirements. Specific decisions for each crop are presented in each crop section.

Prohibitions on AIs and application methods were straightforward. If an AI or application method is prohibited in the proposed regulations, applications using that AI and/or application method were considered prohibited.

New maximum use rates, which we refer to as bee safe use rates, are included in the proposed regulation. The restricted use rates cap the cumulative use rate on a single field in a given season for fields using more than one NGN or multiple methods. We first marked as prohibited any single applications that were over the maximum allowed rate. We then calculated the cumulative use rate for each field by summing the use rate for each allowed application over the course of the growing season. Once a field accrued the maximum cumulative use rate proposed in the regulation, further applications were marked as prohibited. (Applications that had been marked as prohibited by previous steps were not included in the calculation of the cumulative maximum rate.)

Economic Analysis

We estimated the change in pest management costs due to the proposed restrictions. Applications that would be allowed under the proposed regulations would not incur a change on cost. For applications that would have been prohibited, we estimated the change in pest management costs for each crop based on the acres treated, the available alternatives, and the costs per acre of the AIs (Steggall et al. 2018). The baseline total cost was established by multiplying the cost per acre for each target NGN by the acres treated with that target NGN from applications that would be prohibited. This was compared to the cost of the regulated scenario. In the regulated scenario we evaluated, applications of the target AIs would be restricted as outlined in Table 1. To estimate the cost, we assigned all the acres that had been treated with the target NGNs in prohibited applications to the alternative AIs in proportion to the acreage treated with the alternative AIs in 2017-2019 (Steggall et al. 2018).[9] Below we provide details for the general methods applied to all crops and then describe refinements designed to address crop-specific factors. No yield declines were anticipated for these eight crops as a result of the proposed regulation, so changes in pest management costs determined the change in net returns.

Acres treated and pounds applied. The acres treated with each AI and the pounds of AI applied were extracted from the PUR database for each target and alternative AI. These data were used to construct the use trend graphs and tables presented for each crop and the economic analysis. Applications with zero acreage reported were dropped from the study. Total acres treated with insecticides does not correspond to total acres planted or harvested because some acres may have been treated with multiple AIs or treated with the same AI more than once, while other acres may not have been treated with a target NGN or an alternative AI at all.

Selecting representative products. For each AI in each crop, we identified a representative product to use in determining the cost of the proposed regulations. The representative product for an AI was generally the one that was used on the most acres of the crop in question from 2017-2019. When there were substantial disparities in the ranking of products by use between years, 2019 was used because it reflects the most recent decisions by growers. In tomato, the product for most acres treated with spinetoram was applied as a pre-mix product that was not used for the target pests. In this case, the most-used product that was applied for management of the target pests was included instead.

Representative product prices. Once representative products were identified, we determined the price for each product. Prices were obtained from communications with industry members, Farm Business Network reports, internet searches, and recent cost and return studies.

Material costs. The price for the representative products was standardized to cost per pound. For example, if the price was $10/oz, the standardized cost was $10/oz * 16 oz/lb, or $160/lb. Many products are aqueous, and we used the density of the products (provided in the PUR database product table) to convert to cost per pound. Because we are interested in the cost of the AI and not inert ingredients, the cost per pound was multiplied by the percentage of the product that is AI, also in the PUR database product table, to obtain the cost per pound of the AI. The cost of the AI per acre is the cost per pound multiplied by the average use rate (pounds of AI applied/acres treated) for that crop over the study period (Steggall et al. 2018).

Application costs. In some cases, alternatives may require a different application method, which can change the cost per acre of a treatment. Using cost studies and expert consultation, we estimated application costs for aerial spraying, ground spraying, chemigation, and side dressing (Table 4). Chemigation and side dress were assigned a zero cost based on the limited time needed

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[9] Because chlorpyrifos was is no longer an alternative, acres treated with chlorpyrifos are not included in this calculation even for crops in which chlorpyrifos would have been an alternative in 2017-2019.

for chemigation using already installed equipment and the simultaneous application of other products or other operations with side dress. Aerial application costs vary considerably and depend on multiple factors, including but not limited to the size of the field being treated, the type of aircraft being used, the rate of application, and the number of applicators in the area. We used 100 acres at 5 gallons per acre as the average to determine the cost. In cotton, strawberry, and tomato, most aerial applications are made with fixed wing aircraft. In almond, cherry, citrus, grape, and walnut, helicopters are sometimes used, which increases the cost of aerial applications. To account for this, experts estimated a higher cost per acre in these crops.

Table 4. Application Method Costs per Acre

Application method	Cost ($)
Ground	25
Aerial including helicopters	27.5
Aerial mostly fixed wing	17.5
Chemigation	0
Side dressing	0

Application method is recorded in the PUR data. One key caveat is that while ground and aerial applications and fumigation are specified in the pesticide use reports that comprise the PUR database, chemigation, and side dressing are meant to go in a category called ‘Other.’ ‘Other’ captures all methods that are not ground, aerial, or fumigation. For the crops and representative products considered, chemigation and side dress are the only relevant options other than ground and aerial. Because both of these practices have an estimated cost of zero, they can be grouped together for analysis. Accordingly, in this report, aerial and ground applications were foliar and ‘Other’ were soil.

When an AI can be applied to a crop using a variety of application methods, we calculated the average application cost per acre based on the frequency at which each application method is used across acres treated with applications that would be prohibited under the proposed regulations. For example: if half of the prohibited applications of an AI on a crop were ground applied ($25/acre) and the other half were aerial applied including helicopters ($27.50/acre), the average application method cost would be $26.25/acre. Only applications that would be affected by the policy change were included in the calculation because only those applications would need to be replaced.

Net returns scenarios. In order to calculate the cost of the loss of the NGNs for each crop, we compared net returns under the status quo to net returns under the proposed regulation. In this study, available alternatives would allow growers to avoid yield losses for all crops, so the change in net returns is simply the change in pest management costs. The change in cost per acre has two components: the change in the material cost per acre and, when appropriate, the change in application costs. The total change in costs for each NGN is the acres currently treated with that NGN multiplied by the change in the cost per acre. The total change in cost for the crop is the sum of the total change in cost for all NGNs.

Identifying the change in cost per acre required determining an alternative AI. In many instances more than one alternative is available and would likely be used on some acreage. Thus, following Steggall et al. (2018) we defined a composite alternative: each AI was assigned to acres currently treated with prohibited applications of NGNs in proportion to its share of total acres treated with all alternatives. For example, if there were 300 acres of a crop, 200 were treated with an NGN and 100 of those acres were treated with a NGN application that would have been prohibited under the proposed regulation, 50 were treated with alternative 1, 35 were treated with alternative 2 and 15 with alternative 3, then the three alternatives were assigned proportionately to treat a share of the 100 acres of the acres treated with an NGN application that would have been prohibited, with assignments of 50, 35, and 15 acres, respectively (Figure 3). Thus, under the draft regulation 100 acres treated with an NGN would sustain no change in cost per acre, and 100 acres would sustain a change in cost. Note that while the acreage of the three alternatives doubled in this example, the original 100 acres treated with them would be unaffected by the proposed regulation.

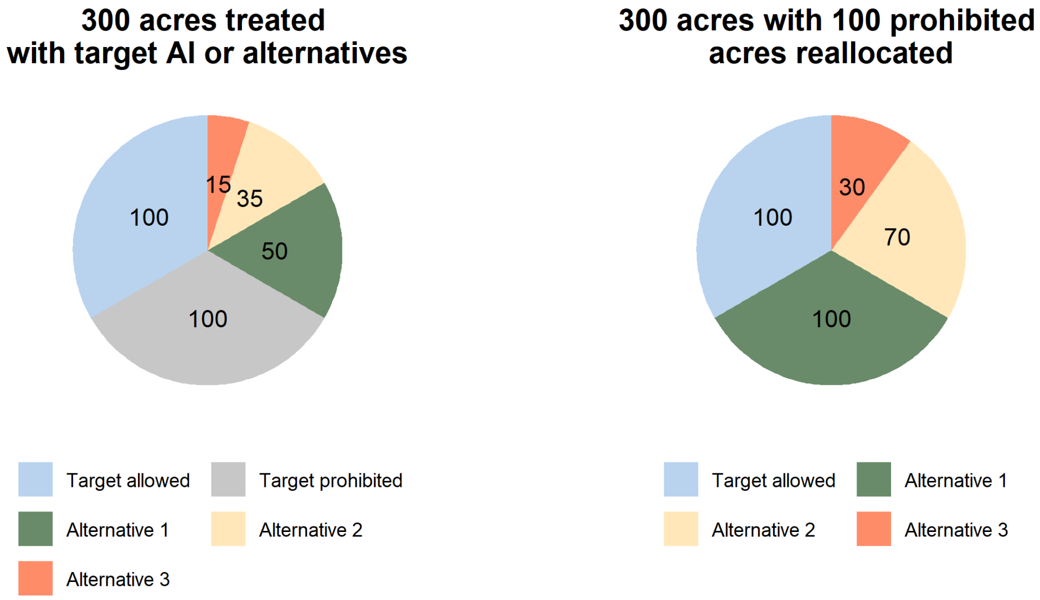

Figure 3: Reallocation of acres treated with prohibited NGN applications to alternatives

The cost per acre under the proposed regulation is reported as the weighted average of the costs of alternatives 1, 2, and 3. In this case, 1, 2, and 3 accounted for 50%, 35%, and 15% respectively of the composite alternative. The total treatment cost is this composite cost per acre multiplied by the 100 acres currently treated with a prohibited NGN application. Costs would not change on acreage currently treated with a non-NGN AI or with a NGN application permitted under the proposed regulation. A minor caveat is that, if applications were identified as being restricted under the proposed regulation in a different order (i.e., multiple application methods before multiple AIs), status quo costs may change by very small amounts, ultimately resulting in in very small differences (less than 1%) in the calculated total cost for the change in cost. Another caveat is that because use is scaled up based on all acres treated, the share of a given alternative in overall use of alternatives may not represent its use as a substitute for NGNs for any specific pest.

Crop-specific considerations. Table 5 summarizes crop-specific refinements to the methodology in Steggall et al. (2018). These refinements addressed unique features of the crop and how it could be affected by the proposed restrictions.

As reported in the second column of Table 5, the analyses for three crops were conducted separately for subsets of prohibited applications: grape, tomato, and walnut. For grape and tomato, the subset was based on the type of product produced: table and raisin grapes versus wine grape, and fresh market versus processing tomatoes. The alternative AIs are different, therefore the acreage shares needed to be calculated separately across the two subsets for each crop. For walnut, the subset was based on the timing of the application: pre-bloom (January to March) and post-bloom (April to December). This is because pests targeted by NGNs in walnut in the pre-bloom period are different than those targeted in the post-bloom period.

The third column of Table 5 reports other assumptions or features of the analysis unique to a specific crop. For almond, pyriproxyfen bait was not included as an alternative AI because the bait products target ants, which NGNs do not. For walnut, spinosad cost per acre was calculated separately for bait and spray because the use rate for bait is orders of magnitude smaller than for spray. As with almond, pyriproxyfen bait is excluded as an alternative AI because it does not target the same pests. Citrus, strawberry, and tomato growing regions differed from the standard PUR-defined regions presented in Table 3.

Table 5. Summary of Methodological Refinements by Crop

Crop	Subsets for defining representative product	Crop-specific considerations
almond		Excludes pyriproxyfen bait as an alternative AI.
cherry		None
citrus	Aggregates orange, lemon, mandarin, grapefruit, and their hybrids	Regions are different from those defined in the PUR.
cotton		None
grape	Table+ raisin, wine	None
strawberry		Regions are different from those defined in the PUR.
tomato	Fresh market, processing	Multiple applications of some alternative AIs included in the composite alternative. Regions are different from those defined in the PUR.
walnut		Spinosad bait and spray treated separately as alternatives. Excludes pyriproxyfen bait as an alternative AI.

Almond

Almond is one of California’s most economically important commodities, ranking behind only milk and dairy products in terms of value of production. Gross receipts for almond totaled $6.1 billion in 2019 (CDFA 2020a). There were 1.18 million bearing acres and 350,000 non-bearing acres of almond in 2019.

Over 80% of the almond crop, nearly $4.9 billion, is exported, making almond California’s most important export agricultural commodity by value. California accounts for all national almond production and is by far the largest producer and exporter in the world. For 2020-2021, the California almond crop was forecast to account for nearly 80% produced worldwide and 90% of almond exchanged through export markets (USDA FAS 2020). Almond was a top three agricultural export commodity to eight of the top ten agricultural export markets in 2019: European Union, India, China/Hong Kong, Canada, Japan, United Arab Emirates, Korea, Turkey, Mexico, and Taiwan (CDFA 2020b).

Almonds are grown throughout the Central Valley, from Redding in the north to Bakersfield in the south, with some additional isolated production closer to the coast near San Luis Obispo (Figure 3). The three largest almond producing counties, Kern ($1.6 billion), Fresno ($1.5 billion), and Stanislaus ($1.2 billion), accounted for 57% of state production in 2019 (CDFA 2020a). Almond was a top four agricultural commodity by value in 13 counties (Kern, Fresno, Stanislaus, Madera, San Joaquin, Merced, Colusa, Glenn, Kings, Yolo, Butte, Solano, and Tehama), the second most important agricultural commodity in two of these counties (Merced and Kings), and the top agricultural commodity in nine (Kern, Fresno, Stanislaus, Madera, San Joaquin, Colusa, Glenn, Yolo, and Solano).

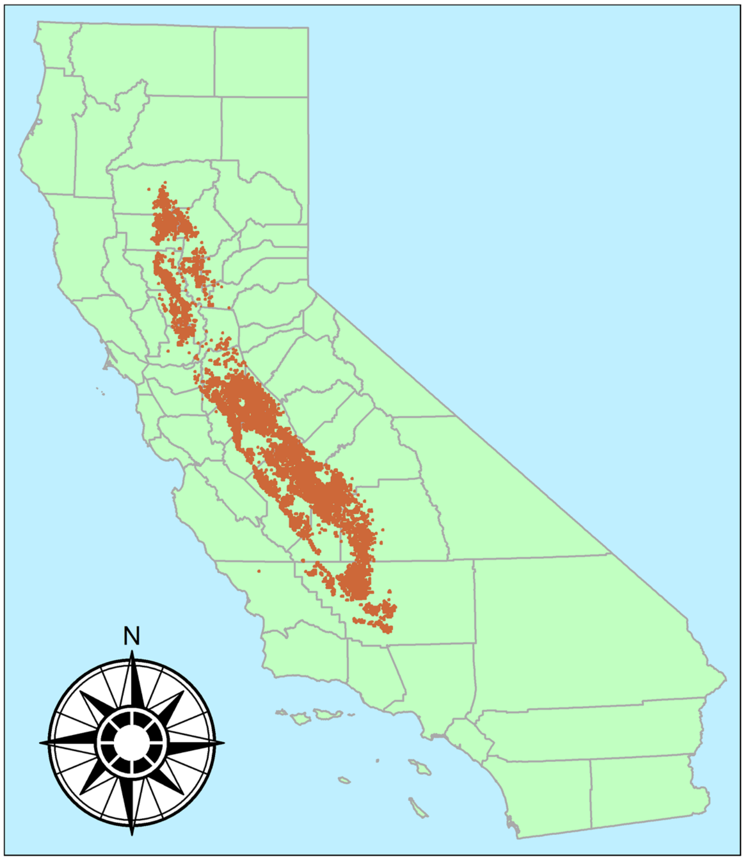

Figure 4. California almond production: 2019

IPM Overview

Given the broad geographic distribution of almond acreage in California, production occurs under a variety of agronomic and climatic conditions, which in turn leads to a diverse array of production practices and patterns of pesticide use. Almond production conditions can broadly be divided between the Sacramento Valley and San Joaquin Valley, although there are idiosyncrasies within each of these macro-regions, most importantly between the southern and northern San Joaquin Valley. Here, pesticide use will be evaluated statewide, which requires some generalization about key pests and their management.

Clothianidin and imidacloprid are the two NGNs used in almond, although neither has substantial use. Clothianidin is currently registered. Imidacloprid was registered until 2015 and growers are allowed to exhaust inventory, so some use was reported during 2017-2019. Clothianidin is used more often, and approximately 85% of the time it is tank mixed as a secondary AI along with major AIs like abamectin and/or methoxyfenozide or chlorantraniliprole. Though clothianidin is considered an alternative AI for the control of plant bugs like leaffooted bug (LFB), it is not considered to be very effective. LFB and other plant bugs are more commonly and effectively controlled with pyrethroids. Consistent with its registration status, imidacloprid use is negligible

(<1% of imidacloprid use). Imidacloprid can be used in the dormant period or in the spring. Dormant applications of imidacloprid are likely via drip irrigation targeting nematodes while spring applications target scale. Growers report occasionally using chemigated imidacloprid against nematodes. This is rare and not effective. As such, alternative AIs for management of nematodes are not considered in this analysis. There are alternative AIs for the control of scale (e.g., oils, insect growth regulators (IGRs)) and nematodes (e.g., 1,3-dichloropropene, spirotetramat) in almond.

Target Pests

Leaffooted bugs. Three leaffooted bug species are sporadic pests of almond: *Leptoglossus zonatus* (most common), *L. clypealis*, and *L. occidentalis*. These leaffooted bugs overwinter as adults in sheltered areas near almond orchards and migrate into orchards in April and May in search of food. Populations of these insects can vary annually across regions, but in the right weather, large populations can emerge and cause significant damage. Adults feed on young nuts using piercing mouthparts, which can cause the forming nuts to abort. On mature nuts, they cause black spots on the kernel or nut drop. Though clothianidin is used to treat leaffooted bugs in almond, it is not the main treatment and some alternatives are more effective. Alternatives include abamectin, bifenthrin, lambda-cyhalothrin, and esfenvalerate. Chlorpyrifos has historically been used to control leaffooted bugs, however, non-granular chlorpyrifos is no longer being sold in California and is not considered as an alternative in this analysis.

Stink bugs. Several stink bugs can be pests in almond: the green stink bug, *Acrosternum hilare* (most common), the redsholdered stink bug (*Thyanta pallidovirens* and *T. custator acerra*), and the Uhler stink bug (*Chlorochroa uhleri*). Stink bug populations develop around almond orchards, often in weedy field margins, and then migrate into orchards as adults. Like leaffooted bugs, their piercing mouthparts damage the nuts. Stink bug damage appears in May through July. Clothianidin may be applied for stink bug, usually in a tank-mix with bifenthrin or lambda-cyhalothrin. Acetamiprid tank-mixed with bifenthrin or lambda-cyhalothrin is the main alternative currently available. Chlorpyrifos would also have been considered an alternative before DPR issued the notice to ban in May 2019.

San Jose scale (*Diaspidiotus perniciosus*). Imidacloprid is occasionally used against scale in the spring. However, this is not common, and more effective alternatives for this spray timing include pyriproxyfen, buprofezin, and carbaryl.

Nematodes. Growers report occasionally using chemigated imidacloprid against nematodes. This is rare and not effective. As such, alternative AIs for management of nematodes are not considered in this analysis.

Target NGN Use: 2017-2019

Neonicotinoids were applied to fewer than 16,000 out of over 1.5 million acres of almond in 2019. Use declined from 2017 to 2019 (Table 6). NGN use primarily consists of acres treated with clothianidin as well as a small number of acres treated with imidacloprid (Table 6). Clothianidin is mostly applied between March-May, with peak applications in April, consistent with when leaffooted bug would be entering orchards. Very few applications were reported during the pre-bloom period (Dec/Jan/Feb) in 2017-2019 (Figure 5).

Table 6. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Almond, 2017-2019

Active ingredient	**--------Pounds applied------**				**------------Acres treated------------**				**Use rate (lb/ac treated)**
	2017	2018	2019	Three-year total	2017	2018	2019	Three-year total	
abamectin	23,547	24,976	25,520	74,043	1,246,788	1,255,422	1,274,871	3,777,082	0.02
acetamiprid	1,487	2,117	3,089	6,693	12,204	15,091	21,647	48,942	0.14
bifenthrin	96,119	134,229	126,756	357,104	577,505	784,147	743,160	2,104,812	0.17
buprofezin	3,930	22,290	13,988	40,208	3,783	12,486	8,971	25,240	1.59
carbaryl	2,680	2,226	116	5,022	1,357	771	116	2,244	2.24
clothianidin*	3,476	2,214	1,523	7,214	35,943	22,728	15,444	74,115	0.10
esfenvalerate	13,285	21,443	20,561	55,288	206,313	320,701	296,300	823,314	0.07
imidacloprid*	304	189	28	521	1,776	2,859	243	4,879	0.11
lambda-cyhalothrin	12,929	19,362	19,542	51,834	344,894	493,948	510,730	1,349,572	0.04
pyriproxyfen	2,352	4,701	3,738	10,791	164,720	261,925	209,188	635,833	0.02

*Target NGN

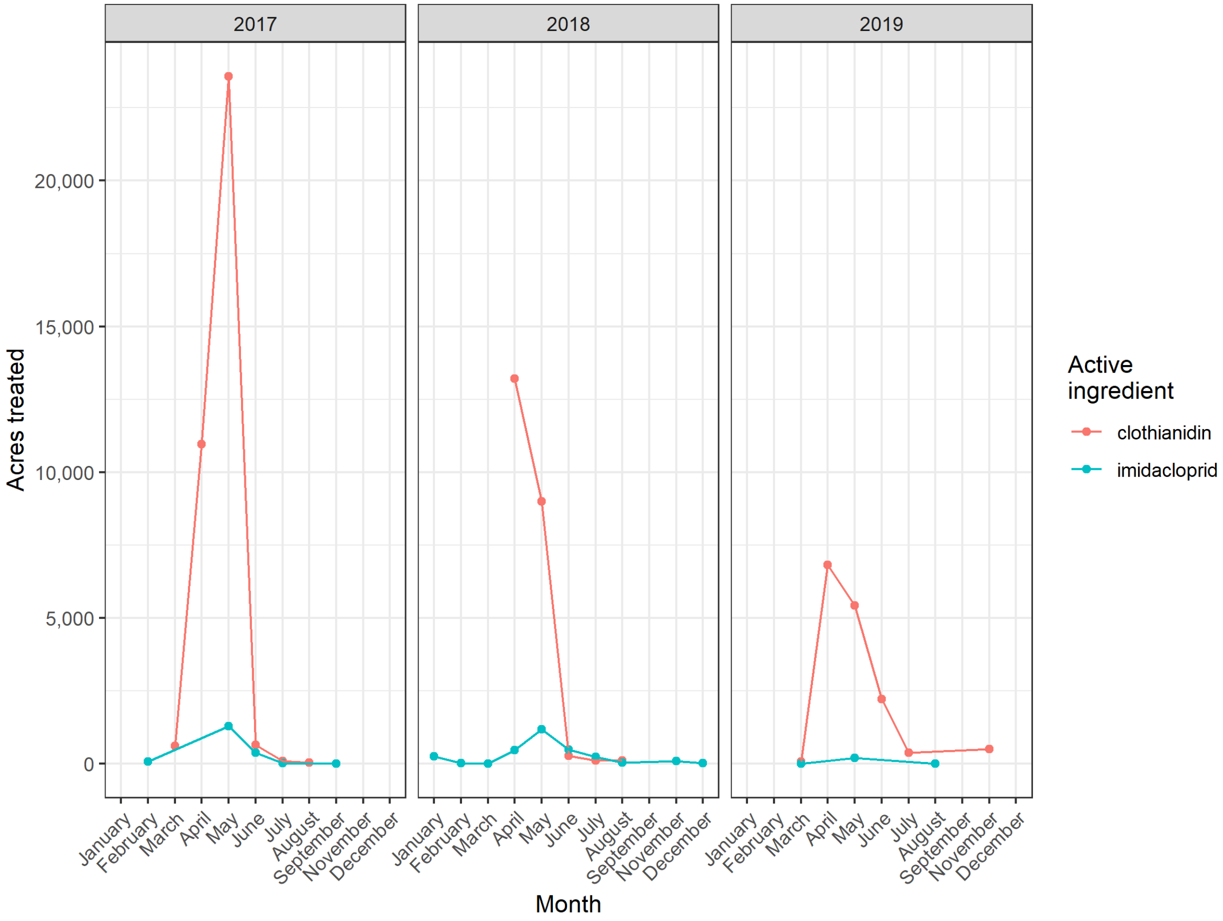

Figure 5. Monthly use of target nitroguanidine-substituted neonicotinoids: Almond, 2017-2019

Proposed Restrictions

Almond is in the tree nut crop group but would have more stringent restrictions than other major tree nuts owing to the regular presence of pollinators. Under the proposed regulations, the use of both NGNs would be allowed to a limited extent. Soil applications would be prohibited. Foliar NGN applications would be allowed after bloom and before harvest, which is consistent with existing use patterns. This period begins roughly at the end of March and ends at roughly the end of August each year. Additionally, neither single applications nor the cumulative use rate would be allowed to exceed 0.2 lb/acre.

Despite having more restrictions that other nut crops, it is unlikely that these restrictions would impact pest management significantly in almond. Historically, only a relatively small share of annual use has occurred during the restricted period (Figure 6). Because imidacloprid is no longer registered, applications of imidacloprid in orchards also applying clothianidin were replaced with clothianidin applications up to the cumulative use rate of 0.2 lb/acre in the analysis; after the cumulative use rate was reached, all further applications were moved to the alternatives. Applications before 1 April and after 31 August were reallocated to the alternatives. The proposed regulation would have still allowed roughly 89-94% of lb of AI previously used and 94-96% of acres treated previously treated from 2017-2019.

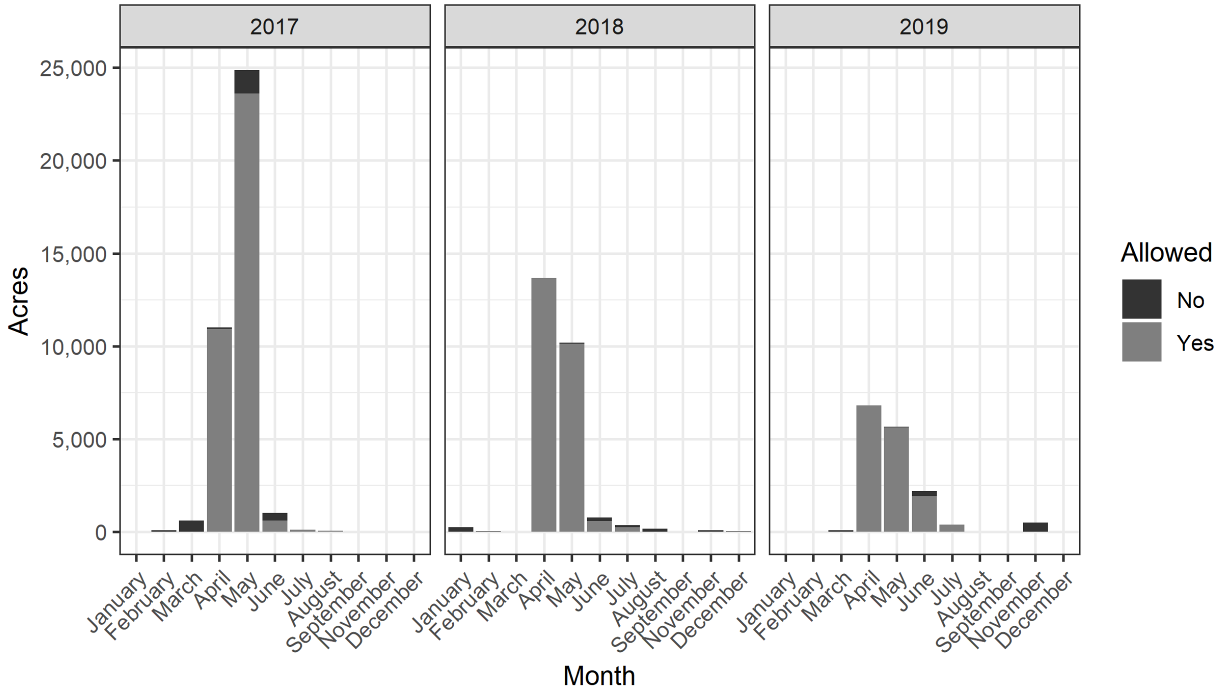

Figure 6: Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Almond, 2017-2019

Economic Analysis

This section presents the anticipated change in net returns to almond if the use of clothianidin and (remaining stocks of) imidacloprid was restricted. This cost includes the change in pesticide material and application costs.

Table 7. Representative Products and Costs Per Acre: Almond, 2017-2019

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
abamectin	Abba Ultra Miticide/Insecticide	6.85	24.96	31.82
acetamiprid	Assail 30 SG Insecticide	36.12	24.97	61.09
bifenthrin	Bifenture EC Agricultural Insecticide	8.38	25.32	33.70
buprofezin	Centaur WDG Insect Growth Regulator	59.17	24.96	84.13
carbaryl	Sevin Brand XLR Plus Carbaryl Insecticide	33.46	25.56	59.03
clothianidin*	Belay Insecticide	14.20	18.56	32.76
esfenvalerate	Asana XL	7.77	25.08	32.85
imidacloprid*	Wrangler Insecticide	7.08	12.69	19.77
lambda-cyhalothrin	Warrior II	7.86	25.11	32.97
pyriproxyfen**	Seize 35 WP Insect Growth Regulator	40.47	25.10	65.57

*Target NGN

** Ant bait was excluded because ants are not targeted by NGNs.

Table 7 presents representative products for each active ingredient used on almond in 2017–2019 and their costs per acre. The total cost per acre is the sum of the material and application costs per acre. The material cost was calculated as the product of the three-year average use rate (lb/ac) and the price per pound of product. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited (i.e., excludes allowed applications). The total cost per acre ranged from $19.77 for imidacloprid to $84.13 for buprofezin. Growers consider other factors in addition to price per acre when deciding which insecticides to use, as discussed above.

Table 8. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Almond, 2017-2019

Active ingredient	Target NGNs available (% of all target and alternative use)	Share of composite alternative (%)
abamectin	45.6	46.0
acetamiprid	0.6	0.6
bifenthrin	25.4	25.6
buprofezin	0.3	0.3
carbaryl	0.02	0.02
esfenvalerate	9.9	10.0
lambda-cyhalothrin	16.3	16.4
pyriproxyfen	0.9	0.9
total	99.0	100.0

Note: Three-year average from 2017-2019.

Averaged over the three-year period 2017–2019 when the NGNs were available, the target NGNs were used on 1% of almond acres treated with a target AI or alternative AIs and alternative AIs were used on 99% of almond acres treated with a target AI or alternative AI. Table 8 shows the average acreage shares for each alternative AI used on almond, with NGNs being available and their share of the composite alternative.

To represent growers' responses in the aggregate if target NGNs were restricted, the use of alternative AIs was scaled up in proportion to their acreage shares, as discussed in the methods section. The two most common alternative AIs were abamectin and bifenthrin, which together accounted for 71% of total almond acres treated with target and alternative AI insecticides, which would be 71.6% of acres treated without the target NGNs. Because use is scaled up based on all use, their shares in the overall use of alternatives may not represent their use as a substitute for NGNs for any specific pest.

Table 9. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Almond, 2017-2019

Active ingredient	**Material cost ($)**	**Application cost ($)**	**Total cost ($)**	**Cost increase for switching to composite alternative (%)**
clothianidin	14.20	18.56	32.76	1.5
imidacloprid	7.08	12.69	19.77	68.2
composite alternative	8.16	25.09	33.25	-

Table 9 shows the per-acre costs for the two target NGNs and the composite alternative, whose price we use as a representative pesticide cost if the NGNs were restricted. The total cost per acre of the composite alternative was $33.25, compared to $32.76 for clothianidin and $19.77 for imidacloprid. Material costs per acre for the composite alternative would decrease for clothianidin users and increase for imidacloprid users. Application costs per acre would increase for both imidacloprid and clothianidin users. Clothianidin users would incur a 1.5% increase in total per-acre costs, and imidacloprid users would see a 68.2% increase.

Table 10. Change in Treatment Cost due to the Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Almond, 2017-2019

Year	**Cost with target NGNs ($)**	**Cost without target NGNs ($)**	**Change in cost ($)**	**Change in cost (%)**	**Share of change due to material costs (%)**	**Share of change due to application costs (%)**
2017	60,022	72,338	12,315	20.5	-77.9	177.9
2018	30,048	31,045	997	3.3	-2.4	102.4
2019	19,871	25,901	6,030	30.3	-71.5	171.5

Table 10 reports the projected changes in total cost due to the restrictions on clothianidin and imidacloprid. Total change in annual costs for 2017-2019 ranged from 3.3% based on 2018 applications to 30.3% (2019), corresponding to a cost increase of $997 to $12,315. The final two columns disaggregate the percent change in costs into the percents due to the change in material costs and application costs. The contribution of material and application costs varied by year, depending on the relative acreage of imidacloprid and clothianidin. Overall, the absolute value of the costs was negligible because very few almond acres were treated with NGNs and the composite alternative costs were virtually the same as clothianidin.

Conclusions and Critical Uses

The estimated total increase in costs to almond from the restrictions on NGNs would be small overall due to the relatively small acreage treated with NGNs. The percentage increase per acre would be small to significant, depending on the year, due to some alternatives being more expensive. As noted earlier, the simple cost of alternatives does not reflect other reasons growers might choose or prefer to use a specific AI as part of their pest management programs. For almond, this was particularly important. Three of the four top alternatives by use were pyrethroids, which can cause secondary pest outbreaks that require additional treatment. Increasing the use of pyrethroids could also drive more pest resistance to this insecticide class. In addition, bifenthrin specifically has been detected in exceedance of allowable levels in multiple waterways through the state, which could conceivably lead to regulations restricting its use.

Cherry

California is the second largest producer of sweet cherry in the US, behind only Washington. There were 34,000 bearing acres of sweet cherry in 2019, which produced 58,100 tons worth over $191 million (CDFA 2020a). Out of the 54,330 tons of utilized production, 49,970 tons (92%) were sold in the fresh market at an average price of $3,760 per ton. The remainder were processed at an average price of $710 per ton. By export value, cherry was the 27th most important agricultural product in California. $85 million of production was exported in 2019, nearly 45% of the total value of California cherry production (CDFA 2020b). California's exports accounted for 28.9% of total cherry U.S. export value. Cherry is grown throughout the Central Valley, with some orchards scattered in the foothills (Figure 7). Production is concentrated in San Joaquin County, which produced over $90 million in cherry, which was 34% of total state production in 2019. The next most important cherry-producing counties were Kern (18% of production value), Fresno (13.2%), Tulare (12%), and Stanislaus (8.6%). Cherry was also a top ten agricultural commodity by value in 2019 for Contra Costa ($6 million).

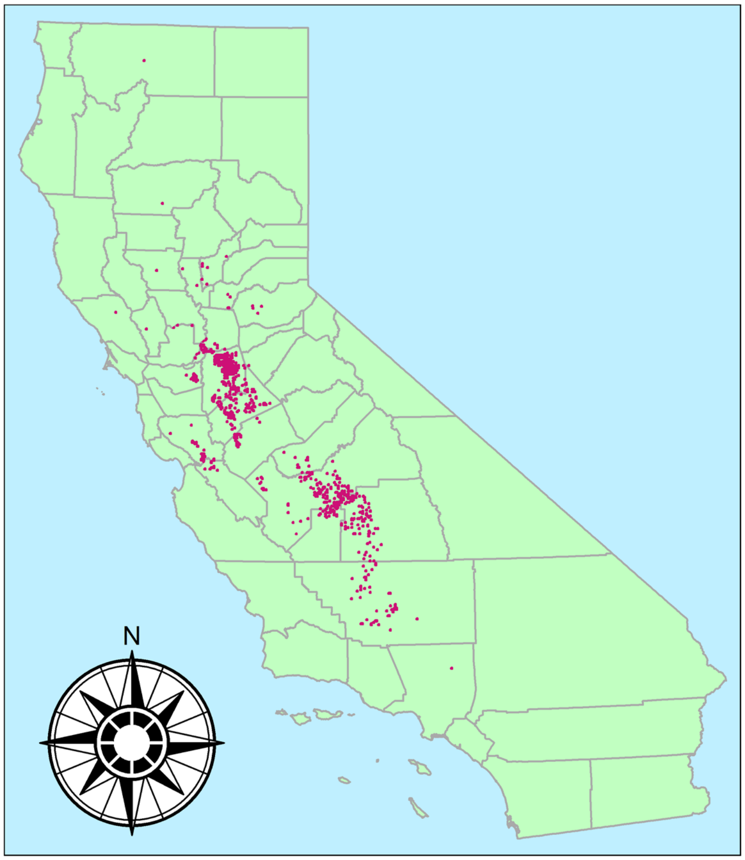

Figure 7. California cherry production: 2019

IPM Overview

Cherry in California is attacked by a variety of insects, diseases, and nematodes. Of the four target NGNs, only imidacloprid and thiamethoxam are registered and used regularly. Imidacloprid and thiamethoxam are used against black cherry aphid (*Myzus cerasi*), cherry leafhopper (*Fieberiella florii*) and mountain leafhopper (*Colladonus montanus*).

Target Pests

Black cherry aphid (*Myzus cerasi*).

Black cherry aphid overwinter as eggs within the orchard and can have multiple generations in the spring, leading to high populations. Severe infestations can cause leaf curling, which can be more severe in young trees. In the summer, black cherry aphid numbers drop substantially in cherry orchards as they migrate to mustard weeds. There are a number of effective alternative insecticides for black cherry aphid: acetamiprid, beta-cyfluthrin, diazinon (delayed dormant treatment or in season), esfenvalerate, flupyradifuone, and lambda-cyhalothrin. Chlorpyrifos was an alternative before its use in California was discontinued in 2020. Sulfoxaflor is not currently registered in cherry but could be in the future at which point it would be an alternative for controlling black cherry aphid. A suite of natural enemies may keep aphids below damaging levels. Conservation of natural enemy habitat and limiting the use of disruptive insecticides may help maintain the natural enemy complex. Acetamiprid, beta-cyfluthrin, esfenvalerate, and lambda-cyhalothrin are quite damaging to natural enemies of black cherry aphid, disrupting biological control. Diazinon is as effective as NGNs but is a water contaminant of high concern in California.

Leafhoppers.

Cherry and mountain leafhoppers are vectors for X-disease, also known as cherry buckskin, that can result in tree death. Cherry leafhopper prefers to feed on cherry. Adults are dark brown, mimicking cherry buds, and are active mid-April to May, July, and September-October. Cherry leafhopper overwinter as eggs in the orchard or on nearby ornamental trees. Cherry leafhopper can be effectively controlled with a diazinon or esfenvalerate as delayed dormant treatment or in-season applications. Fenpropathrin and lambda-cyhalothrin are effective in-season but disrupt natural enemies, as does esfenvalerate (Van Steenwyk et al., 1993; Van Steenwyk and Freeman, 1987). Acetamiprid is effective (Grant and Van Steenwyk 2000).

Mountain leafhopper is also brown as an adult but has a distinctive yellow head on the upper thorax. It overwinters in vegetation or herbaceous crops near orchards. Cherry is not a preferred host of this leafhopper, however, it will feed on trees and thereby spread X-disease. It needs to be controlled in-season, which can be done with pyrethroids (beta-cyfluthrin, fenpropathrin, esfenvalerate, lambda-cyhalothrin), acetamiprid, or diazinon. Pyrethroids are disruptive to natural enemies and could cause mite outbreaks that will then need to be treated (Van Steenwyk and Freeman, 1987). Additionally, in-season application of pyrethroids, acetamiprid, and diazinon can disrupt control of black cherry aphid by killing natural enemies. As noted above, there are water quality concerns with diazinon.

