Diamondback Moth on Desert Cole Crops: Survey Results from 2016-2018

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Introduction

In the fall of 2016, widespread infestations of an invasive diamondback moth (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 greenhouses. 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 very resistant to the 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 2017 and 2018 fall growing seasons, PCAs and growers remained apprehensive about resistant DBM reappearing on their fall crops. Fortunately, DBM populations were much lighter than the 2016 fall season, and we received no complaints from PCAs or growers of uncontrollable DBM infestations, crop damage or yield losses in 2017 and 2018. Furthermore, PCAs reported having no difficulty controlling larvae or adults with commonly used insecticides, including the diamides. Field trials and lab bioassays conducted at YAC confirmed that the local DBM populations were susceptible to these insecticides. Field inspections of transplants yielded no larvae on plants arriving from local and coastal nurseries. Thus, we have concluded that the DBM that appeared in fall 2017 and 2018 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 between the 2016-17, 2017-18 and 2018-2019 growing seasons, we conducted another two-part survey of growers and PCAs from Yuma and Maricopa Co., AZ and Imperial Co., CA in April 2019 to estimate the severity of DBM on direct-seeded and transplanted cole crops.

Survey Methods

A two-part survey was conducted at the annual Lettuce Insect Crop Losses Workshop held at the UA Yuma Ag Center on April 9, 2019. A total of 25 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 extensive list of available insecticides used for DBM control, and asked to estimate the percentage of acers 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.

Impact of DBM on Cole Crop Commodities

The population abundance of DBM in the desert last season was similar to the 2017 season, but significantly lower than what was observed under widespread outbreak conditions in 2016. This is based on 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 both 2018 and 2019 **(Fig 1)**. Although moth numbers were higher in 2019 compared to 2018, field larval populations were low in both spring seasons. This is consistent with the significantly reduced DBM larval populations observed in fields within the Yuma copping system in both seasons. Interestingly, trap catches during the summer months of all three years show that DBM were non-existent in July and August when suitable *brassica* host plants are not available to the pest. In essence, the populations become extinct in the summer. This supports our hypothesis that DBM disappear in the summer, only to reappear in the fall via transplant introductions or on wind currents during weather events. Following these summers of inactivity in DBM trap catches, pheromone trapping data indicates that moths start to appear in traps placed adjacent to recently transplanted and direct-seeded broccoli, cabbage, and cauliflower crops in early-mid September (**Fig 2**). The initial spikes in moth populations in September occurred soon after the remnants of tropical storm Lidia (Sep 4) and a severe monsoon storm (Sep 12) occurred in Yuma in 2017, and in 2018 following the remnants of Hurricane Rosa (Sep 30) in Yuma. This strongly support our assertion that these DBM populations migrated into the area on these storms. This is further supported by similarities in moth counts in traps placed in both transplanted and direct-seeded crops (Fig 2). 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, the DBM populations never reached outbreak status in 2017 or 2018, and unlike 2016, we 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 2018-19 (**Table 1**). A total of 25 completed surveys represented an estimated total of 22,288 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 2018-2019 was similar to 2017-18 and extremely low relative to the 2016 outbreak season. For a direct comparison with estimates from 2016-2017 see https://cals.arizona.edu/crops/vegetables/advisories/more/insect185.html and 2017-18 https://cals.arizona.edu/crops/vegetables/advisories/more/insect214.html. When averaged across all commodities, the percentage of total acres where DBM were considered problematic was about 6% in 2018-19 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 two seasons (**Fig 4 and 5**). Yield losses attributed to DBM in transplanted and direct-seeded commodities were negligible in 2017-18 and 2018-19 as well (**Fig 6 and 7**) compared with unusually high losses in 2016. Consequently, in 2017 and 2018 seasons, PCAs reported that significantly fewer spray applications were required to control DBM in these crops compared with 2016 (**Fig 8-9**). On average, PCAs required a single foliar spray to control DBM in broccoli and cauliflower, and almost 2 sprays in cabbage. These data clearly show how different the DBM infestations were in the three growing seasons.

<u>Insecticide Usage, Efficacy, and Resistance</u>

Estimated insecticide usage for DBM control on cole crop commodities for all three seasons is shown in **Table 2.** Overall, significantly fewer acres were treated and fewer sprays were applied compared during 2017-2018 and even less in 2018-19. Based on treated acres, Radiant, pyrethroids, Lannate and Proclaim were the most commonly applied insecticides used for DBM control last season. Radiant was used by the largest percentage of PCAs and was treated on the largest percentage of acres. Verimark applied as a soil treatment was used on a total of 4655 ac, and was applied as a transplant tray drench on a large percentage of the transplanted cauliflower, cabbage and *Brassica* seed crops (**Fig 10, Table 4**). Among other products that were applied to a large percentage of acres for DBM control included Entrust, Intrepid, Coragen and Xentari. Overall the diamides (Belt, Vetica and Besiege) were used on fewer acres, but performed well compared to 2016. Surprisingly, Exirel, an effective 2nd generation diamide, was used on very few acres compared with 2016.

