

Impact of Diamondback Moth on Desert Cole Crops, 2016-2021

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Introduction

In the fall of 2016, widespread infestations of an invasive diamondback moth, *Plutella xylostella*, (DBM) population occurred in all vegetable growing regions in Arizona and continued throughout the remainder of the spring 2017 growing season. It was quickly determined that the source of the DBM populations originated from infested transplants grown in desert nurseries. Within weeks of transplanting, PCAs and growers found that they could not adequately control the DBM infestations. It was later discovered that the invasive DBM population was resistant to the first generation diamide insecticides (Coragen, Beseige, Belt and Vetica) commonly used to control Lepidopterous larvae. Soon after the first transplanted fields began to harvest in November, several growers reported that seriously infested fields suffered significant yield reductions, and/or incurred extremely high control costs. By late December, DBM populations began to spread from the infested transplanted fields to direct-seeded crops throughout the region, causing further losses. By February, reports of infested broccoli, cabbage, kale, and cauliflower fields were routine. The DBM infestations experienced by Arizona growers in 2016-17 were not anticipated, and overall, resistant DBM caused serious losses in Cole crops.

However, going into the past four growing seasons, PCAs and growers remained apprehensive about resistant DBM reappearing on their fall crops. Fortunately, DBM populations have not reached outbreak levels since the 2016 fall season, and few if any complaints from PCAs or growers of uncontrollable DBM infestations, crop damage or yield losses were received since 2016-17 season. Furthermore, PCAs reported having no difficulty controlling larvae or adults with commonly used insecticides, including the diamides (Coragen/Besiege). Field trials and lab bioassays conducted over the past four seasons at YAC confirmed that the local DBM populations were susceptible to these insecticides. Field inspections of transplants yielded few larvae on plants arriving from local and coastal nurseries. Thus, we have concluded that the DBM that appeared in fall 2017-2020 were a distinctly different population than those that infested crops in the fall of 2016. To document the differences in impact of the DBM on Arizona Cole crops over the past 4 years we conducted two-part surveys of growers and PCAs from Yuma and Maricopa Co., AZ and Imperial Co., CA in April of each year to estimate the severity of DBM on direct-seeded and transplanted Cole crops.

Survey Methods

A two-part survey was conducted during our annual Lettuce Insect Crop Losses Workshop held at the UA Yuma Ag Center in April in 2017-2020. In 2020, the surveys were emailed to PCAs to complete where a total of 12 PCAs and growers completed surveys. In the first part of the survey, respondents were anonymously requested to estimate the acreage they managed by commodity, and of those acres, the percentage where DBM was present. PCA and growers were then asked to estimate the acreage where DBM was considered problematic (i.e., they had difficulty in controlling DBM). They were asked to estimate the number of sprays that were applied to each specific commodity, and the average yield loss attributed to DBM.

In the second part of the survey, the intensity of chemical management required to control DBM, and the associated level of control provided by each insecticide product was estimated. Respondents were provided an inclusive list of available insecticides used for DBM control and asked to estimate the percentage of acres treated for each product and number of sprays applied. To estimate insecticide product performance, respondents were asked to rate the level of control that each product provided in controlling DBM using the following scale: 4-Excellent; 3-Good; 2-Fair; 1-Poor; and 0-No control. Totals and percentages provided in the report were averaged across all completed surveys.

Impact of DBM on Cole Crop Commodities

The population abundance of DBM in the desert in 2020-21 was similar to the past three seasons, but significantly lower than what was observed under widespread outbreak conditions in 2016. This is based on PCA comments and personal observations of experimental and commercial Cole crops during both growing seasons.

Results from areawide pheromone trapping that started in December 2016 show that DBM moth activity was significantly higher in spring 2017 compared to the past four years (**Fig 1**). Although seasonal moth captures varied at lower levels from 2018 to 2020, larval populations in fields were low in each spring and fall season. When DBM infections do reach levels that require control, they have typically been in late spring crops. This is consistent with the significantly reduced DBM larval populations observed in fields within the Yuma copping system. Interestingly, trap catches during the summer months of all three years show that DBM were non-existent in July and August due to the unavailability of suitable *brassica* host plants. In essence, the populations become extinct during this two-month window when Cole crops and brassica weeds are absent. This supports our hypothesis that DBM disappear in the summer, only to reappear in the fall via transplant introductions or on wind currents during monsoon weather events or remnants of tropical storms/hurricanes in Mexico.

Following the inactivity of DBM during the summer, pheromone trapping data indicates that moths begin to reappear in traps placed adjacent to recently transplanted and direct-seeded broccoli, cabbage, and cauliflower crops in early-mid September (**Fig 2**). Early activity appears to be associated with transplants, but during 2018 and 2019 the sharp increases in moth populations in October occurred following the remnants of Hurricane Rosa (Sep 30), and in 2019 following remnants of former Hurricane Lorena up from Baja California (Sept 24). This strongly supports our assertion that these DBM populations migrated into the area on these storms. The similarity in moth counts in traps placed in both transplanted and direct-seeded crops (**Fig 2, 2018 and 2019**) supports this hypothesis. Shortly thereafter, PCAs began reporting DBM larvae appearing on seedling stands and newly transplanted crops. We also began to pick up larvae at this time on direct-seeded broccoli crops at YAC. However, in the fall of 2020, monsoon activity was negligible in Yuma and no tropical storms/hurricanes were reported in the region. Accordingly, we observed higher activity DBM adult in traps adjacent to transplanted fields in mid-September. A similar peak in transplanted fields was observed in November, suggesting that transplants may also play an important role in annual reinfestation of fall Cole crops in the absence of wind events. Fortunately, DBM populations never reached outbreak status since 2016 and we've received no complaints from PCAs or growers of DBM infested transplants originating from local nurseries. Finally, DBM larvae were effectively controlled with both soil (Coragen, Verimark) and foliar (Radiant, Proclaim, Coragen and others) insecticides throughout the growing season.