Other Considerations: Resistance Management

If imidacloprid is not available, pest populations may develop resistance to pyrethroids. A major pest in cherry is spotted winged drosophila (SWD). Though imidacloprid is not directly used for SWD control, there is overlap in the alternatives for aphids and leafhoppers that is important to address. Pyrethroids are an important component of SWD management. Many of the alternatives to NGNs for black cherry aphid and leafhoppers are pyrethroids (beta-cyfluthrin, esfenvalerate, fenpropathrin, lambda-cyhalothrin), as noted above. Given the availability of imidacloprid for managing aphids and leafhoppers, growers and pest control adviser have moved away from using pyrethroids for these pests, even though they can be slightly more effective than the NGNs, in order to minimize the risk of developing pest populations, including SWD, that are resistant to pyrethroids. The greater the use, the more risk of resistance. If growers increased the use of pyrethroids in response to NGN restrictions, then there is greater risk of resistance pest populations, including resistant SWD.

Target NGN Use: 2017-2019

From 2017-2019, 4,181 pounds of NGNs were applied to 39,956 acres of cherry. Imidacloprid is the most heavily used NGN in cherry, followed by thiamethoxam (Figure 8).

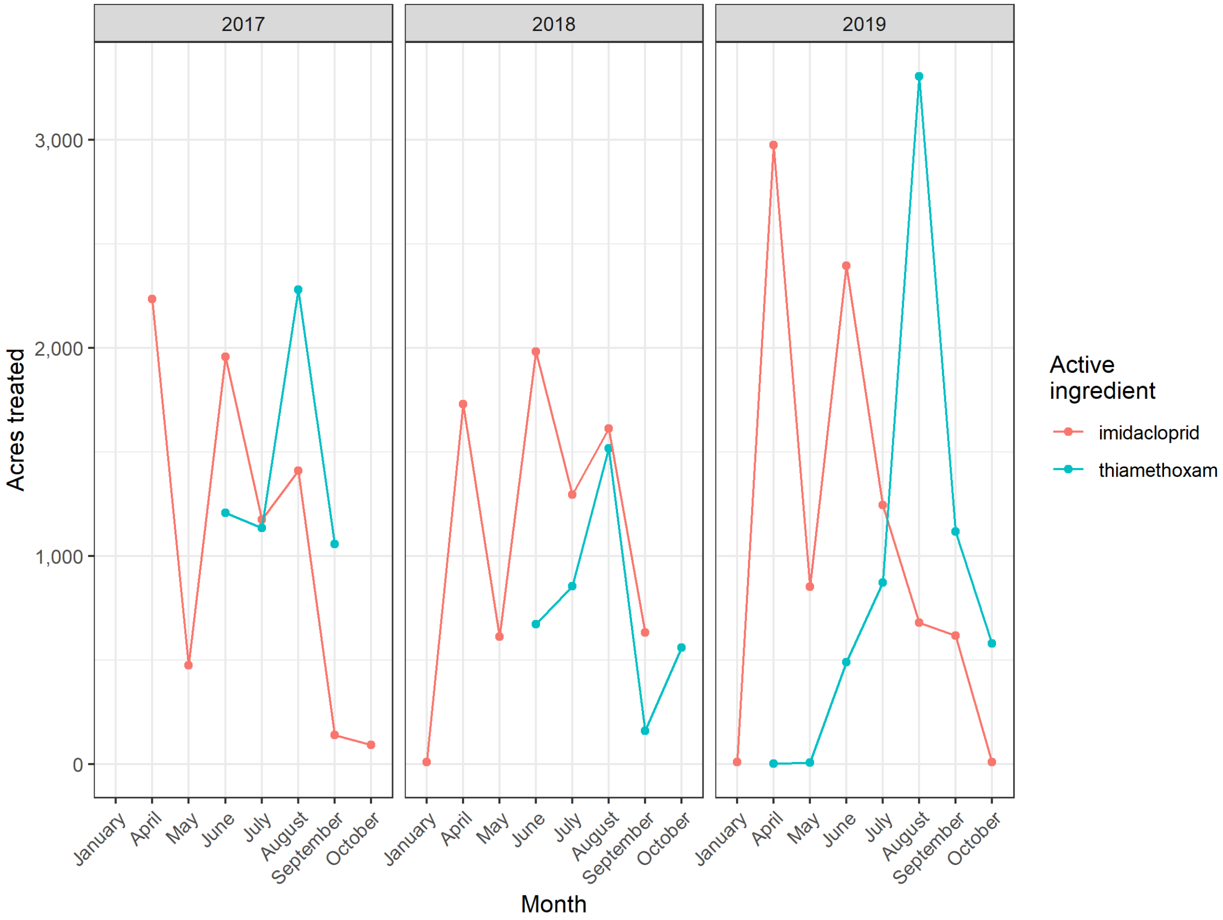

Figure 8. Monthly use of target nitroguanidine-substituted neonicotinoids: Cherry, 2017-2019

In March through May, imidacloprid and thiamethoxam are mainly applied against aphids. After May, they are mainly applied against leafhoppers.

Table 11 reports annual use of NGNs and alternative AIs for the 2017-2019 period based on pounds applied and acres treated. It also includes the average use rate of each AI per acre, calculated by dividing total pounds applied over the three-year period by the total number of acres treated. By acres treated, lambda-cyhalothrin was the most used AI, with over three times as many acres treated as the second most used AI, fenpropathrin.

Table 11. Annual Use of Target Nitroguanidine Substituted Neonicotinoids and Alternative Active Ingredients: Cherry, 2017-2019

Active ingredient	**---------Pounds applied---------**				**-------------Acres treated------------**				**Use rate (lb/ac treated)**
	2017	2018	2019	Total	2017	2018	2019	Total	
acetamiprid	37	33	31	101	297	314	235	846	0.12
beta-cyfluthrin	1	2	2	5	81	72	101	253	0.02
diazinon	594	434	387	1,415	425	332	243	1,000	1.41
esfenvalerate	138	105	64	307	2,289	1,857	1,183	5,329	0.06
fenpropathrin	4,642	5,461	6,802	16,906	14,491	17,151	21,385	53,027	0.32
imidacloprid*	909	966	1,105	2,980	7,478	7,873	8,786	24,137	0.12
lambda-cyhalothrin	1,553	1,318	1,631	4,502	39,318	33,720	41,616	114,653	0.04
thiamethoxam*	468	287	446	1,201	5,679	3,766	6,373	15,819	0.08

*Target NGN

Proposed Restrictions

Cherry is in the stone fruit crop group. Under the proposed regulation, in stone fruit the use of all four NGNs would be allowed to a very limited extent compared to use in 2017-2019. The most restrictive aspect is timing. NGN applications would only be allowed between post-bloom and harvest. For cherry, this is roughly the month of May in most years. Historically, only a small share of annual use has occurred in May (Figure 8). If a field is treated with only one NGN via only one application method, timing would be the only restriction. For fields using more than one NGN and/or more than one application method, there would be additional use rate restrictions: neither single applications nor the cumulative use rate can exceed 0.5 lb/acre (foliar imidacloprid), 0.38 lb/acre (soil imidacloprid) or 0.172 lb/acre (foliar thiamethoxam).

In this analysis, applications outside May were reallocated to alternative AI. For fields using multiple NGNs or methods in May, applications over the restricted use rates were reallocated to alternatives. Only 3.6-5.5% of treated acres and 3.2-12.4% of lbs applied would have been allowed if the proposed regulation had been in effect from 2017-2019 (Figure 9).

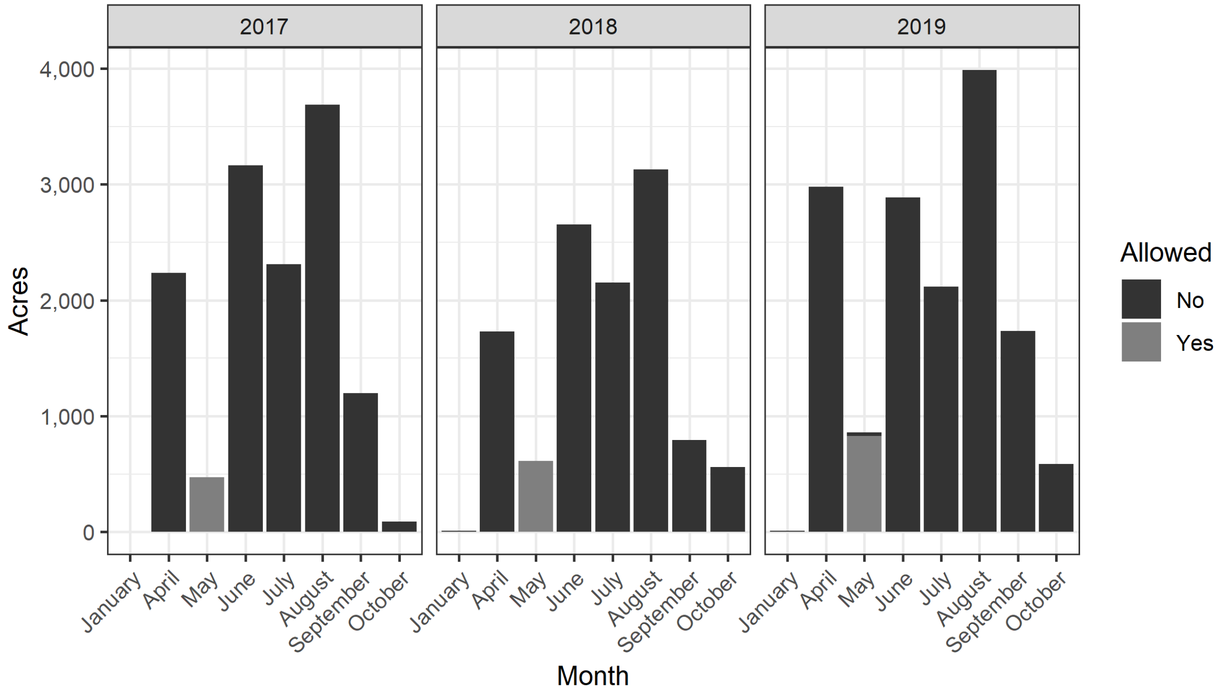

Figure 9. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Cherry, 2017-2019

Economic Analysis

This section presents the estimated change in costs to cherry due to the proposed regulation. In addition to the caveats discussed in the methods section, the costs estimated below do not account for the potential effects of increased insect resistance to pyrethroids discussed above.

Table 12. Representative Products and Costs Per Acre: Cherry, 2017-2019

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
acetamiprid	Assail 30 SG Insecticide	31.48	25.08	56.56
beta-cyfluthrin	Baythroid XL	9.34	25.00	34.34
diazinon	Diazinon 50W	24.45	25.00	49.45
esfenvalerate	Asana XL	6.67	24.84	31.51
fenpropathrin	Danitol 2.4 EC Spray	28.02	24.98	53.01
flupyradifurone	Sivanto 200 Sl	50.90	25.00	75.90
imidacloprid	Admire Pro	10.61	22.82	33.44
lambda-cyhalothrin	Warrior II	8.03	25.00	33.03
thiamethoxam	Platinum 75SG	19.43	25.00	44.43

Table 12 presents representative products for each active ingredient used on cherry in 2017–2019 and their average costs per acre. Average cost per acre for target AIs was calculated using all applications affected by the policy change (i.e., excluding allowed applications). Average cost per acre for AIs in the composite alternative is based on all applications of those AIs. The material cost was calculated as the product of the three-year average use rate (lb/ac) and the price per pound of product. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited, i.e., excluding allowed applications. Most applications on cherry were ground sprays, so the variation in application cost was minimal. The total cost per acre ranged from $31.51 (esfenvalerate) to $75.90 per acre (flupyradifurone). Growers consider other factors in addition to price per acre when deciding which insecticides to use, as discussed above.

Table 13. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Cherry, 2017-2019

Active ingredient	Target NGNs available (% of all target and alternative use)	Share of composite alternative (%)
acetamiprid	0.4	0.5
beta-cyfluthrin	0.1	0.1
diazinon	0.5	0.6
esfenvalerate	2.5	3.0
fenpropathrin	24.6	30.2
flupyradifurone	0.2	0.3
lambda-cyhalothrin	53.2	65.3
total	81.5	100.0

Note: Three-year average from 2017-2019.

Averaged over the three-year period 2017–2019 when the NGNs were available, the target NGNs were used on 18.5% of total cherry acres treated with target or alternative AIs and alternative AIs were used on 81.5% of cherry acreage treated with target or alternative AIs. Table 13 shows the average acreage shares for each alternative AI used on cherry, with and without NGNs available.

To replace applications of target NGNs that would have been prohibited, the use of alternative AIs was scaled up in proportion to their acreage shares, as discussed in the methods section. The two most common alternative AIs were lambda-cyhalothrin and fenpropathrin, together accounting for 77.8% of total cherry acres treated with insecticides, which was 95.5% of acres treated without the target NGNs.

Table 14. Costs Per Acre for Target Nitroguanidine-substituted Neonicotinoids and Composite Alternative: Cherry, 2017-2019

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase for switching to composite alternative (%)
imidacloprid	10.61	22.82	33.44	17.7
thiamethoxam	19.43	25.00	44.43	-11.5
composite alternative	14.35	24.99	39.35	-

Table 14 shows the per-acre costs for the target NGNs as well as the cost of the composite alternative. For cherry, switching to the alternative would increase both the material cost and the application cost for acres treated with imidacloprid. The material cost for thiamethoxam users would decrease when switching to the composite alternative while the application cost is essentially unchanged. Imidacloprid users would incur a total per acre cost increase of 17.7% and thiamethoxam users would incur a cost decrease of 11.5%.

Table 15. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Cherry, 2017-2019

Year	Cost with target NGNs ($)	Cost without target NGNs ($)	Change in cost ($)	Change in cost (%)	Share of change due to material costs (%)	Share of change due to application costs (%)
2017	486,538	499,050	12,512	2.6	-20.9	120.9
2018	410,125	433,885	23,761	5.8	33.9	66.1
2019	548,080	562,588	14,508	2.6	-18.1	118.1

Table 15 reports the calculated change in costs due to the restriction of NGNs. The final two columns of Table 15 disaggregate the percent change in cost into the percent due to the change in material cost and the percent due to the change in application cost. The percent change in total cost for 2017-2019 ranged from 2.6% to 5.8%, corresponding to cost increases of $12,512 and $23,761, respectively. The net effect was small because some of the increase in cost due to switching from imidacloprid to the composite alternative was offset by the decreases in cost due to switching from thiamethoxam to the composite alternative.

Conclusions and Critical Uses

In the case of cherry, the total cost of managing target pests was estimated to increase by at most 5.8% and could increase by as little as 2.6%, due to alternatives being cheaper than thiamethoxam. The magnitude of the total change in net returns would likely be small.

As in other crops, the impact on the development of resistance is a consideration not evaluated here. When there are fewer modes of action that remain available for managing a given pest or set of pests, it is more likely that resistance would develop and that it would develop faster. In cherry, an additional complication to this fundamental biological process is that resistance is a particular concern for a pest not managed with NGNs directly, spotted winged drosophila (SWD). Using NGNs for aphids and leafhoppers allows growers to save other products for use against SWD. Unlike the target pests considered here, SWD can result in substantial yield losses, reducing gross revenues significantly (Walsh et al. 2011).

Citrus

Citrus—specifically grapefruit, lemon, orange, mandarin, and their hybrids—are one of California's top ten most economically important crops. In 2019, California produced 4.3 million tons of citrus from 269,000 acres, generating $2.1 billion in gross receipts. California is the largest producer and exporter of lemon and mandarin, the second largest producer of orange, and the third largest producer of grapefruit in the US. California accounted for 52% of national citrus acreage and 63% of national value (CDFA 2020a; NASS 2020).[10] Export products related to citrus production had gross receipts of $840 million, ranking as California's sixth largest agricultural export commodity by value. California exported $541 million of orange (64% total U.S. exports), $206 million of lemon (91%), $66 million of mandarin (95.2%), and $27 million of grapefruit (27.8%).

Table 16. California Citrus Production Acreage and Value: 2018-2019 Crop Year

Citrus crop	**Acreage (bearing)**	**Production value ($1,000)**
Grapefruit, All	9,000	55,956
Lemon	49,000	644,002
Orange, All	147,000	670,529
Mandarin (and Hybrids)	64,000	735,564
Total Citrus Fruit	269,000	2,106,051

Source: CDFA (2020a).

Note: The acreage values reported here from CDFA (2020a) differ from the values reported in the 2020 California Citrus Acreage Report. As noted by USDA NASS in the latter report, the surveyed acreage values may differ due to data collection reasons, particularly because participation in acreage surveys is voluntary.

Table 16 reports acreage and production value for California citrus fruits in the 2018-2019 crop year. For grapefruit, 68,000 tons were produced on 9,000 bearing acres, for a per acre yield of 18.7 tons and gross revenues of $56 million. For lemon, 948,000 tons were produced on 49,000 bearing acres, for a per acre yield of 19.4 tons and gross revenues of $644 million. For orange, 2.1 million tons were produced on 147,000 bearing acres, for a per acre yield of 14.2 tons and gross revenues of $671 million. Just under 20% of California orange acreage is planted to Valencia, the majority are navel. For mandarin and mandarin hybrids (including tangelo, tangerine and tangor), 1,060,000 tons were produced on 64,000 bearing acres, for a per acre yield of 16.4 tons and gross revenues of $736 million.

There are four major citrus production regions in California: the San Joaquin Valley, Coastal, Inland Southern California, and the Desert (Figure 10). Though most regions grow all cultivars of citrus, the environmental conditions in each region favor some cultivars over others. For example, the cool climate of the coast allows lemon to produce multiple crops, the desert heat

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[10] Bearing acreage for citrus fruit reported throughout this section are based on values from CDFA (2020a). Note that these values differ slightly from those reported in the 2018 California Citrus Acreage Report from USDA NASS. See note to Table 16 for more information.

provides the best conditions for grapefruit, and the San Joaquin Valley's cold winters favor orange and mandarin.

Figure 10. California citrus production and growing regions: 2017

Since 2006, the acreage planted to mandarin has increased significantly in the San Joaquin Valley (by more than 50,000 acres) and the coastal areas of California, while orange plantings (primarily Valencia) have declined somewhat (Figure 11). Other regions and cultivars have remained relatively stable. The increased acreage in citrus classified as mandarin, including satsuma, clementine, mandarin and their hybrids, is due to the popularity of easy peeling fruit with consumers.

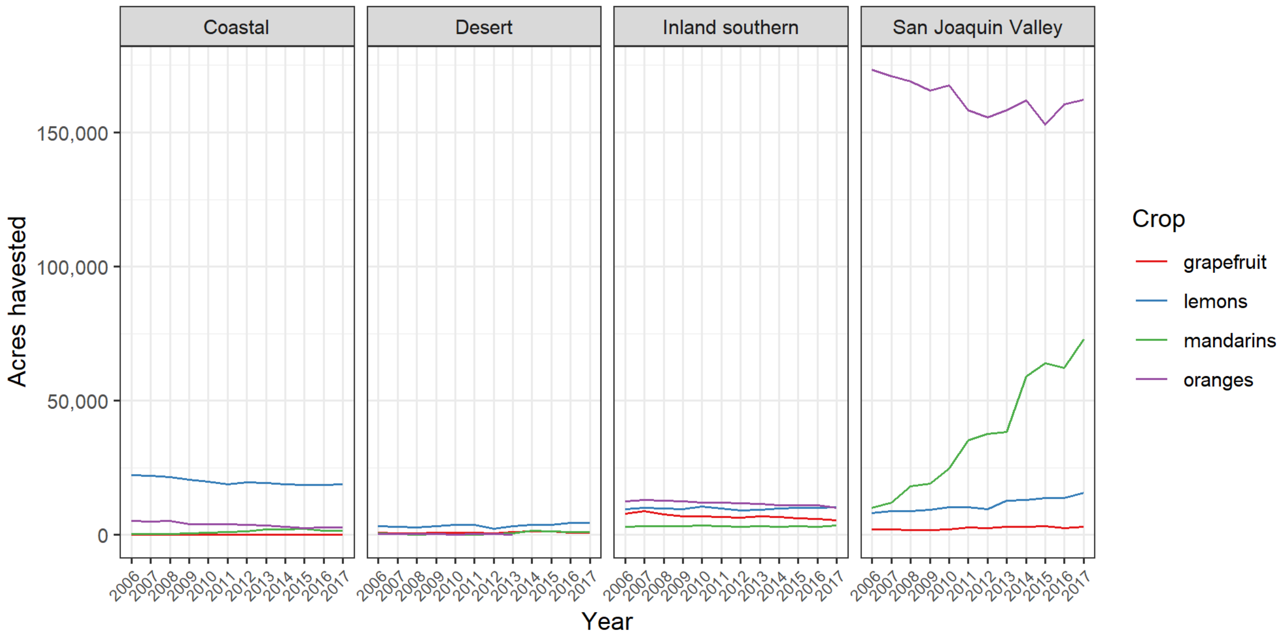

Figure 11. Acres planted to orange, mandarin, lemon and grapefruit by region, 2006-2017

Figure 12 and Figure 13 report exports by destination country and value for California orange and lemon, respectively. The top five export countries for orange are South Korea, Canada, Japan, Hong Kong and China. The top five export countries for lemon are Japan, Canada, South Korea, Australia and Hong Kong.

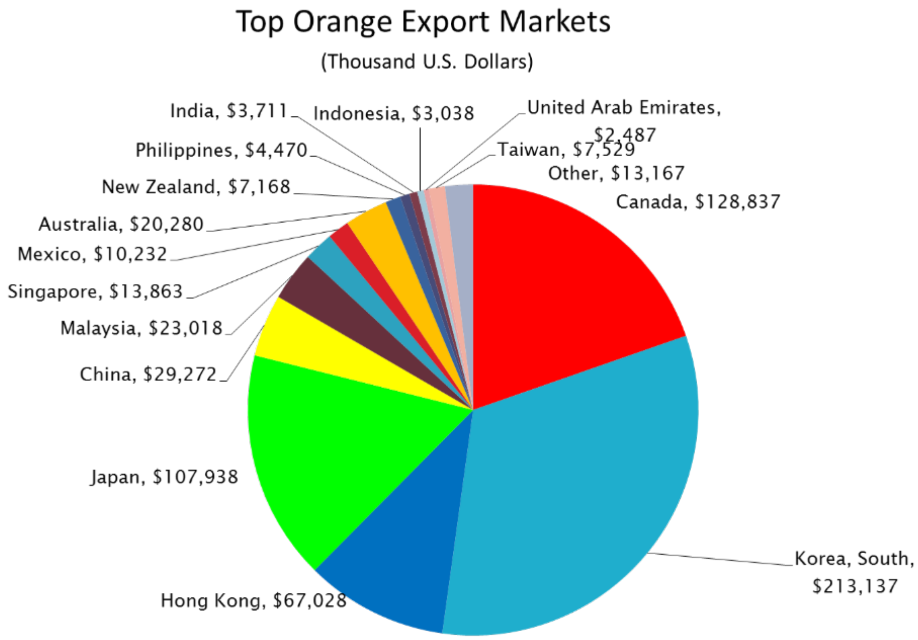

Figure 12. Top export markets: Orange, 2017

Source: https://ccqc.org/

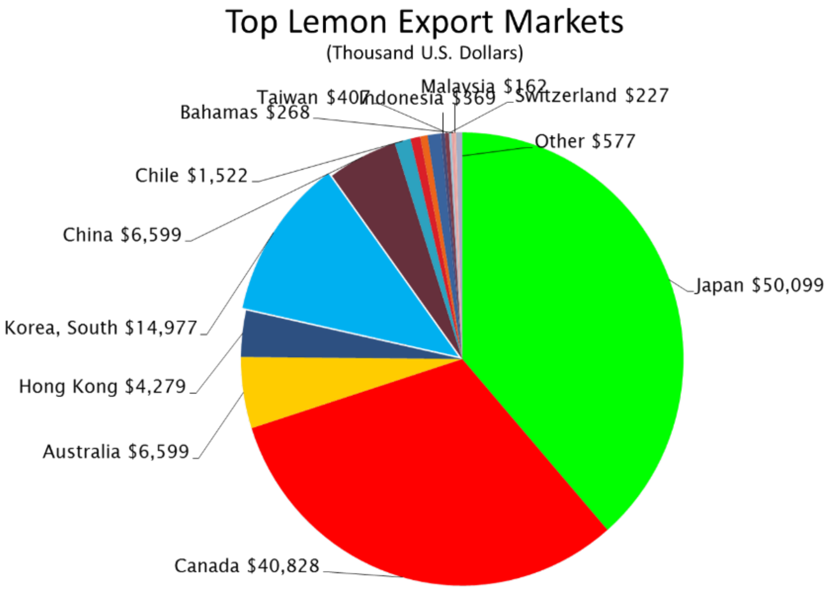

Figure 13. Top export markets: Lemon, 2017

Source: https://ccqc.org/

Not all of the importing countries have fully established maximum residue levels (MRLs) or the levels are below the established US tolerances. If fruit is treated near harvest, growers will not use an insecticide that has a lower or unestablished MRL because they run the risk of the fruit being rejected if that level is exceeded. This is one of the driving forces behind choice of insecticides and influences which alternatives can be used. Growers targeting a specific export market will take its MRLs into account.

IPM Overview

NGNs are used in citrus to manage glassy-winged sharpshooter, citricola scale, citrus leafminer, export quarantine pests such as Fuller rose beetle, and invasive pests such as Asian citrus psyllid (ACP). They are also used to treat nursery citrus plants before shipping and citrus orchards prior to harvest in order to combat the geographic spread of insect pests. Two NGNs are registered for California citrus: imidacloprid and thiamethoxam. Both would be restricted under the proposed regulations, with imidacloprid being more restricted than thiamethoxam.

Within the four growing regions, the combination of cultivar and environment results in different pest complexes that require different management tactics. The hot dry climate of the desert promotes mites, citrus thrips and citrus leafminer. The mild coastal and inland areas of southern California climate support natural enemies year-round and common pests are easily managed without pesticides in this region, with the exception of bud mite infesting lemon and broad mite infesting all varieties of citrus. The more extreme winter and summer temperatures of the San Joaquin Valley reduce the effectiveness of biological control, and common pest problems include California red scale, citrus thrips, citricola scale, katydids and citrus red mite. Because biological control is less effective in this region, there is greater insecticide use.

The arrival of ACP in 2008, and its spread throughout southern California by 2012, has intensified insecticide treatments in the southern region, where treatments were previously infrequent. It has also initiated eradicative treatments in other regions of the state. Asian citrus psyllid is the vector of huanglongbing (HLB, also known as citrus greening), a devastating, incurable bacterial disease of citrus that has reduced Florida citrus production by 50% and is threatening the California citrus industry. Imidacloprid is used for ACP control for multiple reasons: 1) it is used as a systemic where eradication of the pest is occurring because it is the most long-lasting and effective control agent for nymphs that are tucked inside foliage and protected from foliar sprays, 2) it is used as a systemic by nurseries to provide long-term protection of nursery stock going to retail nurseries, and 3) as a foliar, it is used as part of the spray and move program to disinfest orchards of ACP prior to harvest so that ACP is not transported in bulk citrus. In addition to ACP, imidacloprid is used in citrus for glassy-winged sharpshooter, citricola scale, citrus leafminer, and the Fuller rose beetle.

Imidacloprid is unique as a systemic insecticide because it persists in the plant for three or more months at a level that controls key pests such as citrus leafminer, Asian citrus psyllid, and citricola scale. As a soil application, its systemic activity is safer for natural enemies than foliar formulations of neonicotinoids or pyrethroids. The persistence reduces the number of other insecticides that need to be applied. It has well-established MRLs and a short pre-harvest interval, making it convenient to use. It is relatively inexpensive.

Target Pests

Glassy-winged sharpshooter (*Homalodisca vitripennis*). Glassy-winged sharpshooter (GWSS) overwinters in citrus, emerges in spring, and can spread Pierce’s disease in neighboring grape vineyards. Federal funds are provided to reimburse citrus growers for pesticides applied to reduce glassy-winged sharpshooter in citrus in some regions of the state in order to keep populations from migrating into vineyards. An average of 6,000 acres of citrus per year were treated in Kern County (10% of county citrus acreage) between 2001 and 2016, generally during the months of March through July. There have been occasional treatments in Tulare County as well. In the early years of the program, treatments were applied in early spring to reduce the overwintering GWSS adults and again later in the season to control hatching GWSS nymphs (Castle et al. 2005). The treatments were highly effective for many years, however, some populations of GWSS have begun to develop resistance to imidacloprid (Andreason et al. 2018). In response, the treatment program is replacing imidacloprid with alternative insecticides. For a variety of reasons, including data on uptake (Byrne and Morse 2012), growers who use imidacloprid for GWSS have recently changed the timing of application to summer (thereby avoiding impacts on bees). The alternative treatments for GWSS are other foliar neonicotinoids such as acetamiprid and thiamethoxam, beta cyfluthrin, fenpropathrin and flupyradifurone. The neonicotinoids, butenolides, and pyrethroids are the most effective insecticides for controlling this pest (Grafton-Cardwell et al. 2003).

Citricola scale (*Coccus pseudomagnolarium).* Citricola scale is a serious citrus pest in the San Joaquin Valley. Heavy infestations reduce vigor, kill twigs, and reduce fruit set. Additionally, honeydew excreted from the scales causes sooty mold to grow on fruit causing it to be downgraded in the packinghouse, reducing revenues. Citricola scale is not controlled by natural enemies in the San Joaquin Valley because it has only one generation per year and there are long periods of time when it is in a stage unsuitable for parasitism. Thus, citricola scale is a driver of broad-spectrum pesticide use in San Joaquin Valley citrus, and imidacloprid is an effective and common treatment applied during July-September (Grafton-Cardwell and Reagan 2008). The alternatives to imidacloprid are foliar treatments of acetamiprid, thiamethoxam, buprofezin, and carbaryl. Narrow range oil is available for organic use but is not regularly used on its own in conventional groves. Buprofezin, carbaryl and narrow range oil are significantly less effective in controlling citricola scale compared to the neonicotinoids (Grafton-Cardwell and Scott 2011; Grafton-Cardwell and Reger 2019). Foliar formulations of neonicotinoids are most commonly used for this pest. For citricola scale, uses are primarily July-September, after citrus bloom has ended, avoiding impacts on bees.

Citrus leafminer (*Phyllocnistis citrella*). Citrus leafminer attacks all citrus types, tunneling along the surface of new leaves and reducing their photosynthetic capability. Citrus leafminer is mainly a pest of young trees and causes damage by stunting growth. Imidacloprid is one of the most effective tools for reducing citrus leafminer populations because it is translocated to new tissues (the target of citrus leafminer oviposition and tunneling) over many months (Sétamou et al. 2010). The alternative AIs are systemic thiamethoxam and cyantraniliprole and foliar abamectin, chlorantraniliprole, cyantraniliprole, methoxyfenozide, acetamiprid, and diflubenzuron. Narrow range oil is available for organic use but is not regularly used in conventional groves. Imidacloprid can have a longer residual than the foliar treatments (Sétamou et al. 2010). Treatment timing for non-bearing trees would be any time the trees are producing new leaf flush from March-October.

Fuller rose beetle (*Naupactus godmani*). Fuller rose beetle (FRB) does not cause economic damage in California citrus, however South Korea currently considers it a phytosanitary risk because it has not been found in that country. FRB prefers to deposit its eggs in cracks and crevices and the tight space under the calyx of navels is a preferred oviposition site. South Korea is a major export market for California citrus. In years past, if FRB eggs were found on fruit, the load was treated with methyl bromide at its destination. However, with the reduction in uses of methyl bromide worldwide, the expectation is that citrus growers in California will conduct preharvest treatments to eliminate FRB. Imidacloprid is one of several tools that can be used to reduce FRB larvae in the soil. There is currently a seven-point plan in place that requires growers wishing to export to South Korea to treat twice with FRB effective materials during the season, with the second application relatively close to harvest. Alternative active ingredients include foliar applied beta-cyfluthrin, carbaryl, cryolite, thiamethoxam, and cyantraniliprole and soil applied bifenthrin. MRLs are not established for cryolite and the MRL for carbaryl is significantly lower than the US tolerance. Bifenthrin is difficult to use because it is not registered for citrus fruit and so growers must be very careful when applying it to the ground to avoid contact with the fruit. Growers can apply a sticky product to the trunk of trees to help with this pest, but this is extremely labor intensive and hard to maintain. Imidacloprid is a key product for FRB control because it is also effective against citricola scale and one treatment will control both pests.

Asian citrus psyllid (*Diaphorina citri*). Asian citrus psyllid (ACP) is currently the most serious pest of citrus because it is the vector of *Candidatus* liberibacter asiaticus the bacterium thought to be responsible for huanglongbing (HLB) or citrus greening. There is currently no cure for HLB and so the primary method to prevent disease spread is psyllid control. The most important, critical use of imidacloprid is to control ACP and so reduce the spread of HLB. There are a number of alternative insecticides that have efficacy against ACP: beta-cyfluthrin, fenpropathrin, dimethoate, carbaryl, cyantraniliprole, diflubenzuron, fenpyroximate, flupyradifurone spinetoram, spirotetramat, thiamethoxam, and zeta-cypermethrin. However, none of these insecticides have the residual life combined with the anti-feedant qualities of imidacloprid necessary to prevent transmission of disease (Serikawa et al. 2012; Qureshi et al. 2014; Miranda et al. 2016; Langdon and Rogers 2017; Tofangsazi and Grafton-Cardwell 2018). It is difficult to reach young nymphs and eggs inside folded young leaves with foliar insecticides. Systemic imidacloprid can provide 3 months of protection, whereas other products last only 2-4 weeks. Other systemic neonicotinoids (dinotefuran and thiamethoxam) do not provide the same length of protection. Local eradication of ACP has been achieved through the use of systemic imidacloprid in combination with a foliar pyrethroid in both commercial and residential areas of the San Joaquin Valley. Either product alone would not have the same effect because the foliar provides knockdown and surface protection against re-infestation but may not reach the young stages that are protected by leaves. The systemic imidacloprid protects the new flush and reaches the youngest instars when they begin to feed. The nymphs are critical to control because they are the stage that acquires the bacteria and when they molt and fly away, they take the bacteria with them. The anti-feedant quality of the product blocks transmission of the bacterium by psyllid feeding and no other product has the same level of effect. Thus, imidacloprid is a critically needed tool for managing the spread of this devastating disease.

In addition to specific pests, imidacloprid is used for spraying orchards to disinfest them of ACP prior to the fruit being harvested and transported.[11] Alternatives for this spray and move program include cyfluthrin, beta cyfluthrin, fenpropathrin, zeta cypermethrin, and thiamethoxam. The difficulty is that there are seasonal limits for each of these insecticides – lemon are often size-picked gradually over time, and the treatments have to be applied within 14 days of harvest. Growers can exhaust their insecticide options if they harvest an orchard frequently. Alternative programs are to wash or mechanically disinfest fruit after harvest, but these methods can damage the fruit. Systemic imidacloprid is also used by citrus nurseries as a protectant prior to shipping to prevent spread of psyllids and their establishment in retail nurseries (Byrne et al. 2016, 2017). However, nurseries are not considered in this analysis.

Target NGN Use: 2017-2019

A total of 54,842 pounds of imidacloprid was used on 119,495 acres of citrus during 2017. The region of greatest use was the San Joaquin Valley. The majority of applications were made to orange and mandarin in the San Joaquin Valley and lemon in Ventura, Riverside and Imperial counties.

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[11] http://phpps.cdfa.ca.gov/PE/InteriorExclusion/pdf/acpgrowerinformation.pdf

Table 17. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Citrus, 2017-2019

Active ingredient	**----------Pounds applied---------**				**------------Acres treated------------**				**Use rate (lb/ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
(s)-cypermethrin	1,988	1,640	922	4,549	41,947	35,052	19,071	96,070	0.05
abamectin	4,506	4,862	5,255	14,623	167,374	214,892	228,103	610,370	0.02
acetamiprid	4,200	4,520	3,469	12,190	23,617	22,102	17,474	63,193	0.19
beta-cyfluthrin	3,913	3,257	3,408	10,579	106,123	81,821	84,980	272,925	0.04
bifenthrin	3,436	4,355	5,370	13,162	9,107	14,366	18,173	41,645	0.32
buprofezin	45,041	76,223	75,108	196,372	22,663	38,127	37,179	97,970	2.00
carbaryl	20,913	44,518	29,922	95,354	2,545	5,099	4,560	12,204	7.81
chlorantraniliprole	2,056	2,009	1,561	5,627	23,962	22,999	17,475	64,436	0.09
cyantraniliprole	2,392	7,600	11,594	21,586	19,557	70,917	97,962	188,436	0.11
cyfluthrin	1,117	1,989	981	4,087	18,954	30,217	15,097	64,268	0.06
diflubenzuron	8,355	13,702	16,612	38,668	46,029	72,901	81,746	200,676	0.19
dimethoate	6,834	3,136	9,523	19,493	7,928	4,907	11,505	24,340	0.80
fenpropathrin	15,041	18,728	21,042	54,812	42,328	52,795	60,057	155,180	0.35
flupyradifurone	1,032	2,464	2,711	6,206	6,474	16,982	18,722	42,178	0.15
imidacloprid*	54,842	54,461	52,317	202,044	119,495	115,611	111,125	346,232	0.58
malathion	13,666	20,634	24,552	58,851	7,887	6,992	10,904	25,784	2.28
spinetoram	15,001	11,929	10,144	37,074	173,843	134,574	113,575	421,991	0.09
spinosad	2,591	2,294	1,924	6,809	22,856	20,270	18,298	61,424	0.11
spirotetramat	22,605	23,641	23,073	69,319	147,996	152,856	149,313	450,165	0.15
thiamethoxam*	14,585	15,369	13,815	43,769	174,844	183,811	167,973	526,628	0.08

*Target NGN

Timing of imidacloprid applications. Examining the years 2010, 2013, 2016, and 2019, the timing of the use of imidacloprid has changed, shifting from an early season emphasis (March-June) to a summer emphasis (May to September), as shown in Figure 14. This change in timing is associated with a shift in the target pest. In the early years, imidacloprid was used primarily for GWSS control and to encourage vigorous spring growth. During the last 20 years of use, GWSS developed resistance to imidacloprid. Later, imidacloprid became increasingly used for citricola scale in the summer months. In 2012, Byrne and Morse demonstrated that significant uptake of imidacloprid into the tree does not occur until June when the roots become active. Additional studies showed that a higher level of uptake is needed for phloem-feeding ACP control versus xylem-feeding GWSS and the shift in concern to ACP control caused growers to shift use to later in the season (Byrne and Toscano 2007, Sétamou et al. 2010). Notably, these later treatments fully protect bees from the effects of imidacloprid applied to citrus (Byrne et al. 2014a, b, 2017).