The PCA ratings on the insecticide field performance of insecticides used against DBM in 2018-19 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 2017, including the diamide products that were found to be resistant in 2016-17 (**Table 3**). 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) with the exception of the diamides, Assail, Intrepid, and the older organophosphates. Field experiments conducted at YAC in 2018 showed that most products provided *good-excellent* activity consistent with PCA ratings (**Table 5**). Furthermore, Lab bioassays showed that a DBM population collected from the Yuma Ag Center in fall 2018 was highly susceptible to Radiant, Proclaim, and Exirel. However, bioassays of DBM collected from both the Yuma Ag center and 2 commercial fields in Nov 2018 showed reduced susceptibility (high resistance ratios) to Coragen, as did a subsequent DBM collection from field plots at the Yuma Ag Center collected in the spring of 2019.

<u>Conclusions</u>

We previously concluded that the 2016 DBM outbreaks were attributed to the establishment of a resistant population on developing transplants within local greenhouses that then dispersed into commercial cole crop fields at transplanting. This was unusual because in previous years PCAs easily controlled DBM with 1-2 well timed insecticide sprays, as was the case in the fall of 2017 and 2018 where DBM were much lighter and would be comparable to what a PCA would normally expect. Furthermore, the survey clearly indicates that control of the DBM populations in the pst two growing seasons generally required a single spray on 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 fall 2017 and 2018 but it is likely the DBM adults (moths) immigrated in from Mexico, California or elsewhere last summer via storms. 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 (i.e., Radiant, Proclaim, Exirel). However, DBM populations from local fields did show resistance to Coragen, albeit at a lower level than experienced in 2016-17.

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.

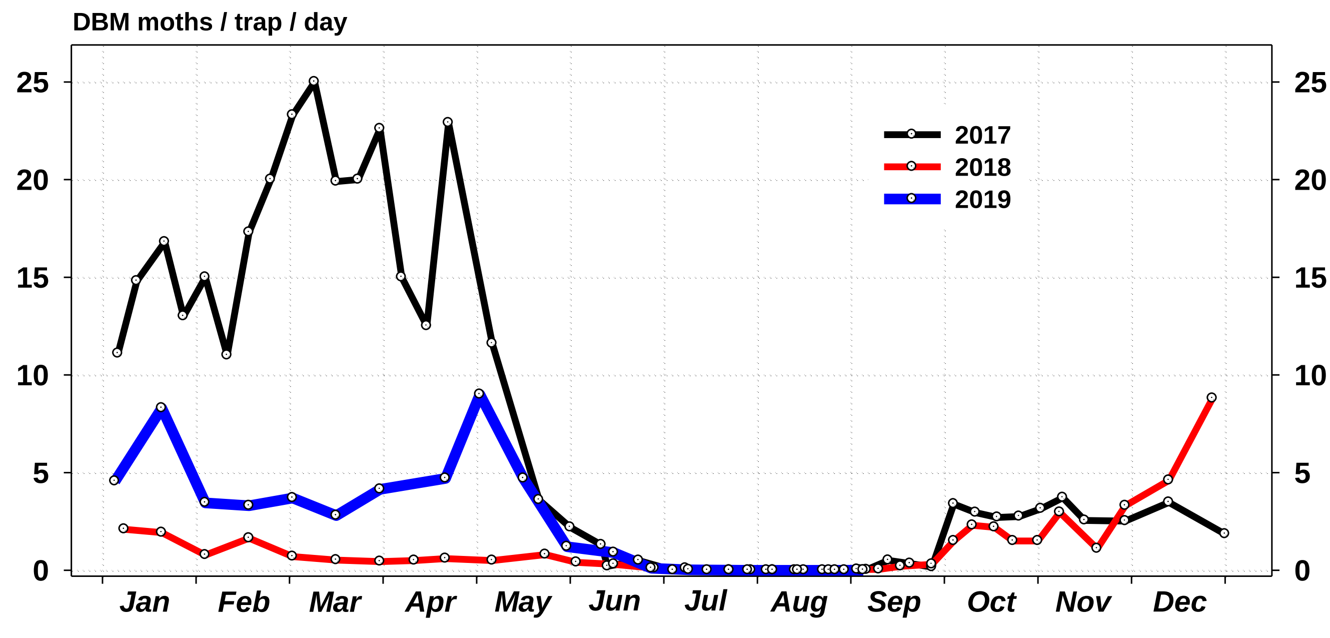

Figure 1. Relative DBM adult activity in Yuma based on pheromone trap catches of moths in 2017, 2018 and 2019. Initial trapping network was established on December 22, 2016.