Results from the first part of the survey clearly show that DBM had a minimal impact on both transplanted and direct-seeded commodities in 2020-21 (**Table 1**). A total of 12 completed surveys represented an estimated total of 15,782 acres of Cole crops in Yuma, Maricopa, and Imperial counties. Transplanted cauliflower and direct-seeded broccoli were the most reported commodities and had the highest numbers of acres where DBM were present. Overall, the estimated average number of acres where DBM were considered problematic, the number of sprays applied to control DBM, and the

average yield loss for all the *brassica* commodities in 2020-21 were similar to the previous three seasons and extremely low relative to the 2016 outbreak season. For a direct comparison with estimates:

From 2016-2017 see <https://acis.cals.arizona.edu/agricultural-ipm/vegetables/vipm-archive/vipm-insect-view/impact-of-diamondback-moth-on-arizona-cole-crops-2017-survey-results> ;

From 2017-18 see <https://acis.cals.arizona.edu/agricultural-ipm/vegetables/vipm-archive/vipm-insect-view/diamondback-moth-on-arizona-cole-crops-2018-survey-results>

From 2018-19 see <https://acis.cals.arizona.edu/agricultural-ipm/vegetables/vipm-archive/vipm-insect-view/diamondback-moth-on-arizona-cole-crops-2018-19-survey-results> .

From 2019-2020 see [200819-impact-of-dbm-on-az-cole-crops-survey-2019-20.pdf \(arizona.edu\)](https://acis.cals.arizona.edu/agricultural-ipm/vegetables/vipm-archive/vipm-insect-view/diamondback-moth-on-arizona-cole-crops-2019-20-survey-results)

When averaged across all commodities, the percentage of total acres where DBM were considered problematic was less than 3% in last season compared with almost 60% in 2016-17 (**Fig 3**). The reduction in problematic acres were similar when considering the major transplanted and direct-seeded commodities grown during the past three seasons (**Fig 4 and 5**). Yield losses attributed to DBM in transplanted and direct-seeded commodities were similarly negligible in 2020-21 as well (**Fig 6 and 7**), but damage to transplanted cabbage was higher than the three previous seasons. These losses were still low compared with unusually high losses in 2016. Consequently, in the 2017-2020 seasons, PCAs reported that significantly fewer spray applications were required to control DBM in these crops compared 2016 during the outbreak (**Fig 8-9**). In 2020-21, PCAs on average required no more than a single foliar spray to control DBM in broccoli and cauliflower, and 1.6 spray in transplanted cabbage. These data clearly show how differently the DBM infestations impacted desert Cole crops during the past four growing seasons.

Insecticide Usage, Efficacy, and Resistance

Estimated insecticide usage for DBM control on Cole crop commodities for all four seasons is shown in **Table 2**. Overall, significantly fewer acres were treated, and fewer sprays were applied during the past four seasons compared with 2016-2017. Based on treated acres, Radiant, pyrethroids, and Proclaim were the most applied insecticides used for DBM control last season. Pyrethroids were applied more frequently and treated on a larger percentage of acres, than Radiant and Proclaim. Verimark was applied as a transplant tray drench on greater than 60% of the transplanted cauliflower crops (**Fig 11**). Verimark usage on transplanted broccoli was up and down in cabbage in 2020-21. Overall, the diamides (Coragen and Besiege) were used on more acres last season and performed well compared to 2016. Surprisingly, Exirel, an effective 2nd generation diamide, usage remains light. However, a new diamide product, Harvanta, was well used (17.7% of acers) in its first year on the market.

The PCA ratings on the insecticide field performance of insecticides used against DBM in 2019-2020 are very consistent with research conducted at the Yuma Ag Center this past season. Based on the survey responses, most of the products used by PCAs performed *Good* to *Excellent* (rating of 3-4) in 2019, including the diamide products that were found to be resistant in 2016-17 (**Table 3; Fig 10**). In contrast, survey results from 2016 showed that the highest any one product rated was a 3.0 (Verimark tray drench) and among foliar products in 2016, most products rated Fair-Good (rating of 2-3) except for the diamides, Assail, Intrepid, and the older organophosphates. Field experiments conducted at YAC in 2020-21 showed that most products provided *good-excellent* activity consistent with PCA ratings (**Table 5**). Furthermore, Lab bioassays showed that DBM populations collected from the Yuma Ag Center in fall 2020 and spring 2021 were highly susceptible to Coragen, Radiant, Proclaim, and Exirel (**Table 4**).

Conclusions

We previously concluded that the 2016 DBM outbreaks were attributed to the establishment of a resistant population developing on transplants within local greenhouses that then dispersed into commercial fields at transplanting. This was unusual because in previous years PCAs easily controlled DBM with 1-2 well timed insecticide sprays, as has been the case since the 2016 outbreak where DBM were much lighter and comparable to what PCAs normally expect. Furthermore, the survey clearly indicates that control of the DBM populations in the past three growing seasons generally required no more than a single spray to prevent outbreaks or yield losses. Growers spent considerably less money controlling the pest and yield losses to DBM were negligible. We are still not completely certain where the DBM populations originated from in the past four seasons (2017-2021), but it is likely the DBM adults (moths) immigrated in from Mexico, California or elsewhere last summer via storms, and brassica transplants. Regardless of origin, it is important to note that DBM populations we saw last season were not resistant to the key insecticides used in the desert for management of Lepidopterous larvae. However, it is uncertain what will appear in desert Cole crops in fall 2021.

Acknowledgement

Special thanks go out to all the PCAs and growers who took time away from their busy schedules to participate in the surveys. Without your efforts, much of the data in this report would not exist. Data for seasonal pheromone trapping and insecticide resistance monitoring presented in this report was supported by two Arizona Department of Agriculture, Specialty Crops Block Grants provided by the USDA Agricultural Marketing Service under the award numbers SCBGP-FB17-42 and SCBGP-FB19-21. Additional funding to support resistance monitoring and field insecticide efficacy was provided by various Syngenta, FMC, Corteva, and UPL.

