THE ECONOMIC IMPACT OF THE SUGARCANE APHID ON SORGHUM PRODUCTION

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ABSTRACT

The sugarcane aphid (SCA) has become the most important pest in sorghum since its detection in 2013. Due to its rapid population growth, great dispersion capacity, and reduced availability of effective insecticides this aphid is capable of causing substantial damage to sorghum production. Little work has been conducted to assess and better understand the economic impact caused by the SCA infestation. The objective of this study was to quantify the economic impact of SCA on sorghum growers in the Lower Rio Grande Valley (LRGV), Texas, where 11.5% of the state production is located. Forty-one local producers were surveyed resulting in a representative sample of 46,578 acres in 2014 and 49,761 acres in 2015. The questionnaire gathers detailed information about yearly crop yields, crop acreage, insecticide application decisions, and management and production practices. Collected data were used to estimate the change in profit associated to the SCA outbreak. Empirical results indicate that the SCA reduced profit by $64.29/acre in 2014 and by $36.17/acre in 2015. At the regional level, the SCA has caused a total economic loss to farmers in the LRGV of about $31.60M.

Keywords: *Melanaphis*, Profit loss, Sorghum pest, South Texas, Yield Penalty.

INTRODUCTION

The sorghum industry in the U.S. is threatened by a new invasive pest, the sugarcane aphid (SCA), capable of causing substantial damage to crop production (Villanueva et al., 2014; Seiter, Lorenz, Studebaker and Kelley, 2015; Knutson et al., 2015; Brown, Kerns and Beuzelin, 2015). The SCA has become the most important pest in sorghum since its detection in 2013. Due to its rapid population growth, great dispersion capacity, and reduced availability of effective insecticides this insect has caused significant economic losses to sorghum growers.

Sugarcane aphids were originally found in the United States in the late 1970's on sugarcane. However, in 2013 the SCA undergone a complete or partial host switch since it now readily colonizes plants in the genus *Sorghum*, but not those in the genus *Saccharum* (sugarcane) (Villanueva et al., 2014). While feeding on sorghum the aphid leaves behind waste also known as honeydew, which has been known to cause multiple problems for growers. The honeydew produced not only can clog a combine harvester due to its stickiness, but it also can cause growers yield to be significantly reduced. The honeydew produced by the insect also supports the growth of fungus which can inhibit plant growth (Villanueva et al., 2014).

In the U.S., sorghum is a multibillion-dollar crop with over 7 million acres planted each year (USDA-NASS, 2015). Texas is the second largest producer of grain sorghum in the country. In 2015, about 2.7 million acres were planted in the state with an estimated economic value of $742.7 million (USDA-NASS, 2015; Salinas and Robinson, 2015). Despite the importance of sorghum production to both national and state economies, very little work has been conducted to assess the economic impact caused by the SCA infestation.

The objective of this study is to estimate the economic impact of the SCA on sorghum growers. Specifically, we focused on assessing the reduction in farm profits associated to the

SCA outbreak in the Lower Rio Grande Valley (LRGV) in Texas. Given its geographical location just north of the Mexico-U.S. border, the LRGV is a key region to timely understand and identify the economic impact of new invasive pests. In 2015, about 310,000 acres of sorghum were planted in the LRGV with and estimated economic value of 92.3 million (USDA-NASS, 2015; Salinas and Robinson, 2015). Production and farming management data were gathered from local growers to estimate their change in profits due to the SCA. Yearly economic loss estimates are provided at both the acre and regional levels. This study also contributes to the current literature in terms of novel approaches to assess the economic impact of invasive species. The valuation methodology developed can be replicated in other areas of the country affected by the SCA, and it can be extended to analyze the economic impact of other invasive pest outbreaks.