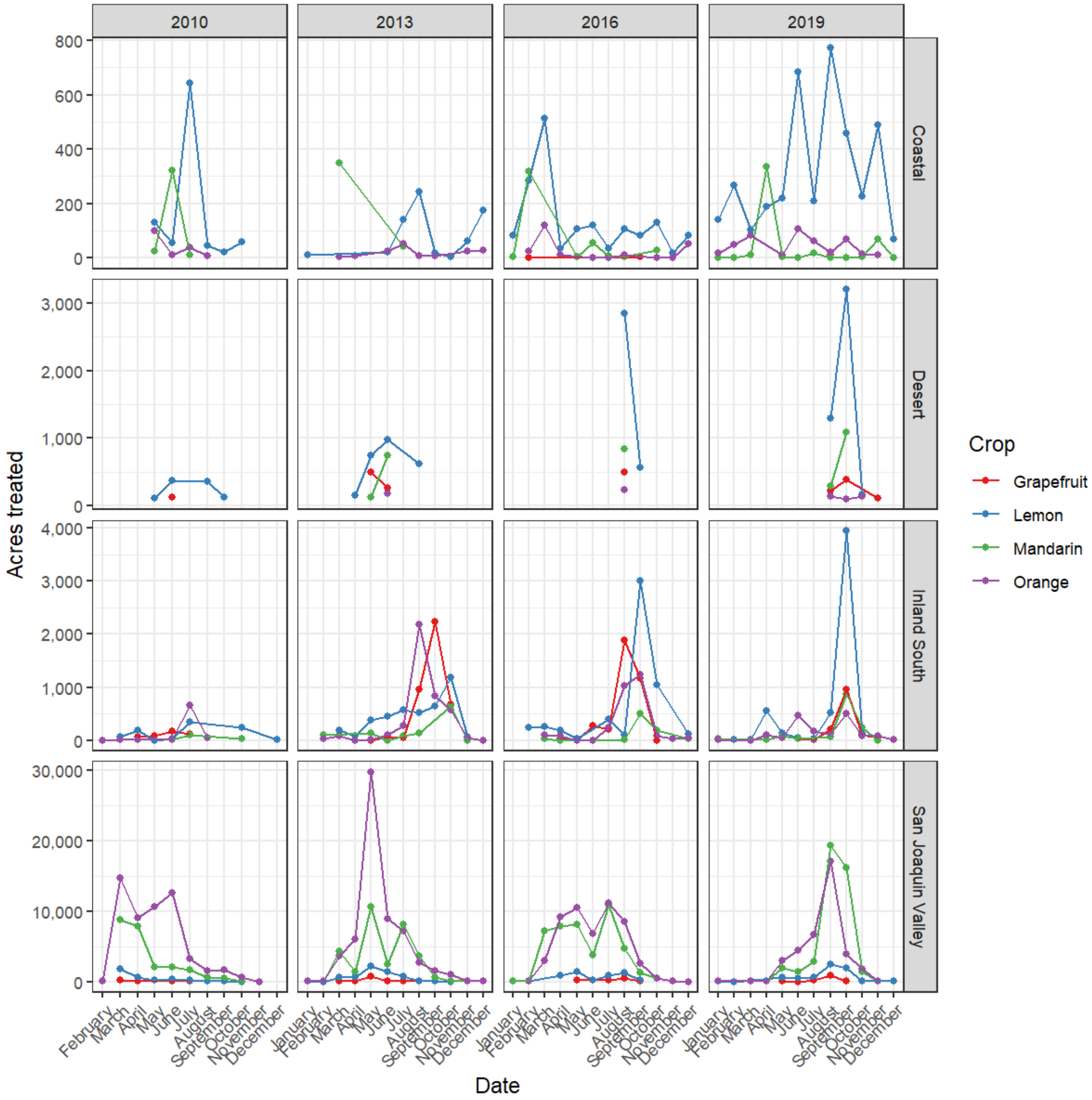

Figure 14. Imidacloprid use by month, region, and crop: Citrus acres treated, 2010, 2013, 2016, and 2019

San Joaquin Valley. The San Joaquin Valley (Stanislaus, Madera, Fresno, Tulare and Kern counties) is the largest growing region, planted with 81% of state citrus acreage. Within the San Joaquin Valley, 63.9% of citrus acreage is in orange and 28.7% is in mandarin. Imidacloprid was first introduced in California in 2001. Its use significantly increased during 2008-10, a few years after less-expensive, generic brands were introduced (Figure 15). Imidacloprid use since 2010 has fluctuated, ranging between 35,000-45,000 lb per year on an average of 90,000-100,000 acres (Table 17). Most growers only treat once per year with the product because the systemic formulation is preferred over the foliar and there is a per season limit of 0.5 lb AI/acre, the maximum and typical single use rate when applied as a systemic to a mature citrus tree. A half rate (0.25 lb/acre) is used to control pests on trees less than 4 years old.

Early on, the majority of imidacloprid uses in the San Joaquin Valley were systemic applications for glassy-winged sharpshooter (GWSS) or citricola scale control, as well as for nematode suppression for improved citrus root health. Over time, GWSS has developed resistance to imidacloprid and its efficacy for managing this pest has declined. Citrus leafminer arrived in California in 2001 and spread throughout the state in the ensuing years and imidacloprid has been used extensively to protect non-bearing citrus (<5% of planted citrus) from leaf damage caused by citrus leafminer, citrus thrips and aphids.

Since 2016, imidacloprid use has increased in response to the periodic appearance of Asian citrus psyllid in the San Joaquin Valley. The suggested grower response to ACP detections in this region, where eradication efforts are underway, is a treatment with a foliar pyrethroid and systemic imidacloprid.[12] These treatments are still low in number in this region, and so the increased use relative to 2010-2017 has changed only slightly. This treatment pattern will change significantly if ACP becomes more widely established in the San Joaquin Valley.

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[12] https://ucanr.edu/sites/ACP/Grower_Options/Grower_Management/Eradication_Strategies/

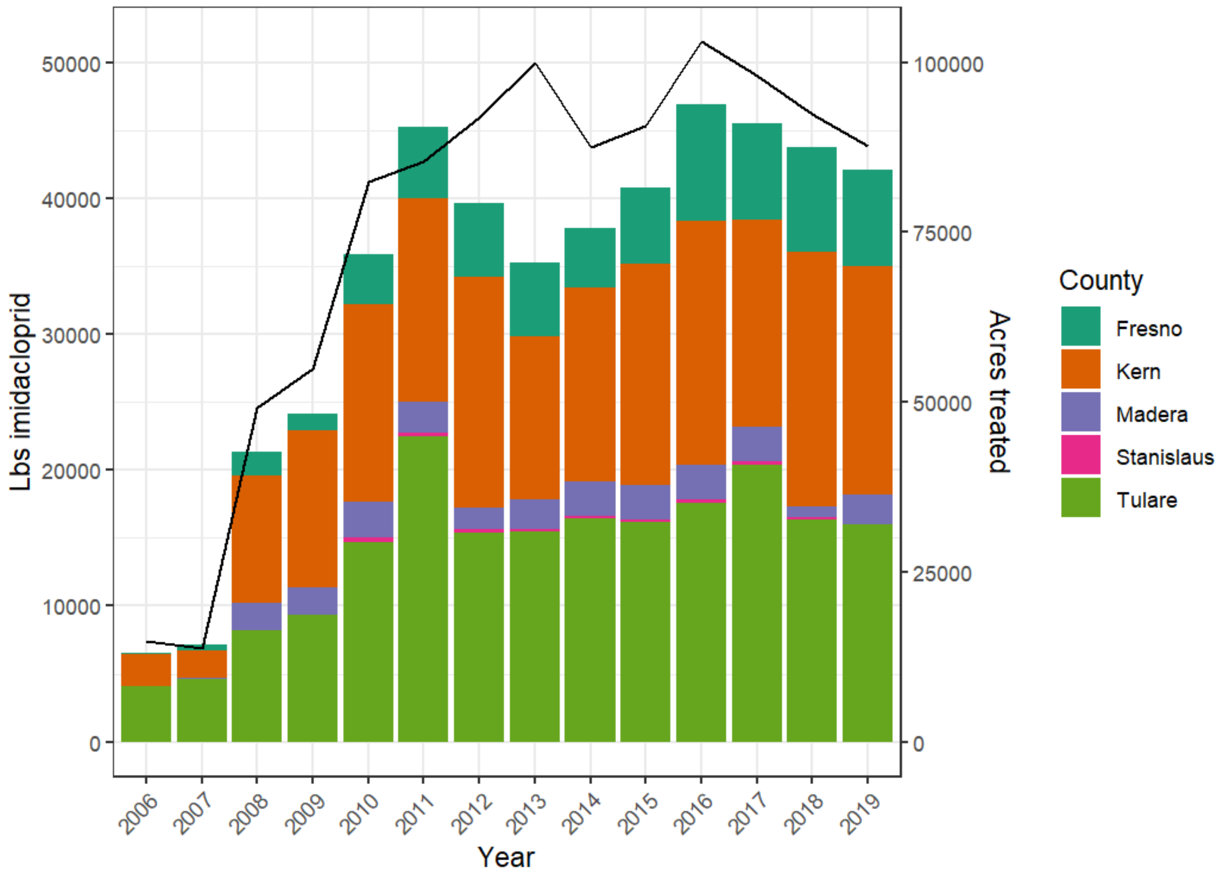

Figure 15 Pounds of imidacloprid used (bars) and acres treated (line): San Joaquin Valley region, 2006-2019

Coastal region. In the Coastal region (Ventura, Santa Barbara, San Luis Obispo and Monterey), the heavy soils and steep hillsides do not allow effective use of systemic imidacloprid in many areas. In 2006, federal funds were provided to growers to treat for GWSS with imidacloprid, and 6,000 lb of imidacloprid were applied on 12,000 acres of citrus (Figure 16). Since that time, imidacloprid has been applied to fewer than 2,000 acres, mostly as foliar treatments in response to ACP eradication efforts (2012-2016) and preharvest treatments to move bulk citrus. There is no seasonal pattern in the use of imidacloprid because bulk citrus treatments are applied to the orchard within 14 days of harvest and lemon harvest can occur at nearly any time of year.

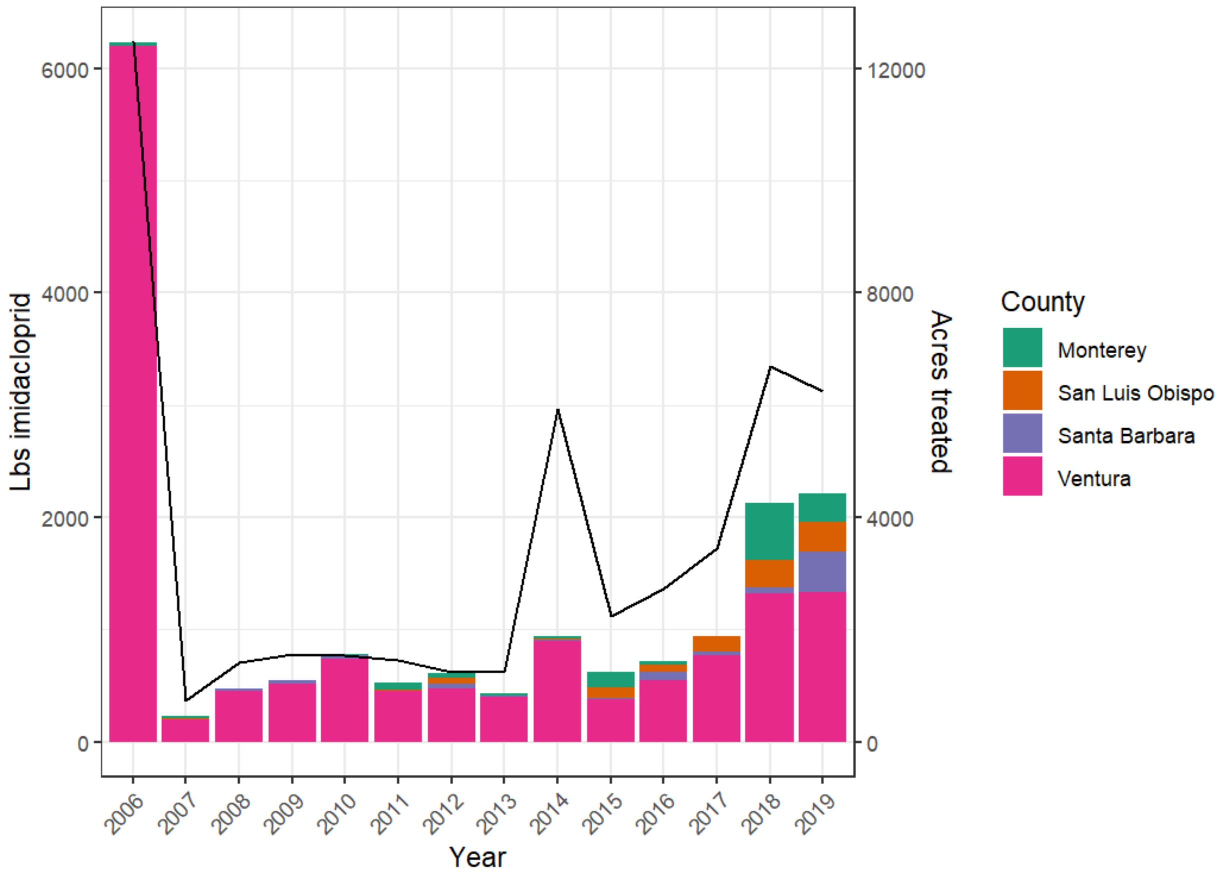

Figure 16. Pounds of imidacloprid used (bars) and acres treated (line): Coastal region, 2006-2019

Desert region. In the Desert region (Imperial County and the Coachella Valley in Riverside County), uses of imidacloprid are almost exclusively for either citrus leafminer on young trees or part of the areawide program to reduce Asian citrus psyllid since 2012 (Figure 17). The Imperial and the Coachella Pest Control Districts coordinate the growers to treat during August and September (Figure 17) with systemic imidacloprid and a winter (December-January) treatment of a pyrethroid. Asian citrus psyllid densities have dropped to nearly undetectable levels in commercial citrus because of this program. In contrast, psyllids can still be found in untreated residential areas. The combination of very effective insecticides and the high heat of these valleys that hardens foliage and limits egg-laying by the psyllids is key to keeping HLB out of this region. There are alternatives to imidacloprid, principally systemic thiamethoxam; however, they are not as persistent or effective as imidacloprid.

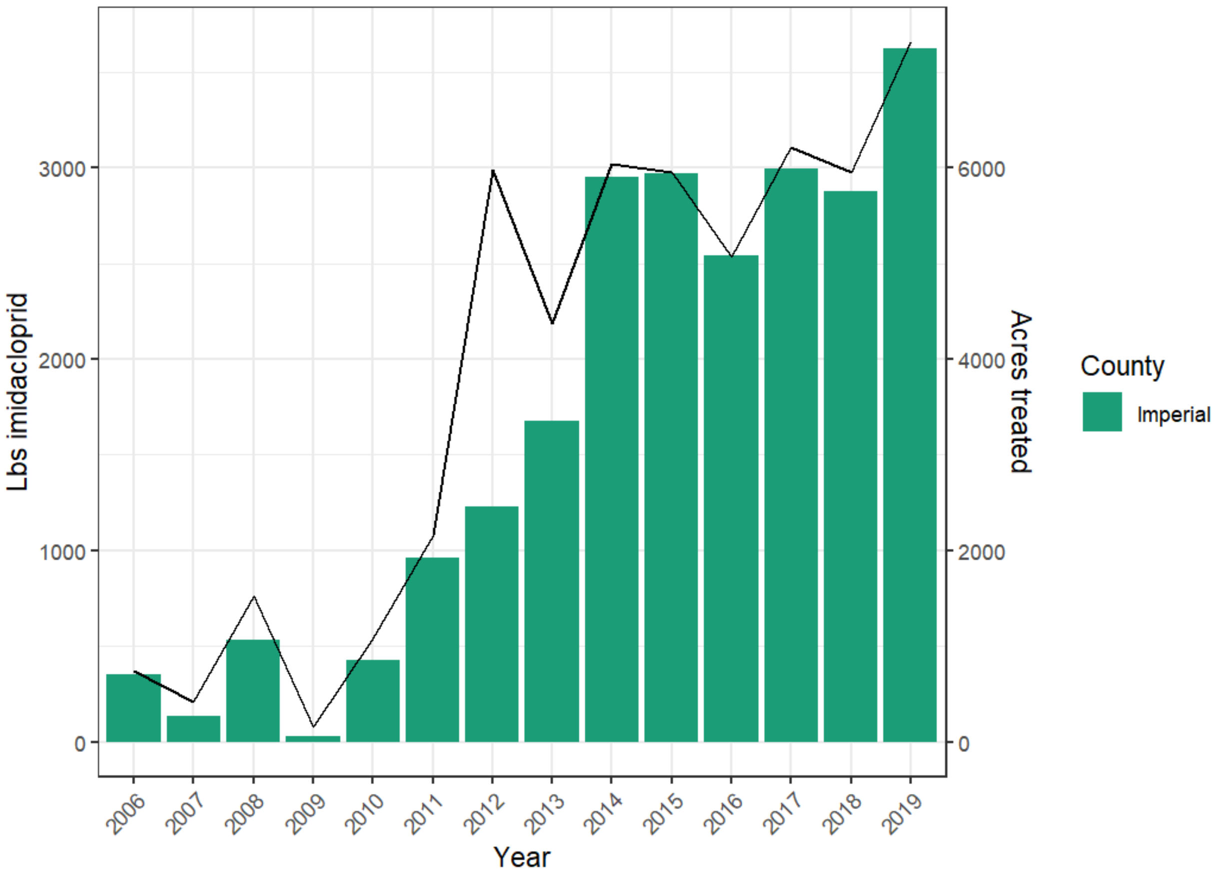

Figure 17: Pounds of imidacloprid used (bars) and acres treated (line): Desert region, 2006-2019

Inland southern California. In the Inland southern California region (San Diego, central Riverside, and San Bernardino), uses of imidacloprid were very limited until ACP appeared and established. Treatments increased from less than 1,000 lb AI/year to more than 5,000 lb AI/year from 2006-2019 (Figure 18). Imidacloprid treatments are applied primarily during July-September for areawide management of ACP.

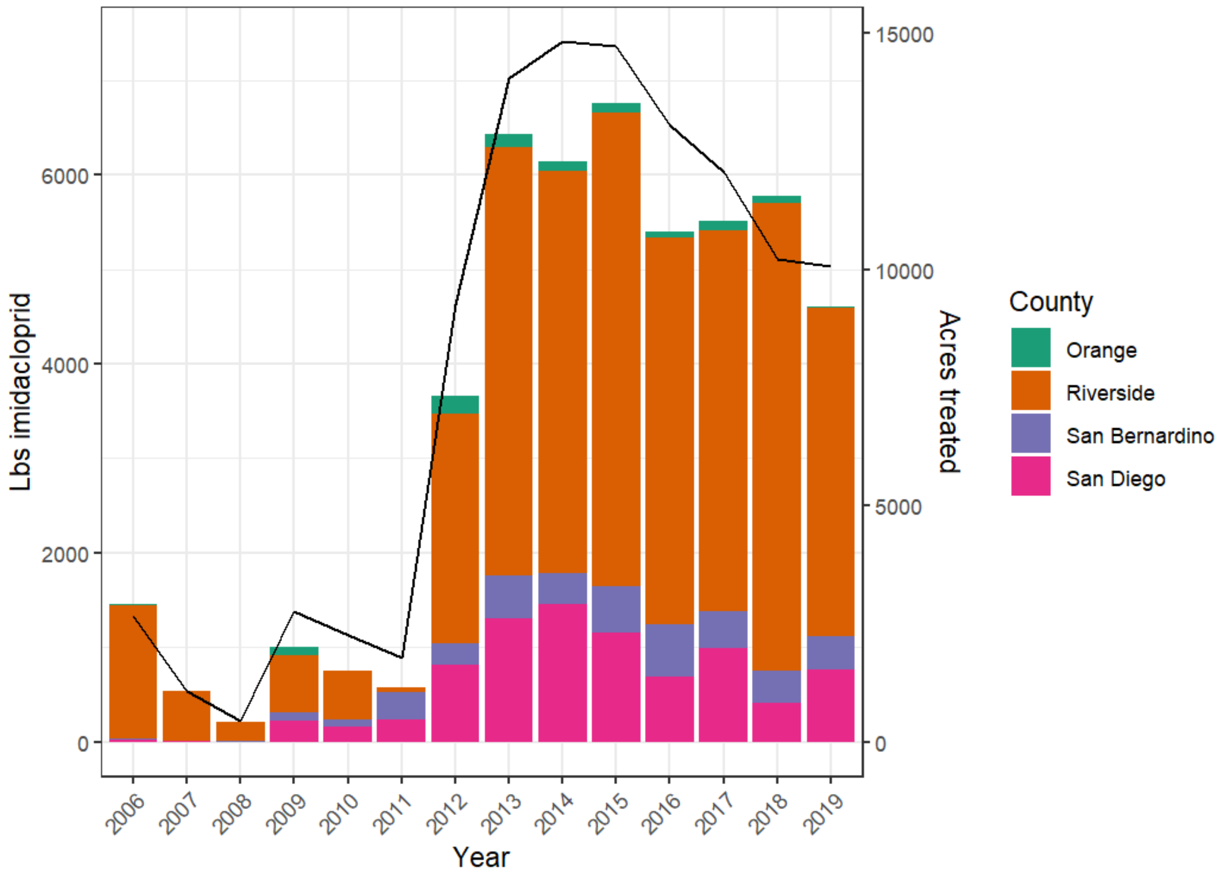

Figure 18: Pounds of imidacloprid used (bars) and acres treated (line): Southern California region, 2006-2019

Statewide use in citrus by month for 2017-2019 is presented in Figure 19.

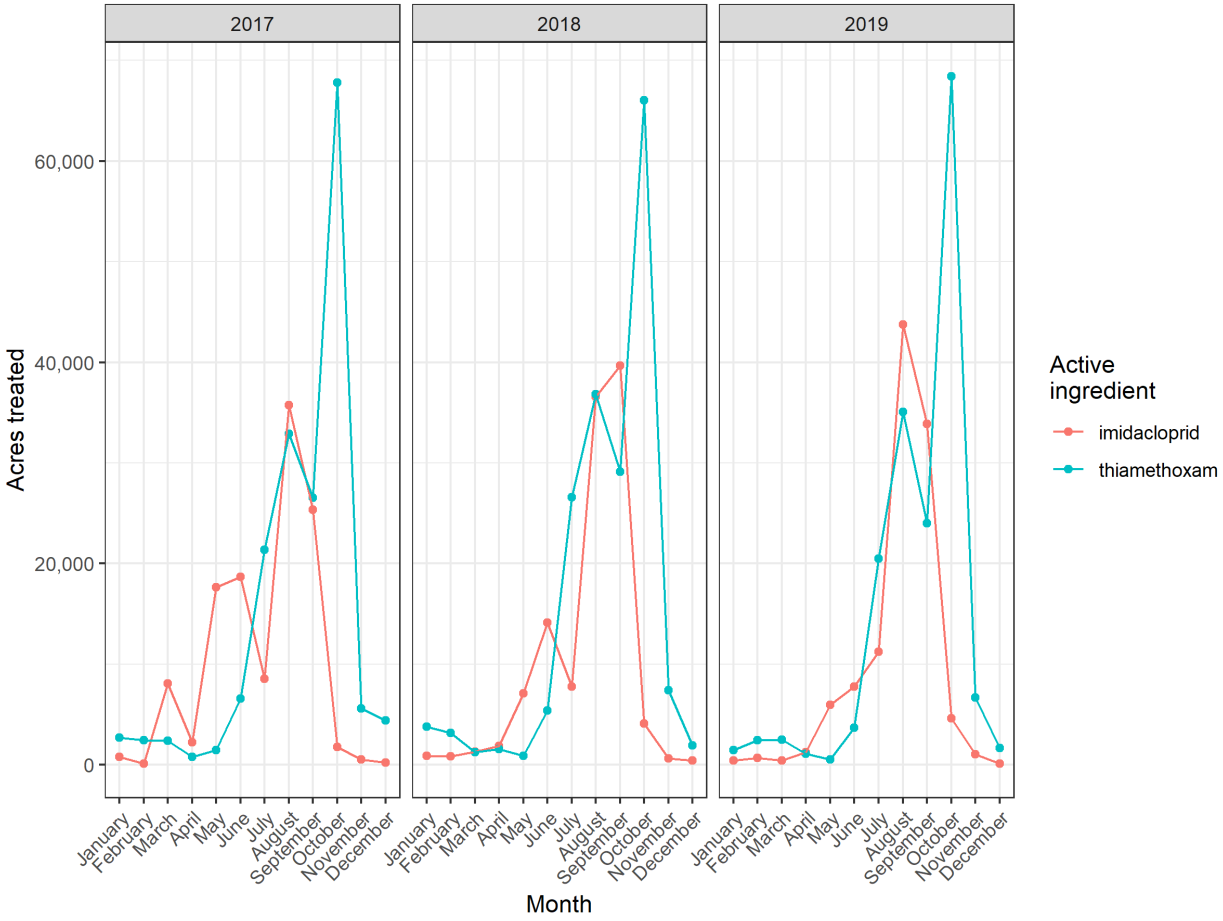

Figure 19: Monthly use of target nitroguanidine-substituted neonicotinoids: Citrus, 2017-2019

Proposed Restrictions

Grapefruit, lemon, orange, and tangerine/tangerine hybrids – the crops that comprise the citrus group in this analysis – are in the citrus fruit crop group. Only imidacloprid and thiamethoxam are registered for use in citrus. Under the proposed regulations, no applications would be allowed during bloom. Soil and foliar applications of thiamethoxam would be permitted up to a cumulative application rate of 0.172 lb of AI/acre for each application method for a total of 0.344 lb of AI/acre. For imidacloprid, soil applications would be allowed from petal fall (late April or early May) until November 10 up to a cumulative application rate of 0.25 lb of AI/acre. This effectively prohibits soil-applied imidacloprid because while the proposed maximum rate is a labeled rate, it has is not been found by users to be efficacious and reportedly is not used. Applying at rates that are not efficacious for pest control can accelerate the development of pesticide resistance. For the purposes of this analysis, we considered this restriction to be the equivalent of a prohibition on soil imidacloprid use. Therefore, all imidacloprid applied to soil was reallocated to the alternatives. This assumption affected only 2,820 to 3,480 acres annually between 2017 and 2019 because most fields using soil applied imidacloprid were over the 0.25 lb of AI/acre limit.

Foliar applications of imidacloprid would be allowed from petal fall until December 1 up to a cumulative application rate of 0.172 lb AI/acre. The only application that would be effective at this rate would be foliar applications for citrus leafminer in newly planted, nonbearing citrus. Thus, foliar applications of imidacloprid would be mostly ineffective for mature citrus.

The proposed regulation contains a major exemption for the proposed restrictions that is highly relevant to NGN use in citrus. Applications for a quarantine pest are exempt from the proposed regulation, including from restrictions on cumulative use rates. ACP management is a critical use of imidacloprid. As discussed in the Target Pest section above, ACP is a critical threat to the citrus industry. Because it is a quarantine pest, all uses of NGNs for ACP would be exempt from the proposed regulation. Due to when and where ACP treatments occur, we assume imidacloprid use in the following regions and time frames to be exempt:

- Inland South region (Orange, Riverside, San Bernardino, and San Diego counties)
    - all use from August 15 to October 15
    - 90% of use from October 16 to August 14
- Desert region (Imperial county)
    - All use
- Coastal region (Venture, Monterey, San Lois Obispo, and Santa Barbara)
    - 90% of use year round
- San Joaquin Valley (Kern, Fresno, Kings, Madera, Merced)
    - No use for ACP (pest was not present until 2020)

Exempted applications were considered allowed and were excluded from the dataset before any other calculations were made. All other imidacloprid use was moved to the alternatives. We assumed the timing restrictions imply a prohibition on applications from December 1 to May 1. Applications during this time were reallocated to alternatives. These early season restrictions would eliminate uses aphids and citrus leafminer control. Outside of that window, soil and foliar applications of thiamethoxam were considered allowed up to a cumulative application rate of 0.172 lb/ac/season for each application method for a total of 0.344 lb/ac/season. Applications over the method rates or the total cumulative rate were prohibited and moved to alternatives. If the proposed restrictions had been in place from 2017-2019, 30.3-36.5% of treated acres and 11.2-13.0% of lb applied would have been allowed under the new restrictions. Figure 20 plots allowed and prohibited applications by month.

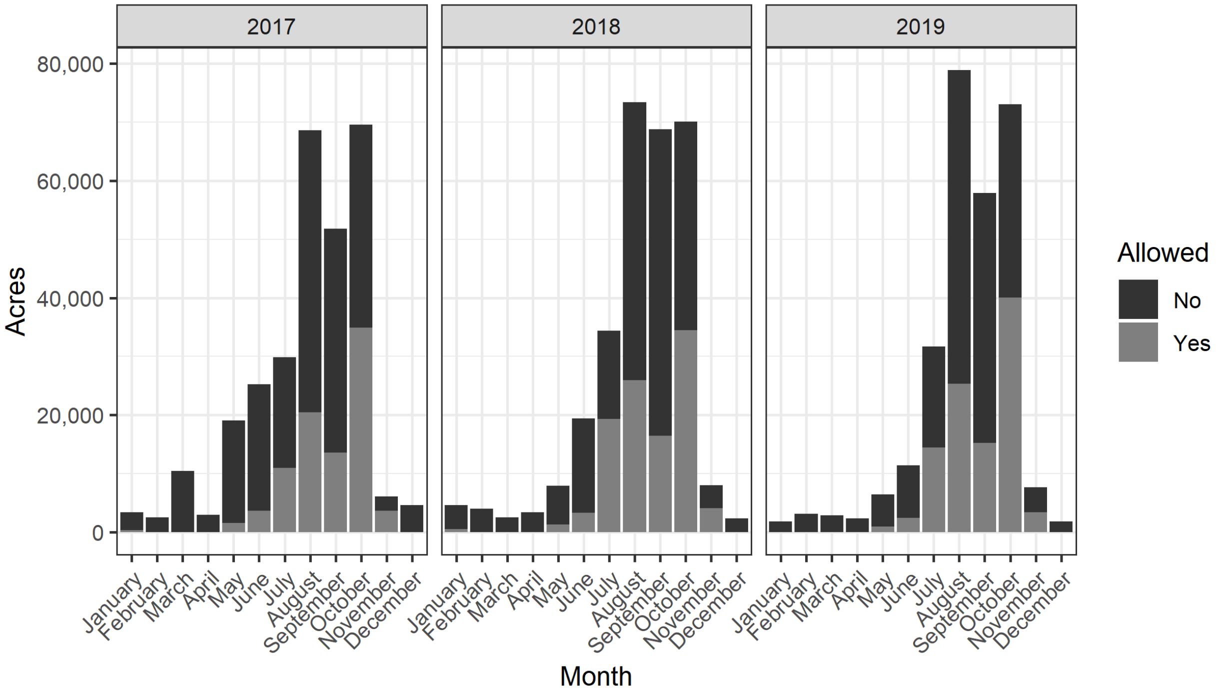

Figure 20. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Citrus, 2017-2019

Economic Analysis

This section presents the estimated change in pest management costs for citrus arising from the proposed restrictions. The cost of the proposed regulation is the difference in material costs and application costs, although the caveats discussed in the methods section apply.

Table 18. Representative Product Cost per Acre: Citrus

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
(s)-cypermethrin	Mustang	4.67	24.86	29.53
abamectin	Agri-Mek SC Miticide/Insecticide	14.9	25.01	39.90
acetamiprid	Assail 70WP Insecticide	67.81	25.00	92.82
beta-cyfluthrin	Baythroid XL	16.90	24.77	41.67
bifenthrin	Brigade WSB Insecticide/Miticide	79.58	25.01	104.59
buprofezin	Centaur WDG Insect Growth Regulator	74.45	25.00	99.45
carbaryl	Sevin Brand XLR Plus Carbaryl Insecticide	116.85	24.90	141.75
chlorantraniliprole	Altacor	42.35	24.94	67.30
cyantraniliprole	Exirel	83.66	24.99	108.65
cyfluthrin	Tombstone Helios Insecticide	8.69	24.83	33.52
diflubenzuron	Micromite 80WGS	52.28	25.00	83.28
dimethoate	Drexel Dimethoate 4EC	9.51	25.01	34.53
fenpropathrin	Danitol 2.4 EC Spray	31.05	25.27	56.32
flupyradifurone	Sivanto 200 SL	41.00	25.06	66.07
imidacloprid*	Admire Pro	28.82	8.77	37.59
malathion	Malathion 8 Aquamul	13.94	25.00	38.94
spinetoram	Delegate WG	59.49	25.02	84.51
spinosad	Success	33.05	24.89	57.94
spirotetramat	Movento	87.55	25.00	112.56
thiamethoxam*	Actara	21.32	24.97	46.29

*Target NGN

Table 18 reports the representative products for each active ingredient used on citrus from 2017 to 2019 and the average cost per acre. Average cost per acre for target AIs was calculated using applications affected by the proposed regulation (i.e., excludes allowed applications of target NGNs), while average cost per acre for AIs in the composite alternative is based on all applications. The average use rate was computed by dividing total pounds applied over the three-year period by the total acres treated. The pesticide material cost was obtained by multiplying the average use rate by the price per pound of active ingredient, which was calculated based on the product formulation and product price. Application costs were calculated based on the different application methods mentioned previously. Including material and application costs, the cost per acre varied significantly for the different AIs, ranging from $29.53 for (s)-cypermethrin to $141.75 for carbaryl. Growers consider a wide variety of factors beyond cost per acre in determining which AI to use, as discussed above.

Table 19. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Citrus, 2017-2019

Active ingredient	Acreage share with target NGNs available (% of all target and alternative use)	Share of composite alternative (%)
(s)-cypermethrin	2.6	3.3
abamectin	16.2	21.1
acetamiprid	1.7	2.2
beta-cyfluthrin	7.2	9.4
bifenthrin	1.1	1.4
buprofezin	2.6	3.4
carbaryl	0.3	0.4
chlorantraniliprole	1.7	2.2
cyantraniliprole	5.0	6.5
cyfluthrin	1.7	2.2
diflubenzuron	5.3	6.9
dimethoate	0.6	0.8
fenpropathrin	4.1	5.4
flupyradifurone	1.1	1.5
malathion	0.7	0.9
spinetoram	11.2	14.6
spinosad	1.6	2.1
spirotetramat	12.0	15.6
total	76.8	100.0

Note: Three-year average from 2017-2019.

Table 19 provides the acreage shares for the alternatives used on citrus from 2017 to 2019. The second column reports the acreage share treated with each alternative active ingredient when imidacloprid and thiamethoxam are available. On average, 23.2% of treated citrus acreage was treated with imidacloprid and thiamethoxam each year. 76.8% was treated with an alternative. Prohibited applications of the target NGNs were replaced proportionately with alternatives AIs. The third column reports the share of each alternative in the composite alternative used to replace applications that would be prohibited under the proposed regulation. The three most applied alternative AIs are abamectin, spirotetramat, and spinetoram, which together would account for 51.3% of treated acreage under the proposed restrictions. Note that because use was scaled up based on all use, their shares in the overall use of alternatives may not represent their use as a substitute for NGNs for any specific pest. Note also that total acreage of citrus treated with a target NGN or alternative AI may not correspond to total citrus acreage because some orchards may receive multiple applications.

Table 20. Costs Per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase of switching to composite alternative (%)
imidacloprid	28.82	8.77	37.59	90.5
thiamethoxam	21.32	24.97	46.29	54.7
composite alternative	46.63	24.99	71.61	-

Table 20 reports the average per acre costs for imidacloprid, thiamethoxam and the cost of the composite alternative. For citrus, switching to alternatives would lead to increases in material cost and application cost. Total cost per acre would rise by $34.02 (90.5%) on imidacloprid-treated acreage and $25.32 (54.7%) on thiamethoxam acreage.

Table 21. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Citrus, 2017-2019

Year	Cost with target active ingredients ($)	Cost without target active ingredients ($)	Change in cost ($)	Change in cost (%)	Share of change due to material costs (%)	Share of change due to application costs (%)
2017	4,737,973	7,654,618	2,916,645	61.6	48.3	51.7
2018	4,802,376	7,865,708	3,063,332	63.8	50.9	49.1
2019	4,452,763	7,420,510	2,967,747	66.6	51.1	48.9

Table 21 summarizes the annual change in total pesticide costs owing to restriction of imidacloprid and thiamethoxam for each of the three base years. The total increase in costs would have been between $2.92 million and $3.10 million, or in percentage terms costs would have increased between 61.6% and 66.6% on acreage treated with an NGN application that would have been prohibited.

Conclusions and Critical Uses

The restrictions from the proposed regulation were estimated to raise the cost of pest management by $2.92 to $3.06 million, a 61.6% to 66.6% increase. However, the increase is relatively small in absolute value on a per acre basis: $34.02 for imidacloprid and $25.32 for thiamethoxam.

Two important policy considerations regard the use of imidacloprid in ACP control and thiamethoxam use for transport of lemons. For the former, we eliminate the estimated share of application that would fall under a quarantine exemption under the proposed regulation. The latter is outside the scope of this analysis, as the data do not enable us to identify applications for transport. Restriction on this particular use could increase costs to citrus above those estimated here.

Imidacloprid is especially important in vector-pathogen situations such as with ACP because it reaches the young instars in the new foliage, it has a long residual, and it has anti-feedant qualities that help prevent disease transmission. These properties are why it is vital to CDFA's control efforts in both commercial and home citrus. It is one of only two insecticides available for residential treatments (beta-cyfluthrin and imidacloprid). It is used heavily in the HLB quarantine areas where treatments of residential and commercial citrus are mandatory. Growers have other insecticide choices for ACP, but it is by far the most efficacious and cost-effective control agent. Without imidacloprid, HLB would be anticipated to spread at a much faster rate in the state. The proposed regulation has an exemption allowing NGN use for quarantine pests. ACP is currently a quarantine pest and is likely to continue to be, but if, for any reason, use for ACP were no longer exempt from the regulation, it would place the entire citrus industry at risk.

Cotton

The vast majority of cotton in California is grown in the San Joaquin Valley, though some is also grown in the southeast region (Low Desert: Palo Verde and Imperial Valleys) and in the Sacramento Valley. Two species of cotton are produced in California: Acala/Upland (*Gossypium hirsutum*) and Pima (*G. barbadense*). Pima is a premium, extra-long staple cotton with longer fibers than upland cotton and commands a higher price.

Cotton generated over $425 million in gross receipts in 2019, a 2.5% decrease from 2018. California is the fifth largest cotton producer by value in the US, accounting for 6.9% of gross national receipts. California exported $438 million in cotton, 7.1% of total US export value in 2019 (CDFA 2020b). Roughly 95% of cotton produced in California were exported. Although cotton was only the 22nd most valuable agricultural commodity in the state, it was the 10th most important agricultural commodity for export.

Cotton acreage had been decreasing gradually until recently when it rapidly expanded from its ten-year low of 164,000 acres planted in 2015 to 304,000 planted acres in 2017 (CDFA 2020a). It decreased to 258,000 acres in 2019. Of the 258,000 acres planted to cotton in 2019, 204,000 acres (79.1%) were planted to American-Pima and 54,000 acres (20.9%) to Upland cotton varieties. California's cotton production is concentrated geographically. The three largest cotton-producing counties in 2019—Kings (42.1% of production value), Fresno (28.6%), and Merced (12.2%)—accounted for 82.9% of state production. Pima cotton was the third most important agricultural commodity in Kings County. Growing regions are defined in Table 3.