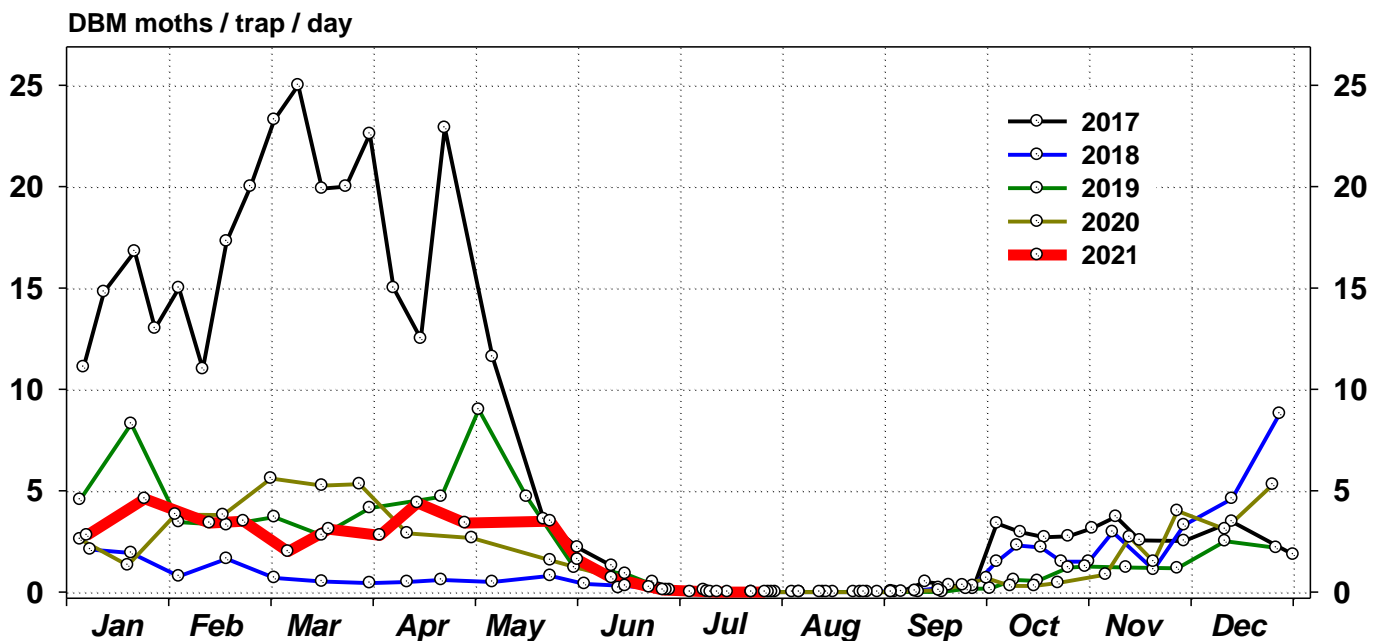


Figure 1. Relative DBM adult activity in Yuma based on pheromone trap catches of moths over the past 4 years. Initial trapping network was established on December 22, 2016.

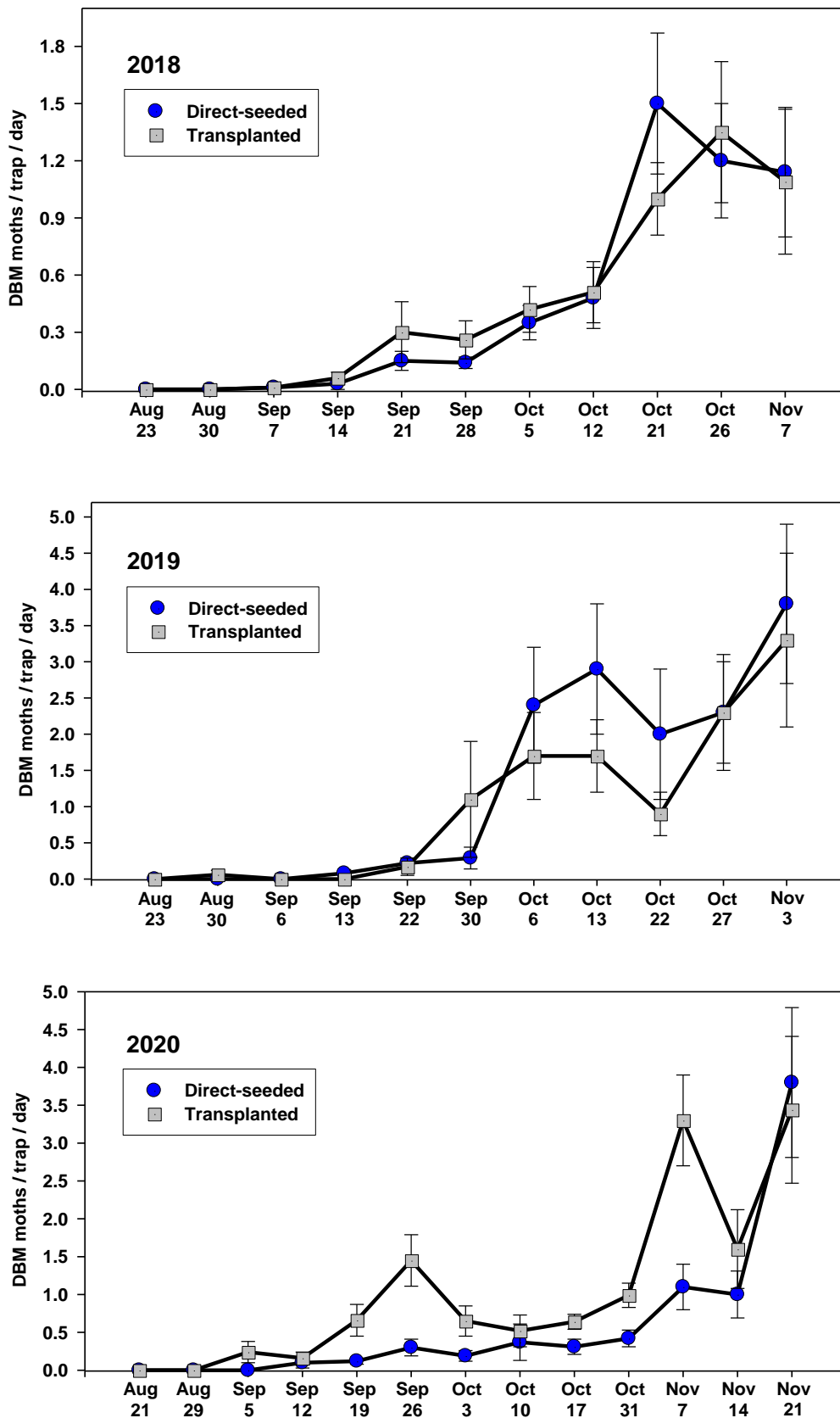


Figure 2. Relative DBM activity in Yuma County based on pheromone trap catches of moths during the fall of 2018-2020 in traps located in transplanted cauliflower and direct-seeded broccoli crops.