BACKGROUND AND LITERATURE REVIEW

A Brief History of the Sugarcane Aphid[1]

The Rio Grande Valley in South Texas is a key agricultural region to both state and national economies. A variety of vegetables and field crops are growth in the area, and given its strategic location any pest that affects this region can have a tremendous impact on the rest of the nation. Such is the case of the sugarcane aphid, *Melanaphis sacchari*[2] (Zehntner) (Hemiptera: Aphididae), an insect that nowadays is considered the most important pest in sorghum nationwide. The insect was first detected in sorghum near Beaumont, TX in June 2013. Now, it is common to encounter large populations of this aphid species on sorghum plants specially before harvest. The most distinctive feature of these late-season infestations is the extensive production of honeydew. Choked combine harvesters and substantial grain losses due to the

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[1] Portions of this section are taken from the work of Villanueva et al. (2014), where Villanueva is a coauthors of this study.
[2] The SCA was initially describe by Zehntner in 1897 and named as *Aphis sacchari* (as cited in Zimmerman, 1948).

sticky honeydew produced by the SCA have been reported in northeast Texas and Louisiana as farmers harvested aphid-infested fields. Later, in 2013 outbreaks of this aphid occurred in grain sorghum fields in south and east Texas; northeastern Mexico; southwest, central and northeast Louisiana and eastern Mississippi).

The SCA is a main pest of sorghum and sugarcane in tropical regions around the world (Africa, Asia, Australia, Central and South America). Though reported in Hawaii in 1896, it was first documented in the continental U.S. on sugarcane in Florida in 1977, and then on sugarcane in Louisiana in 1999. These infestations were characterized by summer outbreaks followed by winter population decline. No previous occurrences resulted in permanent infestation by the pest, and there was no indication, at that time, that the SCA was able to successfully adapt to more temperate environments. However, the SCA observed in late 2013 suddenly preferred sorghum and Johnson grass and its populations grew rapidly causing great damages to sorghum field only without affecting sugarcane, corn or wheat.

Behavior, Damage and Control

Early in the infestation cycle, SCA colonize the lower surfaces of the more mature, lower leaves of sorghum plants. They progressively move upwards and may eventually colonize even the seed heads (panicles). When conditions are favorable, small colonies can quickly grow to large colonies which produce large amounts of sticky honeydew. Highly sticky leaf surfaces may help protect the aphids from predation.

Aphid feeding produces yellow to red or brown leaf discoloration which is visible on both sides of the leaf. Indirect damage is caused by the abundant honeydew which may support the growth of black, sooty mold fungus. Infestations of seedling grain sorghum can kill young plants and later infestations can prevent the formation of grain. Additional harvest-associated losses may occur. Honeydew coated leaves can stick to the inner parts of harvest equipment preventing efficient movement of crop material through the machine. Combines may choke and requiring service time to remove lodged stalks and heads. Losses may also occur as sticky leaves foul grain separation from stalks and leaves in the combine harvester, causing grain to "ride over" and be lost on the ground.

Natural enemies including lady beetles, syrphid fly larvae, green lacewings and parasitic wasps have been observed feeding on SCA. In addition, variety screening work has shown that certain sorghum lines can tolerate SCA feeding without significant leaf damage. However, when aphid populations are increasing rapidly, insecticides may be needed to prevent and reduce yield losses.

Up to 100 percent losses of grain sorghum were reported in 2013. In 2014 some fields in the LRGV that were not treated resulted in losses from 30 to 100 percent. During 2014 and 2015 the majority of the sorghum growers of the LRGV applied one to two sprays of Transform®[3], (sulfoxaflor, Dow AgroSciences) at the recommended rate of 1 ounce per acre and with at least 10 gallons of water per acre to have a great coverage. In 2015, Sivanto® (*flupyradifurone*, Bayer) was fully registered for its use in sorghum, however it has had a discreet adoption among sorghum growers of the LRGV.

METHODS

Sorghum Producers Survey

In order to get the best representation on sorghum in the Rio Grande Valley we contacted over 80 growers altogether in Starr, Willacy, Cameron, and Hidalgo counties by telephone. Participants were randomly selected from a list of growers who signed up to receive the Pest

[3] In 2014 and 2015, Transform WG insecticide was used as a Section 18 Emergency Exemption Label in sorghum.

