ECONOMIC IMPACT OF THE SUGARCANE APHID OUTBREAK IN SOUTH TEXAS

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ABSTRACT

The sorghum industry is threatened by a new invasive pest, the sugarcane aphid (SCA), capable of causing substantial damage to crop production and local economies. Little work has been conducted to assess and better understand the economic implications of the SCA outbreak. The objective of this study was to estimate the economic impact of SCA in the Lower Rio Grande Valley (LRGV), Texas, where 11.5% of the state production is located. Local producers were surveyed to gather detailed information about yearly crop yields, crop acreage, insecticide application decisions, and management and production practices. Collected data were used to estimate the reduction in growers' profit associated to the SCA infestation, as well as the monetary value of the prevented loss attributed to control efforts. Sorghum industry losses were then used to assess the overall economic impact of the SCA outbreak in the LRGV economy in terms of output, value-added, labor income and employment effects.

Keywords: *Melanaphis*, Profit loss, Prevented loss, Regional impact analysis, Sorghum pest, Yield penalty.

JEL Classification: Q10, Q11

INTRODUCTION

Sorghum is a multibillion-dollar crop with over 7 million acres planted each year in the U.S. (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). However, the sorghum industry 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). In fact, due to its rapid population growth, great dispersion capacity, and reduced availability of effective insecticides the SCA has become the most important pest in sorghum since its detection in 2013.

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).

Despite the importance of sorghum production to both national and state economies, very little work has been done to assess the economic impact caused by the SCA infestation. Particularly, the study of the SCA has focused on analyzing its behavior and control methods rather than on understanding its economic implications. No previous study has been conducted to

systematically estimate the economic impact caused by the SCA on both sorghum producers' profit and regional economies

The main objective of this study is to estimate the economic impact of the SCA at both the farm and regional levels. Specifically, we focused on assessing the economic impact associated to the SCA outbreak in the Lower Rio Grande Valley (LRGV), 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 region with and estimated economic value of $92.3 million (USDA-NASS, 2015; Salinas and Robinson, 2015). Both direct and incidental impacts caused by the SCA in 2014 and 2015 are quantified. This study also estimates the monetary value and economic impacts of the control efforts aimed to mitigate the burden caused by this new invasive pest. Furthermore, this study 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 sugarcane aphid, *Melanaphis sacchari*[2] (Zehntner) (Hemiptera: Aphididae), 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. Later in 2013,

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

outbreaks of this aphid occurred in grain sorghum fields in south and east Texas; northeastern Mexico; southwest, central and northeast Louisiana and eastern Mississippi.

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.

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. 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.

In terms of control alternatives, 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.

Economic Impact of Invasive Insect Pests

Several introduction and dissemination pathways of non-indigenous species have been identified and inferred. It has been observed that most invasive pests arrive in association with intentional and accidental human activities such as trade, transportation, cultivation, and tourism. In addition, exogenous alteration of natural habitats can create favorable conditions to the establishment of new invasive species (OTA, 1993).

Approximately 50,000 foreign species have been introduced into the U.S. over the last two centuries. It is estimated that the economic losses associated with invasive species and their control add up to almost $120 billion per year (Pimentel et al., 2005). Some of these non-indigenous species have caused substantial economic damages to the agriculture sector. Particularly, Pimentel et al. (2005) calculated that in the U.S. the total loss to crop production attributed to introduced invasive insect pests is approximately $13.5 billion/year.

The economic impact of invasive pests on specific agricultural industries and regions have been extensively studied. For example, Bolda et al. (2010) analyzed the potential economic effects of spotted wing drosophila (*Drosophila suzukii*) on berry production in California, Oregon and Washington. Authors found that based on maximum observed yield losses this fly could cause an economic damage of about $422 million in the three states. In another study, Hoddle et al. (2003) assessed the economic damage caused by *Scirtothrips perseae* Nakahara on California avocado production. They concluded that this thrips infestation will cause annual economic losses of $8.11 million in the short run and $4.78 million in the long run to avocado producers. Other studies have focused on quantifying the economic impacts of invasive pest on

forests' market and nonmarket goods and services (e.g., Holmes et al. 2009; Pimentel et al., 2005; Rosenberger and Smith, 1997), livestock production (e.g., Taylor et al., 2012), as well as on international economies (e.g., Oliveira et al., 2013; Pyšek and Richardson, 2010).