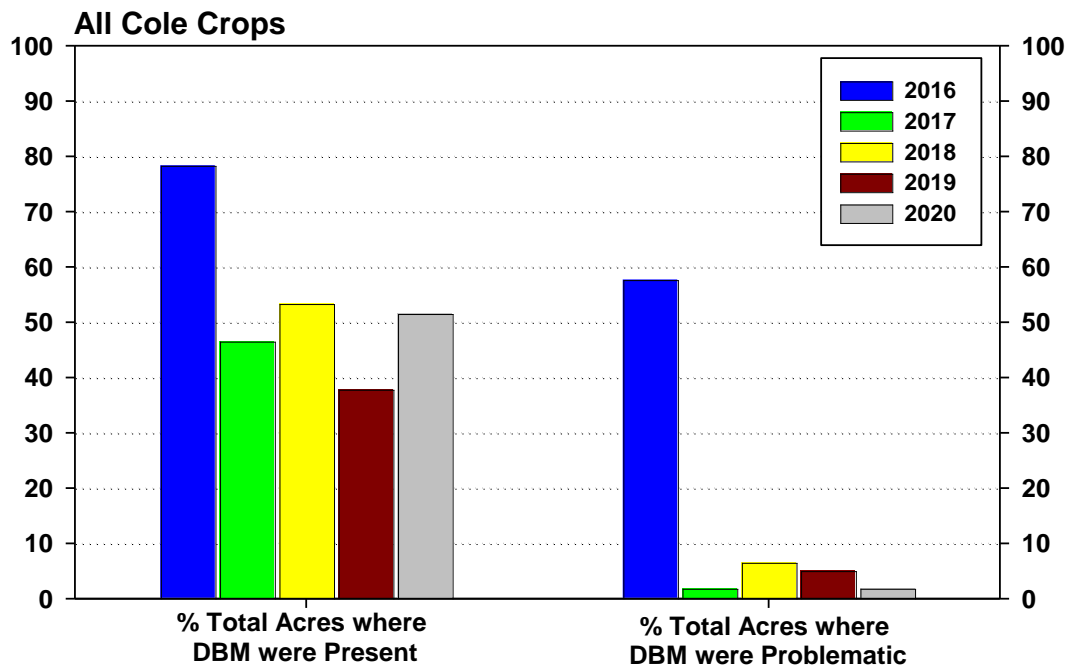


Figure 3. Comparison in the percentage of acres where DBM were present and problematic averaged across all Cole crops in 2016 -2021.

Table 1. Estimated impact of DBM on Cole crop commodities grown in Imperial, Yuma and Maricopa counties, AZ in 2020-21.

Crop	No. PCAs reporting	Total acres	Acres DBM Present ^a	Acres DBM Problematic ^b	Avg. No. Sprays	Max No. Sprays	Yield Loss (%)	Max. Yield Loss (%)
Broccoli-direct seeded	11	6400	2970	175	0.7	1	0	0
Broccoli-transplanted	3	905	820	12.5	0.3	1	0	0
Cauliflower-direct seeded	2	600	300	0	1	1	0	0
Cauliflower -transplanted	8	4096	2301	60	0.5	1	0.4	0.5
Cabbage - direct seeded	1	20	20	1	0	0	0	0
Cabbage - transplanted	3	1335	680	26	2.3	4	2.3	6.7
Baby Kale	4	685	570	0	0.5	1	0	0
Kale-transplanted	1	15	4	0	1	1	0	0
<i>Brassica</i> seed crops	3	26	5	16	0.3	1	1	1.3
Napa/Bok Choy	2	700	700	200	1.5	2	0.5	1
Mizuna/Arugula	1	1000	1000	0	0	0	0	0
		15782	9370	491	0.7	1.2	0.4%	5%

^a Number of acres where DBM was present on plants in the field.

^b Number of acres where DBM was considered a problem; PCAs had difficulty controlling larvae and adults.

^c Average % yield loss in those acres where DBM was considered a problem (difficult to control).

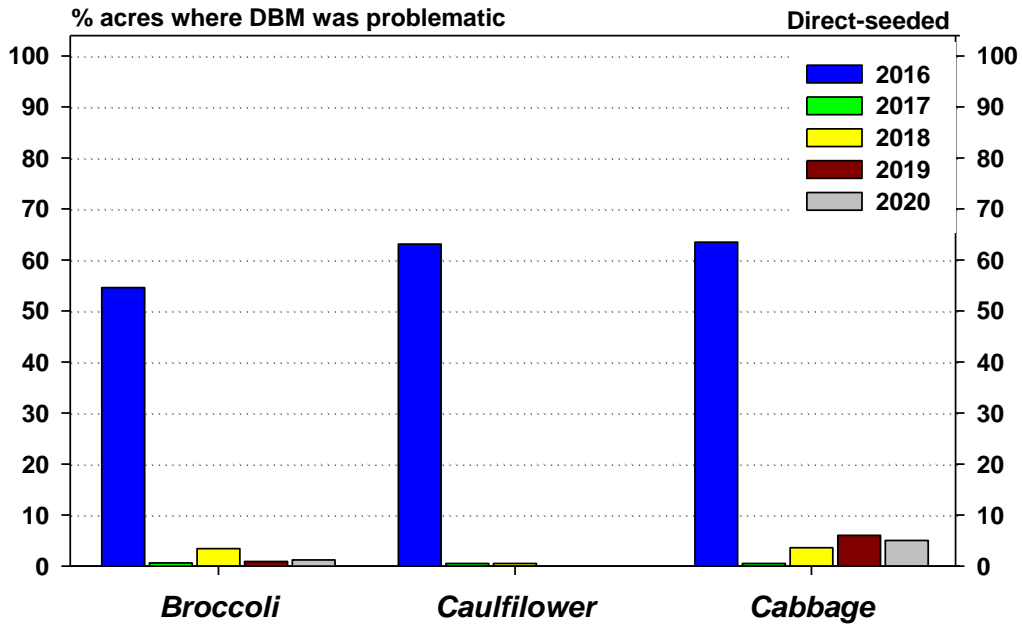


Figure 4. Comparison in the percentage of acres where DBM were considered problematic on direct-seeded Cole crops in 2016-2021.