Cast Newsletter that goes out every week to alert local growers of new pest developments during the growing season. Growers were called twice after the harvesting season (i.e., late June to August), the time when yields were being determined. Growers were first informed of who was calling and that the survey would be kept anonymous. As they agreed to participate in the survey they were asked a series of questions first for the year 2014 and then for their 2015 crop. A total of 41 growers agreed to participate in the study. Namely, we collected data from 39 growers in 2014 and from 41 growers in 2015. In total, we were able to obtain 82 observations for both years. The odd number of growers by year is due to the fact that some growers planted in one year but not the other. The questionnaire gathers detailed information about yearly crop yields, crop acreage, insecticide application decisions, and management and production practices. As a result of this survey we were able to obtain data for a sum of 46,578 acres in 2014 and 49,761 acres in 2015.

Economic Impact Estimation

Even though the SCA has directly and indirectly affected the local economy of the LRGV, in this study we focused on quantifying the direct economic loss caused by this invasive pest at the farm level. Specifically, a functional form for the sorghum growers' profit was defined and estimated to calculate the reduction in profit associated to the SCA infestation in the LRGV. Specifically, the sorghum profit function is given by:

$$\pi_t = p_t Y_t - \boldsymbol{R}_t \boldsymbol{X}_t - a_t N_t - h_t Y_t - C, \tag{1}$$

where the subscript t denotes the year, p is the price of sorghum, Y is the sorghum yield, $\boldsymbol{R}$ is a vector of pesticide prices, $\boldsymbol{X}$ is a vector of pesticide quantities, a represents the pesticide application cost, N is the number of pesticide applications, h is the variable harvesting cost, and C represents all other production costs independent of t, Y, $\boldsymbol{X}$ and N.

The SCA outbreak affects farmers' profit by increasing the production cost due to additional insecticide applications and by reducing the revenues due to lower yields. Namely, the overall impact of the SCA at the farm level is given by the difference between the *ex post* (with SCA infestation) and *ex ante* (without SCA infestation) farm's profit levels. The change in profit due to the SCA outbreak can be represented by:

$$(2) \qquad \begin{aligned} \Delta\Pi_t &= \pi_t^1 - \pi_t^0 \\ &= p_t(Y_t^1 - Y_t^0) - r_{it}^1 x_{it}^1 - r_{jt}^1 x_{jt}^1 - a_t n_t^1 - h_t(Y_t^1 - Y_t^0), \end{aligned}$$

where superscripts 1 and 0 denote the *ex post* and *ex ante* levels, respectively; x_i is the additional insecticide used to control the SCA, r_i is the insecticide price, similarly x_j represents the extra surfactant used, r_j is the surfactant price, n is the number of additional applications needed to spray x_i and x_j.

The different sorghum and input prices used to estimate the overall economic impact of the SCA are presented in Table 1. Sorghum prices are the yearly prices reported by the USDA-NASS (2015), insecticide and surfactant prices were provided by local agrochemical suppliers, and the insecticide application cost and variable harvesting cost are based on Texas' custom rate statistics (Klose, 2013). Additionally, the *ex ante* sorghum yield (or the potential yield in the absence of the SCA) was defined to be proportional to the *ex post* yield reported by farmers. Specifically, it was assumed that in 2014 the presence of SCA reduced the amount of sorghum harvested (yield penalty) by 10 percent on fields that sprayed to control the pest and by 30 percent on counterpart fields that did not spray to control the infestation. In 2015, the yield penalty was assumed to equal to 5 percent and 10 percent in sprayed and non-sprayed fields, respectively. The lower yield penalties in 2015 are due to observed lower infestation rates (Figure 2) and the use of more tolerant sorghum varieties.