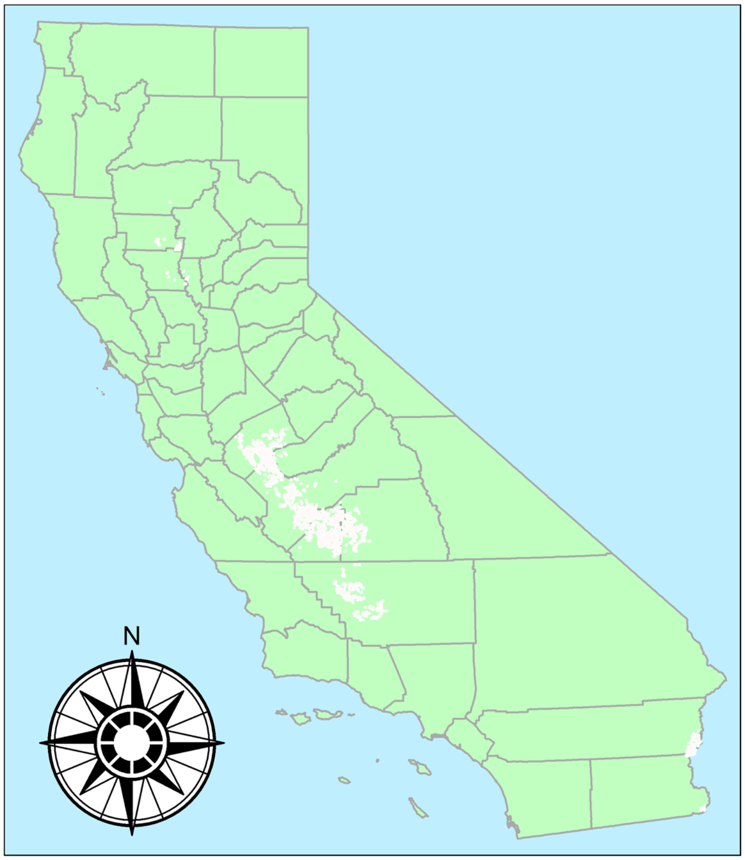

Figure 21. California cotton production: 2019

IPM Overview

In cotton production, the flower bud is called a square and the fruit is called a boll. Cotton lint is the fiber inside the boll. When the bolls mature and dry, they split open, exposing the lint. Pima cotton has a longer growing season and is more susceptible to late-season pest damage than upland cotton.

Cotton grown in California faces damage by a number of insect and mite pests, many of which can reach population levels that require treatment with pesticides to prevent economic damage. These pests can reduce yields directly by causing damage to squares and bolls and also indirectly via stand loss, leaf feeding, or feeding on the vascular system, which reduces the plant's productivity. Aphids and whiteflies can also cause substantial losses in marketable yield and economic returns via effects on lint quality by contaminating exposed cotton lint with sugars from the honeydew they excrete (Godfrey et al. 2000). Lint covered in honeydew is not marketable.

Lygus, aphids, whiteflies, and mites are the key pests in cotton requiring management. Other potential pests include thrips, which can be early-season pests that damage seedlings, although they are typically only a problem under cool, spring conditions. Various caterpillar species can be intermittent pests (through both leaf and square feeding and boll feeding), although one of the most historically important caterpillar pests, pink bollworm, has been eliminated through an intensive area-wide management program. Stink bugs can also be pests, attacking buds, flowers, and bolls. This includes native stink bugs as well as the invasive brown stink bug.

Cotton is used to make fabrics and quality is thus very important, both for individual growers and for entire regions. Minimizing contamination of exposed lint by honeydew from aphids or whiteflies, or so-called “sticky cotton,” is a key concern for cotton growers and ginners in California. Sticky cotton causes problems in roller gins, necessitating special handling. If sticky cotton arrives at a textile mill, processing efficiency and product quality diminish, and shutting down the mill is a possibility. This issue can have region-wide and long-lasting consequences because a reputation of sticky cotton from a given region can negatively impact sales and prices for multiple years, and textile mills can blacklist growing regions over sticky cotton. California has thus far maintained a reputation for producing clean, high-quality cotton.

Cotton has a long history of using IPM for insects, starting in the 1950s. Cotton was one of the first crops University of California IPM chose to promote in the 1970s. Pest managers in cotton currently use IPM methods at both the field and landscape levels (e.g., growers coordinating lygus management in safflower to reduce pressure in cotton), although the extent and level of adoption of IPM practices vary, depending on individual growers and growing regions. California cotton production presents a unique IPM challenge because late-season infestations of both cotton aphid and whitefly can occur simultaneously, something not typically seen in other states, e.g., Arizona, which generally faces whiteflies but not aphids, or Texas, which faces aphids but not whiteflies. The challenge for California is that the three to four-week period immediately before harvest is critical for managing these pests because this is when lint is in danger of being contaminated. However, insecticides do not work as well in this time window and pre-harvest intervals can limit options.

Lygus, cotton aphid, silverleaf whitefly, and spider mites are considered the key pests in California cotton. Management of pests is often interconnected due to the simultaneous presence of multiple pests throughout the season. In addition, insecticide applications targeting one pest can damage natural enemy communities and lead to secondary pest outbreaks. Use of broad-spectrum organophosphate, pyrethroid, and carbamate materials can contribute to outbreaks of spider mites, aphids, whiteflies, and caterpillar pests.

All four NGNs evaluated in this study are registered and used in cotton, although the frequency of use varies by active ingredient, owing to differences in efficacy and label restrictions. NGNs are used to target sucking insect pests, so they are relevant for primary pests, including lygus, cotton aphid, and silverleaf whitefly. Of the four active ingredients, imidacloprid is the only one available under a number of different trade names and as a component of premixes. It is also the most likely to be tank-mixed with other insecticides. Across the state, imidacloprid is applied to substantially more acres than the other NGNs.

How insecticides (including NGNs) are applied varies and is affected by how the cotton crop is grown. Recently, some cotton growers have started to shift away from furrow irrigation towards drip irrigation. The share of cotton acreage using drip irrigation varies by region due to differences in water availability. UCCE experts estimate that around 20% of statewide acreage uses drip irrigation. Unlike furrow irrigation, drip irrigation allows chemigation, i.e., application of insecticides through the drip line.

In addition, drip irrigation can influence how foliar insecticides are applied, although it is not the sole factor affecting this choice. Foliar applications by air are common, especially for fields using furrow irrigation owing to logistical constraints associated with ground applications. Aerial applications make it more difficult to achieve good coverage within a large cotton canopy and on the undersides of leaves where whiteflies and aphids reside. With drip irrigation, ground applications, which improve coverage and insecticide efficacy (especially mid- to late-season), are more feasible, although ground applications with a full plant canopy can be challenging.

Target Pests

Lygus bug (*Lygus hesperus).* Lygus is a perennial problem and usually the most important arthropod pest, particularly in the San Joaquin Valley but also in other regions. Lygus uses over 100 plant species as hosts, including many crop species, and is a highly mobile pest as an adult.

In cotton, lygus injury is primarily from feeding on squares, which causes plants to respond to damage with abscission of the squares. Lygus can also damage young bolls and affect quality. Plants are most susceptible to damage to small squares in the early season, but lygus can cause damage from early square formation (May) through early open boll stages (August). Lygus is a key pest because of the damage it causes and because insecticides targeting lygus can knock out natural enemy communities that are critical for controlling other pest species over the course of the growing season. Since lygus is often targeted for management early on, it sets the stage for economically significant infestations of other pests over the course of the season, especially if broad-spectrum foliar sprays are used. The decision to treat for lygus is based on a combination of lygus densities, whether or not reproduction is occurring (presence of nymphs), and crop characteristics, particularly square retention and how far off square retention is from what is considered normal for a given plant stage.

Lygus infestations can also delay fruit and boll set, an important determinant of yield potential and harvest timing. If many squares are lost, plants may put more resources into vegetative growth, producing tall plants with few bolls. Damage and the accompanying loss of fruiting positions and bolls can extend the season, which is problematic from an agronomic standpoint. Extended seasons and later harvests may necessitate additional irrigation, which increases costs and may not be possible depending on water availability. An extended season also can complicate defoliation because cooler weather requires higher rates of defoliants or multiple applications. Ineffective defoliation leads to leaf trash in the harvested cotton, which reduces quality. An extended season also prevents completion of groundwork before winter rains and increases the period during which open bolls are susceptible to late-season aphid and whitefly issues.

Insecticides are the primary means of lygus management, but several other tactics are also employed. First, agronomic practices to produce a vigorous cotton plant, such as proper weed management, fertilization, and irrigation, can help minimize effects on yield by ensuring retention of squares is sufficient to achieve high yields. Second, management of lygus populations at the regional level has had some success. This involved managing lygus in safflower, a preferred host, with a well-timed, region-wide insecticide application before they migrate into cotton. Host plant resistance (conventional breeding or transgenic) is not currently available.

NGNs are not the primary insecticides used for lygus but are still commonly used since they are softer on natural enemies than many alternative AIs. Lygus management is a balance between reducing lygus populations and averting secondary outbreaks of spider mites, aphids, and whiteflies. Since 2007, flonicamid has been the standard for lygus management in cotton, typically requiring one to three applications, with other insecticides rotating in to varying degrees. It is a selective material that also controls cotton aphid and does not overly harm natural enemy populations. Sometimes a pyrethroid will be added to flonicamid for targeting lygus.

Imidacloprid is occasionally used to manage early-season (low-level) lygus populations, often in conjunction with early-season cotton aphids, although lygus are typically the pest of primary concern. Some of these applications are preventative. Imidacloprid typically suppresses lygus vs. controlling them and it appears that some resistance is present. Imidacloprid will often be tank-mixed with another material (e.g., bifenthrin or other pyrethroids, dimethoate, or novaluron) to improve efficacy and residual and/or control both adults and nymphs. A relatively common imidacloprid pre-mix is imidacloprid plus beta-cyfluthrin.

Clothianidin is also used to target lygus, although its use is restricted to early season. An additional constraint with clothianidin is that there are rotational crop restrictions on the product label for multiple crops from immediately to 12 months after use. In practice, this means that clothianidin cannot be used on cotton when any of the crops on the plant-back restrictions list are on rotation for that field.

Several other active ingredients are used for managing lygus, including pyrethroids (lambda-cyhalothrin, beta-cyfluthrin, bifenthrin, (s)-cypermethrin). Pyrethroids were relied on for lygus control in the 1990s and early 2000s but use of pyrethroids alone has declined owing to resistance problems. Today, they still provide good control and residual in some areas, though they are ineffective in other regions. Since pyrethroids do not conserve natural enemies, their use leads to outbreaks of aphids, spider mites, or whiteflies. Oxamyl is another broad-spectrum material that is used to target lygus, more often in the later part of the season, but it also does not conserve natural enemies leading to outbreaks of other pests. Dimethoate is occasionally used to target lygus, but it is broad spectrum. Acetamiprid (sometimes mixed with a pyrethroid) is sometimes used for lygus, but generally later in the season. Late season applications can also target aphids or whiteflies. Indoxacarb can be used for lygus management, although it only provides suppression and is utilized mostly as a backup material. In 2017 and 2018, another very effective and selective material, sulfoxaflor, was used for lygus management. It was only available under a Section 18 emergency exemption in 2017, 2018, and 2019. Sulfoxaflor is included as an alternative in this analysis but it would not be a viable alternative going forward if the section 18 is not renewed in the future.

Cotton aphid (*Aphis gossypii*). Cotton aphid can be a nearly season-long pest in some areas and is extremely important to manage, with mid- to late-season being the most critical. Aphids siphon off plant nutrients, stunting plants and competing with developing squares and bolls for resources. Infestations on seedling cotton and pre-reproductive cotton generally do not warrant treatment as plants can compensate for injury and natural enemies often effectively reduce aphid populations. During the reproductive growth phase, aphid feeding uses resources otherwise available to developing squares or bolls, reducing yield. After bolls have opened and until harvest, aphids can contaminate exposed lint with honeydew. As discussed, sticky cotton and lint contamination is a severe problem, necessitating low action thresholds during the late-season. The amount of stickiness in lint is not easily quantifiable but sticky cotton can decrease lint prices over entire production regions or cause issues selling cotton for an entire region.

NGNs play a large role in current aphid management practices. Early-season aphids are often managed with imidacloprid, often in conjunction with lygus. An early season application will depress aphid and lygus populations and prevent them from building. In the southeast region of California, imidacloprid is sometimes used early as a pre-plant chemigated insecticide for aphid and fleahopper management. Imidacloprid is used around first bloom or post-bloom to manage aphids. Thiamethoxam is used from mid- to late-season for aphids. Clothianidin is used more for lygus than aphids, but it will incidentally manage aphid populations when used. There are non-NGN materials for aphid management. Flonicamid is effective on aphids and applications that target lygus during the reproductive phase of cotton will also manage aphids. Flonicamid can be used in the absence of lygus to target aphids. However, reliance on flonicamid earlier in the season makes it less useful later in the season, owing to resistance issues.

Acetamiprid is frequently used for aphid (and whitefly) management throughout the season. Flupyradifurone is another alternative material with good activity against aphids, although its use has likely been hampered by price and lower efficacy with aerial applications later in the season. Additionally, it has a one-year plant-back restriction for safflower, which precludes its use in some areas. Naled will be used sometimes for mid/late season aphids.

There are alternative management practices that can help control aphids. Planting and harvesting as early as possible and avoiding late season irrigation can help; however, these practices are somewhat weather dependent and are not typically driven by aphid management. High rates of nitrogen fertilizer can lead to large aphid and whitefly populations. Decreasing fertilizer rates can help manage aphids but can run counter to agronomic decisions aimed to create high yields. Natural enemies can control aphid populations earlier in the year, thus preventing outbreaks mid- to late-season. Conservation of natural enemies, i.e., avoiding the use of broad-spectrum insecticides, is therefore important for avoiding aphid problems. Some upland cultivars are less susceptible to aphids (smooth-leaved varieties typically have fewer aphids than hairy-leaved ones), but this information is not always available to growers and cultivar choice is made based on agronomic considerations. In addition, much of the cotton acreage has shifted to Pima, where less information is available.

Silverleaf whitefly (*Bemesia tabaci* biotype B). Silverleaf whitefly causes problems similar to cotton aphid. Both adults and nymphs are sucking pests, damaging plants by removing nutrients and reducing yields. They also generate honeydew and can contaminate lint later in the season. This pest has become more of an issue in recent years, appearing earlier and producing more generations in cotton over the course of the season. Populations tend to be highest near urban areas and the southern/eastern portions of the San Joaquin Valley. Fields near alternative hosts (such as melons) are also particularly at risk of late-season movement of whiteflies as alternative hosts decline. High rates of nitrogen fertilizer are conducive to whitefly population growth.

Similar to cotton aphids, insecticides are heavily relied upon for silverleaf whitefly management. Some cultivars are less susceptible, but whitefly management does not drive variety choice and information on resistance to whiteflies is generally not available (see aphid section). At the landscape level, avoiding planting cotton by or downwind of known hosts (like melons) can help reduce whitefly pressure. Natural enemies can help regulate whitefly populations and generalist predators are key sources of mortality of whiteflies in cotton fields.

Though NGNs play a role in whitefly management, primarily for moderate whitefly pressure, insect growth regulators (IGRs) are the primary tools. NGNs are mainly used when adult whitefly populations are moderate to high and/or there is greater pressure from immigrating adult whiteflies. Acetamiprid is an alternative to NGNs for managing moderate to high whitefly populations.

The IGRs - buprofezin, pyriproxyfen, and spiromesifen - are good alternatives for low to moderate whitefly populations. They are ideally used to selectively target whiteflies and avoid broad-spectrum materials. IGRs are best suited for strategic use earlier in the season when whitefly populations are small and their growth can be disrupted. These compounds are selective and help conserve natural enemies.

Owing to their selectivity, IGRs are not effective against cotton aphids. This is an important distinction because concurrent infestations of aphids and whiteflies can occur, especially mid- to late-season. One option that controls both pests is flupyradifurone. It is a newer material that is used for mid- to late-season infestations of whiteflies similar to how it is used for aphids and with the same caveats. NGNs, acetamiprid, and flupyradifurone may be used if there is high pressure from immigrating adult aphids earlier in the season, and then followed by IGRs after movement from overwintering sites has subsided.

To avoid harvesting sticky cotton, mid-season management of whiteflies is critical since late-season populations are difficult to control. Late season management often shifts to broad-spectrum materials to reduce populations of immigrating adults. Immigration events can be extremely rapid. Broad-spectrum insecticide use is best avoided until late in the season because of the potential for inducing outbreaks of spider mites or aphids. The NGNs do not play a large role in managing late season aphids, and as such, this particular pest management issue is not part of this analysis.

Stink bugs. A variety of stink bugs attack cotton: Consperse stink bug (*Euschistus conspersus*), Say stink bug (*Chlorochroa sayi*), western brown stink bug (*Euschistus impictiventris*), and brown stink bug (*Euschistus servus*)**.** Generally, stink bugs are not abundant enough in cotton to warrant management. However, the brown stink bug is a new pest in California cotton, so far only in the southeast region, and there is the possibility that its damage could create boll rots. If there is significant feeding and late season rains, then there is a possibility for damage.

Primary tools for managing stink bugs are broad-spectrum insecticides, including acephate, (s)-cypermethrin, bifenthrin, or a pre-mix or tank mix of pyrethroids. Of the NGNs, clothianidin and dinotefuran are the most active on stink bugs and are sometimes combined with a pyrethroid (lambda-cyhalothrin, etc.) to improve efficacy. Dinotefuran is more applicable for cotton because of clothianidin's plant-back label restriction.

Target NGN Use: 2017-2019

Statewide for 2017-2019, imidacloprid was the most-applied NGN by a substantial margin for cotton (by acreage and pounds of AI), followed by clothianidin, thiamethoxam, and dinotefuran (Table 22). Among the alternatives to the NGNs, only flonicamid and acetamiprid were applied to more acres than imidacloprid (540,559 acres), with 1,241,590 and 570,398 acres, respectively. Flonicamid is used as part of a program for managing cotton aphid. It is primarily used for lygus, but applications for lygus also control aphids. However, owing to resistance considerations and maximum use restrictions, it cannot necessarily be used throughout the entire season. The label for Carbine 50 WG specifies no more than three applications at the maximum recommended rate for cotton per year. Acetamiprid can be used as part of a program for managing cotton aphid and silver leaf whitefly.

Table 22. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Cotton, 2017-2019

Active ingredient	**--------- Pounds applied ----------**				**---------- Acres treated -----------**				**Use rate (lb/ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
(s)-cypermethrin	1,735	1,135	696	3,566	36,026	23,002	14,187	73,214	0.05
acephate	30,591	24,873	43,655	99,120	35,265	27,299	48,978	111,542	0.89
acetamiprid	19,099	16,901	15,165	51,165	221,233	181,264	167,901	570,398	0.09
beta-cyfluthrin	915	863	708	2,486	36,883	33,864	28,613	99,360	0.03
bifenthrin	15,963	10,074	14,617	40,654	164,258	107,414	151,204	422,876	0.10
buprofezin	15,531	30,370	5,866	51,767	44,325	86,457	17,085	147,867	0.35
clothianidin	7,453	2,391	4,779	14,623	80,486	29,951	59,374	169,810	0.09
dimethoate	47,208	24,658	33,429	105,295	112,075	67,227	90,075	269,377	0.39
dinotefuran	1,232	2,809	1,614	5,654	12,285	22,995	12,640	47,920	0.12
flonicamid	39,750	31,271	36,438	107,459	458,121	363,938	419,531	1,241,590	0.09
flupyradifurone	10,242	6,501	4,257	21,000	64,065	37,231	29,809	131,105	0.16
imidacloprid	18,563	14,582	17,643	50,787	217,730	147,236	175,592	540,559	0.09
indoxacarb	10,340	5,796	8,878	25,014	110,863	57,259	92,231	260,352	0.10
lambda-cyhalothrin	3,449	2,724	4,549	10,722	97,469	71,055	122,573	291,097	0.04
naled	86,675	70,941	103,844	261,460	74,684	61,855	94,297	230,836	1.13
oxamyl	36,533	67,343	87,187	191,062	38,844	75,925	88,327	203,096	0.94
pyriproxyfen	1,155	3,289	1,592	6,035	17,493	49,109	24,436	91,038	0.07
spiromesifen	8,461	5,305	6,174	19,940	33,794	21,073	24,686	79,553	0.25
sulfoxaflor	10,776	9,089	10,231	30,095	155,920	129,450	149,504	434,875	0.07
thiamethoxam	3,084	1,782	2,582	7,448	51,734	28,784	41,371	121,889	0.06

*Target NGN

The vast majority of cotton acres treated with NGNs are in the San Joaquin Valley, which is also where the majority of cotton is produced. All four NGNs are used to some degree in the San Joaquin Valley at various points during cotton production, with imidacloprid being the most popular, followed by clothianidin, thiamethoxam, and dinotefuran. In the Sacramento Valley, almost all the applications of NGNs in recent years were of imidacloprid. There is a similar pattern in the southeast region.

Use of imidacloprid is highest in June, followed by July (Figure 22). Clothianidin is the second most-used NGN in cotton by treated acreage from 2017-2019, followed by thiamethoxam. Use of clothianidin drops off precipitously after June because the label restricts applications to the early season.

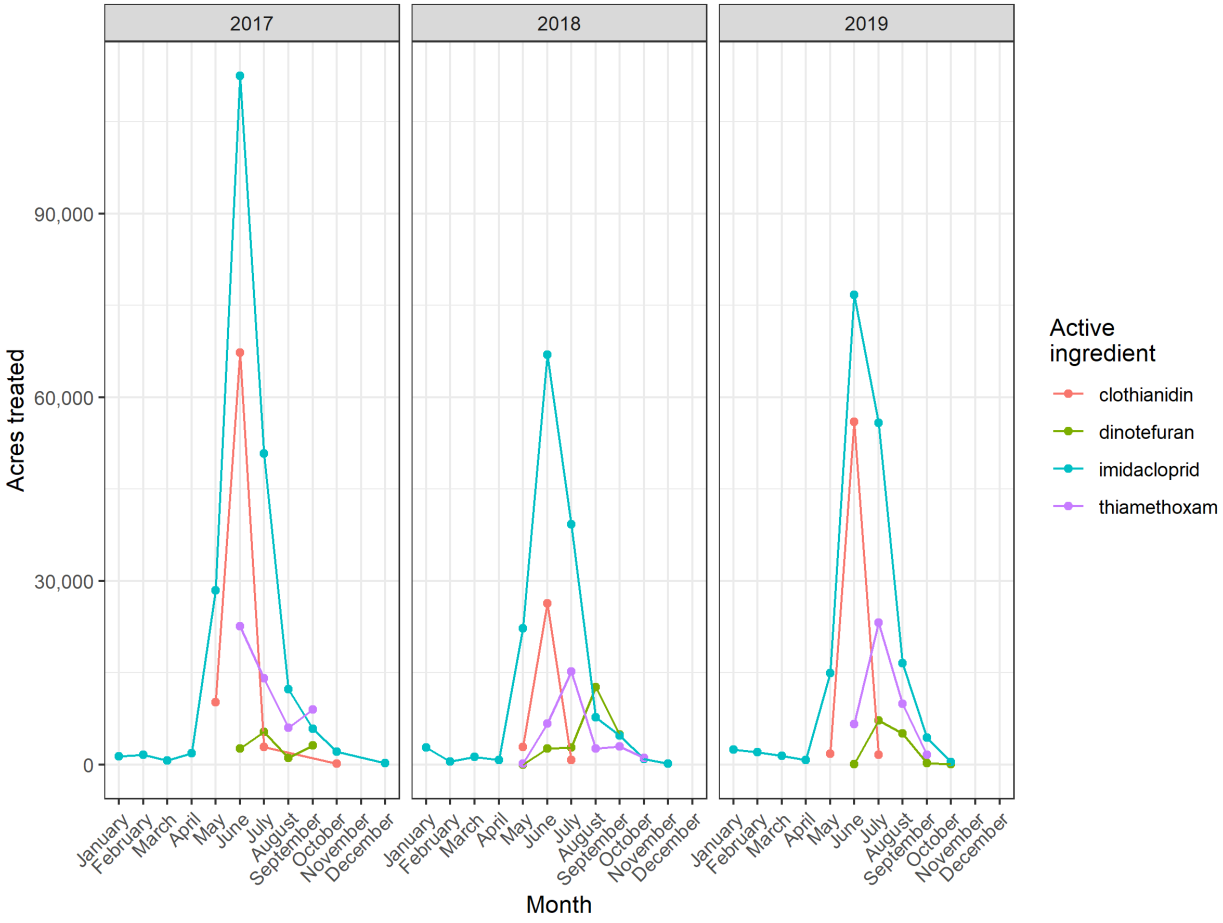

Figure 22. Monthly use of target nitroguanidine-substituted neonicotinoids: Cotton, 2017-2019

Other considerations. Secondary pest infestations are an important consideration. Because of the interconnected nature of IPM of the key pests in cotton (lygus, cotton aphid, silverleaf whitefly, and spider mites), secondary pest outbreaks are a key concern. Pest managers must account for how applications targeting one pest will affect populations of other pests and natural enemies. Effects can be almost immediate as is the case with spider mites, which reproduce very quickly. Additionally, there can be longer-term effects such as late season outbreaks owing to the cumulative effects of a sparse natural enemy community. NGNs play an important role in this regard because they are typically softer on natural enemies than the organophosphates, carbamates, or pyrethroids alternatives. Some NGNs can also be applied systemically through drip irrigation, which could promote conservation of natural enemy communities, although there has not been much research on this practice in California cotton to date.

Resistance management is a significant concern for IPM of cotton pests. All of the pests that are the primary targets of NGNs have repeatedly displayed an ability to develop resistance to the insecticides relied upon to control them. Some of the materials currently used to manage these pests (such as lygus), are no longer as effective as they used to be. Resistance management relies on a combination of availability of multiple modes of action to use in rotation and education about how to use these materials. Overreliance on a key material throughout the season is a sure way to generate resistance. For instance, flonicamid is currently an extremely effective and selective material for lygus and aphids, but if multiple modes of action are not used for lygus management and repeated applications of flonicamid are used instead, there is a strong possibility that insecticide resistance will develop.

Proposed Restrictions

Cotton is in the oilseed crop group. Under the proposed regulations, only the general restrictions would apply unless a grower is using managed pollinators, which is not a practice in cotton. Accordingly, the use of clothianidin, dinotefuran, thiamethoxam, and imidacloprid would be allowed up to the maximum cumulative label rate as long as only one AI and only one application method are used. If more than one AI and/or more than one application method is used, then the cumulative application rate must not exceed 0.3 lbs AI/acre/year for all methods and AIs. All applications would be prohibited during bloom. For cotton, bloom starts around June 21, continues through harvest, and includes the most consequential management period of aphids and whiteflies. Whiteflies tend to be managed less than aphids earlier in the season (i.e., before June 21). The June 21 date is an estimate and is likely on the early side for much of the state in most years. This makes it a conservative estimate for the analysis.

We assumed that applications after June 21 were prohibited and alternatives were used. For fields that only had one NGN AI applied before June 21, those applications were considered allowed. For fields where multiple AIs were applied before June 21, all use was allowed up until a field reached the maximum cumulative use rate of 0.3 lbs AI/acre/year. After that limit, all applications were considered prohibited and replaced with alternatives. Under the proposed regulation, 34.9-41.4% of treated acres and 32.4-37.5% of pounds applied would have been allowed per year. Figure 23 shows allowed and prohibited acres treated by year.

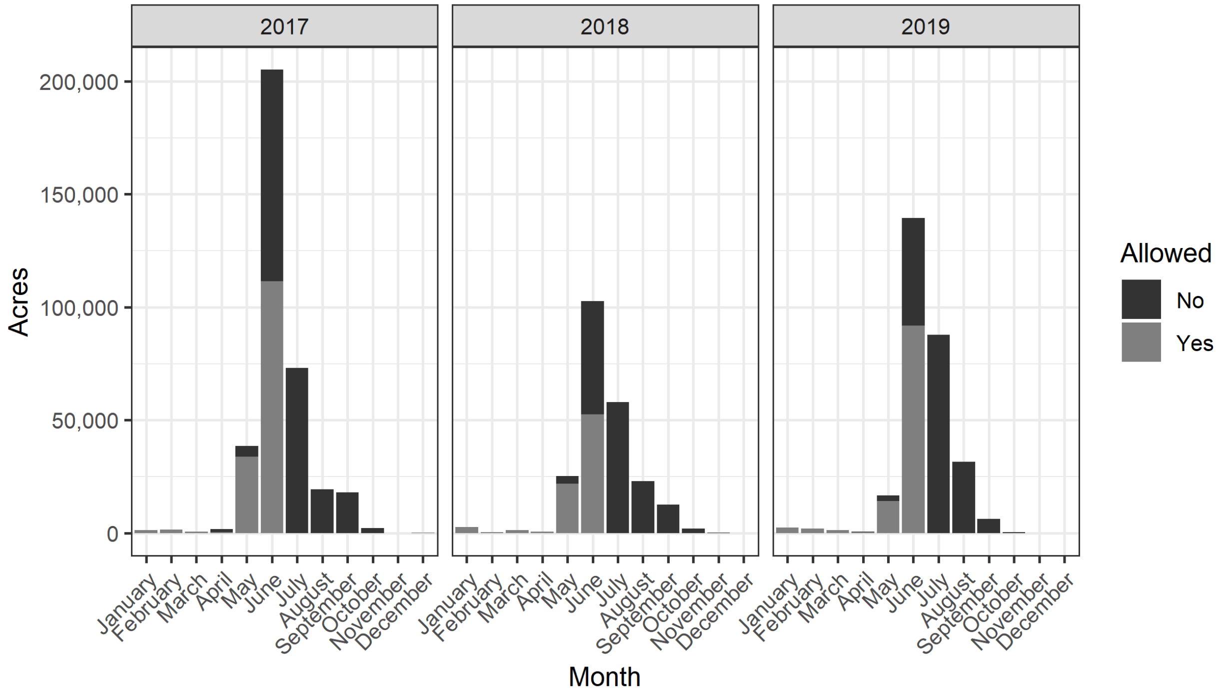

Figure 23. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Cotton, 2017-2019

Economic Analysis

This section presents the estimated change in net revenues in cotton due to the restrictions on the use of the four NGNs.

Table 23. Representative Products and Costs Per Acre: Cotton

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
(s)-cypermethrin	Mustang	3.81	20.29	24.11
acephate	Acephate 97UP Insecticide	13.70	22.19	35.89
acetamiprid	Assail 70WP Insecticide	31.53	18.70	50.23
beta-cyfluthrin	Baythroid XL	10.91	20.25	31.15
bifenthrin	Bifenture EC Agricultural Insecticide	4.75	19.38	24.13
buprofezin	Courier	33.87	18.60	52.47
clothianidin	Belay Insecticide	12.58	23.55	36.13
dimethoate	Dimethoate 400	5.64	20.36	25.99
dinotefuran	Venom Insecticide	24.96	18.38	43.34
flonicamid	Carbine 50WG Insecticide	16.42	20.59	37.01
flupyradifurone	Sivanto Prime	44.64	20.62	65.26
imidacloprid	Wrangler Insecticide	3.55	18.49	22.04
indoxacarb	Dupont Steward EC Insecticide	27.49	21.03	48.52
lambda-cyhalothrin	Warrior II	7.53	19.94	27.47
naled	Dibrom 8 Emulsive	9.14	18.70	27.83
oxamyl	Dupont Vydate C-LV Insecticide/Nematicide	15.83	18.30	34.12
pyriproxyfen	Knack Insect Growth Regulator	0.71	19.44	20.15
spiromesifen	Oberon 2SC Insecticide/Miticide	50.38	21.10	71.48
sulfoxaflor	Transform	19.89	19.06	38.96
thiamethoxam	Centric 40WG	13.11	19.28	32.39

Table 23 presents representative products for each target and alternative AI used on cotton in 2017-2019 and their costs per acre. The material cost per acre is the product of the average use rate (lb/acre treated) over this period and the price per pound. The application cost per acre is the acre-weighted average application cost based on application method across all applications of the AI to the crop. The costs of each application method are presented in the methods section. The total treatment cost per acre is the sum of material and application costs per acre. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited (i.e., excluding allowed applications). There is substantial variation in the total cost per acre of AIs, which ranges from $20.15 (pyriproxyfen) to $71.48 (spiromesifen).

Table 24. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Cotton, 2017-2019

Active ingredient	Target NGNs available (%of all target and alternative use)	Share of composite alternative (%)
(s)-cypermethrin	1.3	1.6
acephate	2.0	2.4
acetamiprid	10.3	12.2
beta-cyfluthrin	1.8	2.1
bifenthrin	7.6	9.1
buprofezin	2.7	3.2
dimethoate	4.9	5.8
flonicamid	22.4	26.7
flupyradifurone	2.4	2.8
indoxacarb	4.7	5.6
lambda-cyhalothrin	5.3	6.2
naled	4.2	5.0
oxamyl	3.7	4.4
pyriproxyfen	1.6	2.0
spiromesifen	1.4	1.7
sufloxaflor	7.8	9.3
total	84.1	100.0

Table 24 shows the average acreage shares for each non-NGN alternative used on cotton in the second column. Averaged over the three-year period 2017-2019 when NGNs were available, NGNs were used on 16.9% of total cotton acres treated with NGNs or alternative AIs, and alternatives were used on 84.1%, reported in the total line for the second column.

If NGNs were restricted, the use of alternative AIs is scaled up in proportion to their acreage shares, as discussed in the methods section. In total they account for 100% of the composite alternative, which replaces prohibited applications of the target NGNs. Shares of the composite alternative are reported in the third column. Flonicamid and acetamiprid were used the most, together accounting for 32.7% of total cotton acres treated with NGN or alternative insecticides, or 38.9% of acres treated with non-NGN alternative AIs. Because use was scaled up based on all use, their shares in the overall use of alternatives may not represent their use as a substitute for NGNs for any specific pest.

Table 25. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Cotton

Active ingredient	**Material cost ($)**	**Application cost ($)**	**Total cost ($)**	**Cost increase for switching to composite alternative (%)**
clothianidin	12.58	23.55	36.13	4.2
dinotefuran	24.96	18.38	43.34	-13.1
imidacloprid	3.55	18.49	22.04	70.9
thiamethoxam	13.11	19.28	32.39	16.3
composite alternative	17.83	19.83	37.66	-

Table 25 shows the average costs per acre for the four target NGNs and the composite alternative, whose price we use as a representative pesticide cost that would be paid by growers if NGNs were restricted. For cotton, switching to the composite alternative would lead to an increase in material costs for all acres using NGNs except for those using dinotefuran. Application costs would increase for all acres using NGNs except for those using clothianidin. Overall, dinotefuran users would reduce their costs by 13.1% when switching to the alternative. Clothianidin users would incur the smallest cost increase (4.2%) and imidacloprid users would incur the largest cost increase (70.9%). Thiamethoxam users would incur a 16.3% cost increase.

Table 26. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids (NGNs): Cotton, 2017-2019

Year	**Cost with target NGNs ($)**	**Cost without target NGNs ($)**	**Change in total cost ($)**	**Change in total cost (%)**	**Share of change due to material costs (%)**	**Share of change due to application costs (%)**
2017	5,481,878	7,293,277	1,811,399	33.0	100.2	-0.2
2018	4,015,634	5,170,756	1,155,122	28.8	96.6	3.4
2019	4,519,293	6,172,334	1,653,041	36.6	97.5	2.5

Table 26 reports the anticipated changes in total cost due to the proposed restriction of NGNs. Insecticide costs for management of the target pests in cotton would increase by approximately by one third. The percent change in costs ranged from 28.8% in 2018 to 36.6% in 2019. In all years, the increase in material costs was greater than the increase in total costs. The reduction in application costs associated with the use of some alternatives partially offset the increase in material costs.

The magnitude of these changes was driven by the large treated cotton acreage and the large material cost differences per acre between imidacloprid ($22.04), the most widely used NGN in cotton, and specific alternatives that accounted for a large share of non-NGN treated acreage: flonicamid ($37.01) and acetamiprid ($50.23).

Conclusions and Critical Uses

A substantial cost increase per treatment is anticipated as a result of the proposed restrictions in cotton. The cost per acre would increase by 70.9% on acres that were treated with imidacloprid and 4.2% on acres that were treated with clothianidin, the two NGNs accounting for a substantial majority of use on cotton. Total annual costs would have increased by $1.16 million to $1.81 million. In addition, secondary pest infestations and faster development of resistance to other active ingredients in cotton pests are important factors influencing future costs that are not addressed here.

Grape

Grape was California's second largest crop by value of production in 2019 and ranked behind milk and cream and almond for all agricultural commodities. In 2019, California produced 5.4 million tons of grapes on 860,000 bearing acres (plus 58,000 non-bearing acres), corresponding to $5.4 billion in gross receipts (CDFA 2020a). California is by far the largest grape-producing state, and accounted for 92% of national bearing acreage, 94% of national production, and 95% of national production value in 2019 ((CDFA 2020a; NASS 2020). Export products related to grape production exceeded $2.3 billion, which was 10.4% of California's total agricultural export value, second only to almond (CDFA 2020b).

There are three categories of grape produced in California: wine, raisin, and table. By bearing acreage, wine grape accounted for 68.6% in 2019, raisin grape 17.3%, and table grape the remaining 14.1% (CDFA 2020a). Production per acre tends to be higher for table and raisin grape than wine grape; as a result, wine grape accounted for 61.7% of production tonnage, while raisin and table grape accounted for 20.1 and 18.2% of production tonnage. Table and wine grape had the highest average value per unit in 2019 at $1,030 per ton and $971 per ton, respectively, compared to only $296 per ton for raisin grape. In terms of total production value, wine grape accounted for 70.3%, table grape 22.5%, and raisin grape 7.1%. Wine grape accounted for 77.6% of non-bearing acreage in 2019, table grape 15.5%, and raisin grape only 6.9%. Note there are many varieties within the main categories of wine, raisin, and table grape. For example, there were at least 30 white wine, 40 red wine, 70 table, and 6 raisin grape varieties reported with standing acreage in 2018 or 2019 (CDFA 2020c). The largest share of standing acreage by variety in 2019 were planted to: Chardonnay for white wine (52.9% of category total); Cabernet Sauvignon for red wine (30.8%); Flame Seedless for table (16.5%); and Thompson Seedless for raisin (83.3%). Data available on pesticide use differentiate only between wine and other grape types, not between raisin and table grape (or varieties within a category).

Grapes are used in a wide variety of products. In 2019, 4.1 million tons of grape—or 63.5% of total production—were crushed for wine, concentrate, juice, vinegar or beverage brandy (CDFA 2018a, d). By variety, most table grapes were sold fresh (1.0 million of the total 1.2 million tons), most raisin grapes were dried (1.29 million of the 1.3 million tons), and virtually all wine grapes were crushed. Not all table grapes are sold fresh to market or raisin grapes are dried, indicating that the distinction between varieties can be ambiguous. For example, 61,056 tons of raisin grapes and 134,470 tons of table grapes were crushed in 2019 (CDFA 2020d).

Grape production of all types occurs throughout the state of California. Figure 24 maps raisin and table grape production, and Figure 25 maps wine grape production. Table grape production is concentrated in Kern ($1,240 million), Tulare ($682 million), and Fresno ($416 million) counties, and is a top ten production value crop in five counties (the previous three plus Riverside and Madera) (CDFA 2020a). Raisin grape production is concentrated in Fresno ($287 million) and Madera ($93 million) and is a top ten production value crop in only these counties. Wine grape was a top ten production value crop in 23 counties. The top three wine grape producing counties, by value, were Napa ($938 million), Sonoma ($654 million), and San Joaquin ($373 million). The former two counties were driven by high-value production per acre compared to other counties, rather than high acreage.