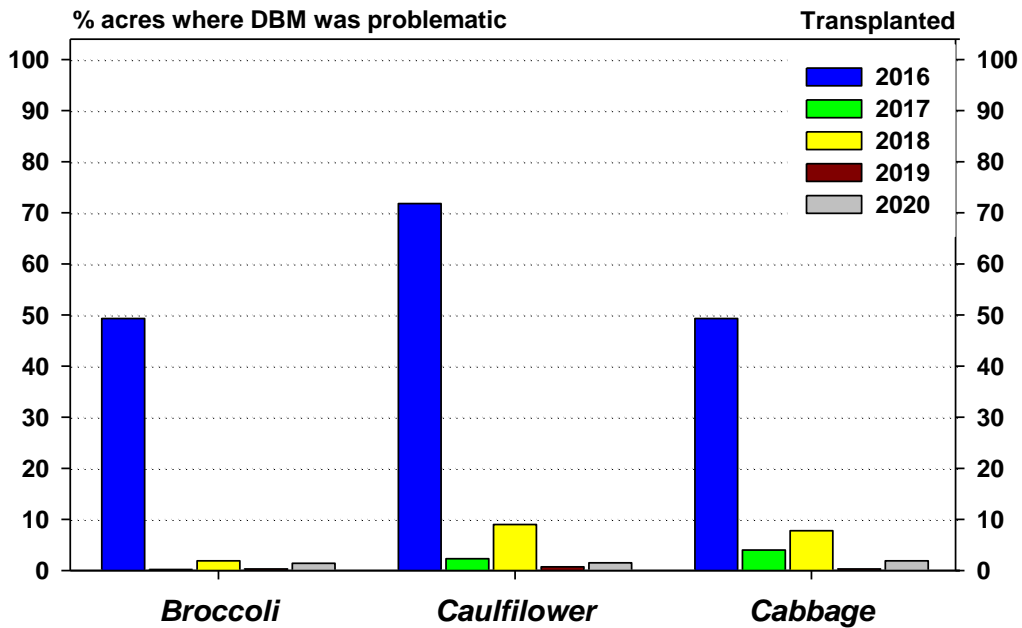


Figure 5. Comparison in the percentage acres where DBM were considered problematic on transplanted Cole crops in 2016-2021.

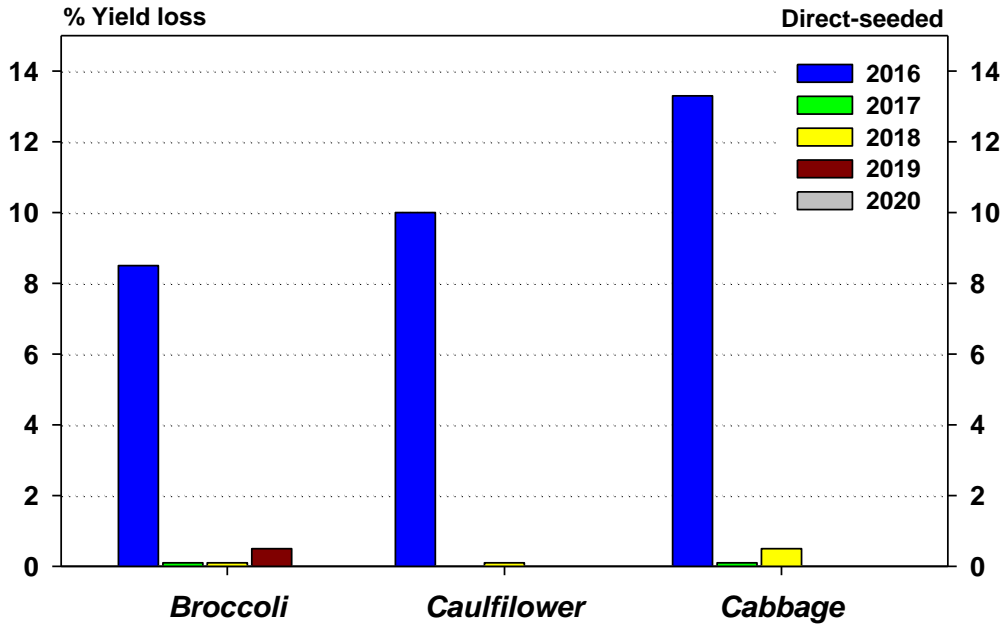


Figure 6. Comparison in the percent yield loss attributed to DBM on direct-seeded Cole crops in 2016-2021.

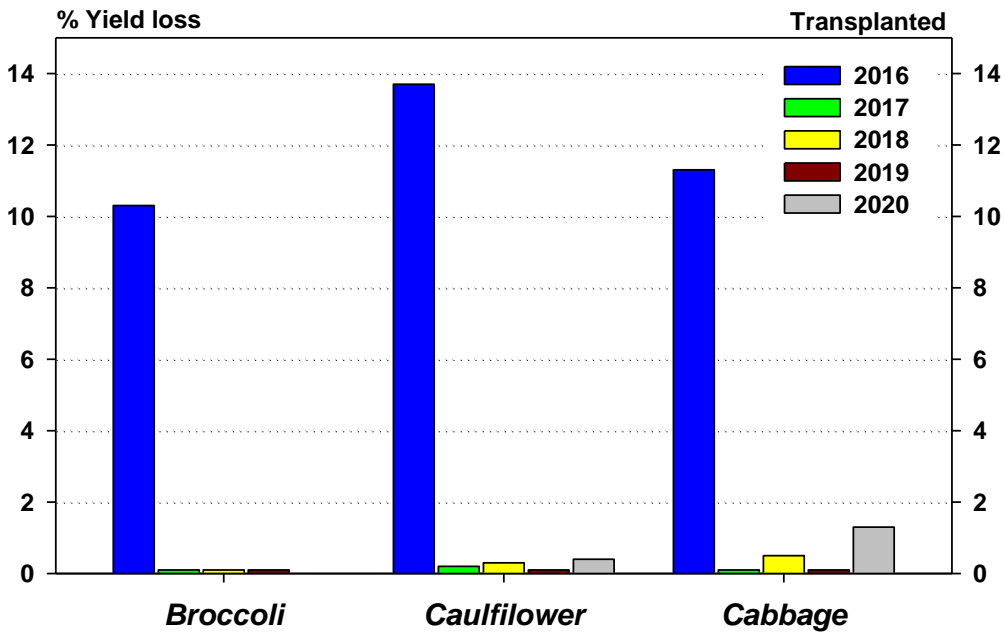


Figure 7. Comparison in the percent yield loss attributed to DBM on transplanted Cole crops in 2016-2021.