RESULTS AND DISCUSSIONS

Survey Results

A complete description of survey responses regarding key farm characteristics and management practices to control the SCA infestation are presented in Table 2. The survey gathered information from a total of 82 sorghum farms, 41 fields by year. The reported average yield in 2014 was 4,544 lb/acre and 4,729 lb/acre in 2015. The average acreage of the considered farms was 1,136 acres in 2014 and 1,214 acres in 2015. Survey results also indicate that about 34 percent of growers farmed on dryland and 66 percent on irrigated farmland. The proportion of irrigated to non-irrigated field remained the same between years. About 48 percent of the observations are from Cameron County, 34 percent from Hidalgo County, 2 percent from Starr County, and 16 percent are from Willacy County.

In terms of farming management practices to control the SCA outbreak, survey results indicate that in 2014, 100 percent of the growers sprayed for the SCA. That was not the case in 2015, as 27 percent of the fields were not sprayed. The decrease in insecticide applications may be related to the fact that there was a reduced number of SCA due to lower climate temperatures and constant rain, plus local predators were able to control these lower SCA populations. Also, surveyed growers stated that when spraying for the pest, on average they sprayed 84 percent and 80 percent of the total area planted in 2014 and 2015, respectively.

A trend was identified concerning the choice of insecticide to control the aphids. Namely, it was found that Transform® (Sufloxofar) was the only chemical used by growers in both years. The heavy rely of growers on a single active ingredient to control the SCA may increase the selection pressure of the insect towards pesticide resistance. Regarding the number of insecticide applications to control the pest, survey results indicate that in 2014, on average, 1.68 insecticide applications were made compared to 0.85 applications in 2015. The higher number of insecticide applications in 2014 can be directly related to higher populations of SCA. The distribution of the number of insecticide applications also differ between years. While in 2014 all fields were sprayed, in 2015 we observed a decrease in the number of insecticide applications, particularly, there were more growers who sprayed only once (61 percent) throughout the year. That fact that most growers only sprayed one time in 2015 for the SCA, may be attributed to a surged in SCA populations late in the season right before harvest causing some growers to make a spray application prior to harvest. Although the number of single sprays may have increased, the amount of fields that were not sprayed in 2015 also increased from 0 percent to 27 percent.

Survey results also suggest that the recommended insecticide application rate was followed by growers. Namely, on average growers applied Transform® at a rate of 1.02 oz/acre compared to the recommended rate of 0.75-1.5 oz/acre (Knutson et al., 2015). Over the two years ground application seemed to be most popular among growers with 66 percent of total applications being ground applications and 34 percent aerial applications. Based on conversations with growers, most of them decided to spray by air because their fields were too wet to get into by ground and they feared losing the crop due to high infestations of SCA, hence aerial application was the only alternative. Furthermore, ground application of insecticide was preferred due to its lower cost and better coverage by use of higher amounts of water per acre. In fact, when spraying by ground growers used between 10 and 30 gallons of water per acre with most of them staying in the lower range of about 10 gallons/acre, and when spraying by air growers used between 3 and 5 gallons of water per acre. On average, growers used 11.77 gallons and 9.65 gallons of water per acre on each insecticide application in 2014 and 2015, respectively. Lastly, Surfactant was used on 92 percent of the insecticide applications when spraying for the

SCA, only three fields in 2014 and 2015 did not include surfactant in their spray application. The individual quantities of surfactant used were calculated to be equal to 0.025 percent of the reported amount of water used on each application.

Economic Impact of the SCA on Growers

The economic loss associated to the SCA in equation (2) was estimated for each farmer based on the reported yields and farming management practices. The individual losses were then aggregated to calculate a representative mean profit loss. With the aim to take into account the differences in acreage among respondents, the average profit loss due to the SCA was estimated as a weighted mean of the individual estimates with weights proportional to the stated acreage.

The estimated yearly economic losses caused by the SCA along with the overall mean profit reduction are shown in Figure 1. On average, the mean economic loss is calculated at \$49.76/acre. The major share of the loss is due to the yield penalty, which reduced revenues by \$34.75/acre. The additional cost incurred to control the SCA was estimated at \$18.83/acre, including \$9.08/acre for insecticide, \$2.81/acre for surfactant and \$6.95/acre for spraying the pesticides. Additionally, the yield penalty caused by the SCA infestation reduced the variable harvesting cost by \$3.81/acre.