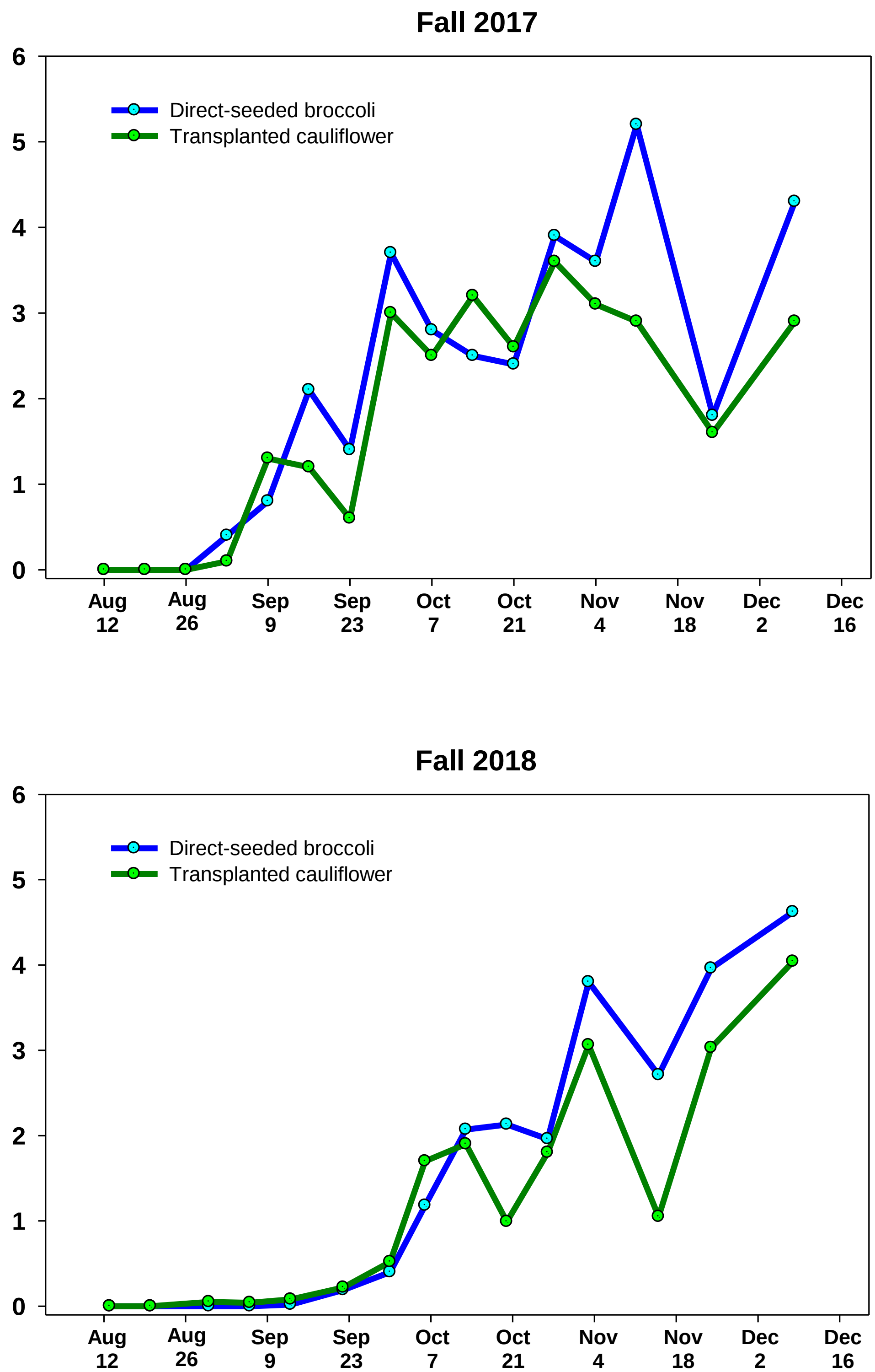

Figure 2. Relative DBM activity in Yuma County based on pheromone trap catches of moths during the fall of 2017 and 2018 from traps located in transplanted cauliflower and direct-seeded broccoli crops.