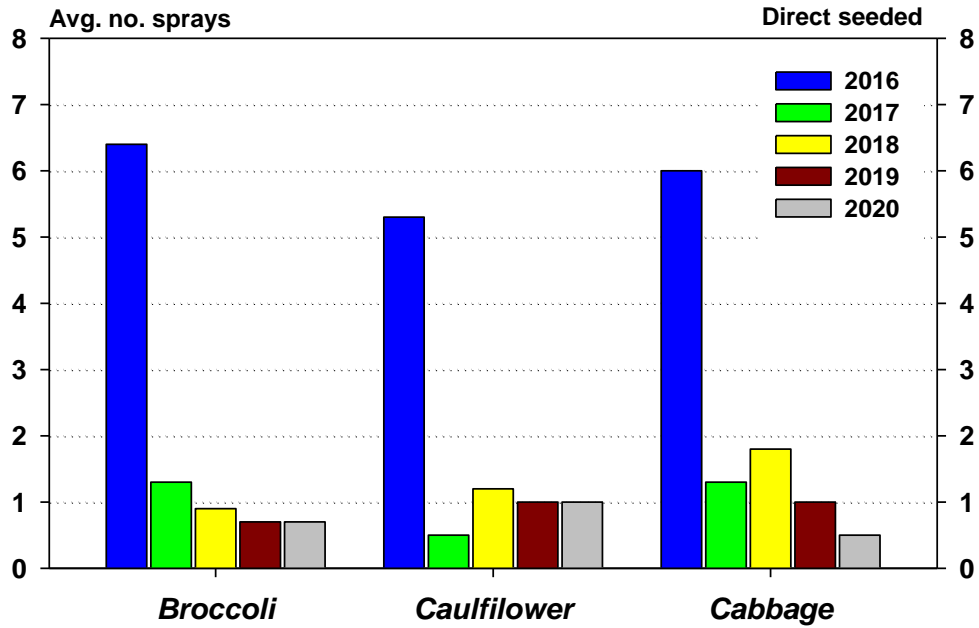


Figure 8. Comparison in the average number of sprays for DBM on direct-seeded Cole crops in 2016-2021.

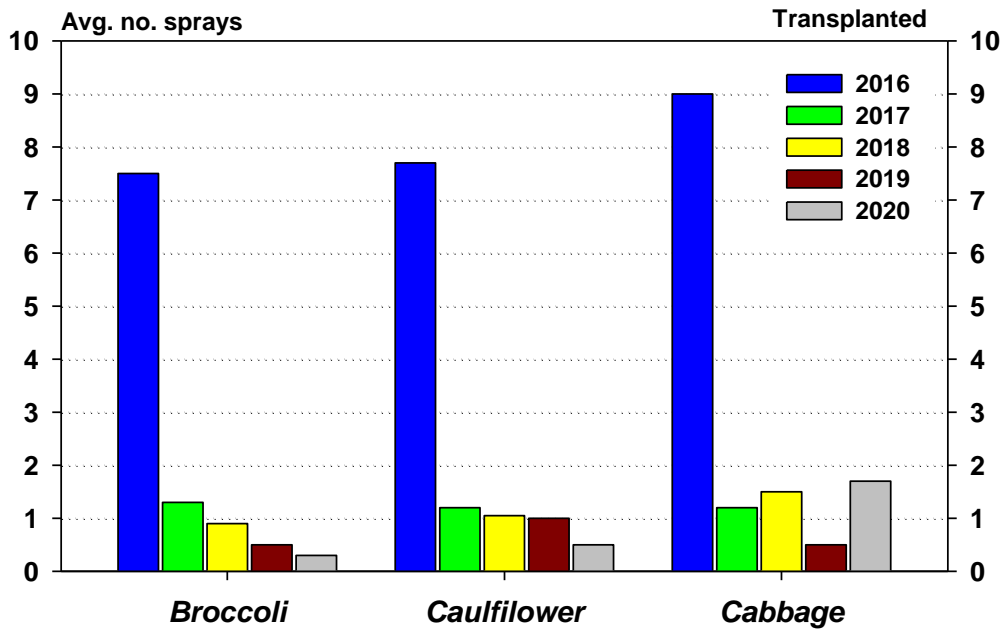


Figure 9. Comparison in the average number of sprays for DBM on transplanted Cole crops in 2016-21.

Table 2. Insecticide Usage for DBM Control on Desert Cole Crops in the 2016-2021 growing seasons.