In terms of annual losses, it was estimated that the SCA reduced profit by \$64.29/acre in 2014 and by \$36.17/acre in 2015. The main difference between years is due to the fact that a lower infestation rate was observed in 2015, which resulted in fewer applications to control the SCA and lower yield penalties. The results from a random sampling of 13 and 15 commercial sorghum yields in 2014 and 2015 in the LRGV, respectively, are shown in Figure 2. The higher temperatures and rain-free weather during the production season of 2014 might have created the optimal conditions to a faster and more aggressive aphid population growth compared to 2015 (NOAA, 2014; NOAA, 2015).

Sensitivity analysis was conducted to evaluate the effect of the hypothesized yield penalties on the economic loss estimates. The magnitude of the yield penalty among years, and between sprayed and non-sprayed fields was varied to estimate annual loss response surfaces. The effect of yield penalty on the economic loss caused by the SCA is shown in Figure 3. In 2014, the reduction in profits due to the SCA outbreak ranges from $32.70/acre (i.e., when the SCA caused no yield reduction in sprayed fields and a yield penalty of 15 percent in non-sprayed fields) to $93.73/acre (i.e., with yield penalties of 20 percent and 40 percent for sprayed and non-sprayed fields, respectively). Likewise, in 2015 the economic loss attributed to the SCA varies from $20.43/acre (i.e., when yield penalties are set to 0 percent for sprayed fields and to 5 percent for non-sprayed fields) to $76.23/acre (i.e., with yield penalties of 15 percent and 25 percent for sprayed and non-sprayed fields, respectively).

The sample-based estimated losses caused by the SCA along with the sensitivity analysis' bound estimates were used to infer the total economic loss of the SCA in the LRGV's sorghum producers. According to USDA-NASS (2015) 317,200 and 310,000 acres of sorghum were planted in the LRGV in 2014 and 2015, respectively. Aggregated impacts were calculated by multiplying the estimated annual loss by the corresponding sorghum acreage. It is estimated that in 2014 the SCA caused a total economic loss to farmers in the LRGV of about $20.39M ($10.37M, $29.73M). In 2015 the economic loss was calculated to be equal to $11.21M ($6.33M, $23.63M). Therefore, after its appearance in 2013 the overall reduction in profits due to the SCA infestation in the LRGV is estimated at $31.60M ($16.71, $53.36). The aggregated economic loss represents about 15.2 percent of the total value of sorghum production in the

LRGV in the years 2014 and 2015, where the total value of sorghum produced is based on Salinas and Robinson (2015).

SUMMARY AND CONCLUSIONS

The sugarcane aphid has become the most important pest in sorghum since its detection in 2013. Due to its rapid population growth, great dispersion capacity, and reduced availability of effective insecticides this aphid is capable of causing substantial damage to sorghum production. Despite the importance of sorghum crop to both national and state economies, very little work has been conducted to assess and better understand the economic impact caused by the SCA infestation.

The objective of this study was to assess the economic impact of SCA on sorghum growers in the Lower Rio Grande Valley, Texas, where about 11.5 percent of the state production is located. To this aim, 41 local producers were surveyed resulting in a representative sample of 46,578 acres in 2014 and 49,761 acres in 2015. The questionnaire gathers detailed information about yearly crop yields, crop acreage, insecticide application decisions, and management and production practices. Collected data were used to estimate the change in profit associated to the SCA outbreak at the farm level. The valuation methodology developed in this study can be replicated in other areas affected by the SCA, and it can be extended to analyze the economic impact of other invasive pest outbreaks.

SCA infestation affects farmers' profit by increasing the production cost due to additional insecticide applications and by reducing the revenues due to lower yields. Estimation results suggest that on average the SCA caused a loss of $49.76/acre between 2014 and 2015. The major share of the loss was due to the decrease in yields, which reduced revenues by $34.75/acre. The total cost to control the aphids was estimated at $18.83/acre, including insecticide, surfactant and application costs. The SCA also caused a reduction on the variable harvesting cost of $3.81/acre. In terms of annual losses, it was estimated that the SCA reduced profit by $64.29/acre in 2014 and by $36.17/acre in 2015. The difference in losses between years is attributed to a higher infestation rate in 2015, caused by optimal weather conditions that favored a rapid growth and spread of the pests. Additionally, the estimates of the economic loss caused by the SCA infestation were found to be sensitive to the magnitude of the yield penalties used.