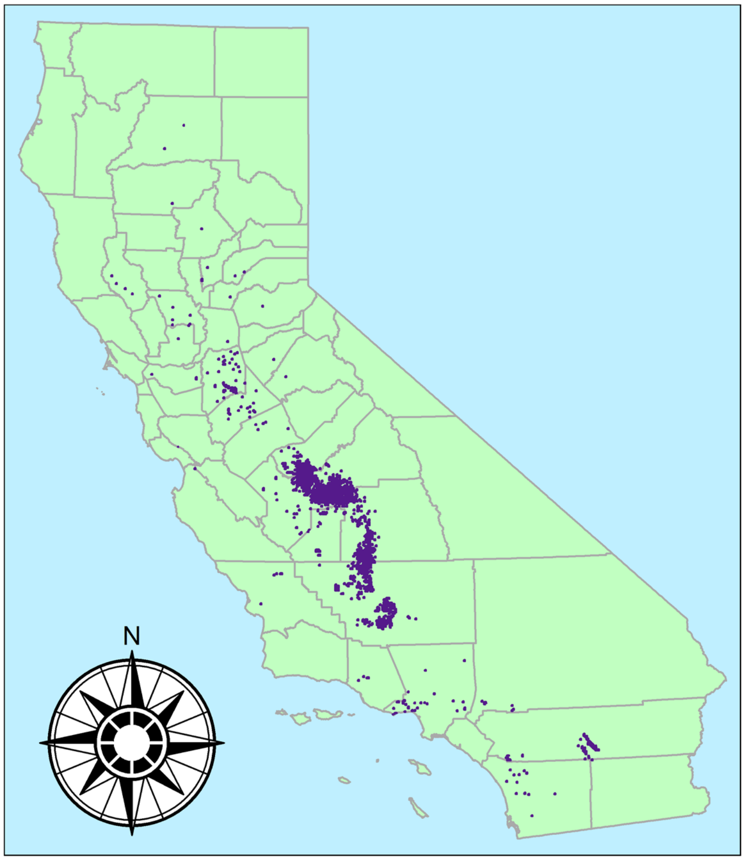

Figure 24. California raisin and table grape production: 2019

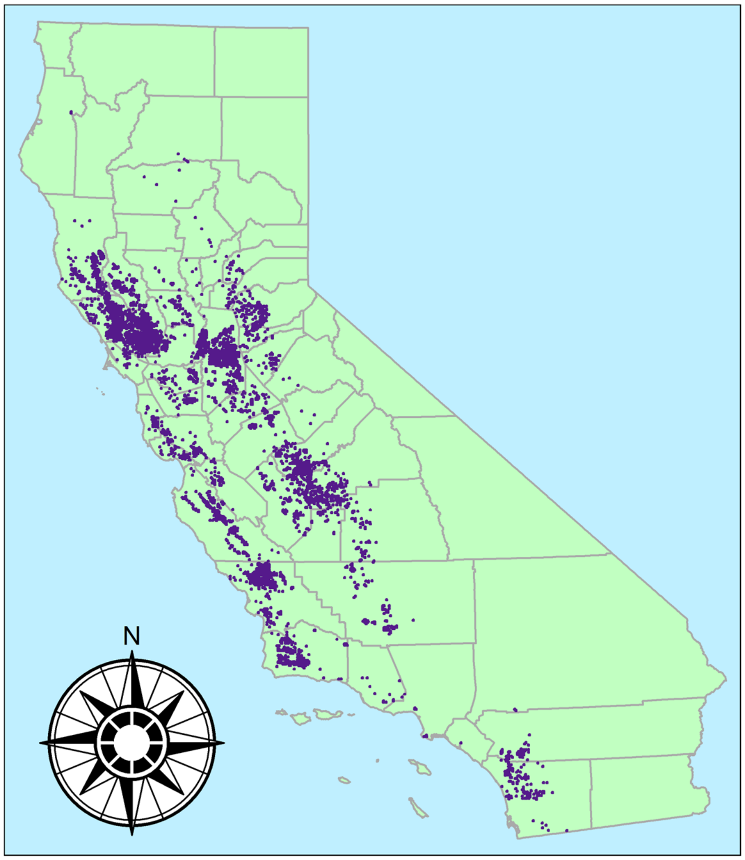

Figure 25. California wine grape production: 2019

IPM Overview

Grape growers use NGN products against leafhoppers (western grape, variegated, Virginia creeper), mealybugs (grape, obscure, long tail, pink hibiscus and vine), sharpshooters, and grape phylloxera. Vine mealybug is a problem in all grape growing areas but can be especially damaging in warmer areas, such as the southern San Joaquin Valley. Raisin grape and table grape are concentrated in the warmer growing areas than wine grape, and, accordingly, tend to have more problems with vine mealybug. As detailed below in the target pest section, there are alternatives for leafhoppers and mealybugs but phylloxera management does not have good neonicotinoid alternatives. All four NGNs – clothianidin, dinotefuran, imidacloprid, and thiamethoxam – are subject to the proposed restrictions in grape.

Target Pests

Mealybugs. Grape (*Pseudococcus maritimus*), obscure (*Pseudococcus viburni*), long tail (*Pseudococcus longispinus*), pink hibiscus (*Maconellicoccus hirsutus*), and vine (*Planococcus ficus*) mealybugs all attack grape in California. Mealybugs feed by using their sucking mouthparts to pierce the plant tissue and extract sap from the phloem, reducing plant vigor. They excrete honeydew, which can cause the growth of sooty mold on the fruit. Different grape varietals are differentially susceptible to mealybug damage from mold. All five mealybugs can transmit diseases.

The vine mealybug is more difficult to control than the *Pseudococcus* spp. mealybugs, i.e., grape, obscure, long tail, and hibiscus mealybugs. Vine mealybug is more difficult to control because, unlike the *Pseudococcus* mealybugs, which only produce two generations per year, vine mealybug can produce multiple generations per year. Thus, vine mealybug can develop large and damaging populations late in the season as the grapes are maturing. Adding to the problem, vine mealybugs may hide in the grape bunches, making them harder to kill with contact insecticides. This is especially an issue in warmer regions as higher temperatures allow for even more generations of vine mealybug.

Alternatives to NGNs for mealybug control are spirotetramat, acetamiprid, flupyradifurone, fenpropathrin, and beta-cyfluthrin. Chlorpyrifos was an alternative, but it is no longer available for use in California. Sulfoxaflor is not currently registered in grape but may be in the future.

For vine mealybug, growers use a series of treatments that include imidacloprid. Haviland et al. (2011) found that a combination of spirotetramat significantly reduce vine mealybug damage and Van Steenwyk et al. (2016c) found that sequential use of spirotetramat and flupyradifurone was effective. The NGNs are a part of that program but could be replaced with acetamiprid or extra applications of spirotetramat. However, heavier use of spirotetramat could lead to resistance and growers are already encouraged to rotate it with other active ingredients to prevent this. As spirotetramat is the primary effective AI besides imidacloprid, it would be difficult to rotate it in order to manage resistance without incurring yield loss.

Additionally, growers have access to mating disruption products. Use of mating disruption has been increasing, especially with the 2016 registration of a product with a user-friendly formulation. Mating disruption decreases the need for chemical controls. Mealybugs are attacked by a variety of natural enemies, but they do not regularly produce sufficient control (Daane et al. 2012; Walton et al. 2012). The most useful one, *Anagyrus pseudococci*, can be released into vineyards to supplement control (Daane et al. 2012). However, the California supply of *A. pseudococci* has been unreliable, making it difficult for growers to use it in pest control.

Sharpshooters. Blue-green sharpshooters (*Graphocephala atropunctata*) and glassy-winged sharpshooters (*Homalodisca vitripennis*) are serious pests in vineyards because they vector Pierce's disease (*Xylella fastidiosa*), for which there is no treatment. CDFA has a Pierce's disease program, with USDA funding, that addresses glassy-winged sharpshooter. The best strategy is to keep sharpshooters from entering the vineyards in the first place and remove infected vines immediately. This is done by managing and treating surrounding areas and crops, especially citrus and avocado, and releasing biological control agents. Over the past 20 years, Riverside's area-wide management program focused on citrus has demonstrated the effectiveness of these types programs (CDFA 2019). However, if sharpshooters are present in a vineyard, NGNs can be used to knock down the populations. This is most effective if done immediately after sharpshooters arrive. Insecticides do not kill the eggs, and accordingly, populations are difficult to manage once reproduction commences. The alternatives are acetamiprid, flupyradifurone, and fenpropathrin.

Leafhoppers. The leafhopper complex that attacks grape includes western grape leafhopper (*Erythroneura elegantula*), variegated leafhopper (*Erythroneura variabilis*), and Virginia creeper leafhopper (*Erythronuera ziczac*). The three species have somewhat different ranges in California, but the damage they cause to grape is similar. Grape leafhopper is found in the Sacramento, San Joaquin, and North Coast valleys as well as the warmer areas of the central coast. Variegated leafhopper is a pest mostly in the Central Valley and southern California but can go as far north as the San Joaquin Valley and Napa. Virginia creeper leafhopper is found in the Sacramento Valley, the North Coast wine region, and the northern Sierra foothills.

Leafhopper nymphs and adults feed on the contents of plant cells in grape leaves, causing light yellow spots. Large populations can lead to defoliation, but even moderate populations reduce the photosynthetic efficacy of the plants. Additionally, leafhopper frass can cause sooty mold on the fruit, a concern for table grape.

In addition to the NGNs, leafhoppers can be controlled with acetamiprid, beta-cyfluthrin, bifenthrin, *Burkholderia*, fenpropathrin, flupyradifurone, and pyrethrin. Flupyradifurone, *Burkholderia*, *Chromobacterium subtsugae* strain A, and pyrethrin were all equally effective for Virginia creeper and grape leafhopper in one efficacy study (Van Steenwyk et al. 2018). There are also natural enemies that attack the leafhoppers and provide control in some areas and situations. The parasitoids *Anagrus erythroneurae* and *Anagrus daanei* are particularly important for western grape and Virginia leafhopper. The cultural practice of removing basal leaves during berry set and two weeks after is also helpful. Limiting overly vigorous growth can suppress populations. These cultural controls can supplement biological control and often eliminate the need for treatment.

Grape phylloxera (*Daktulosphaira vitifoliae*). Grape phylloxera is a small insect, somewhat like an aphid, that feeds on the roots of grape causing vines to be stunted or die. It is more of a problem in regions with cooler, clay heavy soil such as Napa, Sonoma, Lake, Mendocino, Monterey, Sacramento, and Yolo counties.

Resistant root stock is the best way to control phylloxera. However, NGNs are currently a crucial part of control phylloxera on non-resistant varieties. On the east coast of the USA, grape phylloxera can be effectively treated with soil drenches of imidacloprid, fenpropathrin, clothianidin, spirotetramat, and pyriproxyfen (Johnson et al. 2009). Spirotetramat is the only alternative for the type of phylloxera in California (Van Steenwyk et al. 2009). As discussed earlier, more intensive use of spirotetramat is problematic due to the potential effect on the development of resistance. Although not considered in this analysis, the continued development of phylloxera-resistant grape root stock would benefit California growers.

Target NGN Use: 2017-2019

The timing of applications and total acres treated did not vary much across years for raisin/table grape

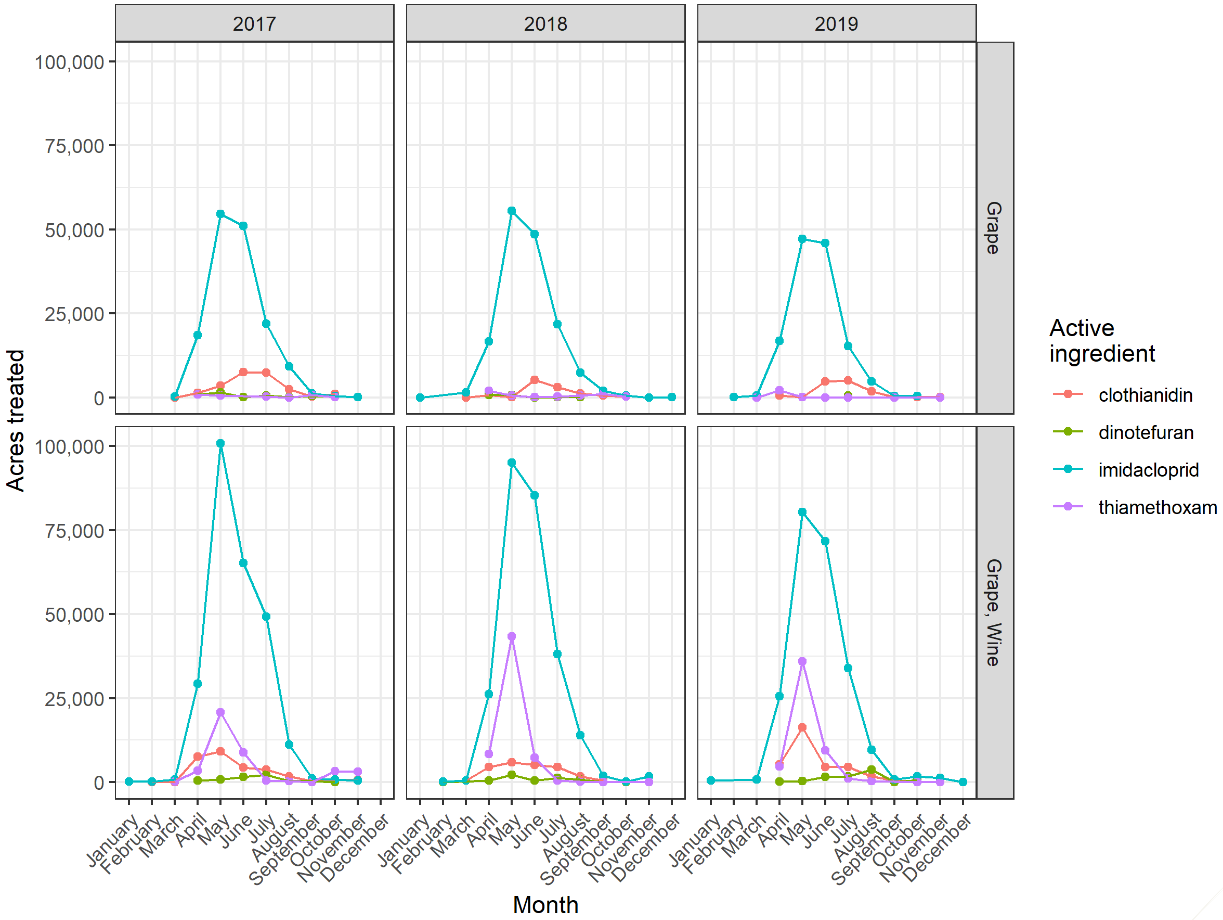

Figure 26). Over the three-year period, total applications of NGNs, most notably imidacloprid and thiamethoxam, increased in wine grape. The pattern of use over the course of the year remained fairly similar. The increasing use in wine grape is due to greater vine mealybug pressure, lower price, and ease of use of the NGNs. Applications early in the year are done through chemigation. Applications starting around August are mostly for leafhopper and are applied with air-blast speed sprayers.

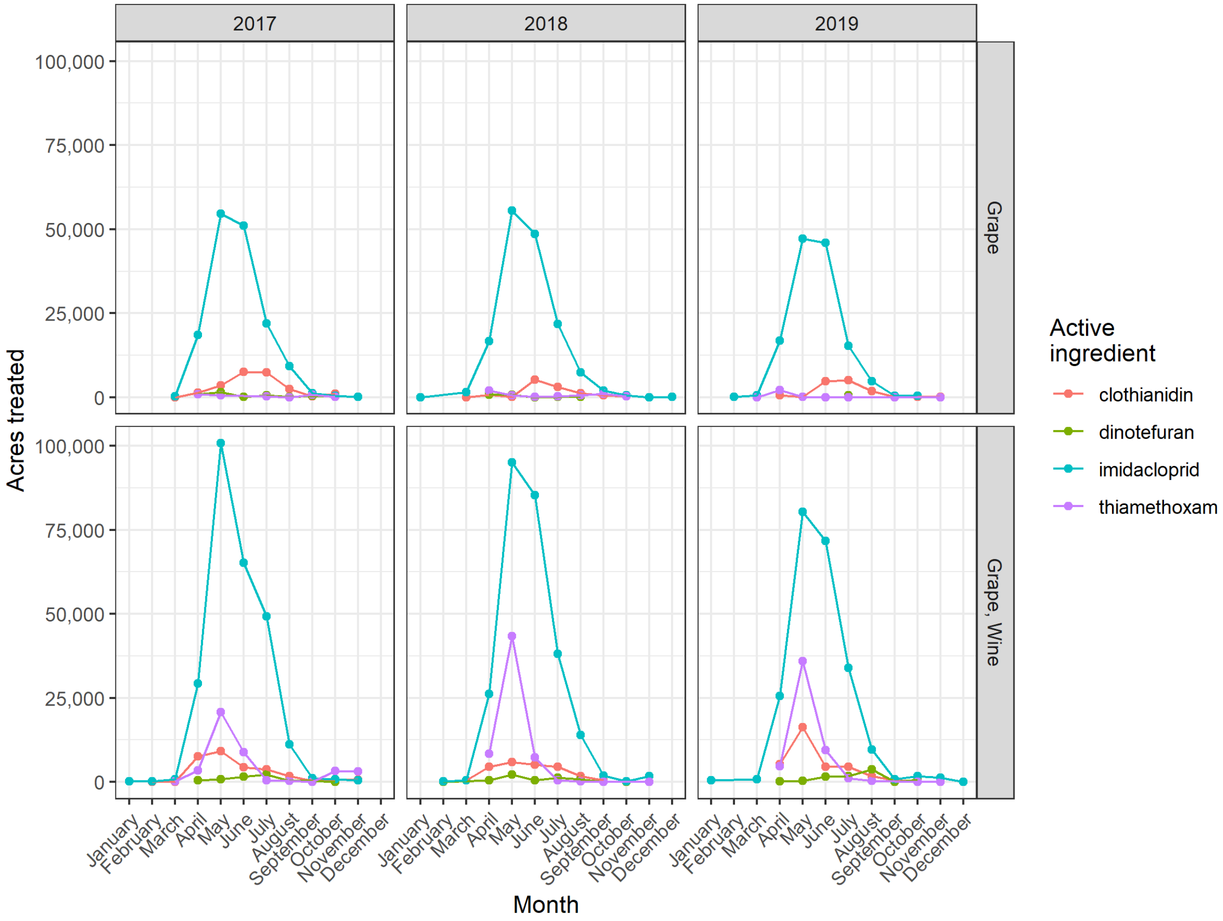

Figure 26. Monthly use of target nitroguanidine-substituted neonicotinoid use: Raisin and table grape and wine grape, 2017-2019.

Table 27 reports the annual and total use of target and alternative active ingredients over the 2017-2019 period, measured as acres treated and as total pounds of active ingredient for raisin/table grape. Table 28 reports the same information for wine grape. Over 1 million acres in total were treated with NGNs over the three-year period. Restriction of the NGNs would have a significant impact on use patterns. Spirotetramat, a major alternative to NGNs, was applied to just under a million acres. Given the potential development of resistance owing to increased use of spirotetramat, restriction in NGN use could have substantial effects on use patterns.

Table 27. Annual Use of Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Raisin and Table Grape, 2017-2019

Active ingredient	**----------Pounds applied-----------**				**--------------Acres treated--------------**				**Use rate (lb/ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
acetamiprid	1,465	1,053	1,039	3,557	15,559	11,298	11,680	38,537	0.09
beta-cyfluthrin	879	768	949	2,596	33,238	28,636	37,325	99,199	0.03
bifenthrin	45	76	59	181	604	763	672	2,039	0.09
buprofezin	36,512	34,619	33,816	104,947	67,460	58,544	58,457	184,462	0.57
Burkholderia sp	10,663	12,650	6,118	29,431	2,981	2,636	1,035	6,652	4.42
clothianidin*	2,349	1,187	1,271	4,808	23,704	11,372	12,709	47,785	0.10
dinotefuran*	748	224	157	1,128	3,896	1,627	591	6,114	0.18
fenpropathrin	6,055	6,606	4,415	17,076	21,182	23,090	17,339	61,611	0.28
flupyradifurone	615	698	559	1,871	3,436	4,375	3,222	11,033	0.17
imidacloprid*	50,492	36,077	32,025	118,593	157,235	154,041	131,673	442,949	0.27
lavandulyl senecioate	541	863	774	2,179	31,022	46,912	63,007	140,941	0.02
spirotetramat	16,495	16,179	14,638	47,312	148,378	144,181	129,544	422,103	0.11
thiamethoxam*	207	545	198	950	2,469	5,061	2,455	9,985	0.10

* Target NGNs

Table 28. Annual Use of Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Wine Grape, 2017-2019

Active ingredient	**----------Pounds applied-----------**				**--------------Acres treated--------------**				**Use rate (lb/ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
acetamiprid	1,345	2,040	1,375	4,760	17,425	25,480	19,048	61,953	0.08
beta-cyfluthrin	94	93	113	300	3,339	3,126	3,348	9,814	0.03
bifenthrin	17	40	54	112	352	425	511	1,287	0.09
buprofezin	16,842	11,215	5,771	33,827	22,596	17,830	8,355	48,781	0.69
Burkholderia sp	4,256	3,131	15,406	22,793	670	612	3,422	4,704	4.85
clothianidin*	3,944	3,080	5,135	12,158	28,428	22,561	32,905	83,894	0.14
dinotefuran*	1,075	994	1,092	3,161	5,887	5,376	8,061	19,324	0.16
fenpropathrin	376	574	591	1,541	1,558	1,609	2,399	5,566	0.28
flupyradifurone	649	1,760	1,132	3,541	4,616	11,572	7,030	23,218	0.15
imidacloprid*	79,886	85,092	71,300	236,278	259,283	263,088	226,060	748,431	0.32
lavandulyl senecioate	607	1,404	3,413	5,424	43,737	93,819	130,909	268,465	0.02
spirotetramat	23,211	23,339	24,976	71,526	202,378	204,725	223,244	630,347	0.11
thiamethoxam*	4,707	6,570	6,053	17,331	40,273	59,957	51,473	151,703	0.11

* Target NGNs

Proposed Restrictions

Grape is part of the berry crop group. Grapes do not use managed pollinators. Accordingly, the use of clothianidin, dinotefuran, thiamethoxam, and imidacloprid would be allowed up to the maximum label rate as long as only one AI and only one application method are used. If more than one AI and/or more than one application method is used then the cumulative application rate for soil applications must not exceed 0.2 lbs AI/acre/year and the cumulative application rate for foliar applications must not exceed 0.1 lbs AI/acre/year for all NGNs. All applications would be prohibited during bloom.[13]

All four NGNs are registered in grape. Imidacloprid is by far the most widely used () and is the most crucial for its role in managing vine mealybug. Chemigation, a soil application, is the most effective way to reach vine mealybug, a key pest. In a given field, any number of applications of one (and only one) NGN was allowed (subject to label restrictions). In fields that used multi-method of imidacloprid and only imidacloprid, foliar use was switched to soil use and all applications were allowed. In fields using multiple NGNs where soil imidacloprid cumulative use was under 0.2 lbs imidacloprid, soil applications of other NGNs were considered allowed up to 0.2 lbs of all NGN AIs is reached. For fields that foliar imidacloprid cumulative use was under 0.1 lbs imidacloprid, foliar applications of other NGNs were considered allowed until 0.1 lbs of all NGN AIs was reached. Applications over the thresholds were considered prohibited and moved to alternatives. There are no known pest management reasons that applications could not be conducted pre- and post-bloom or even entirely post-bloom. Thus, we assumed that grower would simply move those applications outside of bloom. Under the draft proposed regulation, 79.5% to 85.0% of acres treated, and 83.6-84.6% of pounds applied would have been allowed on table and raisin grape, and 82.9% to 88.5% of acres treated, and 86.8% to 87.7% of pounds applied would have been allowed on wine grape. Figure 27 shows acres and pounds that would have been allowed by month.

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[13] Estimating a consistent bloom time in grape is not possible due to differences between varieties and weather variation from year to year.

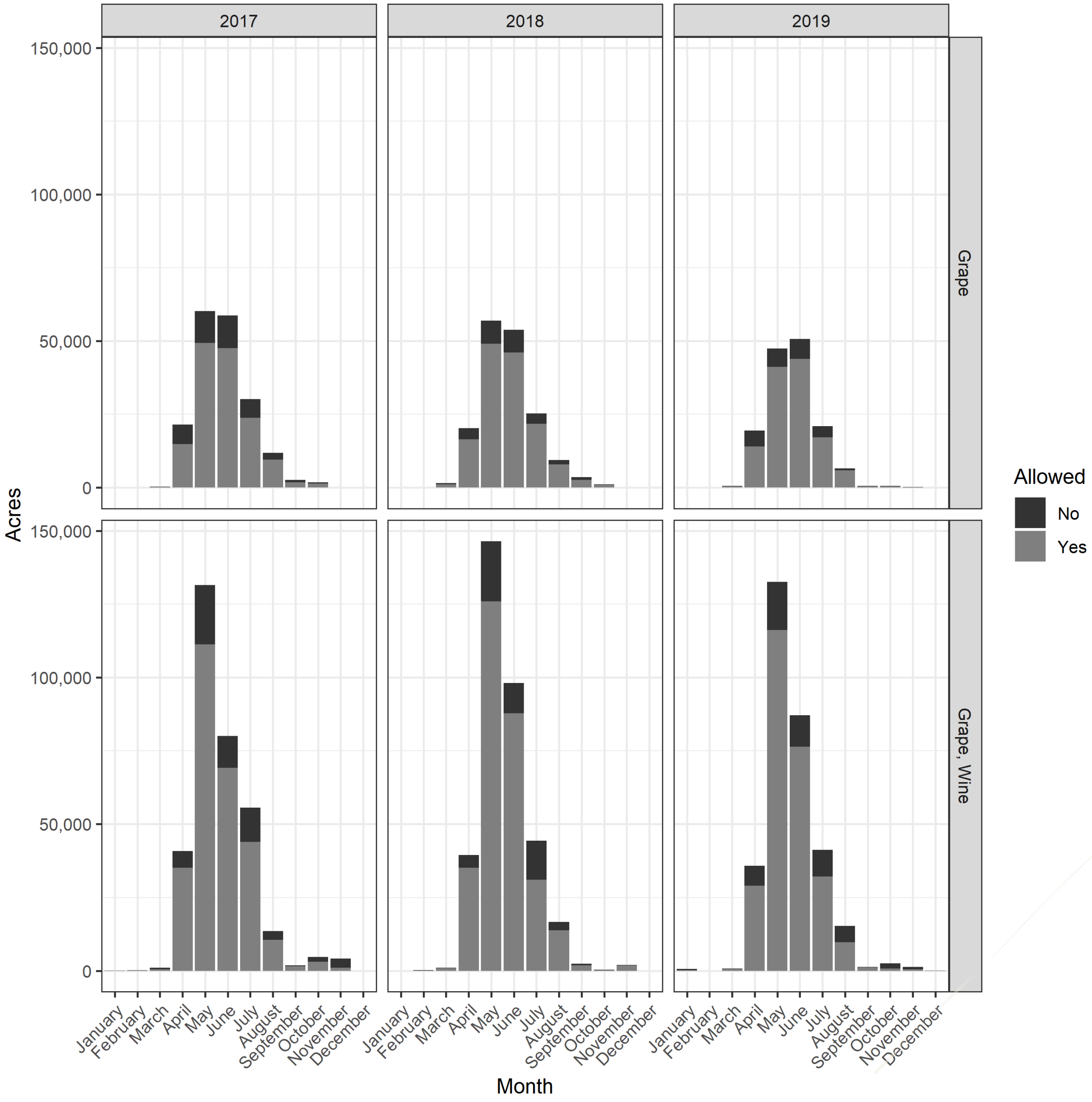

Figure 27. NGN use in grape that would have been allowed with the proposed restrictions: 2017-2019

Economic Analysis

This section presents the estimated change in costs to grape production from the proposed regulation. This cost includes the change in pesticide material costs and changes in application costs when an alternative treatment requires a different application method. We report costs separately for raisin/table grape and wine grape because of differences in pest management practices and differentiated PUR data. No reduction in yield or quality is anticipated due to the use of alternatives, so gross revenues will not change as a result of the restrictions.

Table 29 presents representative products for each active ingredient used on raisin and table grape in 2017-2019 and their costs per acre. Table 30 presents the same information for wine grape. The material cost per acre is the product of the average use rate (lb/acre) over this period and the price per pound. The application cost per acre is the acre-weighted average application cost based on application method across all applications of the AI to the crop. The costs of each application method are presented in the methods section. The total treatment cost per acre is the sum of the material and application cost per acre. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited (i.e., excluding allowed applications).

Table 29. Representative Products and Costs Per Acre: Raisin and Table Grape

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
acetamiprid	Assail 30 SG Insecticide	24.38	25.00	49.38
beta-cyfluthrin	Baythroid XL	11.41	25.00	36.41
bifenthrin	Brigade WSB Insecticide/Miticide	22.31	25.10	47.41
buprofezin	Applaud 70 DF Insect Growth Regulator	36.57	25.00	61.58
burkholderia	Venerate	67.43	25.00	92.43
clothianidin	Belay Insecticide	14.91	24.79	39.71
dinotefuran	Venom Insecticide	39.03	18.27	57.30
fenpropathrin	Danitol 2.4 EC Spray	24.36	25.01	49.37
flupyradifurone	Sivanto 200 SL	47.26	24.77	72.03
imidacloprid	Admire Pro	24.56	8.73	33.29
lavandulyl senecioate	Checkmate VMB-F	26.16	25.00	51.16
spirotetramat	Movento	63.73	24.99	88.71
thiamethoxam	Platinum 75 SG	15.03	15.09	30.11

Table 30. Representative Products and Costs Per Acre: Wine Grape

Active ingredient	Representative product	Material Cost ($)	Application cost ($)	Total cost ($)
acetamiprid	Assail 30sg Insecticide	20.29	24.80	45.09
beta-cyfluthrin	Baythroid XL	13.34	25.14	38.48
bifenthrin	Brigade WSB Insecticide/Miticide	21.82	25.19	47.01
buprofezin	Applaud 70 DF Insect Growth Regulator	44.58	24.69	69.27
burkholderia	Venerate	73.85	24.42	98.27
clothianidin	Belay Insecticide	21.66	18.73	40.40
dinotefuran	Venom Insecticide	39.05	18.85	57.91
fenpropathrin	Danitol 2.4 EC Spray	24.33	25.00	49.33
flupyradifurone	Sivanto 200 SL	42.50	24.53	67.03
imidacloprid	Admire Pro	27.08	10.94	38.02
lavandulyl senecioate	Checkmate VMB-F	34.19	23.58	57.78
spirotetramat	Movento	64.52	24.53	89.04
thiamethoxam	Platinum 75 SG	27.45	16.28	43.73

Differences in the cost per acre for representative products between the two categories of grape are due to different average use rates and percentages of treatments using different application methods over the period. The NGNs have lower average application costs because they were frequently applied through chemigation. There was substantial variation in the total cost per acre of AIs, ranging from $30.11 per acre for thiamethoxam to $92.43 for burkholderia in table and raisin grape, and from $38.02 per acre for imidacloprid to $98.27 for burkholderia in wine grape. In both cases, *Burkholderia* sp strain a396 had the highest cost. This AI is primarily used in organic production but is potentially a viable alternative in conventional vineyards. As its share of acres with and without the NGNs being available was less than 0.5%, its high per-acre cost had a very small effect on the overall changes in material and total treatment costs.

Table 31. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Raisin and Table Grape, 2017-2019

Active ingredient	Target NGNs available (% of all target and alternative use)	Share of composite alternative (%)
acetamiprid	2.6	4.0
beta-cyfluthrin	6.7	10.3
bifenthrin	0.1	0.2
buprofezin	12.5	19.1
burkholderia	0.5	0.7
fenpropathrin	4.2	6.4
flupyradifurone	0.8	1.1
lavandulyl senecioate	9.4	14.3
spirotetramat	28.7	43.8
Total	65.5	100.0

Table 32. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Wine Grape, 2017-2019

Active ingredient	Target NGNs available (% of all target and alternative use)	Share of composite alternative (%)
acetamiprid	3.0	5.9
beta-cyfluthrin	0.5	0.9
bifenthrin	0.1	0.1
buprofezin	2.4	4.7
burkholderia	0.2	0.5
fenpropathrin	0.3	0.5
flupyradifurone	1.1	2.2
lavandulyl senecioate	12.6	24.8
spirotetramat	30.8	60.4
Total	51.0	100.0

Note: Three-year average from 2017-2019.

The second column of Table 31 shows the average acreage shares for each non-NGN alternative used on raisin and table grape. Table 32 presents the same information for wine grape. Averaged over the three-year period 2017-2019, NGNs were used on 34.5% of total table/raisin grape acres treated with target NGNs or alternatives and on 49.0% of total wine grape acres treated with target NGNs or alternatives.

The third column reports the share of each alternative AI in the composite alternative. To represent the situation if NGNs were restricted, the use of alternative AIs was scaled up in proportion to their acreage shares, as discussed in the methods section. The main alternative insecticides for table/raisin grape were buprofezin and spirotetramat, together accounting for

41.2% of total table/raisin grape acres treated with insecticides, or 62.9% of acres treated with non-NGN insecticides. Spirotetramat and lavandulyl senecioate were the main alternative insecticides for wine grape, accounting for 85.2% of acres treated with non-NGN insecticides. Because use was scaled up based on all use, their shares in the overall use of alternatives may not represent their use as a substitute for NGNs for any specific pest.

Table 33. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and Composite Alternative: Raisin and Table Grape

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase for switching to composite alternative (%)
clothianidin	14.91	24.79	39.71	72.3
dinotefuran	39.03	18.27	57.30	19.4
imidacloprid	24.56	8.73	33.29	105.5
thiamethoxam	15.03	15.09	30.11	127.2
composite alternative	43.42	24.99	68.42	-

Table 34. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and Composite Alternative: Wine Grape

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase for switching to composite alternative (%)
clothianidin	21.66	18.73	40.40	89.6
dinotefuran	39.05	18.85	57.91	32.3
imidacloprid	27.08	10.94	38.02	101.4
thiamethoxam	27.45	16.28	43.73	75.1
composite alternative	52.25	24.33	76.58	-

Table 33 and Table 34 report the average per acre costs for the four target NGNs as well as the cost of the composite alternative, used as a representative pesticide cost per acre if NGNs were restricted. For both categories of grape, switching to the alternative would lead to an increase in total cost per acre, owing to increases in both material and application costs. For raisin/table grape, dinotefuran users would incur the lowest cost increase (19.4%) and imidacloprid users would incur the largest cost increase (105.5%) (Table 33). For wine grape, dinotefuran users would also incur the lowest cost increase (32.3%) and imidacloprid users would incur the largest cost increase (101.4%) (Table 34).

Table 35. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids (NGNs): Raisin and Table Grape, 2017-2019

Year	Cost with target NGNs ($)	Cost without target NGNs ($)	Change in cost ($)	Change in cost (%)	Share of change due to material costs (%)	Share of change due to application costs (%)
2017	1,099,667	1,791,305	691,638	62.9	89.1	10.9
2018	682,881	1,170,677	487,795	71.4	86.7	13.3
2019	387,605	610,182	222,577	57.4	113.0	-13.0

Table 36. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids: Wine Grape, 2017-2019

Year	Cost with target NGNs ($)	Cost without target NGNs ($)	Change in cost ($)	Change in cost (%)	Share of change due to material costs (%)	Share of change due to application costs (%)
2017	2,030,264	3,529,316	1,499,052	73.8	81.4	18.6
2018	1,997,257	3,443,167	1,445,910	72.4	80.3	19.7
2019	2,270,571	3,904,749	1,634,178	72.0	80.3	19.7

Table 35 (raisin and table grape) and Table 36 (wine grape) report the anticipated changes in cost due to the restriction of NGNs. For table and raisin grape, the percent change in costs ranged from 57.4% in 2019 to 71.4% in 2018 (Table 35). For wine grape, the percent change in costs ranged from 72.0 in 2019 to 73.8% in 2017 (Table 36). The final two columns of the tables disaggregate the percent change in costs into the percent due to the change in material costs and the percent due to the change in application costs. For table grape and raisin, the increase in total costs was due to the material costs of switching to more expensive pesticides. The material cost increased by over 100% each year, while application costs ranged from a 13.0% decrease in 2019 to a 13.3% increase in 2018. For wine grape the majority of the increase was due to the increase in material costs.

Conclusions and Critical Uses

There is a moderate cost increase estimated under the proposed restrictions, less than $700,000 per year in table and raisin grape and less than $1.5 million per year in wine grape. The use rate restrictions on vineyards using more than one NGN were a major driver of increased costs. Growers could choose to switch all use to one NGN and retain the full label use rate. This was not analyzed but would lower the estimated increases in cost.

Strawberry

California is the largest strawberry producer in the U.S., accounting for 89% of national production. There were 35,400 harvested acres in 2019, which produced 1,025,000 tons worth over $2.2 billion (CDFA 2020a). Strawberries are mainly sold in the fresh market, which has a higher price per unit than the processed market. A small portion of production goes into the processing market. In 2019, strawberries sold in the fresh market were worth over $1.9 billion. The remainder was processed. The average price of the two types was $2,160 per ton in 2019. By export value, strawberry was the 10th most important agricultural product in California. $402 million of production was exported in 2019. California's exports accounted for 90.4% of national strawberry exports by value. The three largest strawberry producing counties, Monterey ($724 million), Santa Barbara ($512 million), and Ventura ($452 million), accounted for 78.9% of state production in 2019. The next most important strawberry-producing counties were San Luis Obispo (11.8% of production value) and Santa Cruz (7.9%). Strawberry was also the third highest agricultural commodity by value in 2019 for Orange County ($13 million produced). Figure 28 maps the distribution of California strawberry production.[14]

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[14] Although strawberry nursery production occurs in multiple counties, only Siskiyou County reports pesticide applications and acreage productions to the state. Some of the acreage in the figure may be nursery production rather than commercial fruit production.