Insecticide	2020-21		2019-2020		2018-2019		2017-18		2016-17	
	% Acres treated	Avg. no. sprays	% Acres treated	Avg. no. sprays	% Acres treated	Avg. no. sprays	% Acres treated	Avg. no. sprays	% Acres treated	Avg. no. sprays
Pyrethroid	60.8	2.2	37.8	2.5	28.5	2.4	50.2	2	98.2	3.3
Radiant	56.5	1.4	42.1	1.6	37.5	1.5	57.9	1.4	85.4	5.5
Proclaim	44.2	1.2	28.2	1.1	21.9	1.1	29.4	1.2	83.9	2.9
Verimark	18.6	1	13.9	1	22.6	1	34.6	1	-	-
Besiege	18.2	1	0.7	1	4.7	1	5	1	41.9	2.4
Harvanta	17.7	1.7	-	-	-	-	-	-	-	-
Entrust	14.6	1.7	7.8	1.7	8.5	1.7	17	1.8	32.5	2.2
Xentari/Agree	14.5	1	6.2	1.7	7.5	1.1	32.4	1.8	6.3	1
Lannate	13.9	1	5.8	1.5	6.2	3	19.7	1.3	49.8	2.5
Intrepid	13.9	1	4.8	1	9.9	1.5	20.9	1	9.3	1
Coragen (soil)	8.7	1	13.8	1	8.3	1	13.7	1	14.1	1.4
Movento	8	1	-	-	-	-	-	-	-	-
Assail	7	1	1.1	1	0.7	1	0	0	-	-
Exirel	6.5	1	2.7	1	3.9	1	1.7	1	18.1	1.2
BtNow	2.4	1	-	-	-	-	-	-	-	-
Avaunt	1.9	1	2.1	1	1.4	1	10.1	1	14.7	1.2
Coragen (foliar)	0.5	1	11.9	1	6.1	1	12.5	1	42.6	1.4
Belt	-	-	0	0	5.1	1.5	9.3	1	65.1	2.8
Cormoran	-	-	-	-	1.3	1	2.9	1	39.4	1.7
Phreromone	-	-	12.7	1	8.4	1.5	-	-	-	-
Malathion	-	-	-	-	-	-	5.2	1	22.9	1.8
Dibrom	-	-	-	-	-	-	3.3	1	15.1	1.2
Acephate	-	-	-	-	-	-	1.9	1	5	1.2
Chlorpyrifos	-	-	-	-	-	-	0.4	1	25.7	1.2

^a Total treated acres estimated by multiplying: Avg. % acres treated * Avg. no. of applications * Acreage estimated by participating PCAs in the survey.

Table 3. Performance Rating ^a for insecticides used for DBM Control on Desert Cole Crops in the 2016-21 growing seasons.

	2020-2021		2019-2020		2018-2019		2017-18		2016-17	
	No. PCAs using product ^a	Rating ^b	No. PCAs using product ^a	Rating ^b	No. PCAs using product ^a	Rating ^b	No. PCAs using product ^a	Rating ^b	No. PCAs using product ^a	Rating ^b
Verimark	5	4.0	6	4.0	9	3.9	10	4.0	2	3.0
Exirel	2	4.0	4	3.8	5	3.8	2	4.0	7	2.6
Harvanta	3	4.0	-	-	-	-	-	-	-	-
Lannate	1	4.0	2	3.5	3	3.7	6	3.2	15	2.4
Intrepid	1	4.0	3	2.7	2	3.0	5	2.6	6	1.7
Entrust	2	3.5	5	3.8	3	4.0	5	3.8	11	2.7
Coragen (Foliar)	1	4.0	3	2.7	6	3.3	6	3.5	16	1.1
Radiant	10	3.5	13	3.6	21	3.5	17	3.7	20	2.5
Proclaim	9	3.3	8	3.4	13	3.3	12	3.7	19	2.3
Besiege	5	3.0	2	2.5	2	2.0	2	3.5	7	1.0
Coragen (soil)	2	3.0	4	3.0	1	3.5	3	3.7	3	2.3
Pyrethroid	8	3.0	7	2.9	10	2.5	11	2.9	19	1.3
Avaunt	2	3.0	4	2.8	4	2.8	4	2.8	11	1.0
Xentari/Agree	2	3.0	3	2.7	5	2.8	8	3.0	17	2.6
Movento	2	2.5	2	2.5	1	4.0	2	4.0	6	2.6
Assail	1	2.0	1	4.0	1	3.0	0	-	9	1.0
BtNow	1	2.0	1	2.0	-	-	-	-	-	-
Pheromone	-	-	1	3.0	1	3.0	-	-	-	-
Cormoran	-	-	-	-	1	4.0	1	4.0	-	-
Belt	-	-	-	-	2	3.5	4	3.3	9	1.7
Dibrom	-	-	-	-	-	-	1	4.0	16	2.3
Acephate	-	-	-	-	-	-	1	4.0	3	1.7
Malathion	-	-	-	-	-	-	2	3.5	4	1.5
Chlorpyrifos	-	-	-	-	-	-	1	2.0	5	1.6

^a A total of 12 PCAs in 2020-21 ; 16 PCAs in 2019-20; 25 PCAs in 2018-19; 25 PCAs in 2017-18; and 20 PCA surveys in 2016-17.

^b Performance rating is based on the level of control achieved under field conditions for each product using the following scale: 4-Excellent control; 3-Good control; 2-Fair control; 1-Poor control; and 0-No control.

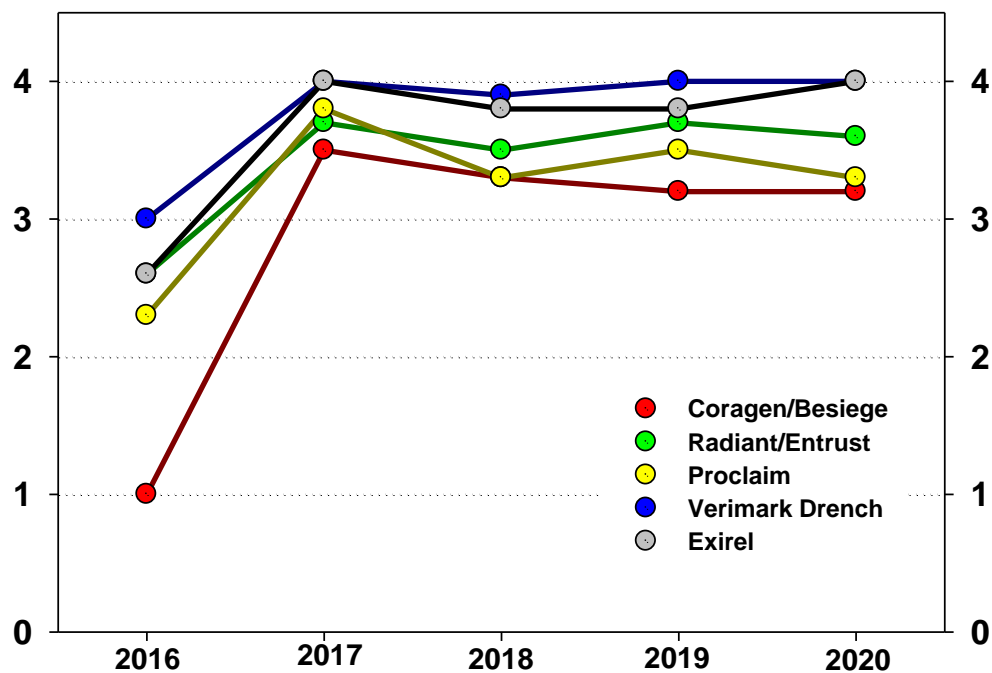


Figure 10. Avg. Performance Rating for the major insecticides used for DBM Control on Desert Cole Crops. Rating is based on the level of control achieved under field conditions for each product using the following scale: 4-Excellent control; 3-Good control; 2-Fair control; 1-Poor control; and 0-No control.