Results also suggest that after it appearance in 2013, the SCA has caused a total economic loss to farmers in the LRGV of about $31.60M. Namely, farmers' profits were reduced in $20.39M and $11.21M in 2014 and 2015, respectively. The aggregated economic loss represents about 15.2 percent of the total value of sorghum production in the LRGV in the same period of time.

Table 1. Sorghum and Input Prices by Year

Parameter	Units	Value	
		2014	2015
Sorghum Price	$/cwt	7.23	7.55
Insecticide Price	$/oz	7.30	7.50
Surfactant Price	$/oz	0.55	0.58
Aerial Application Cost	$/acre	9.60	10.00
Ground Application Cost	$/acre	7.30	8.00
Variable Harvesting Cost	$/cwt	0.75	0.89

Table 2. Description and Summary Statistic of Survey Responses.

Variable	2014		2015		Total	
	n	Mean (Standard Error)	n	Mean (Standard Error)	n	Mean (Standard Error)
Surveyed farms	41		41		82	
Yield (lb/acre)	41	4,543.68 (308.38)	41	4,729.47 (225.71)	82	4,639.65 (193.14)
Acreage	41	1,136.05 (182.44)	41	1,213.69 (220.49)	82	1,174.87 (142.28)
Farmland type		0.34 (0.07)		0.34 (0.07)		0.34 (0.05)
0=Irrigated	27		27		54	
1=Dryland	14		14		28	
Field location						
Cameron	19		20		39	
Hidalgo	14		14		28	
Starr	1		1		2	
Willacy	7		6		13	
Sprayed to control the SCA		1.00 (0.00)		0.73 (0.07)		0.87 (0.04)
0=No	0		11		11	
1=Yes	41		30		71	
Total area sprayed to control the SCA (%)	41	83.84 (3.89)	30	79.55 (6.05)	71	82.03 (3.39)
Insecticide used to control the SCA		1.00 (0.00)		0.73 (0.07)		0.87 (0.04)
0=None	0		11		11	
1=Transform	41		30		71	
Additional insecticide applications due to the SCA		1.68 (0.08)		0.85 (0.10)		1.27 (0.08)
0	0		11		11	
1	14		25		39	
2	26		5		31	
3	1		0		1	
Insecticide application rate to control the SCA (oz/acre)	41	1.01 (0.01)	30	1.02 (0.03)	71	1.02 (0.01)
Type of insecticide application to control the SCA		0.61 (0.06)		0.77 (0.07)		0.66 (0.05)
0=Aerial	27		8		35	
1=Ground	42		27		69	
Water used on each insecticide application aimed to control the SCA (gallons/acre)	41	11.77 (1.95)	30	9.65 (0.62)	71	10.87 (1.15)
Additional surfactant used due to the SCA		0.93 (0.04)		0.90 (0.06)		0.92 (0.03)
0=No	3		3		6	
1=Yes	38		27		65	