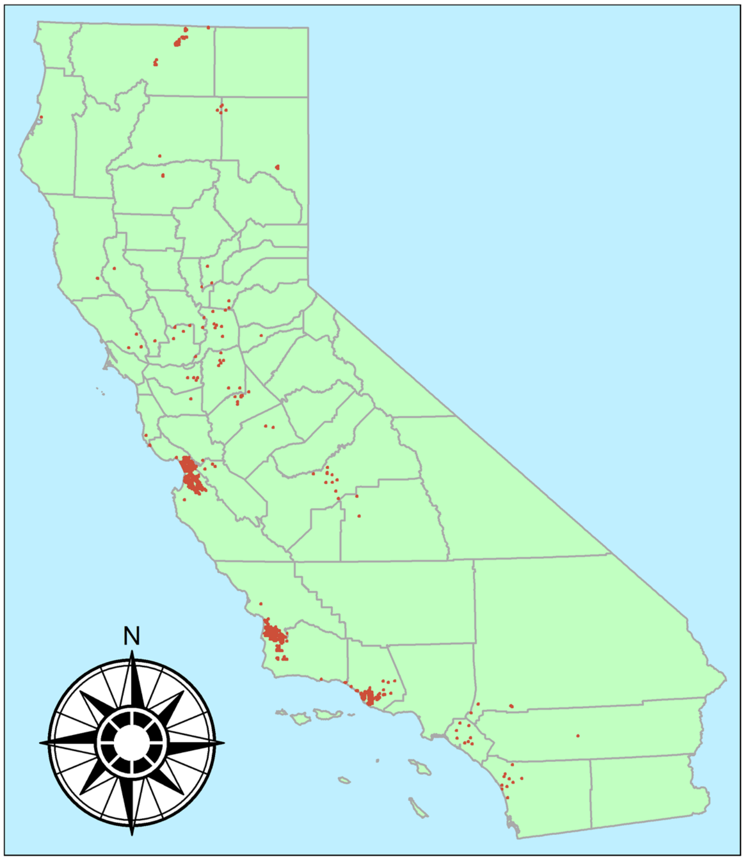

Figure 28. California strawberry production: 2019

Strawberry Production Systems

Strawberry production occurs in four designated ‘districts’ in California’s Central Coast region: (from south to north): Orange-San Diego-Coachella district, Oxnard, Santa Maria, and Salinas-Watsonville. Production in these districts for calendar year 2018 are presented in Table 37. Until recently, the percentage of total California production in the Oxnard district was much greater than at present, and more similar to that of Santa Maria and Salinas-Watsonville. (Production has been shifting to Mexico, which has lower costs and fewer regulations.) Of these ‘districts’, production practices in the Orange-San Diego-Coachella and Oxnard districts are most similar to one another, as are those in the Santa Maria and Salinas-Watsonville districts.

Table 37. California Strawberry Acreage and Yield: 2018[15]

District	Acreage	Total production (Tons)
Southern California	819	18.720
Oxnard	9,110	359,000
Santa Maria	11,750	536,000
Central coast	12,420,	650,500

The most important difference in production practices in these regions is best characterized by use of two distinctly different seasonal planting systems. In the "summer planting" system that is typical in the Orange-San Diego-Coachella and Oxnard districts, the annual strawberry crop is planted during summer for fruit harvest in fall through spring. In the "fall planting" system of Santa Maria and Salinas-Watsonville districts, the annual strawberry crop is planted from late September to mid-November, depending on the location, and fruit harvest begins in the spring and continues through early fall. Table 38 presents typical planting periods, flowering periods, and harvest periods for California's production areas.

Table 38. Flowering and Harvest Periods by Production Region: Strawberry

District	Planting Period	Flowering Period	Harvest Period
Southern California	mid Sept-mid Oct (Fall planting)	Nov-Apr (Fall planting)	Dec-Apr (Fall planting)
Oxnard	mid July-Sept (Summer Planting)	Oct-May (Summer Planting)	Oct-early June (Summer Planting)
Santa Maria	mid Oct-mid Nov	Feb-Nov	mid Feb-Nov
Central coast	mid Oct-mid Nov	Late Feb-Nov	mid March-Nov

Strawberry is a perennial plant, but in California commercial production it is typically managed as an annual crop, although a small percentage of the acreage is kept for a second year of harvesting. Strawberries are harvested in California every month of the year, with peak statewide production occurring in late spring. This year-round production can be attributed to the use of cultivars that have broad environmental adaptation, the use of innovative production systems that maximize yield, fruit quality, harvest efficiency, and the use of pest and pathogen-free soil environments.

Strawberry cultivars are classified into two general groups: "short-day" and "day-neutral." Transplants of certified stock are used for both groups. Short-day cultivars form flower buds when exposed to daily light periods (photoperiods) of 14 hours or less. They grow vegetatively during the short days of fall and produce fruit early in the spring. In California growing areas with mild winters, short-day cultivars continue forming flower buds throughout the winter. The transplant stock comes from high-elevation nurseries where temperatures are low enough to provide adequate chilling (Darrow 1966). Day-neutral cultivars, also called "ever-bearing," form

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[15] https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/2018/2018cropyearcactb00.pdf

flower buds throughout the year, irrespective of photoperiod, as long as temperatures are favorable and therefore produce ripe berries in summer and continue into the fall after production has tapered off and ended for short-day cultivars. In California, short-day cultivars are typically planted in the Southern California and Oxnard districts while both short-day and day-neutral cultivars are grown in the Santa Maria and Salinas-Watsonville districts. When production is tapering off and ends in the southern districts, production increases in the northern districts allowing year-around production in the state.

California strawberries are primarily grown for the fresh market, although there is a substantial market for processing strawberries that are picked for freezing or juice. Because the price for the processing market is very low relative to the fresh market, few if any California growers produce strawberry primarily for processing. Instead, growers tend to sell for this purpose when there is no market for fresh berries from a particular region, such as late spring berries from southern California and the Oxnard district when other growing regions are in full production or when there are substantial cull berries (acceptable for processing) present. These cull fruit often are the result of insect feeding or contamination that results from the presence of large numbers of insects. Because of the low value of processing berries and because appearance is not crucial, they are rarely treated with insecticides except to prevent the presence of insects in harvested and processed fruit.

IPM Overview

Two NGNs are registered for and applied to control sucking insect pests in California strawberry: imidacloprid and thiamethoxam. Insect pests associated with NGN labels for California strawberry include aphids, leafhoppers, lygus bugs, root weevils and grubs, and whiteflies. The importance of these insects may vary by region and year. Strawberry regions are defined in Table 39.

Table 39. Strawberry Growing Regions

Region	Counties
Southern California	Orange, San Diego, Riverside, San Bernardino
Oxnard	Ventura
Santa Maria	Santa Barbara, San Luis Obispo
Central Coast	Monterey, Santa Cruz, Santa Clara, San Benito

Target Pests

Aphids. Several aphids affect strawberry. The most important of these occur early in the fruiting season and can become problematic in all production districts. These include the green peach aphid (*Myzus persicae*), the strawberry aphid (*Chaetosiphon fragaefolii*), and the melon aphid (*Aphis gossypii*). The most common type of damage associated with aphid feeding is contamination of the fruit with the honeydew that they produce and the associated growth of sooty mold fungi on the honeydew. In addition, when aphids molt, their caste skins stick to the fruit. Fruit contamination with honeydew, sooty mold and insect skins renders the fruit unmarketable for the fresh market, greatly reducing the value of the fruit. Aphids can also transmit viruses that significantly reduce fruit yield, among them strawberry mottle virus, strawberry crinkle virus, and strawberry mild yellow edge virus.

The seriousness of viruses transmitted by aphids varies by production system. Aphid transmitted viruses are not a serious problem in annual production plantings when the strawberry transplants are certified as virus-free, but they can become a problem in strawberry plants that are grown for more than one year. Aphids present the biggest risk for nurseries, which are not included in this analysis. Aphid control to prevent transmission of viruses is a major concern for California strawberry nursery production because the nurseries undergo a state certification process before their transplants can be sold, and all nurseries routinely treat for aphids to meet certification standards.

Early season aphids in production fields can be controlled with imidacloprid applied by chemigation before the initiation of harvest, and this application is useful to prevent virus infection when there is a source of virus nearby. In the absence of virus, they are more commonly controlled when their populations begin to build after harvest begins. Foliar applications of thiamethoxam are a common and effective control for aphids during the harvest season. Acetamiprid is a direct alternative to a foliar thiamethoxam spray. Other alternatives include foliar applications of flonicamid, naled, and the pyrethroids bifenthrin and fenpropathrin. In general, foliar applications of these alternative insecticides can be substituted for thiamethoxam on a spray for spray basis. Flupyradifurone, a butenolide insecticide that recently received a Section 2(ee) registration for lygus bug control in strawberry, could also prove an alternative to the NGNs. However, only two applications a year can be made, and growers would likely target lygus with those sprays because they are considered to be a more serious pest problem and are more difficult to control with currently registered insecticides.

Lygus bug (*Lygus hesperus).* Lygus bug is considered the most important insect pest of fresh market strawberry production. Adults and nymphs feed on developing fruit, resulting in distortion of the fruit that is referred to as “catfacing.” Such damaged fruit cannot be marketed as fresh fruit. If untreated, damage will commonly exceed 35% in a typical strawberry field. Lygus is present at damaging levels every year in all growing districts except southern California.

The primary insecticides used for lygus bug control for the last 25 years include bifenthrin, fenpropathrin, and malathion, but high levels of resistance to these chemicals are found in lygus populations (Zalom 2009), particularly in Watsonville-Salinas, Santa Maria, and Oxnard. In most production districts naled and acetamiprid are also used for lygus control but are only considered moderately effective. Novaluron is fairly effective for control of lygus nymphs early season and flonicamid is fairly effective at reducing lygus feeding but does not kill the insects very quickly. The efficacy of both of these chemicals is reduced when lygus populations become greater as the harvest season progresses. The NGN thiamethoxam is also used for lygus control in California strawberry. As a stand-alone product, its efficacy is modest and similar to that of acetamiprid or naled. However, it is most useful when applied in a tank mix with another insecticide such as naled, novaluron, or a pyrethroid to enhance their efficacy (Joseph and Bolda 2016).

Thiamethoxam is applied at least once each season to about 25% of California strawberry fields, mostly in a tank mix with another product. A newer AI, flupyradifurone, is effective against lygus (Joseph and Bolda 2016) and is considered an alternative. However, flupyradifurone can only be applied twice during a season so additional sprays for lygus control are still necessary.

Strawberry growers have incorporated use of vacuum machines from time to time when the local lygus bug populations become resistant to the primary insecticides used for their control. In these cases, weekly or twice-weekly vacuuming is usually used in combination with whatever insecticides are available for their control to reduce the total amount of catfacing. Vacuums have been shown to reduce the number of lygus adults by 75% and nymphs by about 9 to 50% each time a field is vacuumed (Pickel et al. 1994).

In 2019, sulfoxaflor, a sulfoximine insecticide, a new chemical became available for use by California strawberry growers specifically for lygus control under a Section 18 registration. Previous field trials on strawberry in the Central Coast production area by UC Cooperative Extension personnel indicate the expected efficacy of sulfoxaflor to be somewhat better than thiamethoxam used with a tank mix partner, and similar to that of novaluron and flonicamid (Zalom 2012; Joseph and Bolda 2016). Sulfoxaflor applications are restricted at this time to a maximum of 28,000 acres and may not be used before 7 pm or after 3 am. Because there is only one year of data available, for consistency across years we do not include it in the composite alternative. In 2019, it accounted for 5.3% of acres treated with an NGN or alternative AI and 5.6% of acres treated with an alternative AI. Estimated losses for 2019 would have been larger if sulfoxaflor was included. Its cost per acre was substantially higher than the other alternative AIs and raised the cost of the composite alternative from $52.87 per acre to $55.45 per acre, an increase of 4.9%.

Root weevils and grubs. Several species of root beetles are associated with strawberry in other US growing areas. Those species that are reported to occur in California include the black vine weevil (*Otiorhynchus sulcatus*), the cribrate weevil (*Otiorhynchus cribricollis*), Fuller rose weevil (*Pantomorus cervinus*), and two species of scarab beetles (*Hoplia dispar* and *H. callipyge*). These are only an occasional problem, primarily in nonfumigated fields following another host crop such as alfalfa, or in second-year strawberry fields. Adults feed on foliage, but the damage is insignificant. The larvae (grubs) of all of the species feed on roots and crowns for one to two years (in the case of Hoplia beetles) and can kill the plants. Unless the current California production system, which largely includes annual plantings and preplant soil fumigation, changes dramatically, they are not likely to become a significant problem (Bolda et al. 2008).

Soil fumigation with 1,3-dichloropropene, chloropicrin, metam sodium, and metam potassium for control of soil pathogens effectively eliminates any root beetles that might be present before transplanting, but root beetles could invade and be present in strawberry fields that have been planted for two or more years. This practice is rare in the primary strawberry production districts, but it occasionally occurs in small u-pick farms. In cases where root weevils are present, either imidacloprid or thiamethoxam applied by chemigation provide effective control. Diazinon applied by chemigation is also effective in controlling these beetles. Owing to the very limited acreage and scope of this pest problem in strawberry, diazinon was not included in the alternatives to NGNs in this report.

Whiteflies. The most important whitefly pest of California strawberry is the greenhouse whitefly (*Trialeurodes vaporariorum*), which occurs in all growing regions. Other whiteflies present in strawberry fields include the iris whitefly (*Aleyrodes spiroeoides*) and the strawberry whitefly (*Trialeurodes packardi*). Whiteflies reduce yield directly through their feeding on leaf tissue that stunts plant growth and reduces fruit quality (Bi and Toscano 2007). They can also have an economic impact indirectly by producing sticky honeydew on the fruit surface that provides a substrate for the growth of sooty mold fungi which renders the fruit unsuitable for the fresh market. Greenhouse whiteflies can transmit plant viruses including strawberry pallidoses associated virus and beet pseudo yellows virus that can result in rapid plant decline when they are present in tandem or with other plant viruses. Serious greenhouse whitefly outbreaks, often accompanied by virus transmission to strawberry, have occurred on several occasions in the last decade in the Oxnard, Santa Maria, and Salinas-Watsonville districts, resulting in significant crop losses for growers.

Prevention of whitefly establishment in new strawberry fields is essential when greenhouse whiteflies are present, especially during periods when an outbreak is occurring, to prevent virus transmission and to reduce the number of treatments that might need to be applied for control during the harvest season. Studies have shown that imidacloprid applied by chemigation at or shortly after transplanting is the most effective approach for controlling greenhouse whiteflies (BI et al. 2007; McKee et al. 2007). Applications with the insect growth regulator pyriproxyfen or other alternative chemicals such as spiromesifen (Bi et al. 2007), a tank mix of malathion and fenpropathrin, or the NGN thiamethoxam applied after whitefly populations begin to build during the harvest season are far less effective in preventing whitefly populations from building to damaging levels. As a result, one or more of these chemicals will need to be applied more than once during the harvest season to control a greenhouse whitefly outbreak, with the estimated number of applications generally ranging from two to four.

Target NGN Use: 2017-2019

Imidacloprid is virtually always applied to the soil by chemigation, which is relatively simple for growers because all California strawberry cultivation uses drip irrigation. Owing to a 14-day preharvest interval (soil-applied) and a continual harvest once fruit are being produced, imidacloprid cannot be applied by chemigation, for all practical purposes, once harvest is initiated. Accordingly, imidacloprid is only applied once preharvest. This practice is used on about 30% of California strawberry acreage in a given year but varies somewhat in number of acres treated and distribution between districts depending on pest outbreaks (particularly of whiteflies) that might have occurred the previous season. This variability is apparent in Figure 29, which plots use of imidacloprid and thiamethoxam by month and year. In each district, imidacloprid use peaks during planting.

In theory, imidacloprid can also be used as a foliar application, but this rarely occurs during the harvest season because of its 7-day pre-harvest interval when applied as a foliar spray because strawberry fruit are typically harvested on a more frequent schedule. (Growers often harvest at 3-day intervals.) In addition, label restrictions exclude the foliar use of imidacloprid once the plants begin to bloom. As Figure 29 shows, imidacloprid use is essentially zero outside of planting season for three of the four production districts. The Santa Maria district is the only exception, with some summertime use.[16]

The proposed restrictions, discussed in detail below, are such that most to all of the use of imidacloprid would not be restricted because it is almost entirely used before the start of bloom. However, it is a target of the regulation. We have included historical use of imidacloprid in Figure 29 but do not provide alternatives to its use or include imidacloprid in the economic analysis.

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[16] There are at least three possible reasons for this summertime use. First, whitefly outbreaks have been occurring more recently in the Santa Maria district than in the other districts, and during an outbreak, growers may apply imidacloprid even at the expense of losing a couple harvests. Other districts may have previously had summertime use when there were active outbreaks in those locations as well. Second, if a grower has a second-year field he may treat it in the summertime before pulling it out so that adult whiteflies don't emigrate to nearby first-year fields. Lastly, a small proportion of fields in the Santa Maria area are summer-planted, so this use could represent pre-harvest applications to those fields.

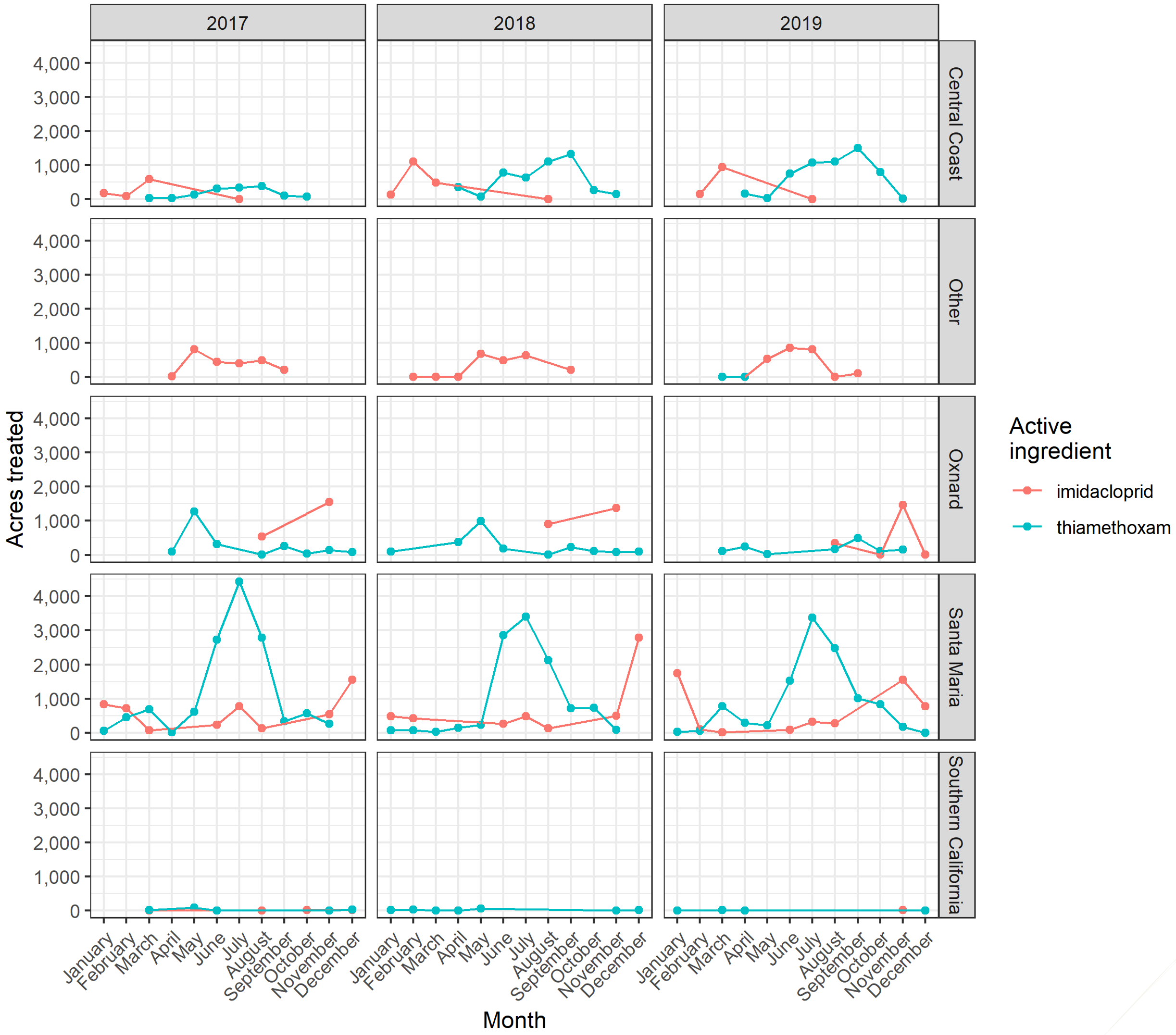

Figure 29. Nitroguanidine-substituted neonicotinoid use trends: Strawberry, 2017-2019

Thiamethoxam can be applied as a soil treatment by chemigation or as a foliar spray. In California strawberry it is mostly applied via foliar spray, in part because of a 50-day pre-harvest interval for the chemigated product and also because of differences in efficacy of soil-applied neonicotinoids depending on soil texture. Thiamethoxam is most effective when used on heavy soils, while imidacloprid is very effective in light soils but ineffective in heavy soils. California's coastal strawberry growing regions typically feature lighter soils. Thiamethoxam use varied considerably for the Central Coast, Oxnard and Santa Maria regions over the 2017-2019 period, while use was negligible in the Southern California region and observed only in 2019 in other areas (Figure 29).

Table 40. Use Trends for Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Strawberry Thiamethoxam, 2017-2019

Active ingredient (AI)	**----------Pounds applied-----------**				**-------------Acres treated------------**				**Use rate (lb/ treated acre)**
	2017	2018	2019	Total	2017	2018	2019	Total	
acetamiprid	4,409	3,675	3,053	11,137	34,741	28,860	24,436	88,037	0.13
bifenthrin	5,865	5,282	5,458	16,605	55,377	48,264	49,737	153,377	0.11
fenpropathrin	5,157	5,078	5,370	15,604	18,073	17,195	18,922	54,190	0.29
flonicamid	4,845	4,380	4,027	13,252	55,486	50,726	46,933	153,145	0.09
flupyradifurone	3,665	3,255	4,086	11,006	20,122	17,997	26,394	64,513	0.17
malathion	53,845	53,395	49,956	157,196	27,141	26,858	24,587	78,585	2.00
naled	12,817	12,019	13,463	38,298	12,774	11,971	13,375	38,119	1.00
novaluron	5,435	4,832	4,835	15,102	72,756	65,151	73,104	211,011	0.07
thiamethoxam*	1,028	1,073	1,105	3,207	16,682	17,405	17,459	51,545	0.06

*Target NGN

Table 40 reports pounds applied, acres treated, and the average use rate for thiamethoxam and alternative active ingredients applied to strawberry. Novaluron was applied to the most acres in the 2017-2019 period, used on over four times as many acres as thiamethoxam.

We have not included a similar table for imidacloprid because its use would not be affected by the proposed restrictions in strawberry.

Other Considerations

Secondary pest outbreaks and the development of resistance to specific active ingredients are other factors that would be influenced if imidacloprid and thiamethoxam were restricted on strawberry.

Resistance management. Repeated applications of insecticides with similar modes of action create selection pressure on resident insect populations that could lead to control failures. Many examples of control failures due to whiteflies and aphids have been documented in agricultural production systems worldwide, so a case can be made for maintaining imidacloprid and thiamethoxam uses as tools since relatively few alternative chemicals are registered on strawberry. In addition, lygus bugs are an annual problem as well as a very damaging insect that is difficult to kill effectively with any insecticide, so multiple insecticide applications must be made each year in every production district for their control. The synergistic action of thiamethoxam with other chemicals such as novaluron and pyrethroids when applied in a tank mix (combination spray) are especially valuable in achieving greater levels of lygus control than individual sprays of these or other alternative chemicals, thereby reducing the total number of times individual sprays need to be applied.

Resistance management is done, in part, by rotating the use of products with different modes of action to reduce selection pressure on pests. For strawberry growers, it is important to maintain a variety of registered products since so few products actually become registered owing to the low number of acres produced nationally relative to other crops, i.e., limited market for registrants. In addition, the short pre-harvest interval necessary to make a chemical compatible with the frequent (often twice a week) picking schedule of fresh market berries, and the relatively great contribution of strawberry fruit to the US EPA 'risk cup' calculation for a product since the fruit are consumed fresh shortly after harvest. The risk cup contribution means that registrants may choose not to register an effective chemical on strawberry because it might preclude its use on a crop with far greater acreage but where less residue may be present at harvest. As a result, maintaining an effective chemical class such as NGNs plays a more critical role in resistance management in strawberry production than in other crops since they may not be quickly replaced by a similarly effective product representing a different chemical class for a specific use, and therefore loss of a given chemical class can have an even greater impact.

Proposed Restrictions

Strawberry is in the berry crop group. Under the proposed regulations, the use of imidacloprid and thiamethoxam – the only two NGNs registered for the crop – would be allowed up to the maximum label rate, provided only one AI and only one application method are used. If more than one AI and/or more than one application method is used the soil application rate must not exceed 0.2 lbs AI/acre/year and foliar applications rate must not exceed 0.1 lbs AI/acre/year. No applications would be allowed once the plants have started blooming. If a grower uses managed pollinators, all use would be prohibited. However, this provision will not impact strawberries in California. Varieties grown in California are not self-incompatible and therefore no benefit to yield, quality or appearance is achieved through use of managed pollinators. In fact, the California Annual *Pollination Survey Results* from the California State Beekeepers Association from 2009 through 2018 (e.g., CSBA, 2018) show that there is no record of managed bees used in California strawberries. Accordingly, the analysis was conducted as if no strawberry grower used managed pollinators.

The bloom time restriction seriously impacts strawberry. The use of thiamethoxam occurs after bloom has started. All applications of thiamethoxam were considered prohibited and would be replaced with alternatives. In contrast, almost all imidacloprid use already occurs before bloom because that is when the pest management benefits are greatest, as discussed above. As such, all imidacloprid applications were considered allowed and would not need to be replaced with alternatives. In other words, 100% of imidacloprid applications were allowed and 0% of thiamethoxam applications were allowed. Accordingly, 36.7-39.0% of treated acres and 80.3-82.7% of pounds applied would have been allowed per year if the proposed regulation had been in place from 2017-2019. Because only imidacloprid use would have been allowed, these percentages are equivalent to the percent of NGN use that was imidacloprid.

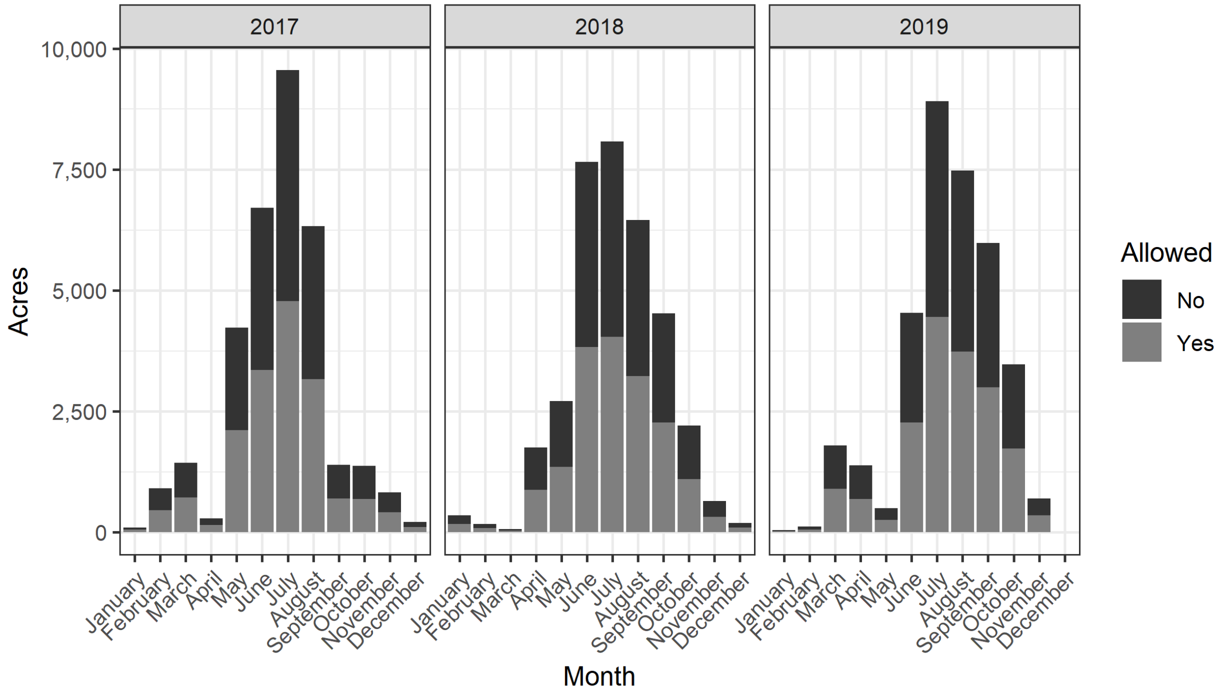

Figure 30: Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed/prohibited under the proposed restrictions: Strawberry, 2017-2019

Economic Analysis

This section presents the expected change in costs for strawberry production owing to the restrictions that would be placed on the use of thiamethoxam. This cost includes changes in pesticide material costs and application method costs. In addition to the caveats discussed in the methods section, the costs estimated below do not account for the potential effects of increased insect resistance to pyrethroids or for costs associated with managing secondary pest outbreaks.

Table 41 presents representative products for each active ingredient used on strawberry in 2017–2019 and their costs per acre. The material cost per acre is the product of the average use rate (lb/acre) over this period and the price per pound. The application cost per acre is the acre-weighted average application cost based on application method across all applications of the AI to the crop. The costs of each application method are presented in the methods section. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited (i.e., excluding allowed applications). The total treatment cost per acre is the sum of the material and application cost per acre. Total cost per acre ranged from $32.99 for naled to $72.21 for flupyradifurone. Growers consider other factors in addition to price per acre when deciding which insecticides to use, as discussed above.

Table 41. Representative Products and Costs per Acre: Strawberry, 2017-2019

Active ingredient	Representative product	Material Cost ($)	App Cost ($)	Total Cost ($)
acetamiprid	Assail 70 WP Insecticide	44.47	24.68	69.15
bifenthrin	Brigade WSB Insecticide/Miticide	27.26	24.67	51.93
fenpropathrin	Danitol 2.4 EC Spray	25.31	24.82	50.13
flonicamid	Beleaf 50 SG Insecticide	33.05	24.88	57.94
flupyradifurone	Sivanto 200 SL	47.54	24.67	72.21
malathion	Malathion 8 Aquamul	12.21	24.79	37.00
naled	Dibrom 8 Emulsive	8.10	24.89	32.99
novaluron	Rimon 0.83 EC Insecticide	22.47	24.92	47.39
thiamethoxam	Actara	15.93	24.98	40.91

Averaged over the three-year period, thiamethoxam was used on 5.8% of total strawberry acres treated with target NGNs or alternative AIs, and alternative AIs were used on 94.2% of strawberry acreage treated with target NGNs or alternative AIs. The second column of Table 42 shows the average acreage shares for each alternative AI used on strawberry. Total acres treated does not correspond to total acres of strawberry grown because some growers may have used multiple AIs on the same field. The third column reports the share of each alternative AI in the composite alternative.

If the target NGNs were unavailable, the use of alternative AIs was scaled up in proportion to their acreage shares, as discussed in the methods section. The three most common alternative AIs for thiamethoxam—novaluron, flonicamid, and bifenthrin—together accounted for 58.0% of strawberry acres treated, which is 61.5% of acres treated without thiamethoxam. Because use was scaled up based on all use, their shares in the overall use of alternatives may not represent their use as a substitute for NGNs for any specific pest.

Table 42. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Strawberry, 2017-2019

Active ingredient	Acreage share with target active ingredients available (% of all target and alternative use)	Share of composite alternative (%)
acetamiprid	9.9	10.5
bifenthrin	17.2	18.2
fenpropathrin	6.1	6.4
flonicamid	17.2	18.2
flupyradifurone	7.2	7.7
malathion	8.8	9.3
naled	4.3	4.5
novaluron	23.6	25.1
Total	94.2	100.0

Note: Three-year average from 2017-2019. Numbers may not add to 100% due to rounding

Table 43 reports the average per acre costs for the target NGN, thiamethoxam, as well as the cost of its composite alternative, whose price we used as a representative pesticide cost if the NGNs were restricted. The composite alternative for thiamethoxam was $0.05 less expensive to apply, but its material costs were $12.50 per acre more expensive than thiamethoxam (Table 43). Overall, thiamethoxam users would incur an increased cost of 29.2%.

Table 43. Average Cost per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Strawberry. 2017-2019

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase for switching to composite alternative (%)
thiamethoxam	15.93	24.98	40.91	29.2
composite alternative	28.07	24.80	52.87	-

Table 44 reports the expected change in costs owing to the restrictions on thiamethoxam. The total annual change in costs from the 29.2% cost increase ranged from $199,609 in 2017 to $208,904 in 2019. Per-acre costs were a small share of per-acre gross revenues. At 580 cwt per acre and an average value of $108 per cwt, 2019 statewide average revenues were $62,749 per acre.[17] On a per acre basis, the cost of one application of the composite alternative to replace one application of thiamethoxam was $52.87 per acre, less than one-tenth of a percent of average gross revenues.

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[17] Revenues include fresh and processed sales. Acreage and yield are not reported separately for fresh market and processing strawberry (CDFA, 2020). Often both fresh and processing strawberry are harvested from a planted acre.

Table 44. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Strawberry, 2017-2019

Year	Cost with target NGNs ($)	Cost without target NGNs ($)	Change in cost ($)	Change in cost (%)	Share of change due to material costs (%)	Share of change due to application costs (%)
2017	682,428	882,037	199,609	29.2	101.5	-1.5
2018	711,992	920,248	208,256	29.2	101.5	-1.5
2019	714,205	923,108	208,904	29.2	101.5	-1.5

If sulfoxaflor were included in the calculation of the cost of the composite alternative, the total change in cost for 2019 would have been $236,080 and the percent increase would have been 32.8%.

Conclusions and Critical Uses

Prohibiting thiamethoxam in strawberry would result in an estimated $199,609 to $208,904 increase in material and application costs. In percentage terms these increases are moderate. On a per acre basis they amount to less than one-tenth of one percent of gross revenues.

Tomato

Tomato was California's nineth largest commodity by value of production in 2019, with gross revenues of $1.2 billion (CDFA 2020a). Exports were $735 million (CDFA 2020b). Tomatoes in California are grown for two markets: fresh and processed. California is the largest producer of processing tomato and the second largest producer of fresh tomato in the U.S., behind only Florida. In California, there were 19,700 acres of fresh tomato and 228,000 acres of processing tomato in 2019, which produced 324,200 and 11,186,300 tons worth $279 million and $895 million, respectively (CDFA 2020a).

Fresh tomato production is concentrated in Merced County ($51 million, 27.2% of California production), Santa Barbara ($44 million, 23.8%), and Kern County ($27 million, 14.3%) in 2019. Other top fresh tomato-producing counties include Fresno (11.7%), and Santa Benito (8.6%). $30 million (10.7%) of fresh tomato were exported in 2019, which made fresh tomato the thirty-sixth largest agricultural product ranked by export value (CDFA 2020b). Figure 31 displays the geographic distribution of California's fresh tomato production.

Processing tomato production is also concentrated in Fresno County, which produced $284 million (33.3%) in 2019. The next largest processing tomato-producing counties were Kings (13.9%), Yolo (12.6%), San Joaquin (9.4%), and Merced (8.9%). Processing tomato was the eighth most important agricultural export for California, with a value of $623 million. 73% of processing tomato were exported (CDFA 2020b). Figure 32 displays the geographic distribution of California's processing tomato production.

There are a variety of horticultural practices and crop uses, especially within the fresh market category. Fresh market tomato plants are grown as bushes or on poles. Pole tomato production consists primarily of indeterminate varieties that are harvested over a long period of time during the production season, while bush tomato tends to be determinate varieties and picked once (or at most a few times) during the season. The length of the production season has a significant impact on the pest complex and abundance of pests because insect populations tend to increase with the length of the production season. Because fresh tomatoes are typically used whole by consumers, appearance is important, and growers strive to produce unblemished fruit. In some cases, insecticides are applied as much to protect the appearance (quality) of fresh market tomatoes as to protect yield. Some fresh tomatoes are grown in greenhouses, which requires a different pest management program. Greenhouse production accounts for less than two percent of California fresh tomato production by yield, so we do not address it here.

Tomatoes intended for processing are primarily determinate varieties grown for a single mechanical harvest. Canneries process the tomatoes into juice, paste, diced, and whole pack products. Tomato varieties grown tend to be prescribed by the canneries for various desired processing attributes. Growers enter into contracts with canners for production of tomatoes for delivery during a window of time. Producing predictable tomato yield (volume) for delivery to canneries within a specified window of time is particularly important for growers. Tomato fruit must also pass inspection by state graders for 'worm' damage and 'mold' below specified limits. Although some pest damage can be tolerated on tomato processed for juice and paste, canners can impose restrictions for blemished fruit when it is used for diced and whole pack since this damage would potentially be apparent to consumers. Most canners also test tomatoes sent to the canneries for insecticide residues to ensure that they are in compliance not only with US regulations but also with tolerances of other countries where the products might be shipped. Because insecticide tolerances are not coordinated internationally, and some countries have lower tolerance or no tolerance for some insecticides that can be used in the US, restrictions on use permitted by a canner may well be lower than what is permissible on a product's label.

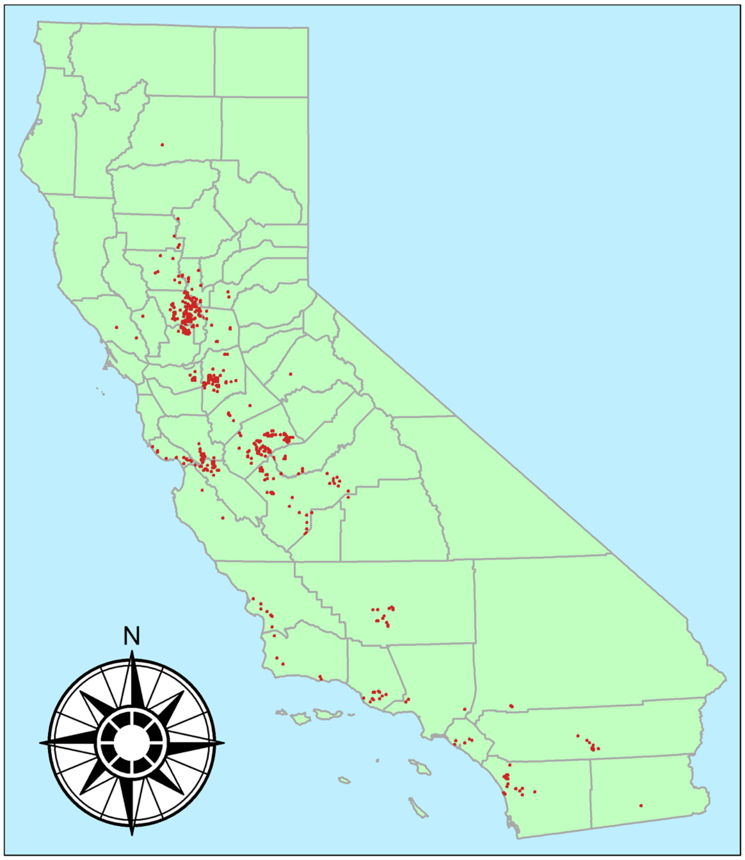

Figure 31. California fresh market tomato production: 2019

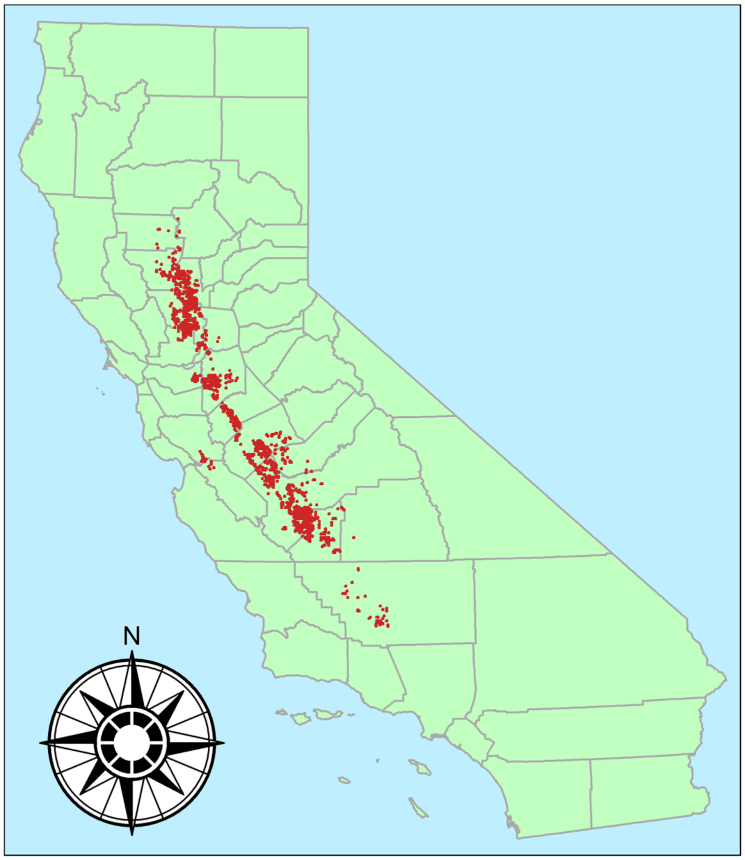

Figure 32. California processing tomato production: 2019

Tomato production varies by region of the state, as does the significance of particular pest species, which is affected by climate, production season, and horticultural practices. In order to evaluate alternatives for NGNs in pest management programs, we define five production areas for fresh tomato and three production regions for processed tomato. The primary fresh market tomato-growing regions include the South Coast and San Joaquin Valley, with limited production in the following regions: Southern Desert, Central Coast, and Sacramento Valley. Processing tomato growing regions include the San Joaquin and Sacramento Valleys, with limited production in the Central Coast region.