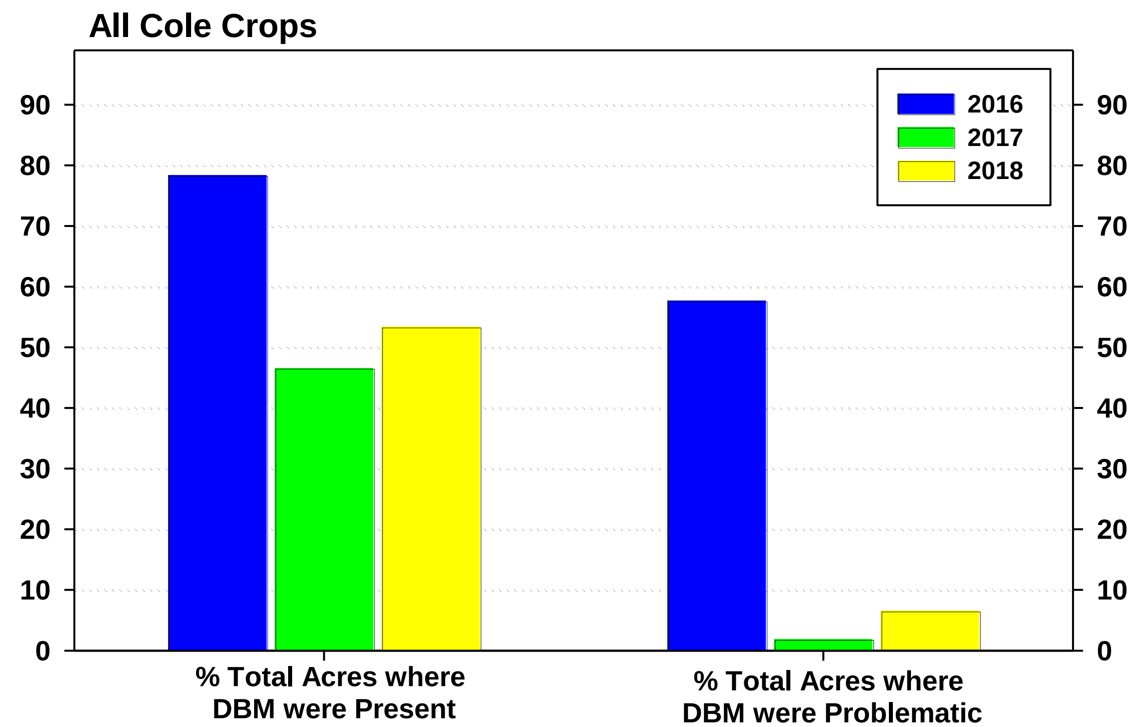

Figure 3. Comparison in the percentage of acres where DBM were present and problematic averaged across all cole crops in 2016 -2018.

Table 1. Estimated impact of DBM on cole crop commodities grown in Yuma and Maricopa counties, Arizona in 2018-2019.

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	21	9284	5559	312	0.9	2.5	0.1	2
Broccoli-transplanted	7	2055	627	40	0.8	2	0.1	0.5
Caulfilower-direct seeded	4	590	341	0	1.3	2	0.1	0.5
Cauliflower -transplanted	24	5571	2550	501	1.1	3	0.3	2
Cabbage - direct seeded	3	116	108	39	2.1	4	3.0	10
Cabbage - transplanted	8	2603	1789	205	1.8	4	0.5	2
Brassica seed crops	6	604	504	290	1.1	2.5	0.2	1
Baby Kale	8	1165	201	0	1.4	5	0.0	0
Kale-transplanted	5	150	76	0	1.6	5	0.0	0
Napa/BokChoy -direct seeded	1	150	150	100	3.0	3	0.0	0
Napa/BokChoy -transplanted	-	-	-	-	-	-	-	-
Mizuna/Arugula	-	-	-	-	-	-	-	-
Brussel sprouts	-	-	-	-	-	-	-	-
		22288	**11905**	**1487**	**1.5**	**3.3**	**0.4**	**10%**

[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).

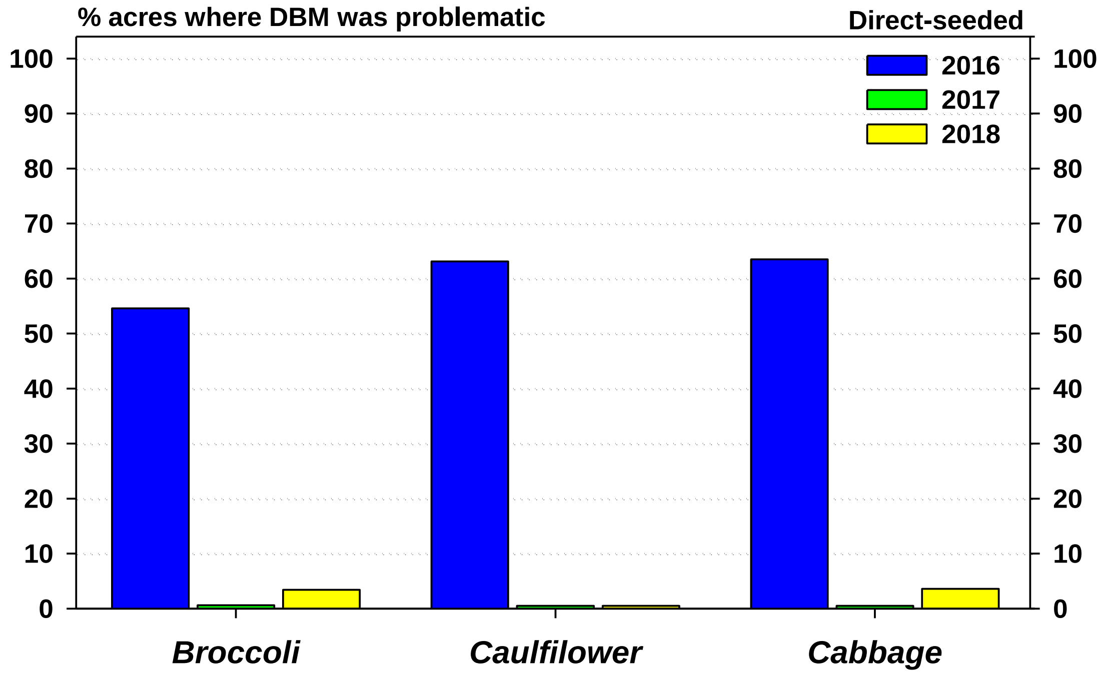

Figure 4. Comparison in the percentage of acres where DBM were considered problematic on direct-seeded cole crops in 2016, 2017 and 2018