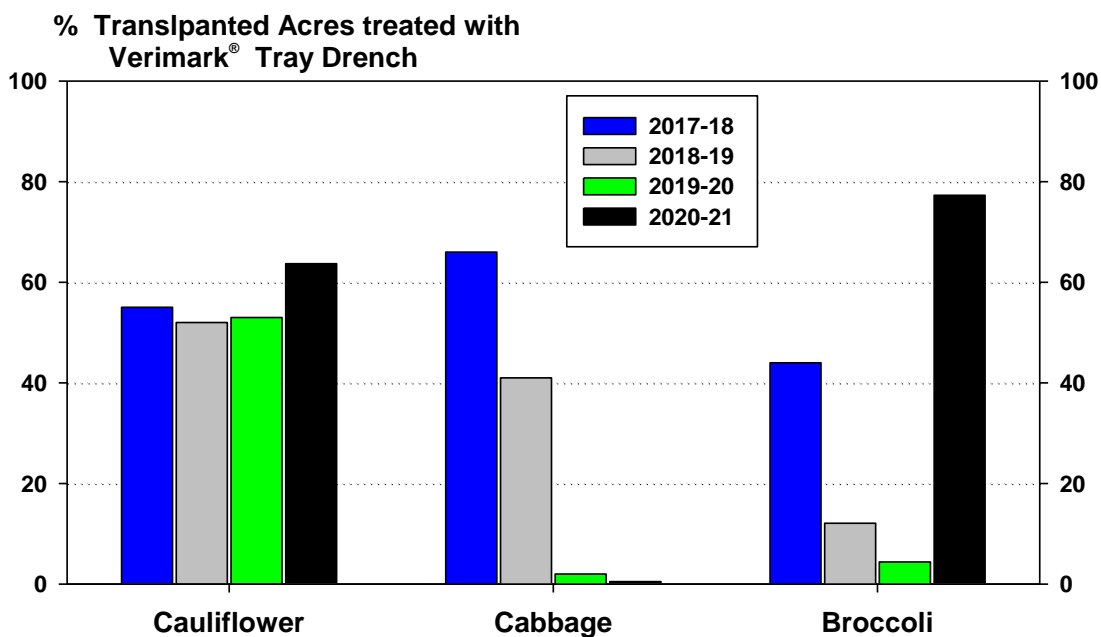


Figure 11. Percentage transplanted acres treated with Verimark Tray Drench in 2017-21.

Table 4. Relative toxicity of key insecticides against Arizona field collected populations of diamondback moth, *P. xylostella*.

Field Population	Date collected	Proclaim		Radiant		Coragen/Besiege		Exirel/Verimark	
		LC ₅₀ ¹	RR ²	LC ₅₀	RR	LC ₅₀	RR	LC ₅₀	RR
UA-YAC_ Susceptible	Fall 2017	0.11	-	0.70	-	1.33	-	0.97	-
Scottsdale, AZ	Fall 2016	1.23	11.2	12.15	17.4	590.1	443.7	-	-
Roll, AZ	Fall 2016	0.87	7.9	9.15	13.0	392.5	295.1	-	-
Yuma, AZ- Co. 9	Fall 2016	0.71	6.5	16.51	23.6	588.0	442.1	-	-
Yuma, AZ- Co. 11	Fall 2016	0.26	2.4	15.99	22.8	731.7	550.2	4.22	4.4
Yuma, AZ - Co. 13	Fall 2016	0.83	7.5	2.50	3.6	411.4	309.3	-	-
Yuma, AZ - Co. 14	Fall 2016	5.84	53.0	7.11	10.2	190.2	143.6	-	-
UA-Yuma Ag Center, AZ	Spring 2017	1.35	12.3	-	-	246.8	185.6	-	-
Roll, AZ	Fall 2018	2.55	23.2	27.74	39.6	161.3	121.3	20.19	20.8
Yuma Valley, AZ	Fall 2018	3.93	35.7	25.17	36.0	485.9	365.3	15.24	15.71
UA-Yuma Ag Center, AZ	Fall 2018	0.47	4.3	5.17	7.4	176.8	132.9	7.64	7.8
UA-Yuma Ag Center, AZ	Spring 2019	3.12	28.3	66.0	94.3	114.4	86.0	11.74	12.1
UA-Yuma Ag Center, AZ	Fall 2019	0.15	1.4	1.12	1.6	1.8	1.4	1.98	2.0
UA-Yuma Ag Center, AZ	Spring 2020	0.29	2.6	1.84	2.6	7.62	5.7	0.81	0.8
UA-Yuma Ag Center, AZ	Fall 2020	0.24	2.3	1.23	1.1	6.1	4.6	1.35	1.4
UA-Yuma Ag Center, AZ	Spring 2021	0.48	4.4	1.56	1.5	5.9	4.4	6.12	6.3

¹ mg [AI]/ml; LC₅₀ calculated from laboratory bioassays using standard IRAC methods <https://irac-online.org/>

² Resistance ratio = LC₅₀ of the field collected population / LC₅₀ of the susceptible population (YAC -Susceptible 2017; collected from the Yuma Agricultural Center in fall 2017)

Table 5. Activity of insecticides against DBM larval populations based on PCA field performance, and local research that evaluated field efficacy and laboratory bioassays in Yuma Arizona, 2020-21.

	Insecticide Activity Against DBM Larvae		
	PCA Surveys	Field Efficacy	Lab Bioassay
Radiant			
Proclaim			
Xentari / Agree			
Entrust			
Exirel			
Harvanta			
Avaunt			
Verimark			
Dipel / BtNow			
Lannate			
Coragen (soil)			
Coragen (Foliar)			
Besiege			
Pyrethroids			
Assail			
Pheromone			
Movento			
Intrepid			