IPM Overview

Tomato in California is attacked by a variety of insects, diseases, and nematodes. With very few exceptions, NGNs are registered for and applied to control sucking insect pests. All four NGN AIs are registered for tomato. Imidacloprid and thiamethoxam are the most widely used. Imidacloprid is commonly applied as a soil treatment through chemigation, as a band spray during planting then sprinkled or furrow-irrigated, or as a foliar spray either as a stand-alone product, a premix, or tank-mixed with other products. Mixes are used to enhance efficacy against certain insect species and/or to control additional target pests. Thiamethoxam can also be applied to the soil at planting as a band spray or through chemigation. It is used less commonly than imidacloprid because it more easily moves through the soil and beyond the root zone, and its residual efficacy is not as long. Clothianidin and dinotefuran are more recently registered insecticides relative to imidacloprid and thiamethoxam and are less commonly applied. Both can be applied through chemigation or as foliar sprays.

Target Pests

Target pests for NGNs on fresh market and processing tomato include aphids (green peach aphid, potato aphid and others), flea beetles, leafhoppers (primarily beet leafhopper), leafminers, Lygus, potato psyllid, stink bugs, thrips, and whiteflies. The importance of these insects varies by region, year, and whether the crop is for the fresh or processed market. The target pest section includes information on pests targeted with any of the four NGNs to give a complete picture of their use even though most imidacloprid use would continue to be allowed under the proposed restrictions (see Proposed Restrictions section below).

Aphids. Several aphids affect tomato. The most important ones are the green peach aphid (*Myzus persicae*) and other early season aphids, and the potato aphid (*Macrosiphum euphorbiae*) that occurs later in the season. Feeding by green peach aphid can injure young plants that are stressed by water or other factors, but the major concern is their potential to transmit viral diseases such as alfalfa mosaic virus. Virus transmission can be a concern in all growing areas, and it is particularly important in the Southern Desert and the San Joaquin Valley. Early season aphids rarely require treatment and although they are controlled with soil-applied NGNs or chemigation they are usually not a target of these applications unless the field is located near a potential source of alfalfa mosaic virus. In practice, in the absence of virus risk these aphids are incidentally controlled by insecticides applied for other pests, and if an insecticide would need to be applied, effective alternative products include spirotetramat, pymetrozine, flonicamid, flupyradifurone, and acetamiprid.

Potato aphid injures tomato plants by distorting leaves and stems and stunting plants (Hummel et al. 2004). High populations that occur six to eight weeks before harvest can significantly reduce yield, and populations that reduce the plant canopy closer to harvest can cause sunburn of fruit. Potato aphid is primarily of concern for fresh market and processing tomato in the northern San Joaquin Valley and Sacramento Valley. NGNs are not usually applied specifically for potato aphid but provide control incidentally when they are used for other insects by chemigation or foliar sprays during the season. When an insecticide is needed specifically to control potato aphid, alternatives to the NGNs include spirotetramat, flonicamid, pymetrozine, pyrethroids (e.g., lambda-cyhalothrin, fenpropathrin and others), and acetamiprid.

Beet leafhopper (*Circulifer tenellus*). The beet leafhopper is a serious insect pest of both fresh market and processing tomato on the west side of the San Joaquin Valley region, and to a lesser extent in the Sacramento Valley. The major concern is transmission of beet curly top virus, which stunts young plants and can result in a virtually complete loss in heavily infected fields. About 50% of the total fresh market and processing tomato acreage in the San Joaquin Valley is at risk for infection in years when insect and virus pressure are high. Spring plantings tend to be most heavily affected. 2013 was a particularly heavy year for beet curly top virus infection. UC Farm Advisors and tomato canners attributed the relatively high early season use of NGNs in the San Joaquin Valley tomato crop in subsequent years to be the result of growers' reactions to experiencing that year's losses. A preventative soil application of imidacloprid is considered the most effective approach available for suppressing beet curly top virus infection of fields in years when high populations of beet leafhoppers are expected to move to fields from their overwintering sites in spring. When preventative NGN treatments are not applied, foliar applications of dinotefuran or thiamethoxam are applied if and when beet leafhoppers are detected in fields. Alternatives for foliar applications include dimethoate and flupyradifurone. A newly registered insecticide, cyantraniliprole, has been used effectively when applied to greenhouse transplants, but this has proven to be an expensive ($100-$120 per acre) approach and logistically difficult for individual growers and nurseries with large acreages. Cyantraniliprole, when applied to the soil through chemigation at planting or soon thereafter, produces feeding cessation, which is useful in suppression of curly top transmission. Some growers have similarly applied chlorantraniliprole for leafhopper control, but this use has not been shown to be effective.

Flea beetles. Flea beetles are a pest of seedling processing tomato in the San Joaquin and Sacramento Valley regions (Zalom 2003). These beetles slow growth by causing damage to young leaves and stalks. The economic impact of this damage has declined with the transition from direct seeding to transplanting when establishing tomato fields. Flea beetles occasionally become a late season pest when leaves are senescing, and they begin feeding on the fruit instead. Imidacloprid is effective as a pre-plant application for flea beetle control in direct seeded fields. Carbaryl bait is an effective alternative to NGNs for early season control. Dinotefuran, clothianidin and foliar application of thiamethoxam are effective in controlling flea beetles later in the season. Pyrethroid insecticides including lambda-cyhalothrin and esfenvalerate are also effective and generally less costly. Pyrethroid applications for flea beetles would be of more concern if applied early in the season owing to potential disruption of natural biological control for other pests but are of less concern late in the season.

Lygus bug (*Lygus hesperus)*. Lygus are most common in San Joaquin Valley tomato fields and to a lesser degree in the Sacramento Valley. Adult Lygus are highly mobile insects and tend to move to tomato after the preferred hosts, such as alfalfa and safflower, are harvested. They feed on tomato fruit, causing small surface cracks that are primarily an issue for fresh market tomato and diced or whole pack processing tomato. Lygus bugs seldom reach treatable levels in tomato. NGNs targeting other insects at mid-season may provide incidental Lygus control. Although NGNs in combination with another insecticide such a pyrethroid or clothianidin applied alone can be used to control Lygus, they are generally not applied with Lygus as the target pest species. In the relatively unusual event that Lygus populations are sufficiently great as to warrant treatment, alternative products including flonicamid, lambda-cyhalothrin, and fenpropathrin alone or in combination with acetamiprid are considered as effective as NGNs for control.

Stink bugs. Several stink bug species attack both fresh market and processing tomato, primarily in the Sacramento and central and northern San Joaquin Valley regions. About 10% of the total tomato acreage in these regions can be seriously affected. They inject saliva into fruit when feeding that results in fissures below the surface of the fruit. This damage is unacceptable for fresh market fruit and whole pack processing tomato (Zalom et. al. 1997a). Yeasts and other pathogens may also be injected into the fruit as a result of their feeding, resulting in rejection of processing tomato loads or a reduced price owing to ‘mold damage’ identified by state graders. Occurrence of damaging levels of stink bugs appears to be cyclical, with widespread injury occurring every 8 to 10 years followed by recurring damage for several consecutive years. Because stink bugs must reinvade tomato fields each year, usually in June or later, much of the damage occurs nearer field edges so fruit from only a portion of each field is damaged (Zalom et. al. 1997b).

Stink bugs are particularly difficult insects to control with any insecticide. NGNs are generally not regarded as effective when applied alone as a foliar spray as they are when applied in a premix or when tank mixed with a pyrethroid insecticide such as lambda–cyhalothrin, fenpropathrin and others (Cullen and Zalom 2007). These uses would likely be replaced directly with acetamiprid in the tank mix, which would otherwise remain the same.

Thrips. The primary thrips species that infests tomato in all regions of California is the western flower thrips (*Frankliniella occidentalis*) although onion thrips (*Thrips tabaci*) is often found on tomato as well, particularly on the west side of the San Joaquin Valley. Very high populations of thrips can somewhat reduce yield through flower abortion that results from their feeding. However, the most serious damage caused by thrips is their transmission of tomato spotted wilt virus, which can seriously reduce yield (Sevik and Arli-Sokmen 2012). Tomato spotted wilt virus is an important concern on fresh market tomato in all regions, and on processing tomato in the Fresno and Merced County areas of the San Joaquin Valley. A host plant resistance-breaking strain of tomato spotted wilt virus was first found in 2016 that has made the need for thrips control with insecticides even more critical.

NGNs are applied to some extent for thrips control in the South Coast and San Joaquin Valley regions, although soil-applied imidacloprid has not been shown to lower tomato spotted wilt virus incidence. Dinotefuran applied as a foliar spray can control thrips but is less effective than alternative chemicals. Spinetoram and spinosad are very effective alternatives to NGNs for thrips control. However, insecticide resistance to these spinosyns has been documented for thrips in a number of crops, so rotating insecticide classes to reduce insecticide resistance risk is an important consideration. Additionally, the total number of spinosyn applications that can be made during a season is restricted by their labels. Other products that can provide similar or better control of thrips than NGNs on tomato include methomyl, dimethoate, and flonicamid. However, methomyl and dimethoate are especially disruptive of natural biological control of other insects such as leafminers and can result in secondary outbreaks that require additional insecticide applications for those species. Abamectin is moderately effective in knocking down thrips populations, although considerably less effective than NGNs or the alternatives listed above. Cyantraniliprole suppresses foliar-feeding thrips, and when applied as a soil application through chemigation produces feeding cessation. However, more research is needed in California to determine if this will result in suppression of tomato spotted wilt virus spread by western flower thrips.

Tomato psyllid. The tomato psyllid (*Bactericera cockerelli*) has become a serious pest of fresh market tomato in coastal growing regions. It is also found in the San Joaquin Valley, but populations tend to be lower there and treatments are seldom applied for its control. Nymphs, in particular, inject a toxin while feeding on leaves that results in a disorder known as psyllid yellows that stunts plant growth. No fruit is produced if younger plants are affected, and nonmarketable fruit is produced if older plants become infected. Imidacloprid applied to soil at planting by drench or through chemigation is a preferred method of control because of its extended residual efficacy, but additional treatments of spirotetramat (which provides very good control), pymetrozine, spinetoram, and abamectin are applied to fresh market pole tomato to provide sufficient protection through the extended harvest period. A rotation scheme for reducing risk of insecticide resistance is presented by Prager et al. (2016). These alternative products can also be applied for tomato psyllid control without applying imidacloprid, but application of these products would have to begin earlier in the season and would result in additional applications as well as increased potential for insecticide resistance to occur.

A rotation of methomyl and permethrin could also result in increased yield compared to imidacloprid but was less cost-effective than using imidacloprid at planting followed by the alternative materials in rotation (Prager et al. 2016). Methomyl is particularly disruptive of natural biological control and its use is discouraged due to the likelihood of secondary pest outbreaks, particularly leafminers. Pyrethroids such as permethrin are also disruptive to natural enemies in pole tomato, which remain in production for an extended period.

Whiteflies. The most common whiteflies that infest California tomato are the greenhouse whitefly (*Trialeurodes vaporariorum*), which occurs in all growing regions except the Southern Desert, and the sweetpotato whitefly (*Bemisia tabaci* biotype B), which occurs in the desert areas and the south coast as well as in areas of the southern and central San Joaquin Valley where populations have increased dramatically in recent years. Leaf feeding by the greenhouse whitefly is not considered damaging except when they occur at high densities but feeding by the sweetpotato whitefly results in uneven ripening of fruit that renders them unmarketable. The high densities recently observed in some central San Joaquin Valley tomato fields resulted in some fields having symptoms of uneven ripening of close to 50%. Feeding also resulted in collapse of the plant canopy prior to harvest and yield losses owing to sunburn of fruit.

Whiteflies are of particular concern to growers because both species are known to transmit viruses to tomato. The potential damage from viruses is much greater than the direct damage caused by whiteflies. The greenhouse whitefly transmits tomato infectious chlorosis virus, and the sweetpotato whitefly transmits tomato yellow leaf curl virus. Tomato yellow leaf curl is the most damaging whitefly-transmitted virus worldwide. It was not found in California until recently when it was detected in the Imperial Valley and Coachella Valley in the South Desert region, so there is an imminent threat to California growers, particularly given the serious recent San Joaquin Valley outbreaks of sweetpotato whitefly.

Crop losses due to viruses on both fresh market and processing tomato have reached 90% in other parts of the world where NGNs have not been applied for control of the whiteflies that transmit the viruses. NGNs are the most effective insecticides for suppressing virus transmission since they can protect young plants while providing the residual protection necessary to suppress virus spread. Imidacloprid applied at planting as a soil application or through drip is the standard method for controlling virus spread by whiteflies worldwide, and dinotefuran applied similarly is equally effective. Whiteflies can be controlled later in the season with insecticides other than NGNs, such as spirotetramat, acetamiprid, and spiromesifen. The insect growth regulators buprofezin and pyriproxyfen also provide control, but they cannot limit an already large population when used alone so they must be used strategically as part of a program. Multiple applications using AIs with different modes of action would need to be made in rotation to protect plants from virus spread.

A newly registered insecticide, flupyradifurone, appears to be a promising alternative to imidacloprid when applied at planting, and also suppresses whiteflies as a foliar application later in the season. Reflective mulches can be effective to repel whiteflies for the first 4 to 6 weeks following planting until they are obscured by the plant canopy, but this practice would be impractical to use to any great extent on the large acreages of tomato planted in the San Joaquin Valley, and insecticides would still need to be applied later in the season to protect the plants from virus spread.

Other Considerations

In addition to the direct efficacy and cost considerations of using alternatives to NGNs, secondary pest outbreaks and resistance management are key considerations.

Secondary pest outbreaks. Early season soil or drip application of NGNs are important to prevent virus transmission by beet leafhopper (beet curly top virus) and sweetpotato whitefly (tomato yellow leaf curl virus) in areas where these pests commonly occur, as well as for tomato psyllid control for fresh market pole tomato. This NGN use provides protection for at least the first six weeks after planting. Growers would invariably substitute other products to control these insects soon after planting, and because alternative insecticides do not have the residual efficacy of the NGNs, multiple applications would likely be made. It is probable that two to four times as many applications would be needed to control the same pests. Most of the alternative products would be applied to foliage and many are more disruptive of natural biological control than are the NGNs. Therefore, outbreaks of other insects and arthropods, including broad and spider mites, are more likely to occur necessitating additional insecticide sprays for their control.

Resistance management. Resistance management is always of concern when applying insecticides, and the risk increases with each additional spray of products with similar modes of action. Resistance management benefits from the availability of NGN insecticides, particularly when they are applied a single time at planting because fewer applications of effective alternative insecticides will be necessary during the season due to NGNs' residual efficacy when applied at this time.

Target NGN Use: 2017-2019

Most fresh market tomato acreage treated with NGNs is in the San Joaquin Valley, where most fresh market tomato production occurs. Imidacloprid is the primary NGN applied to tomato acreage and is substantially greater in most areas except the central and south coast, where thiamethoxam and dinotefuran are more widely used some years. Clothianidin has not been widely used in fresh market tomato. Figure 33 reports monthly target NGN use for both fresh market and processing tomato. Table 46 reports annual use of target NGNs and alternative active ingredients on fresh market tomato for 2017-2019.

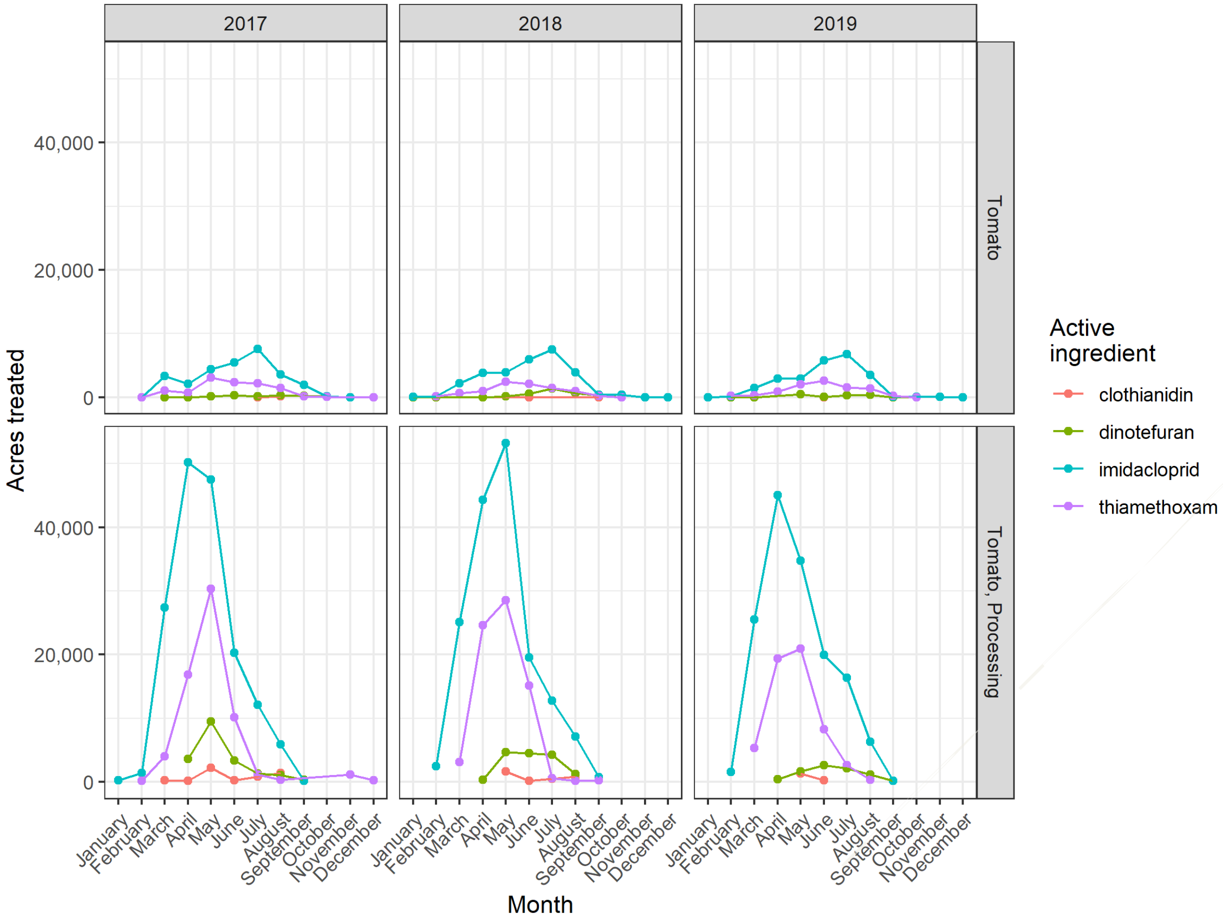

Figure 33. Monthly use of target nitroguanidine-substituted neonicotinoids: Fresh market and processing tomato, 2017-2019

Most acreage treated with NGNs for processing tomato is in the San Joaquin Valley where the majority of production occurs. NGNs are also used in the Sacramento Valley and coastal areas. As is the case for fresh market tomato, imidacloprid is the primary NGN used in both the San Joaquin and Sacramento Valley regions. Thiamethoxam was less used in the San Joaquin Valley.

Clothianidin and dinotefuran were applied to proportionally more acres in the Sacramento Valley than in the San Joaquin region mid-season, possibly for stink bug control. Table 46 reports annual use of the target NGNs and alternative active ingredients on processing tomato for 2017-2019

Table 45. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Fresh Market Tomato, 2017-2019

Active ingredient	**--------Pounds applied---------**				**-----------Acres treated-----------**				**Use rate (lb /ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
abamectin	85	198	170	453	5,482	12,834	10,798	29,113	0.02
acetamiprid	388	420	296	1,103	5,584	5,870	3,972	15,426	0.07
buprofezin	775	140	257	1,171	2,161	366	702	3,229	0.36
clothianidin*	11	1	0	12	141	8	1	149	0.08
cyantraniliprole	296	533	488	1,317	1,782	4,889	5,090	11,761	0.11
dimethoate	1,748	1,418	1,082	4,248	4,006	3,397	2,908	10,311	0.41
dinotefuran*	209	530	221	960	1,290	3,090	1,350	5,730	0.17
esfenvalerate	268	214	232	714	5,739	4,702	5,156	15,598	0.05
fenpropathrin	418	626	193	1,237	2,335	3,163	949	6,447	0.19
flonicamid	186	102	221	508	1,593	806	1,747	4,146	0.12
flupyradifurone	1,222	789	803	2,815	7,263	5,455	4,558	17,276	0.16
imidacloprid*	4,507	4,186	3,273	11,966	28,589	28,349	23,648	80,587	0.15
lambda-cyhalothrin	647	491	538	1,676	22,494	18,112	19,135	59,741	0.03
methomyl	4,094	3,501	3,085	10,681	5,169	5,286	4,853	15,308	0.70
novaluron	93	106	280	479	1,202	1,360	3,596	6,157	0.08
permethrin	125	331	267	723	1,194	2,948	2,745	6,887	0.11
pymetrozine	139	70	117	326	918	516	627	2,061	0.16
pyriproxyfen	113	51	71	235	1,848	850	1,181	3,879	0.06
spinetoram	1,411	1,032	1,105	3,548	30,113	20,908	22,897	73,918	0.05
spinosad	198	229	157	584	2,102	2,100	1,193	5,396	0.11
spiromesifen	185	187	147	519	1,456	1,571	1,211	4,237	0.12
spirotetramat	41	168	100	310	514	2,232	1,280	4,027	0.08
thiamethoxam*	583	462	503	1,548	11,079	9,066	9,219	29,363	0.05

* Target NGNs

Table 46. Annual Use of Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Processing Tomato, 2017-2019

Active ingredient	**--------Pounds applied---------**				**-----------Acres treated-----------**				**Use rate (lb /ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
abamectin	928	875	955	2,758	64,241	60,710	62,977	187,929	0.01
acetamiprid	829	1,044	1,913	3,786	12,881	17,024	30,344	60,248	0.06
buprofezin	59	148	106	313	152	389	280	821	0.38
clothianidin*	339	206	100	645	5,109	3,100	1,513	9,722	0.07
cyantraniliprole	81	431	377	889	620	5,919	4,414	10,953	0.08
dimethoate	31,294	27,973	18,059	77,326	72,629	70,913	49,009	192,551	0.40
dinotefuran*	3,900	3,577	1,805	9,282	19,046	14,923	8,144	42,112	0.22
esfenvalerate	1,190	745	617	2,552	25,716	15,798	13,125	54,639	0.05
fenpropathrin	285	165	114	564	1,500	865	548	2,914	0.19
flonicamid	14	27	147	188	156	303	1,539	1,997	0.09
flupyradifurone	499	436	421	1,355	2,818	2,752	2,609	8,179	0.17
imidacloprid*	35,121	56,682	30,278	122,082	165,164	165,319	149,598	480,081	0.25
lambda-cyhalothrin	2,305	2,735	3,410	8,450	79,115	94,824	118,757	292,696	0.03
methomyl	4,002	1,042	1,021	6,065	5,351	1,492	1,917	8,760	0.69
novaluron	344	421	121	887	4,723	6,012	1,693	12,427	0.07
permethrin	709	1,059	517	2,284	5,831	10,400	5,861	22,091	0.10
pymetrozine	NA	NA	6	6	NA	NA	72	72	0.09
pyriproxyfen	38	109	27	175	566	1,612	408	2,586	0.07
spinetoram	1,590	1,427	1,195	4,211	35,803	30,945	26,223	92,971	0.05
spinosad	489	241	442	1,172	7,788	3,332	6,373	17,493	0.07
spiromesifen	3	-	-	3	20	-	-	20	0.15
spirotetramat	70	233	174	476	925	2,937	2,217	6,079	0.08
thiamethoxam*	3,153	3,739	3,167	10,059	64,474	72,443	56,919	193,835	0.05

* Target NGNs

Proposed Restrictions

Tomato is in the Fruiting Vegetables crop group. Under the proposed regulations, the use of clothianidin, dinotefuran, thiamethoxam, and imidacloprid would be allowed up to the maximum label rate provided only one AI and only one application method are used. If more than one AI and/or more than one application method is used, then the cumulative application rate for all soil and foliar applications would not be allowed to exceed 0.172 lbs AI/acre/year for all NGNs combined. All applications would be prohibited during bloom. If managed pollinators are used, applications would only be allowed from planting until the development of the third leaf on the main shoot. Managed pollinators are not used in field-grown fresh market or processing tomato production; however, bumblebees may be used in greenhouse tomato production to improve fruit set. We assume for this analysis that growers will not use managed pollinators.

Imidacloprid is the most heavily used NGN (Figure 33) and the most critical as it protects transplants from several virus vectors. One particular use of imidacloprid and thiamethoxam is that either can be used in a tank mix or pre-mix to control stink bug. This specific use has a drop-in alternative: acetamiprid. Applications where imidacloprid or thiamethoxam were used as a tank mix or pre-mix with a pyrethroid were replaced directly with acetamiprid.[18] Other imidacloprid use almost exclusively occurs before bloom and would continue to be allowed. The use of clothianidin, dinotefuran, and thiamethoxam, however, mostly occurs after bloom. Clothianidin and dinotefuran applications were considered prohibited and replaced with alternatives. We estimated that roughly 10% of thiamethoxam use occurs before bloom; these applications were considered allowed long as imidacloprid had not already been used in the field. Acres receiving thiamethoxam applications once bloom begins were replaced with roughly two applications of the composite alternative to achieve similar control as for each thiamethoxam application. In fields that applied imidacloprid using both soil and foliar application methods, we assumed that growers would keep the soil applications because those are more critical for managing aphids, beet leafhoppers, and whiteflies. Foliar applications after soil applications were allowed up to a cumulative use rate of 0.172 lbs/AI/year and then moved to alternatives. This is likely an overestimate of the impact because some growers would be able to use soil applications a second time, thereby avoiding the new use restrictions and allowing imidacloprid use up to current label limits.

With these restrictions, 24.8-31.2% of acres and 30.6-38.8% of pounds applied would have been allowed annually on fresh market tomato, and 22.0-35.8% of acres and 29.9-54.6% of pounds applied would have been allowed annually on processing tomato. Figure 34 Figure 27 shows acres and pounds that would have been allowed by month for fresh tomato (upper panel) and processed tomato (lower panel).

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[18] When mixing with pyrethroids, multiple-methods restriction is not considered in this analysis if the replacement would not contain an NGN.

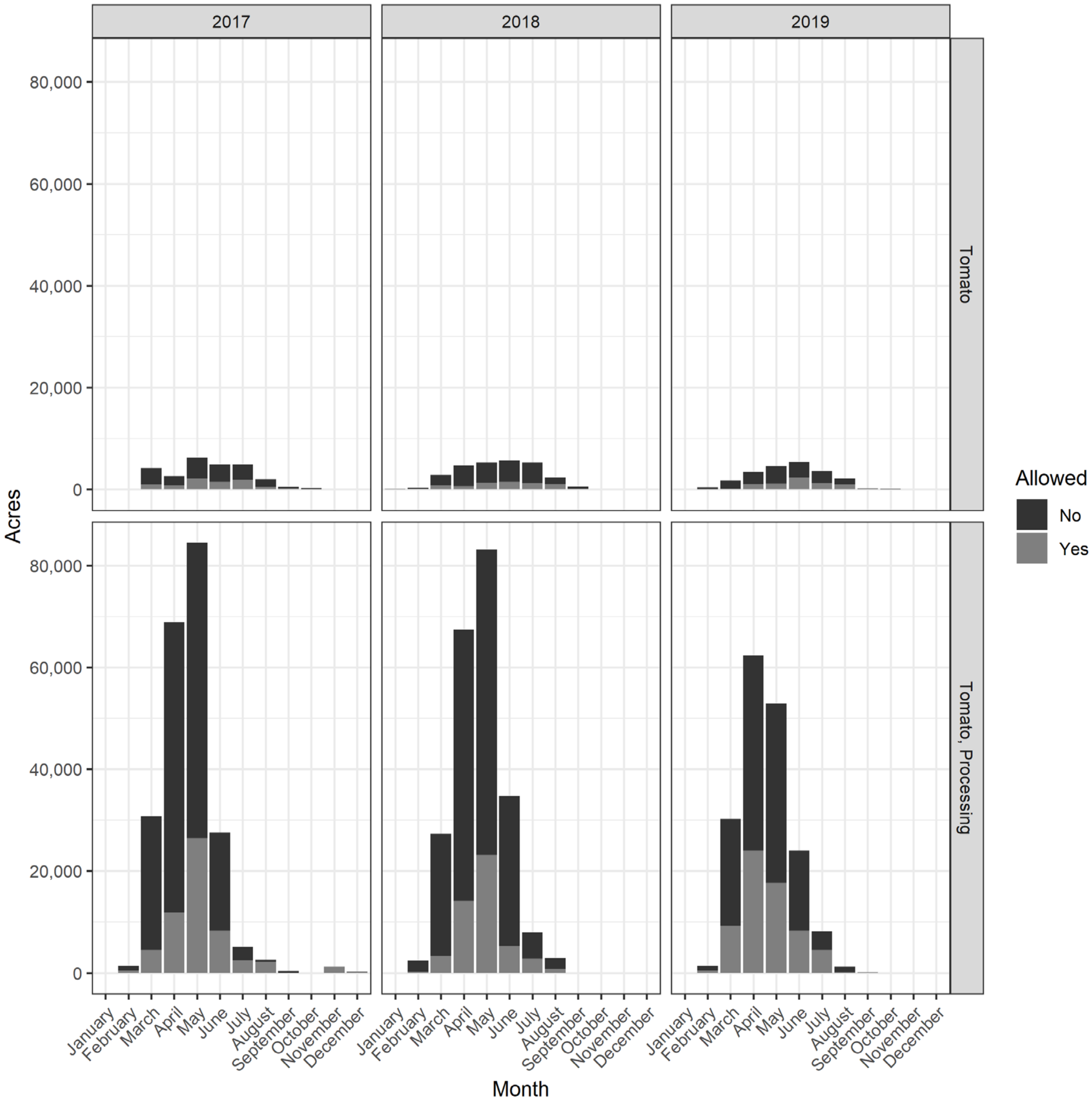

Figure 34: NGN use in tomato that would have been allowed with the proposed restrictions: 2017-2019

Economic Analysis

This section presents the estimated change in costs of pest management in tomato owing to the proposed restrictions of the four NGNs. This cost includes the change in pesticide material and application costs. In the absence of any anticipated effect on yields, gross revenues will not change. However, to prevent a change in yields, we anticipate that multiple sprays of alternative insecticides will be necessary to replace thiamethoxam sprays. To account for this, we calculated the cost of two applications of the composite alternative to these acres.

In addition to the caveats discussed in the methods section, the costs estimated below do not account for the potential effects of increased insect resistance to pyrethroids.

Table 47. Representative Products and Costs Per Acre: Fresh Tomato

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
abamectin	Epi-Mek 0.15 EC Miticide/Insecticide	11.03	22.28	33.31
acetamiprid	Assail 70WP Insecticide	25.14	19.98	45.12
buprofezin	Talus 70DF	59.55	22.52	82.07
clothianidin*	Belay Insecticide	11.98	22.66	34.63
cyantraniliprole	Exirel	81.77	20.47	102.24
dimethoate	Drexel Dimethoate 4EC	4.89	22.74	27.64
dinotefuran*	Venom Insecticide	35.40	21.97	57.38
esfenvalerate	Asana XL	5.29	21.67	26.97
fenpropathrin	Danitol 2.4 EC Spray	16.87	19.20	36.07
flonicamid	Beleaf 50 SG Insecticide	46.84	24.29	71.13
flupyradifurone	Sivanto Prime	45.40	21.86	67.27
imidacloprid*	Admire Pro	4.39	22.19	26.57
lambda-cyhalothrin	Besiege Insecticide	33.05	22.40	55.44
methomyl	Du Pont Lannate SP Insecticide	30.02	21.07	51.08
novaluron	Rimon 0.83 EC Insecticide	24.42	22.79	47.21
permethrin	Perm-Up 3.2 EC Insecticide	8.12	22.48	30.60
pymetrozine	Fulfill	38.64	22.74	61.38
pyriproxyfen	Knack Insect Growth Regulator	0.65	23.55	24.20
spinetoram	Radiant SC	41.67	21.62	63.29
spinosad	Entrust	91.43	24.72	116.15
spiromesifen	Oberon 2SC Insecticide/Miticide	24.64	24.91	49.55
spirotetramat	Movento	43.75	22.31	66.07
thiamethoxam*	Platinum 75 SG	8.08	9.00	17.09

*Target NGN

Table 48. Representative Products and Costs Per Acre: Processing Tomato

Active ingredient	Representative product	Material cost ($)	Application cost ($)	Total cost ($)
abamectin	Agri-Mek SC Miticide/Insecticide	9.12	21.91	31.03
acetamiprid	Assail 30SG Insecticide	16.59	22.95	39.54
buprofezin	Courier 40SC Insect Growth Regulator	36.85	23.61	60.46
carbaryl	First Choice Carbaryl Cutworm Bait	20.00	24.53	44.53
clothianidin*	Belay Insecticide	9.67	25.00	34.67
cyantraniliprole	Exirel	59.29	22.40	81.69
dimethoate	Dimethoate 400	3.67	22.75	26.42
dinotefuran*	Venom Insecticide	46.59	11.97	58.55
esfenvalerate	Asana XL	5.40	23.27	28.68
fenpropathrin	Danitol 2.4 EC Spray	17.01	20.80	37.81
flonicamid	Beleaf 50 SG Insecticide	35.92	19.55	55.47
flupyradifurone	Sivanto Prime	46.18	24.53	70.71
imidacloprid*	Admire Pro	6.00	23.98	29.98
lambda-cyhalothrin	Besiege Insecticide	34.02	23.06	57.08
methomyl	Du Pont Lannate SP Insecticide	29.79	19.68	49.47
novaluron	Rimon 0.83 EC Insecticide	22.41	21.02	43.42
permethrin	Perm-Up 3.2 EC Insecticide	6.80	21.29	28.09
pymetrozine	Fulfill	21.01	25.00	46.01
pyriproxyfen	Knack Insect Growth Regulator	0.72	25.00	25.72
spinetoram	Radiant SC	39.32	23.46	62.78
spinosad	Entrust	56.62	22.55	79.17
spiromesifen	Oberon 2SC Insecticide/Miticide	29.85	17.50	47.35
spirotetramat	Movento	44.56	23.05	67.61

*Target NGN

Representative products for each active ingredient used on tomato and their costs per acre are presented in Table 47 (fresh market) and Table 48 (processing). The material cost per acre is the product of the average use rate (lb/acre) over this period and the price per pound. The application cost per acre is the acre-weighted average application cost based on application method across all applications of the AI to the crop. The costs of each application method are presented in the methods section. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited (i.e., excluding allowed applications). The total treatment cost per acre is the sum of the material and application cost per acre.

There is substantial variation in the price per acre of AIs, ranging from $17.09 per acre (thiamethoxam, a target NGN) to $116.15 per acre for fresh market tomato (spinosad an alternative AI) and from $14.41 per acre (thiamethoxam) to $81.69 per acre (cyantraniliprole) for processing tomato.

Table 49. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Fresh Market Tomato, 2017-2019

Active ingredient	**Target NGNs available (% of all target and alternative use)**	**Share of composite alternative (%)**
abamectin	7.1	9.9
acetamiprid	3.8	5.2
buprofezin	0.8	1.1
cyantraniliprole	2.9	4
dimethoate	2.5	3.5
esfenvalerate	3.8	5.3
fenpropathrin	1.6	2.2
flonicamid	1	1.4
flupyradifurone	4.2	5.9
lambda-cyhalothrin	14.5	20.3
methomyl	3.7	5.2
novaluron	1.5	2.1
permethrin	1.7	2.3
pymetrozine	0.5	0.7
pyriproxyfen	0.9	1.3
spinetoram	18	25.1
spinosad	1.3	1.8
spiromesifen	1	1.4
spirotetramat	1	1.4
Total	71.8	100

Note: Three-year average from 2017-2019. Numbers may not add to 100% due to rounding.

Because there is a specific alternative for the imidacloprid and thiamethoxam when tank mixed with pyrethroid, we excluded such applications when computing the cost per acre of the composite alternative. The second column of Table 49 reports the average acreage shares for each non-NGN alternative AI used on fresh market tomato with NGNs available excluding application of a tank mix that also contains a pyrethroid. Averaged over the three-year period, 2017–2019, NGNs were used on 28.2% of total fresh market tomato acreage treated with insecticides and alternative AIs were used on 71.8% of fresh market tomato acreage treated with insecticides.

If NGNs were restricted, the use of alternative AIs is scaled up in proportion to their acreage shares, as discussed in the methods section. The third column of the table reports the share of each alternative AI in the composite alternative. The two most common alternative AIs were lambda-cyhalothrin and spinetoram for fresh market tomato, together accounting for 32.5% of the acres treated when NGNs were available and scaling up to 45.4% of use if NGNs were restricted.

Table 50. Average Annual Acreage Shares of Alternative Insecticides for Target Nitroguanidine-substituted Neonicotinoids (NGNs) and Shares of Composite Alternative: Processing Tomato, 2017-2019

Active ingredient	Target NGNs available (% of all target and alternative use)	Share of composite alternative (%)
abamectin	10.1	16.6
acetamiprid	3.2	5.3
buprofezin	0.05	0.1
carbaryl	8.3	13.6
cyantraniliprole	0.6	1.0
dimethoate	10.4	17.0
esfenvalerate	2.9	4.8
fenpropathrin	0.2	0.3
flonicamid	0.1	0.2
flupyradifurone	0.4	0.7
lambda-cyhalothrin	15.8	25.9
methomyl	0.5	0.8
novaluron	0.7	1.1
permethrin	1.2	2.0
pymetrozine	0.01	0.02
pyriproxyfen	0.1	0.2
spinetoram	5.0	8.2
spinosad	0.9	1.5
spiromesifen	0.003	0.01
spirotetramat	0.3	0.5
total	60.9	100

Note: Three-year average from 2017-2019. Numbers may not add to 100% due to rounding.