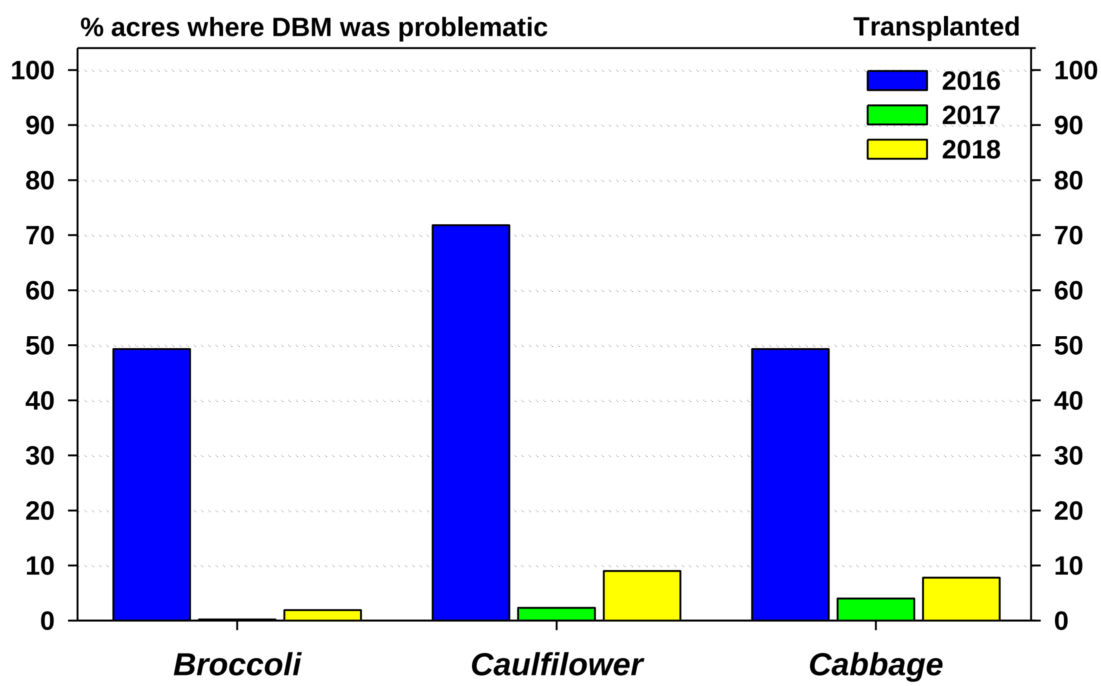

Figure 5. Comparison in the percentage acres where DBM were considered problematic on transplanted cole crops in 2016, 2017 and 2018.

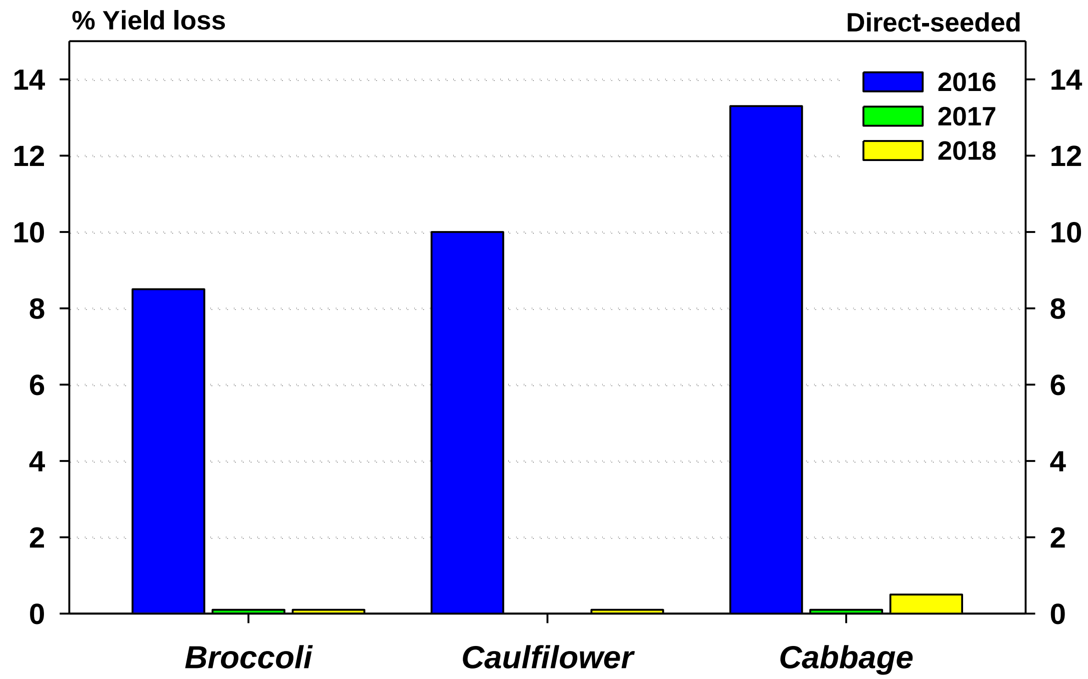

Figure 6. Comparison in the percent yield loss attributed to DBM on direct-seeded cole crops in 2016-2018.