Little is known about the economic impact attributed to the SCA outbreak in Texas. To the best of our knowledge the only reported loss estimates associated to the SCA are from Louisiana sorghum producers. Namely, Kerns et al. (2015) estimated that in 2013 the SCA caused a total economic loss of about $7.7 million to the Louisiana sorghum industry. Compared to Kerns et al. (2015) study and all the aforementioned valuation efforts, where they only estimated the direct economic losses (i.e., revenue loss and/or control cost) caused by non-indigenous species on specific host agricultural industries, in this study we focused on assessing both the direct effects of the SCA on sorghum production as well as the incidental region-wide economic impacts resulting from the SCA infestation.

METHODS

Sorghum Producers Survey

In order to get the best representation on sorghum production 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 Cast Newsletter that is distributed 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 their output 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 usable 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 of the SCA on Sorghum Growers

The SCA has directly and indirectly affected the local economy of the LRGV. First, we focused on quantifying the direct economic loss caused by this invasive pest at the farm level. To this aim, a functional form for the sorghum growers' profit was defined and estimated to calculate the reduction in profit associated to the SCA infestation. 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. This change in profit due to the SCA outbreak can be represented by:

$$(2) \qquad \Delta\Pi_t = \pi_t^1 - \pi_t^0$$

$$= p_t(Y_t^1 - Y_t^0) - r_{it}^1 x_{it}^1 - r_{jt}^1 x_{jt}^1 - a_t n_t^1 - h_t(Y_t^1 - Y_t^0),$$

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, and 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 economic impact of the SCA are presented in Table 1. Sorghum prices are the yearly prices reported by 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 the presence of SCA reduced the amount of sorghum harvested (yield penalty) by 10 percent and 5 percent on fields that sprayed to control the pest in 2014 and 2015, respectively. On the other hand, the yield penalty on non-sprayed fields was set to be equal to the observed mean yield difference between sprayed and non-sprayed fields, plus the expected yield loss on sprayed fields. Namely, survey results indicate that, on average, the expected yield on non-sprayed fields were 39.6 percent and 17.8 percent lower than their counterpart sprayed fields in 2014 and 2015, respectively. The lower yield penalties in 2015 are attributed to lower infestation rates (Figure 1) and the use of more tolerant sorghum varieties.

The change in profits described in equation (2) can be redefined to estimate the prevented profit loss attributed to private and public control efforts as well as farmers' own efforts to

mitigate the damage caused by the SCA. Specifically, the economic value of the prevented damages is given by:

$$\Delta\Pi_t' = \pi_t^1 - \pi_t' \tag{3}$$

$$= p_t(Y_t^1 - Y_t') - r_{it}^1 x_{it}^1 - r_{jt}^1 x_{jt}^1 - a_t n_t^1 - h_t(Y_t^1 - Y_t'),$$

where the *no control* scenario is represented by the superscript "′". Note that protected profit is equal to the monetary value of the prevented yield loss minus the additional pesticide application and harvesting costs due to the SCA infestation. In this part of the analysis, the prevented profit loss of non-sprayed fields was set be to zero because $Y_t^1 = Y_t'$ and no additional control expenses were incurred. In contrast, the protected yield on sprayed fields was calculated based on the sample mean relative difference between sprayed non-sprayed fields.

Economic Impact of the SCA on the LRGV Economy

Direct revenue alone fails to capture the full economic impact of losses. Income losses to farmers, landlords, and shareholders was that money that would have been spent in the economy under normal circumstances; additional losses occurred because this money did not circulate through the economy. Similarly, as a result of reduced spending on harvesting, harvesting operations spent less on business supplies and wages. At the same time, farmers spent more than expected on insecticides, surfactants, and pesticide application, and a portion of these expenses were paid to local suppliers. These businesses and their employees' households in turn made purchases in the economy, stimulating additional economic activity. The multiplier effect recognizes that the total effect on output, employment, personal income, and government revenue in the region is greater than the initial dollar lost.

Sorghum industry economic loss estimates (i.e., actual and prevented losses) were used to assess the overall economic impacts of the SCA infestation in the LRGV. Specifically, the

IMPLAN economic modeling tool and data (IMPLAN Group, 2014) were used to develop multipliers for the effects of the SCA in the LRGV economy, accounting for relationships between each of 536 industry sectors as well as private households and governments. The model calculates multipliers based on the purchasing patterns of industries and institutions in the regional economy. Each industry and region combination has a unique spending pattern and a unique multiplier.