The second column of Table 50 reports the average acreage shares for each non-NGN alternative AI used on processing tomato, excluding tank mixes that also included a pyrethroid. Averaged over the three-year period, 2017–2019, when NGNs were available, NGNs were used on 39.1% of total acres treated and alternative AIs were used on 60.9% of acreage treated. Note that total acres treated w does not correspond to total acres of tomato grown because some growers may have used multiple AIs on the same field.

The two most common alternative AIs were dimethoate and lambda-cyhalothrin for processing tomato, together accounting for 26.2% of the acres treated without NGNs when NGNs were available. Scaling up, together they account for 42.9% of the composite alternative for prohibited applications.

Table 51. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Fresh Tomato

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase for switching (%)
clothianidin	11.98	22.66	34.63	58
dinotefuran	35.4	21.97	57.38	-5
imidacloprid	4.39	22.19	26.57	102
thiamethoxam	8.08	9.00	17.09	254
composite alternative*	32.75	21.92	54.68	-

*Cost per application of the composite alternative. Two applications required when substituting for thiamethoxam.

Table 51 reports average per acre costs for the NGNs and the composite alternative for fresh market tomato. Switching to the alternative would lead to a 58% increase in cost on acres using clothianidin in applications that would have been prohibited, an 5% decrease for dinotefuran, an 102% increase for imidacloprid (excluding pre-bloom use, which is unaffected), and a 254% increase for thiamethoxam. The percentage changes would be large for thiamethoxam because each prohibited application would be replaced by two applications of the composite alternative. For tank mixes of imidacloprid or thiamethoxam with a pyrethroid, the increase in the cost per acre for imidacloprid was $18.55, a 70% increase, and for thiamethoxam was $28.03, a 164% increase.

Table 52. Costs per Acre for Target Nitroguanidine-substituted Neonicotinoids and the Composite Alternative: Processing Tomato

Active ingredient	Material cost ($)	Application cost ($)	Total cost ($)	Cost increase for switching (%)
clothianidin	9.67	25.00	34.67	26
dinotefuran	46.59	11.97	58.55	-25
imidacloprid	6.00	23.98	29.98	34
thiamethoxam	7.96	6.45	14.41	220
composite alternative*	20.85	22.96	43.80	-

*Cost per application of the composite alternative. Two applications required when substituting for thiamethoxam.

Table 52 reports average per acre costs for the target NGNs and the composite alternative. Switching to the alternative would lead to a 26% increase in cost on acres using clothianidin, a 25% decrease for dinotefuran, a 34% increase for imidacloprid (excluding prebloom use), and a 220% increase for thiamethoxam. As mentioned previously, the composite alternative would be applied twice to replace thiamethoxam applications. For tank mixes, the increase in the cost per acre for imidacloprid was $9.56, a 32% increase and for thiamethoxam was $25.13, a 174% increase.

Table 53. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Fresh Market Tomato, 2017-2019

Year	Cost with target NGNs ($)	Cost without target NGNs ($)	Change in cost ($)	Change in costs (%)	Change in material cost (%)	Change in application cost (%)
2017	664,533	1,904,764	1,240,231	186.6	71.8	28.2
2018	753,128	1,886,306	1,133,177	150.5	73.4	26.6
2019	598,964	1,690,270	1,091,306	182.2	72.1	27.9

*Of the total increase in costs, the cost increase from directly substituting acetamiprid into mixes with pyrethroids is $324,059 in 2017, $262,278 in 2018, and $281,683 in 2019.

Table 54. Change in Treatment Costs due to Restriction of Target Nitroguanidine-substituted Neonicotinoids (NGNs): Processing Tomato, 2017-2019

Year	Cost with target NGNs ($)	Cost without target NGNs($)	Change in cost ($)	Change in cost (%)	Change in material cost (%)	Change in application cost (%)
2017	3,705,328	8,650,783	4,945,454	133.5	46.4	53.6
2018	3,455,477	9,105,105	5,649,627	163.5	47.3	52.7
2019	2,789,683	7,142,486	4,352,802	156.0	50.2	49.8

*Of the total increase in costs, the cost increase from directly substituting acetamiprid in mixes with pyrethroids is $356,698 in 2017, $345,993 in 2018, and $397,017 in 2019.

Table 53 (fresh market tomato) and Table 54 (processing tomato) report the change in material and application costs due to the restriction of NGNs. Costs increase for both. Substituting for the restricted NGNs would result in a 150.5% to 186.6% increase in total treatment costs for fresh market tomato acreage treated with prohibited applications of the NGNs, with a total cost increase between $1.1 million and $1. 2 million. For processing tomato, the increase would be 133.5% to 163.5%, with a total cost increase of $4.4 million to $5.6 million on acres treated with prohibited applications of the NGNs. Comparing the two tables, the cost increase was smaller in absolute value, but larger in percentage terms, for fresh market tomato. The smaller absolute increase in costs for fresh market tomato was due to differences in acreage treated between the two types of tomato: fresh market tomato averaged 12,644 annual acres treated with NGNs from 2017-2019, compared to 98,161 average annual acres for processing tomato. The higher percentage increase for fresh tomato was due to the higher cost of the composite alternative relative to the NGNs.

Conclusions and Critical Uses

In the case of tomato, the most critical uses of NGNs – imidacloprid prior to bloom – would still be allowed. Other uses pre-bloom would also be allowed if imidacloprid is not used or if all use stays below the new cumulative threshold. Uses over the threshold or after bloom would change to alternatives. Utilizing alternative pesticides for the target pests due to the proposed regulation increases estimated costs for both fresh market and processing tomato. The two types face different impacts from the proposed restrictions. Fresh market tomato has a larger percentage increase in costs per acre than processing tomato, but due to the larger acreage treated with NGNs, processing tomato has a higher total cost.

Walnut

California accounts for nearly all national production of walnut and is the second largest producer of walnut in the world, second only to China. For 2020-2021, California was forecasted to account for half of world export value (USDA FAS 2020). Gross receipts for walnut totaled nearly $1.29 billion in 2019, which was the seventh largest agricultural commodity by production value (CDFA 2020a). About 97% of this production value, nearly $1.25 billion, was exported, making walnut California's fifth most important export agricultural commodity by value. Walnut is a top three agricultural export commodity to seven of the top ten agricultural export markets in 2019: European Union, Turkey, United Arab Emirates, Japan, Mexico, India, and Taiwan. There were 365,000 bearing acres of walnut in 2019, plus 75,000 non-bearing acres. The three largest walnut-producing counties, San Joaquin ($291 million), Butte ($214 million), and Tulare ($149 million), accounted for 43.4% of state production in 2019. Walnut was a top four agricultural commodity by value in ten counties (San Joaquin, Butte, Glenn, Sutter, Tehama, Colusa, Yuba, Placer, Shasta, and Lake), the second most important agricultural commodity in three of these counties (Glenn, Sutter, and Yuba), and the top agricultural commodity in two (Butte and Solano). In 2019, 72% of walnuts were sold shelled, the remainder marketable in-shell.

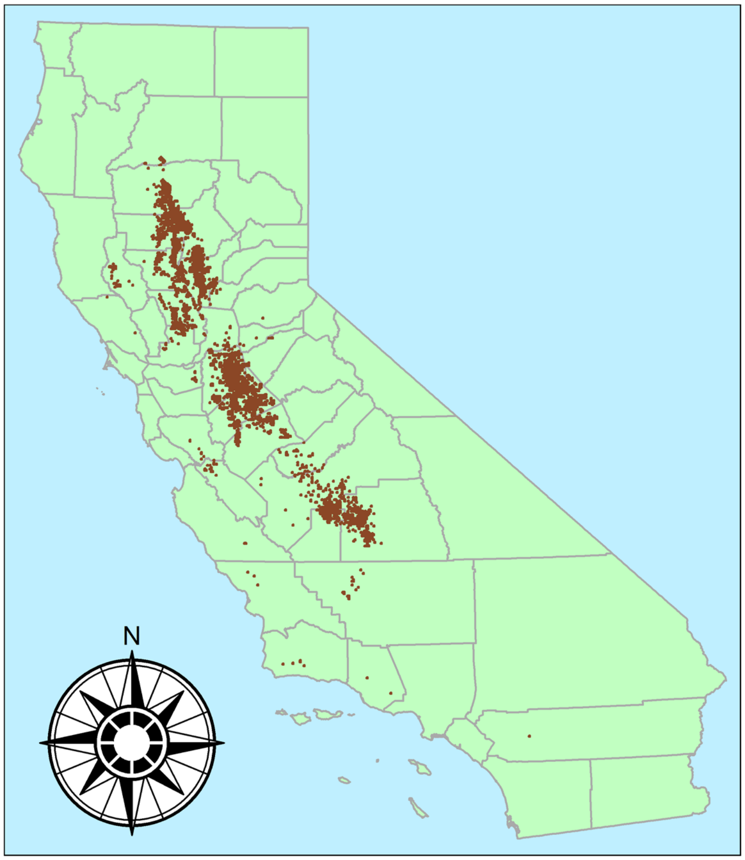

Figure 35. California walnut production: 2019

IPM Overview

California walnut is attacked by a variety of primary and secondary pests. Primary pests—codling moth, navel orangeworm and walnut husk fly—attack the nuts and cause direct damage to the marketable crop. Secondary pests—twospotted spider mite, walnut and dusky-veined aphid, European fruit lecanium and frosted scale—attack the tree's foliage, twigs and small limbs, which damage the tree through leaf drop and reduced vigor. Primary pests may require annual application of some control measures, while secondary pests require occasional (less frequent than annual) control measures. A number of minor walnut pests, which can do significant damage to the tree under special conditions, require treatment if they become abundant.

There are two NGN insecticides registered for use on walnut: clothianidin and imidacloprid. DPR's proposed regulation restricts use to only one of the two each year and prohibits applications during bud and bloom. For this analysis, we consider this time period to be February – early May depending on location. However, there is not a pest management reason to use either NGN before the end of bloom. The applications in April and May likely occur after bloom for a particular orchard. As such, that use is considered to be allowed.

Target Pests

Aphids. Walnut aphid (*Chromaphid juglandicola*) and dusky-veined aphid (*Callaphis juglandis*) can reduce tree vigor and nut size, resulting in lower yield quantity and quality. Additionally, aphids produce honey dew, which encourages growth of sooty mold. Sooty mold reduces nut value by changing its color to black and increasing nut sunburn. Both aphid species overwinter as eggs on the walnut trees, hatch in the spring, and settle onto leaves. They reproduce by cloning and can have multiple generations during the summer. Prior to the 1970s, walnut aphid was a significant pest; however, introduction of the parasitic wasp *Trioxys pallidus* brought it under control statewide. Dusky-veined aphids are not a host for *T. pallidus* but are preyed upon by a variety of generalist natural enemies. Research has established economic injury levels for aphids on walnut, which informs growers on when insecticide applications may be necessary. Generally, aphids are kept below injury levels by biological control agents. However, broad-spectrum insecticides, like pyrethroids, applied to control codling moth and walnut husk fly can disrupt the natural enemies and cause aphid outbreaks. Although both clothianidin and imidacloprid are effective, it is more common for growers to use imidacloprid. Either could serve as an alternative for the other without changing pest management outcomes.

Walnut husk fly (*Rhagoletis completa*). Walnut husk fly is a visually striking insect that can damage walnut yields in several ways. Large populations in the early season can lead to kernels being shriveled and moldy at harvest. Larvae feeding can cause significant staining of the walnut shells and make the shells difficult to remove (an issue primarily for in-shell sales). For walnut husk fly, both imidacloprid and clothianidin are effective. It is more common for growers to use imidacloprid. Either could serve as an alternative for the other without changing pest management outcomes.

Target NGN Use: 2017-2019

Imidacloprid was applied to roughly 75,000 - 86,000 acres a year from 2017-2019 while clothianidin was only applied to roughly 4,000 - 5,600 acres annually in the same time frame (Table 55). The majority of imidacloprid is applied in June-August (Figure 36) for aphids and walnut husk fly. Neither product is used much in the pre-bloom season (January-April). Small amounts of imidacloprid and clothianidin were applied in April, likely to address problems with scale. Imidacloprid, which is much more widely used than clothianidin, was applied to more acres in 2017 than the following two years.

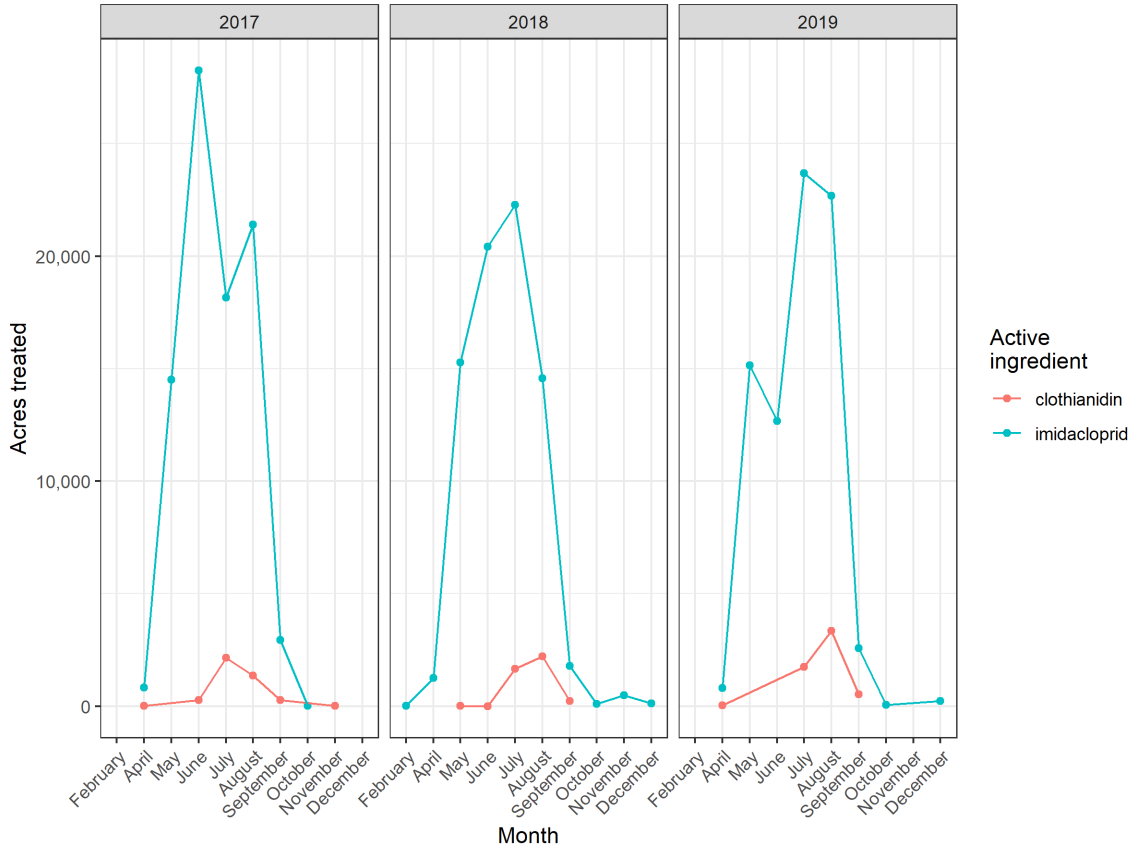

Figure 36. Monthly use of target nitroguanidine-substituted neonicotinoids: Walnut, 2017-2019

As discussed in the IPM Overview section above, imidacloprid is a drop-in replacement for clothianidin in fields that used both AIs.

Table 55. Annual Use of Target Nitroguanidine-substituted Neonicotinoids and Alternative Active Ingredients: Walnut, 2017-2019

Active ingredient	**--------Pounds applied---------**				**-----------Acres treated-----------**				**Use rate (lb /ac)**
	2017	2018	2019	Total	2017	2018	2019	Total	
clothianidin*	399	391	563	1,343	4,092	4,128	5,664	13,884	0.10
imidacloprid*	7,265	6,494	8,292	22,051	86,095	76,287	77,924	240,306	0.09

*Target NGNs

Proposed Restrictions

Walnut is in the tree nut crop group. Only imidacloprid and clothianidin are regularly used. Imidacloprid is more widely used than clothianidin (Figure 36). Applications in fields that had only one of the NGN AIs in a year were considered allowed. For fields that used more than one AI, all applications were considered allowed if the cumulative use rate was at or below 0.2 lbs AI/acre/year. For fields that used both NGNs and exceeded the new cumulative use rate, we assumed that the imidacloprid applications would be kept and clothianidin applications were replaced with an imidacloprid application because imidacloprid use is more common. This less than 2% of acres treated (Figure 37), as walnut growers rarely used more than one NGN AI per year.

Figure 37 shows what the use in 2017-2019 would have been if the new restrictions had been in place. Under the proposed restrictions 99% of treated acres and lb applied would still have been allowed.

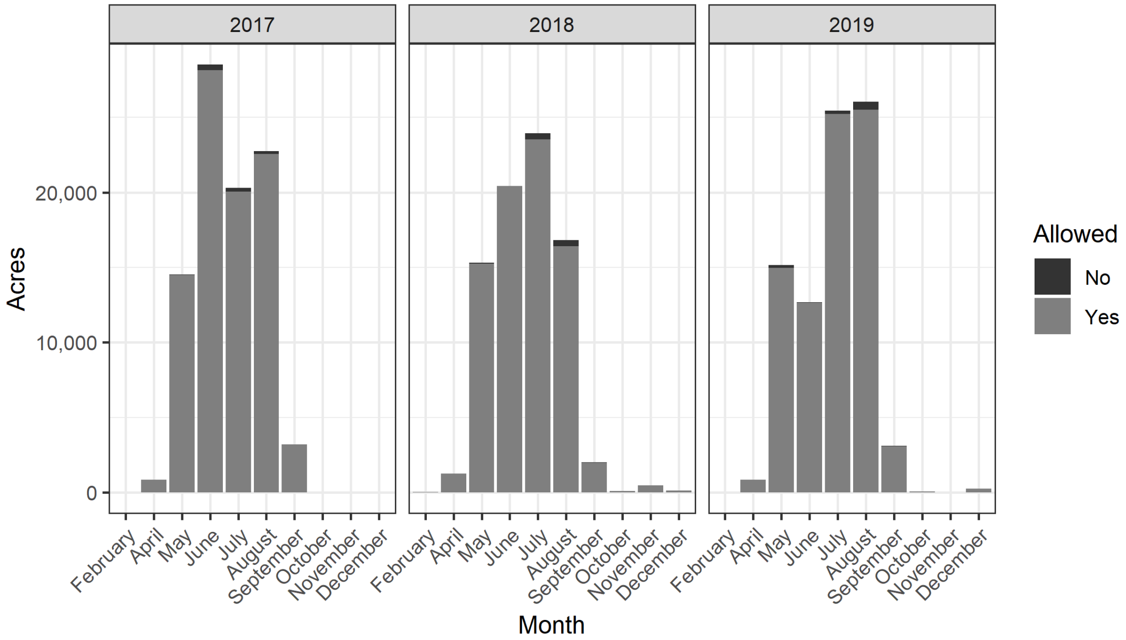

Figure 37. Monthly use of target nitroguanidine-substituted neonicotinoids that would have been allowed under the proposed restrictions: Walnut, 2017-2019

Economic Analysis

This section presents the estimated change in costs to walnut if only one NGN were available for use after bloom. Imidacloprid is as effective if not more effective than clothianidin, so using it as a replacement for clothianidin would have no negative yield consequences. Imidacloprid would only be used as an alternative in fields where both imidacloprid and clothianidin had been applied within one year. The cost of the proposed policy is the difference in material costs and application costs though the caveats discussed in the methods section apply.

Table 56. Representative Products Cost per Acre in 2018: Walnut

Active ingredient	Representative product	Material Cost per acre($)	App Cost per acre($)	Total Cost per acre($)
clothianidin	Belay	15.03	25.55	40.58
imidacloprid	Leverage	57.99	13.37	71.37

Table 56 reports the representative products for clothianidin and imidacloprid on walnut for 2017-2019. The material cost per acre is the product of the average use rate (lb/acre) over this period and the price per pound. The application cost per acre is the acre-weighted average application cost based on application method across all applications of the AI to the crop. The costs of each application method are presented in the methods section. The total treatment cost per acre is the sum of the material and application cost per acre. The application cost per acre is the average of the application cost of each method used for an AI, weighted by the share of that application method in the acres treated with that AI that would have been prohibited (i.e., excluding allowed applications). At $71.37 per acre, imidacloprid is 75.9% more expensive than clothianidin at $40.58 per acre. Growers consider a number of factors including cost per acre in determining which pesticide to apply.

When imidacloprid and clothianidin are used on the same field, meaning one would be prohibited under the proposed regulation, the imidacloprid is scaled up to compensate for clothianidin – this only occurred on 2% of acres.

Table 57. Change in Treatment Costs due to Restriction of Nitroguanidine-substituted Neonicotinoids (NGNs): Walnut Pre-Bloom, 2017-2019

Year	Cost with target active ingredients ($)	Cost without target active ingredients ($)	Change in cost ($)	Change in cost (%)	Share of change due to material costs (%)	Share of change due to application costs (%)
2017	7,243	12,739	5,496	75.9	139.5	-39.5
2018	8,968	15,773	6,805	75.9	139.5	-39.5
2019	4,585	8,065	3,479	75.9	139.5	-39.5

Table 57 reports the change in treatment costs due to restricting applications to one AI per field per growing season. For walnut, insecticide material and application costs increase by 75.9% under the proposed policy. However, this is only a change in between $3,479 – $6,805 for the whole state. The magnitude of the total change in net returns is likely to be small.

Conclusions and Critical Uses

For walnut, the proposed restrictions have little impact on use. As such, pest management costs are only estimated to increase by $3,479 – $6,805 for the whole state, which would be only a very small change in net returns.

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Appendix A: Draft Text of Proposed Regulation

This draft text of the proposed regulation was provided by DPR to CDFA on 5/6/2021.

TEXT OF PROPOSED REGULATIONS

TITLE 3. CALIFORNIA CODE OF REGULATIONS
DIVISION 6. PESTICIDES AND PEST CONTROL OPERATIONS
CHAPTER 4. ENVIRONMENTAL PROTECTION
SUBCHAPTER 6. POLLINATOR PROTECTION
ARTICLE 2. NEONICOTINOID PESTICIDE EXPOSURE PROTECTION

Section 6990. Definitions and Scope

(a) For the purposes of this article, the following definitions apply:
(1) "Bloom" means the period from the onset of flowering until petal fall is complete. For citrus subject to section 6984, the bloom period is as defined in section 6984(b).
(2) "Crop group" means the groupings of agricultural commodities specified in 85 Fed. Reg. 70985 (Nov. 6, 2020).
(3) "Growing season" means the time period from planting until harvest is completed for a particular annual crop or biennial crop, and is not more than one year (365 days) for perennial crops.
(4) "Managed pollinators" means bees introduced in a field to provide pollination services to the crops in the field.
(5) "Neonicotinoid" means a pesticide containing any of the following active ingredients in the nitroguanidine insecticide class of neonicotinoids: clothianidin, dinotefuran, imidacloprid, and thiamethoxam.
(6) The term "lbs. ai/A/season" means the application rate in unit of pounds (lbs.) of neonicotinoid active ingredient (ai) per acre (A) per growing season.

(b) The provisions of this article apply to foliar, soil, or both foliar and soil applications of products containing one or more neonicotinoid active ingredients when used for the production of the following agricultural commodities:
(1) Berries and small fruits (Crop Groups 13 and 13-07)
(2) Bulb vegetables (Crop Group 3 and 3-7)
(3) Cereal grains (Crop Groups 15 and 16)
(4) Citrus fruit (Crop Groups 10 and 10-10)
(5) Cucurbit vegetables (Crop Group 9)
(6) Fruiting vegetables (Crop Groups 8 and 8-10)
(7) Herbs and spices (Crop Groups 19, 25, and 26)
(8) Leafy vegetables including brassica (cole) (Crop Groups 4, 4-16, 5, 5-16 and 22)
(9) Legume vegetables (Crop Groups 6 and 7)
(10) Oilseed (Crop Group 20)

(11) Pome fruits (Crop Groups 11 and 11-10)
(12) Root and tuber vegetables (Crop Groups 1 and 2)
(13) Stone fruits (Crop Groups 12 and 12-12)
(14) Tree nuts (Crop Groups 14 and 14-12)
(15) Tropical and subtropical fruit, edible and inedible peel (Crop Groups 23 and 24)
(16) Coffee, peanuts, globe artichoke, mint, hops (female plants only), and tobacco

(c) The following applications are not subject to this article:
(1) An application made to an agricultural commodity grown inside an enclosed space, insect exclusionary structure, or insect exclusionary netting if both of the following conditions are met:
(A) The agricultural commodity is fully covered by the enclosed space, insect exclusionary structure, or insect exclusionary netting for the entire duration of the bloom period; and
(B) Managed pollinators are not introduced into the enclosed space, insect exclusionary structure, or insect exclusionary netting.
(2) An application made to address a local emergency declared by the U.S. Department of Agriculture or the California Department of Food and Agriculture pursuant to Government Code section 8630.
(3) An application to control a quarantine pest declared by the U.S. Department of Agriculture or the California Department of Food and Agriculture if the operator of the property obtains written recommendation of a licensed agricultural pest control adviser. The operator of the property shall retain the written recommendation for at least two years after the application occurs.

(d) For purposes of this article, if at any point during the growing season the operator of the property uses managed pollinators at the application site, then the operator of the property is presumed to have intended to use managed pollinators at the time of application.

Section 6990.1. Neonicotinoid Use on Berries and Small Fruits Crop Groups (Crop Groups 13 and 13-07)

The provisions of this section apply to any neonicotinoid application made to a crop in the berries and small fruits crop groups, with the exception of mulberries. Application of a neonicotinoid to mulberries is not subject to the provisions of this article.

(a) Application of a neonicotinoid is prohibited during bloom.
(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.3 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.2 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.1 lbs. ai/A/season.

(c) Except as specified in subsection (d), if managed pollinators will be used during the growing season, application of a neonicotinoid is prohibited.

(d) *Grapes.* If managed pollinators will be used to pollinate grapes during the growing season, an application of a neonicotinoid to grapes may be made under the application rate and timing restrictions listed in the following table. These restrictions apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Grapes				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin, Dinotefuran, Imidacloprid, or Thiamethoxam	0.2 lbs. ai/A/season	Apply only up until bud break	0.1 lbs. ai/A/season	Apply only between post-bloom (all flower hoods fallen) and harvest

Section 6990.2. Neonicotinoid Use on Bulb Vegetables Crop Groups (Crop Groups 3 and 3-07)

When crops in the bulb vegetables crop groups are harvested before bloom, an application of a neonicotinoid to these crops is not subject to the provisions of this article. Otherwise, an application of a neonicotinoid to these crops is prohibited.

Section 6990.3. Neonicotinoid Use on Cereal Grains Crop Groups (Crop Groups 15 and 16)

The provisions of this section apply to any neonicotinoid application made to a crop in the cereal grains crop groups with the exception of barley, oats, rice, rye, triticale, and wheat. An application of a neonicotinoid to barley, oats, rice, rye, triticale, or wheat is not subject to the provisions of this article.

(a) Application of a neonicotinoid is prohibited from heading (inflorescence or tassel emergence) to harvest.
(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.306 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.18 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.126 lbs. ai/A/season.

(c) If managed pollinators will be used during the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Cereal Grains Crop Group		
	Soil Application	Foliar Application

Active Ingredient	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin, Dinotefuran, Imidacloprid, or Thiamethoxam	0.18 lbs. ai/A/season	Apply only at pre-planting or planting	0.126 lbs. ai/A/season	Apply only between pre-planting until heading (inflorescence or tassel emergence)

Section 6990.4. Neonicotinoid Use on Citrus Fruit Crop Groups (Crop Groups 10 and 10-10

The provisions of this section apply to any neonicotinoid application made to a crop in the citrus fruit crop groups.

(a) Application of a neonicotinoid is prohibited during bloom.

(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.422 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.25 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.172 lbs. ai/A/season.

(c) The application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Citrus Fruit Crop Group				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin	0.2 lbs. ai/A/season	Apply only between petal fall and September 13	0.172 lbs. ai/A/season	Apply only between petal fall and December 1
Dinotefuran	0.172 lbs. ai/A/season	Apply only between petal fall and January 31	0.172 lbs. ai/A/season	Apply only between petal fall and December 1
Imidacloprid	0.25 lbs. ai/A/season	Apply only between petal fall and November 10	0.172 lbs. ai/A/season	Apply only between petal fall and December 1
Thiamethoxam	0.172 lbs. ai/A/season	Apply only between petal fall and January 31	0.172 lbs. ai/A/season	Apply only between petal fall and December 1

Section 6990.5. Neonicotinoid Use on Cucurbit Vegetables Crop Group (Crop Group 9)

The provisions of this section apply to any neonicotinoid application made to a crop in the cucurbit vegetables crop group.

(a) Application of a neonicotinoid is prohibited during bloom.
(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.736 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.536 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.2 lbs. ai/A/season.

(c) Except as provided in subsection (d), if managed pollinators will be used within the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Cucurbit Vegetables Crop Group				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin	0.2 lbs. ai/A/season	Apply only from pre-planting until primary side shoot formation	0.2 lbs. ai/A/season	Apply only from pre-planting until bloom
Dinotefuran	0.536 lbs. ai/A/season	Apply only from pre-planting until bloom	0.172 lbs. ai/A/season	Apply only from pre-planting until bloom
Imidacloprid	0.2 lbs. ai/A/season	Apply only from pre-planting until primary side shoot formation	0.172 lbs. ai/A/season	Apply only from pre-planting until bloom
Thiamethoxam	0.172 lbs. ai/A/season	Apply only from pre-planting until fifth true leaf on main stem unfolded	0.172 lbs. ai/A/season	Apply only from pre-planting until bloom

(d) Exception: If managed pollinators will be used for cucumbers during the growing season, then foliar applications of either dinotefuran, imidacloprid, or thiamethoxam are prohibited. For foliar applications of clothianidin and soil applications of all neonicotinoids, the rates and timing restrictions listed in subsection (c) apply.

Section 6990.6. Neonicotinoid Use on Fruiting Vegetables Crop Groups (Crop Groups 8 and 8-10)

The provisions of this section apply to any neonicotinoid application made to a crop in the fruiting vegetables crop groups.

(a) Application of a neonicotinoid is prohibited during bloom.
(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate must not exceed 0.172 lbs. ai/A/season.
(c) Except as provided in subsection (d), if managed pollinators will be used to pollinate crops in the fruiting vegetables crop groups during the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Fruiting Vegetables Crop Group				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin, Dinotefuran, Imidacloprid, or Thiamethoxam	0.172 lbs. ai/A/season	Apply only from pre-planting until third leaf on main shoot unfolded	Prohibited	

(d) Exceptions: If managed pollinators will be used for peppers, goji berry, ground cherry, martynia, okra, roselle, or tomatillo during the growing season, then application of a neonicotinoid is prohibited.

Section 6990.7. Neonicotinoid Use on Herbs and Spices Crop Group (Crop Group 19, 25, and 26)

When crops in the herbs and spices crop group are harvested before bloom, an application of a neonicotinoid to these crops is not subject to the provisions of this article. Otherwise, an application of a neonicotinoid to these crops is prohibited.

Section 6990.8. Neonicotinoid Use on Leafy Vegetables Including Brassica (Cole) Crop Groups (Crop Groups 4, 4-16, 5, 5-16 and 22)

When crops in the leafy vegetables, brassica (cole), stalk, and stem crop groups are harvested before bloom, an application of a neonicotinoid to these crops is not subject to the provisions of this article. Otherwise, an application of a neonicotinoid to these crops is prohibited.

Section 6990.9. Neonicotinoid Use on Legume Vegetables Crop Groups (Crop Groups 6 and 7)

The provisions of this section apply to any neonicotinoid application made to a crop in the legumes vegetable crop groups.

(a) Application of a neonicotinoid is prohibited during the bloom period.

(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate must not exceed 0.126 lbs. ai/A/season.
(c) If managed pollinators will be used during the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Legume Vegetable Crop Group				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin	Prohibited		Prohibited	
Dinotefuran	Prohibited		0.126 lbs. ai/A/season	Apply only from pre-planting until bloom
Imidacloprid	Prohibited		Prohibited	
Thiamethoxam	Prohibited		Prohibited	

Section 6990.10. Neonicotinoid Use on Oilseed Crop Group (Crop Group 20)
The provisions of this section apply to any neonicotinoid application made to a crop in the oilseed crop group.
(a) Application of a neonicotinoid is prohibited during bloom.
(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate must not exceed 0.3 lbs. ai/A/season.
(c) If managed pollinators will be used during the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Oilseed Crop Group				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin	Prohibited		Prohibited	
Dinotefuran	Prohibited		Prohibited	
Imidacloprid	Prohibited		0.3 lbs. ai/A/season	Apply only from pre-planting until the

			beginning of main stem elongation
Thiamethoxam	Prohibited	Prohibited	

Section 6990.11. Neonicotinoid Use on Pome Fruits Crop Groups (Crop Groups 11 and 11-10)

The provisions of this section apply to any neonicotinoid application made to a crop in the pome fruits crop groups.

(a) Application of a neonicotinoid is prohibited during bloom.

(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.567 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.38 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.187 lbs. ai/A/season.

(c) The application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Pome Fruit Crop Groups				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin, Dinotefuran, Imidacloprid, or Thiamethoxam	0.38 lbs. ai/A/season	Apply only between post-bloom and harvest	0.187 lbs. ai/A/season	Apply only between post-bloom and harvest

Section 6990.12. Neonicotinoid Use on Root and Tuber Vegetables Crop Groups (Crop Groups 1 and 2)

The provisions of this section apply to any neonicotinoid application made to a crop in the root and tuber vegetables crop groups, except for cassava. Application of a neonicotinoid to sweet or bitter cassava is not subject to the provisions of this article.

(a) If any of the following crops will be harvested before bloom, then the provisions of this article do not apply: arracha, artichokes (Chinese and Jerusalem), carrots, chicory roots, garden beets, sugar beets, turnip, turnip-rooted chervil, turnip-rooted parsley, parsnip, radish, oriental radish, rutabaga, and skirret. Otherwise, if these crops are harvested after bloom or are grown for seed this section applies.
(b) Application of a neonicotinoid is prohibited during the bloom period.

(c) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.388 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.338 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.05 lbs. ai/A/season.

(d) If managed pollinators will be used during the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (b) and (c):

Application Rate and Timing Restrictions for Crops in the Root and Tuber Vegetables Groups				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin	0.2 lbs. ai/A/season	Apply only at pre-planting or planting	0.05 lbs. ai/A/season	Apply only from pre-planting until the beginning of main stem elongation or crop cover
Dinotefuran	0.338 lbs. ai/A/season	Apply only from pre-planting until the beginning of main stem elongation or crop cover	0.05 lbs. ai/A/season	Apply only from pre-planting until the beginning of main stem elongation or crop cover
Imidacloprid	0.2 lbs. ai/A/season	Apply only at pre-planting or planting	0.05 lbs. ai/A/season	Apply only from pre-planting until the beginning of main stem elongation or crop cover
Thiamethoxam	0.2 lbs. ai/A/season	Apply only at pre-planting or planting	0.05 lbs. ai/A/season	Apply only from pre-planting until the beginning of main stem elongation or crop cover

Section 6990.13. Neonicotinoid Use on Stone Fruits Crop Groups (Crop Groups 12 and 12-12)

The provisions of this section apply to any neonicotinoid application made to a crop in the stone fruits crop groups.

(a) Application of a neonicotinoid is prohibited during bloom.

(b) If both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate of 0.92 lbs. ai/A/season may be applied provided that:
(1) Soil application rate must not exceed 0.38 lbs. ai/A/season; and
(2) Foliar application rate must not exceed 0.54 lbs. ai/A/season.

(c) The application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Stone Fruits Crop Groups				
Active Ingredient	Soil Application		Foliar Application	
	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin	0.38 lbs. ai/A/season	Apply only between post-bloom and harvest	0.2 lbs. ai/A/season	Apply only between post-bloom and harvest
Dinotefuran	0.38 lbs. ai/A/season	Apply only between post-bloom and harvest	0.54 lbs. ai/A/season	Apply only between post-bloom and harvest
Imidacloprid	0.38 lbs. ai/A/season	Apply only between post-bloom and harvest	0.5 lbs. ai/A/season	Apply only between post-bloom and harvest
Thiamethoxam	0.38 lbs. ai/A/season	Apply only between post-bloom and harvest	0.172 lbs. ai/A/season	Apply only between post-bloom and harvest

Section 6990.14. Neonicotinoid Use on Tree Nuts Crop Groups (Crop Groups 14 and 14-12)

The provisions of this section apply to any neonicotinoid application made to a crop in the tree nuts crop groups, except for pistachio, beechnut, gingko, and pecans. Application of a neonicotinoid to pistachio, beechnut, gingko, or pecans is not subject to the provisions of this article.

(a) Application of a neonicotinoid is prohibited during bloom.

(b) Except for almonds as provided in subsection (d), if both soil and foliar application methods are used on the same crop, or if multiple neonicotinoids are applied to the same crop, a total maximum combined application rate must not exceed 0.2 lbs. ai/A/season.

(c) Except for almonds as provided in subsection (d), if managed pollinators will be used during the growing season, the application rate and timing restrictions listed in the following table apply in addition to the limitations in subsections (a) and (b):

Application Rate and Timing Restrictions for Crops in the Tree Nuts Crop Groups		
	Soil Application	Foliar Application

Active Ingredient	Maximum Application Rate	Required Timing	Maximum Application Rate	Required Timing
Clothianidin, Dinotefuran, Imidacloprid, or Thiamethoxam	Prohibited		0.2 lbs. ai/A/season	Apply only between post-bloom and harvest

(d) *Almonds.* The rates and timing restrictions listed in subsection (c) are required for any application of a neonicotinoid made to almonds, regardless of whether managed pollinators are used.

Section YYYY.15. Neonicotinoid Use on Tropical and Subtropical Fruit, Edible and Inedible Peel Crop Groups (Crop Groups 23 and 24)

The provisions of this section apply to any neonicotinoid application made to a crop in the tropical and subtropical fruit, edible and inedible peel crop groups.

(a) Application of a neonicotinoid is prohibited during bloom.

(b) Application of more than one neonicotinoid active ingredient during the growing season is prohibited.

(c) Use of more than one application method, soil or foliar, during the growing season is prohibited.

(d) If managed pollinators will be used during the growing season, then application of a neonicotinoid is prohibited.

Section 6990.16. Neonicotinoid Use on Miscellaneous Crops

The provisions of this section apply to any neonicotinoid application made to a miscellaneous crop: coffee, peanuts, globe artichoke, hops, mint, and tobacco.

(a) *Coffee and peanuts.*
(1) Application of a neonicotinoid is prohibited during bloom.
(2) Application of more than one neonicotinoid active ingredient during the growing season is prohibited.
(3) Use of more than one application method, soil or foliar, during the growing season is prohibited.
(4) If managed pollinators will be used during the growing season, then application of a neonicotinoid is prohibited.

(b) *Globe artichoke, hops, mint, and tobacco.* When globe artichoke, hops, mint, and tobacco crops are harvested before bloom, an application of a neonicotinoid to these crops is not subject to the provisions of this article. Otherwise, an application of a neonicotinoid to these crops is prohibited.