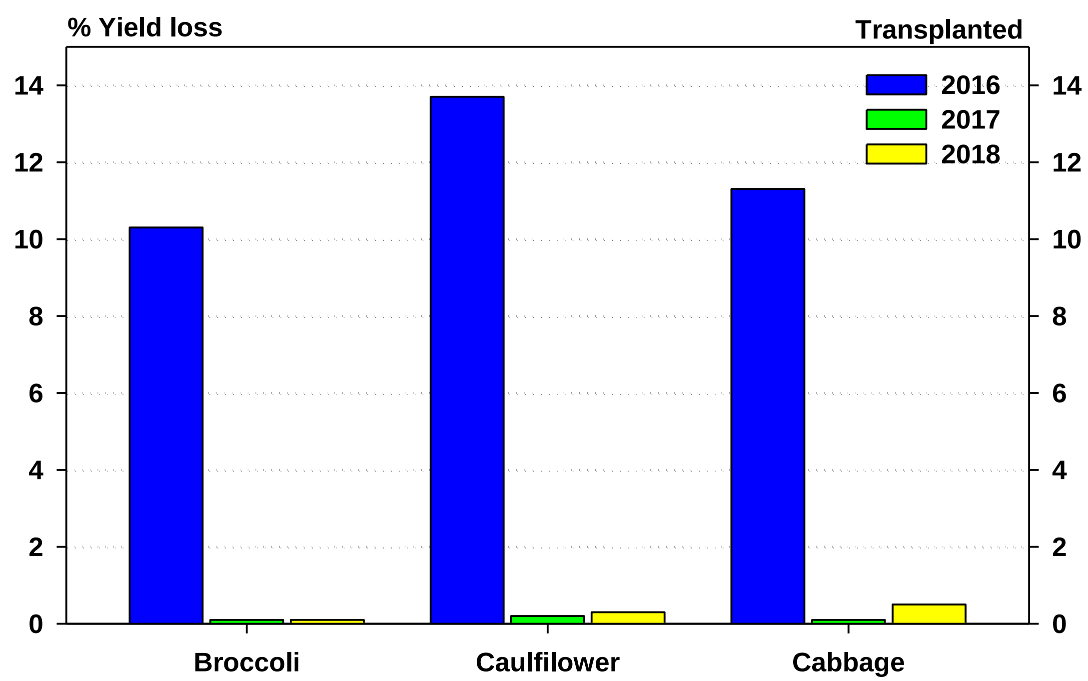

Figure 7. Comparison in the percent yield loss attributed to DBM on transplanted cole crops in 2016-2018.

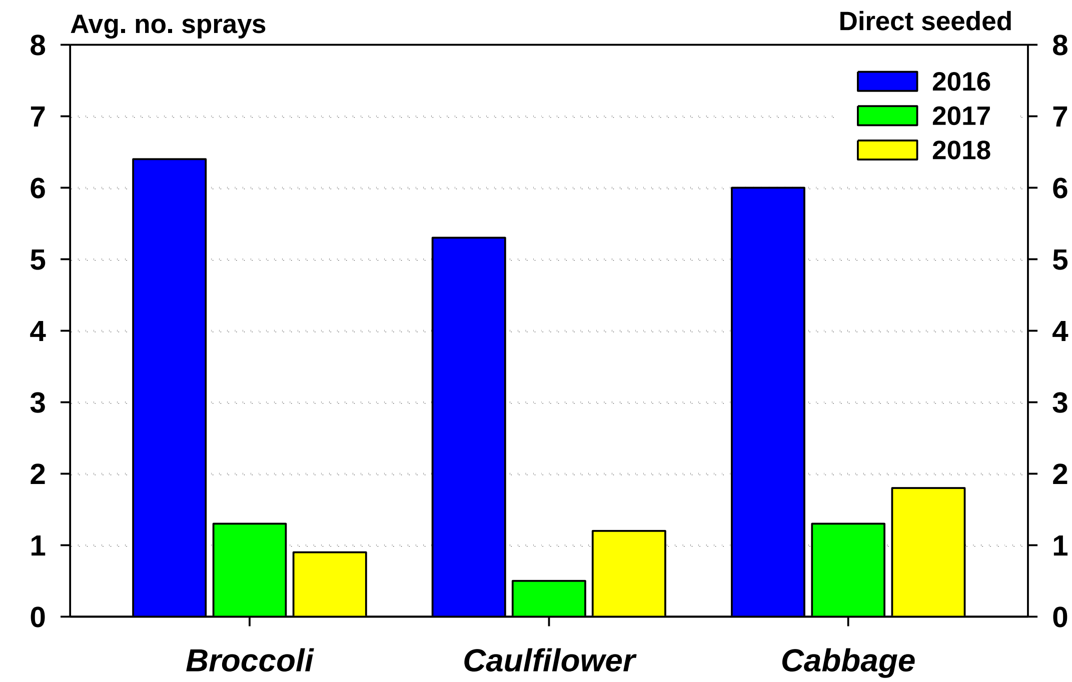

Figure 8. Comparison in the average number of sprays for DBM on direct-seeded cole crops in 2016-2018.