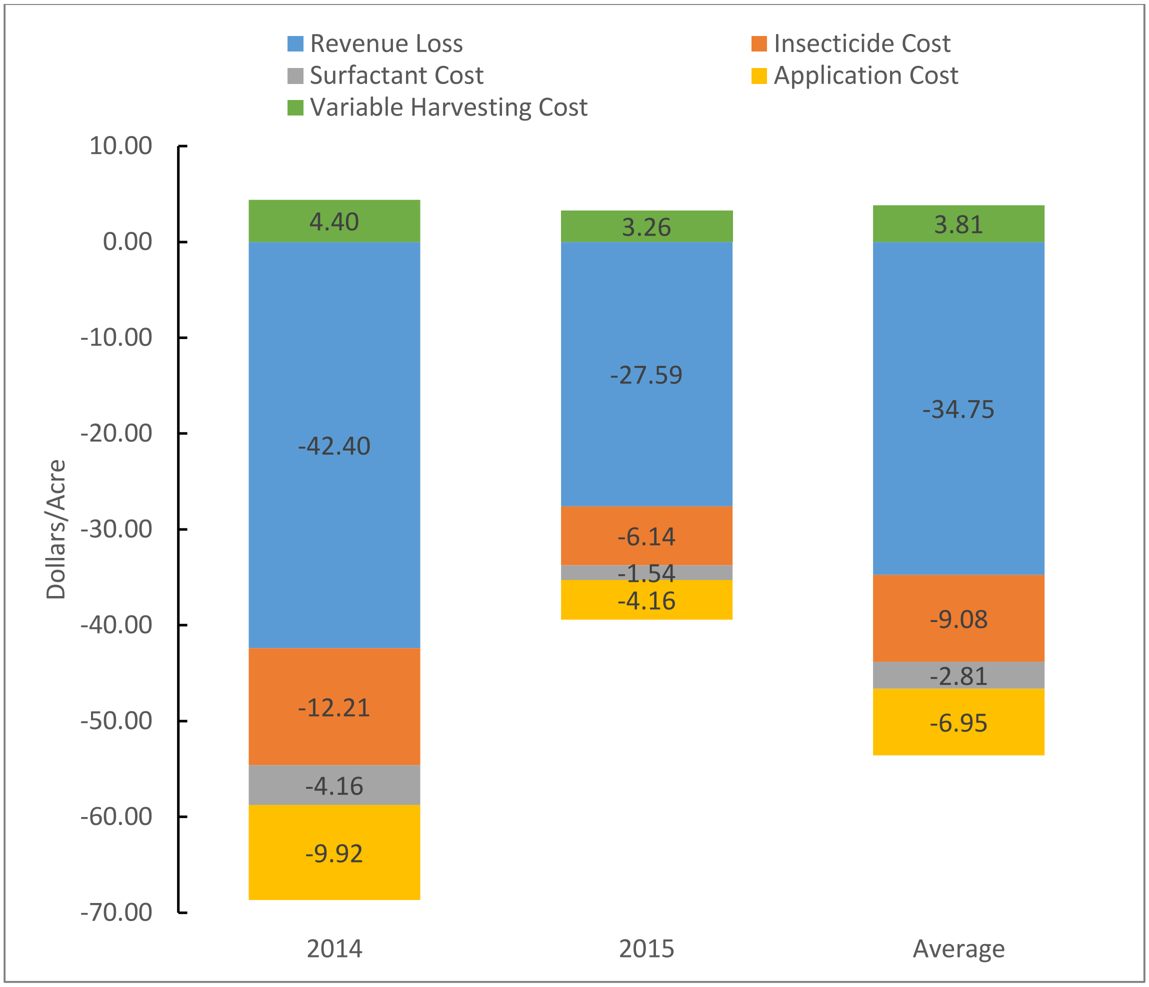

Figure 1. SCA average and annual economic loss by input class.