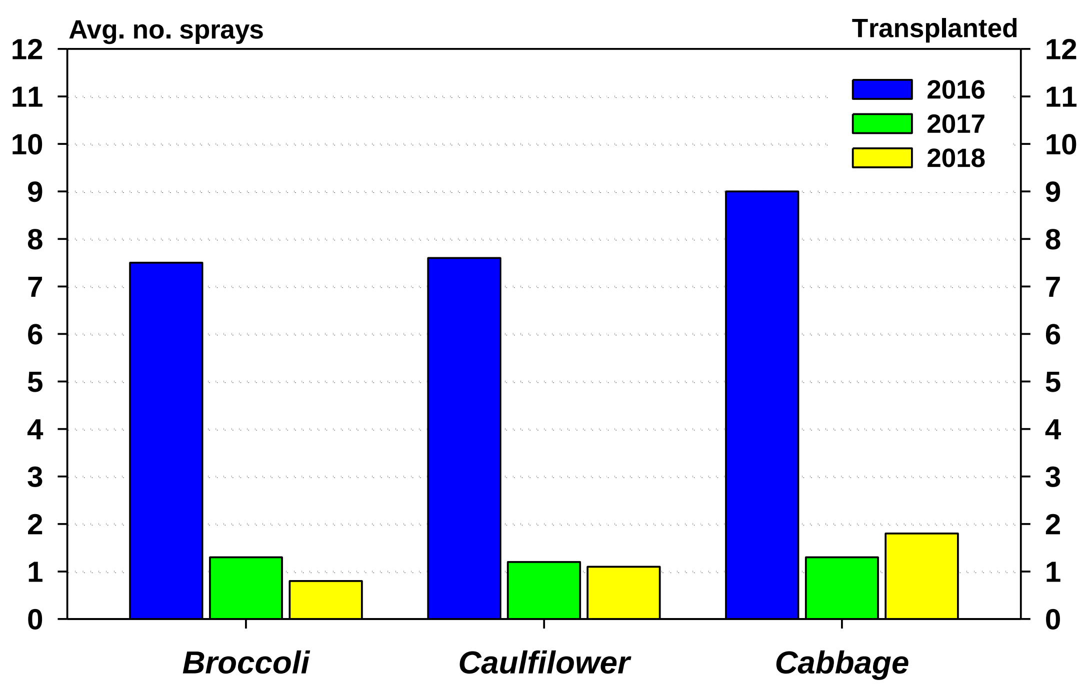

Figure 9. Comparison in the average number of sprays for DBM on transplanted cole crops in 2016-18

Table 2. Insecticide Usage for DBM Control on Desert Cole Crops in the 2017-18 and 2018-19 growing seasons.

	2018-2019				2017-18				2016-17			
Insecticide	**% PCAs using product**	**% Acres treated**	**Avg. no. sprays**	**Treated acres [a]**	**% PCAs using product**	**% Acres treated**	**Avg. no. sprays**	**Treated acres [a]**	**% PCAs using product**	**% Acres treated**	**Avg. no. sprays**	**Treated acres [a]**
Pyrethroid	38	28.5	2.4	13,332	52	50.2	2	19,519	100	98.2	3.3	70,117
Radiant	81	37.5	1.5	11,576	76	57.9	1.4	20,894	95	85.4	5.5	101,629
Lannate	12	6.2	3	5,865	29	19.7	1.3	6,676	75	49.8	2.5	26,938
Proclaim	50	21.9	1.1	4,957	57	29.4	1.2	10,412	95	83.9	2.9	52,645
Verimark	38	22.6	1	4,655	67	34.6	1	7,680	-	-	-	-
Intrepid	12	9.9	1.5	3,056	24	20.9	1	5,051	10	9.3	1	2,012
Entrust	12	8.5	1.7	2,973	24	17	1.8	6,854	55	32.5	2.2	15,470
Belt	8	5.1	1.5	2,019	19	9.3	1	2,072	75	65.1	2.8	39,440
Coragen (soil)	8	8.3	1	1,712	14	13.7	1	3,052	15	14.1	1.4	4,271
Xentari/Agree	19	7.5	1.1	1,658	38	32.4	1.8	14,150	15	6.3	1	1,363
Coragen (foliar)	23	6.1	1	1,248	28	12.5	1	2,778	80	42.6	1.4	12,904
Besiege	8	4.7	1	960	10	5	1	1,117	55	41.9	2.4	21,758
Exirel	23	3.9	1	800	10	1.7	1	370	45	18.1	1.2	4,700
Vetica	4	1.6	1	332	10	0.7	1	150	20	6.4	1	1,385
Avaunt	15	1.4	1	286	19	10.1	1	2,240	35	14.7	1.2	3,817
Cormoran	4	1.3	1	266	5	2.9	1	648	80	39.4	1.7	14,492
Assail	4	0.7	1	155	0	0	0	0	-	-	-	-
Dipel	-	-	-	-	19	12.7	1.8	5,605	15	5	1	1,082
Malathion	-	-	-	-	10	5.2	1	1,150	35	22.9	1.8	8,919
Dibrom	-	-	-	-	5	3.3	1	740	30	15.1	1.2	3,921
Acephate	-	-	-	-	5	1.9	1	420	25	5	1.2	1,298
Chlorpyrifos	-	-	-	-	5	0.4	1	81	45	25.7	1.2	6,673

A total of 25,452 ac was reported from 25 PCA surveys 2017-18, and a total of 22,115 ac were reported from 20 surveys 2016-17.

[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 2016-19 growing seasons.