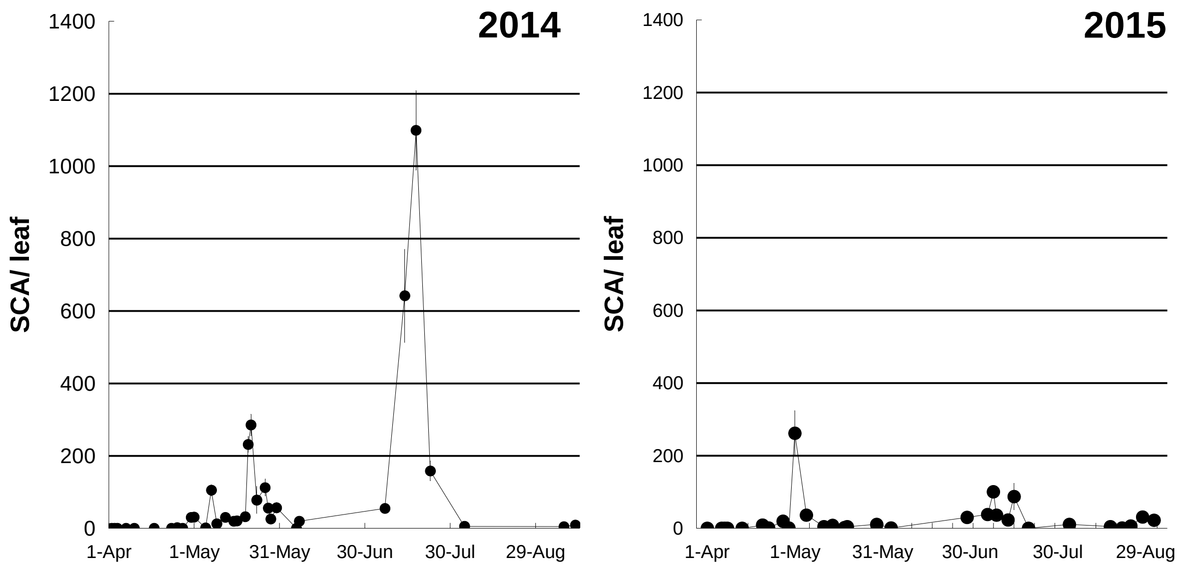

Figure 2. Mean number of SCA per leaf in the Lower Rio Grande Valley by year.

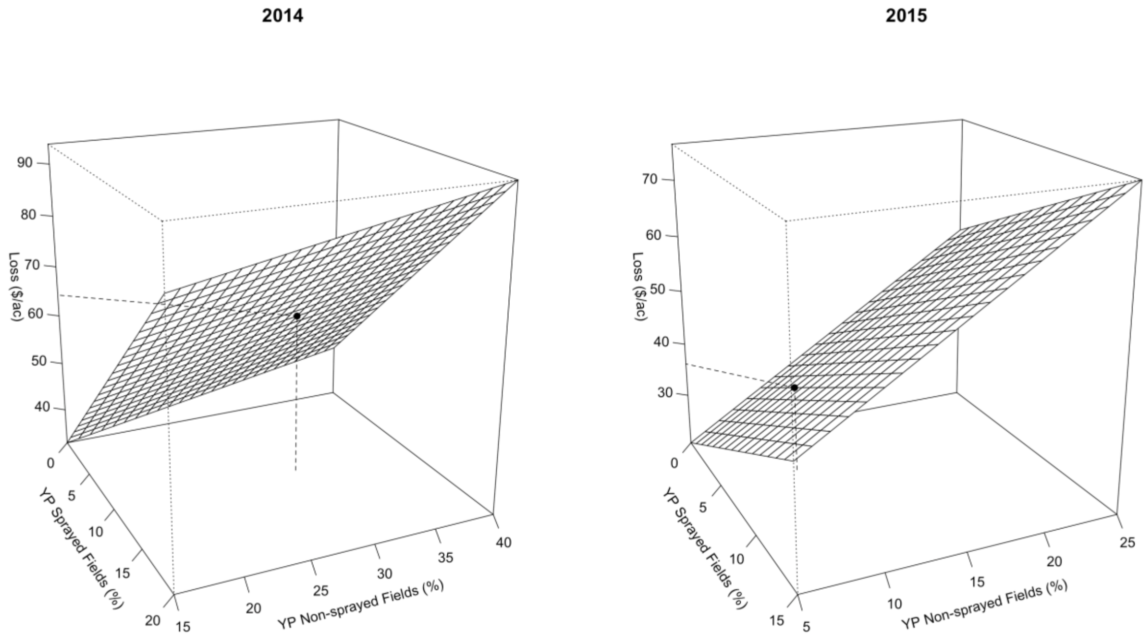

Figure 3. SCA annual economic loss by yield penalty (YP) in sprayed and non-sprayed fields. The dot on the loss response surface denotes the reference scenario.

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