	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]
Entrust	3	4.0	5	3.8	11	2.7
Cormoran	1	4.0	1	4.0	-	-
Vetica	1	4.0	2	4.0	6	2.6
Verimark	9	3.9	10	4.0	2	3.0
Exirel	5	3.8	2	4.0	7	2.6
Lannate	3	3.7	6	3.2	15	2.4
Radiant	21	3.5	17	3.7	20	2.5
Belt	2	3.5	4	3.3	9	1.7
Coragen (soil)	1	3.5	3	3.7	3	2.3
Proclaim	13	3.3	12	3.7	19	2.3
Coragen (Foliar)	6	3.3	6	3.5	16	1.1
Intrepid	2	3.0	5	2.6	6	1.7
Assail	1	3.0	0	-	9	1.0
Xentari/Agree	5	2.8	8	3.0	17	2.6
Avaunt	4	2.8	4	2.8	11	1.0
Pyrethroid	10	2.5	11	2.9	19	1.3
Besiege	2	2.0	2	3.5	7	1.0
Dibrom	-	-	1	4.0	16	2.3
Acephate	-	-	1	4.0	3	1.7
Malathion	-	-	2	3.5	4	1.5
Dipel	-	-	4	2.8	-	-
Chlorpyrifos	-	-	1	2.0	5	1.6

[a] A total of 25 PCA surveys in 2018-19; 25 PCA surveys in 2017-18; 20 surveys 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.

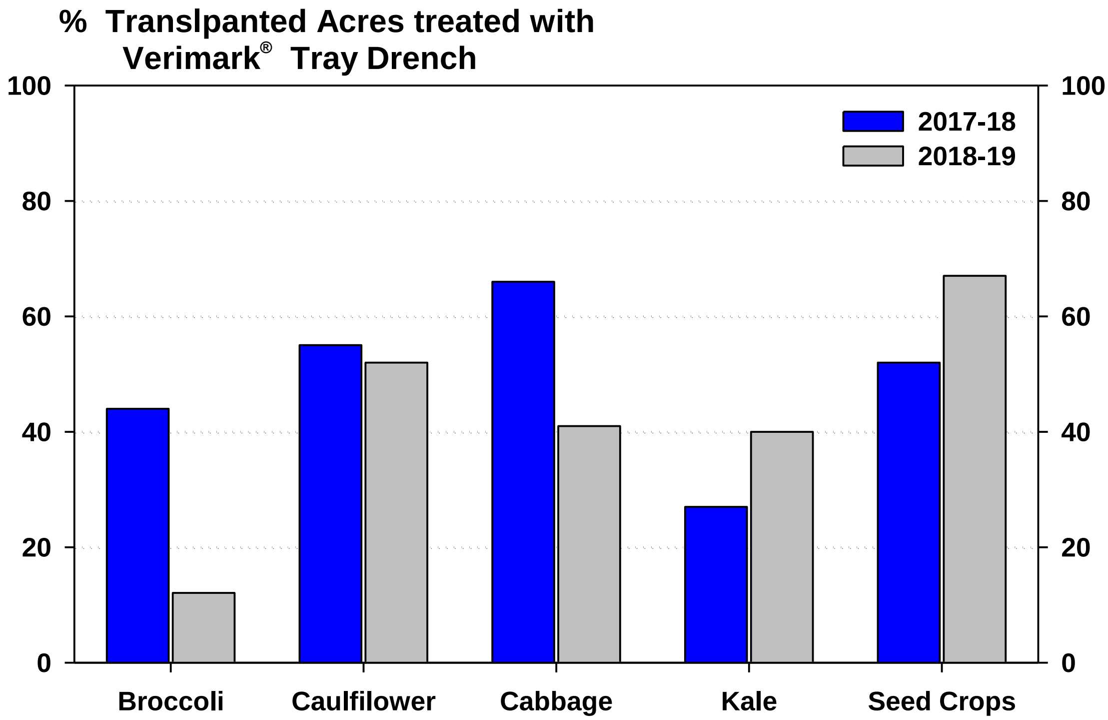

Figure 10. Average number of transplanted acres treated with Verimark Tray Drench in 2017-18 and 2018-19.

Table 4. Cole crop acres treated with Verimark® as a tray drench treatment in 2017-18 and 2018-19.

	2018-2019		2017-2018	
Crop	**Total acres transplanted**	**Total acres treated**	**Total acres transplanted**	**Total acres treated**
Broccoli	2055	250	1555	680
Cauliflower	5571	2863	5765	3200
Cabbage	2603	1078	3490	2290
Kale	150	60	575	155
Seed crops	604	404	165	85

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, 2018-2019

	Insecticide Activity Against DBM Larvae		
	PCA Surveys	**Field Efficacy**	**Lab Resistance**
Radiant	Good	Good	Good
Proclaim	Good	Good	Good
Xentari	Good	Fair	
Entrust	Good	Good	
Exirel	Good	Good	Good
Avaunt	Good	Good	
Dibrom	Good	Fair	
Lannate	Good	Good	
Coragen	Good	Fair	Poor
Besiege	Good	Good	Good
Pyrethroids	Good	Good	
Lorsban Adv.	Fair		
Cormoran	Good	Fair	
Vetica	Good		
Belt	Good		
Malathion	Good		
Intrepid	Fair	Fair	

Good
Fair
Poor