Farm profit losses were modeled as changes to the income of households making $75-100K annually. Farm losses consisted of revenue losses due to aphid damage less additional pesticide costs plus savings from decreased harvest costs. While revenue losses removed money from both farmers and the overall economy, farmers faced decreased profits due to increased pesticide costs but insecticides, surfactants, and pesticide application created additional activity in the regional economy. Conversely, lower farm profits were partially mitigated by decreased harvest costs, but this resulted in decreased harvest activity in the regional economy. The offsetting decreases in harvest costs and increases in application costs were modeled as a net industry change affecting the agriculture support activities sector. Increased insecticide and surfactant costs were modeled as commodity changes. The pesticide and other agricultural chemicals manufacturing sector does not exist in the LRGV so the chemical cannot be purchased from a local pesticide industry but rather must be purchased from any business selling the commodity.

At the regional-level, the reduction in farmers' revenues and additional production expenditures caused by the SCA outbreak are defined as the *direct effect* of the infestation. These direct effects result in two types of multiplier effects: *indirect effects* from the purchase of inputs

among local industries and *induced effects* from the expenditures of institutions such as households and governments benefitting from increased the activity among local businesses.

Four types of multiplier effects are reported in the impact analyses. *Output or sales multipliers* measure the effect of direct spending (or loss) on overall economic activity in the region. The *value-added multiplier* is a more appropriate measure of regional welfare. The value-added multiplier measures the event's contribution to regional gross domestic product (GDP). It is the value added to the state regional economy or the return to resources used in the production of the event. The *labor income or personal income multiplier* measures the effect of the event on incomes of households in the region and is appropriate for discerning the benefit to residents. The *employment multiplier* measures the effect of the event on regional employment in various economic sectors. Thus, this region-wide analysis allowed us to measure the overall economic impacts of both actual and prevented profit losses on the LRGV economy caused by the SCA outbreak.

RESULTS AND DISCUSSION

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 aphids 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 reliance of growers on a single active ingredient to control the SCA may increase the selection pressure of the insect towards pesticide resistance. Additionally, in 2014 and 2015, Transform® was used as a Section 18 Emergency Exemption Label in sorghum, and its continuity in the market is under debate (EPA, 2016).

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 surge in SCA populations late in the season right before

harvest causing some growers to make a spray application to prevent further yield losses. 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 amount 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 Sorghum Industry

The economic loss associated to the SCA in equation (2) as well as the prevented profit loss attributed to control efforts described in (3) were estimated for each farmer based on reported

yields and farming management practices. Individual valuations were then aggregated to calculate representative mean estimates. With the aim to take into account the differences in unobserved farm characteristics among respondents, the average profit loss due to the SCA and prevented loss were estimated as weighted means of the individual estimates with weights proportional to the stated acreage.

The estimated yearly economic losses caused by the SCA along with the mean profit reduction are shown in Table 3. On average, the mean economic loss was calculated at $61.88/acre. The major share of the loss is due to the yield penalty, which reduced revenues by $52.14/acre. The additional expenses incurred to control the SCA were estimated at $15.54/acre, including $6.49/acre for insecticide, $2.10/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 $5.80/acre.

In terms of annual losses, it was estimated that the SCA reduced profit by $68.96/acre in 2014 and by $55.25/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 a higher proportion of untreated fields and fewer insecticide applications on those fields that sprayed to control the SCA. For illustration purposes, the results from a random sampling of 13 and 15 commercial sorghum fields in 2014 and 2015 in the LRGV, respectively, are shown in Figure 1. Higher aphid populations during the months June and July were observed in 2014. Also, the SCA scouting results summarized on Figure 1 support the fact that most growers sprayed 2 times to control the pest in 2014 given the recommended application threshold of 100 aphids per leaf. It is believed that 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. Yield penalty bounds are based on survey responses in combination with field observations and conversation with local growers. The effect of yield penalty on the estimated economic loss caused by the SCA is shown in Figure 2. In 2014, the reduction in profits due to the SCA outbreak ranges from $39.69/acre (i.e., assuming that the SCA caused no yield reduction in sprayed fields and a yield penalty of 40 percent in non-sprayed fields) to $98.58/acre (i.e., with yield penalties of 20 percent and 60 percent for sprayed and non-sprayed fields, respectively). Likewise, in 2015 the economic loss attributed to the SCA varies from $34.70/acre (i.e., when yield penalties are set to 0 percent for sprayed fields and to 15 percent for non-sprayed fields) to $81.93/acre (i.e., with yield penalties of 15 percent and 30 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 industry. According to USDA-NASS (2015) 317,200 and 310,000 acres of sorghum were planted in the region in 2014 and 2015, respectively. Aggregated impacts were calculated by multiplying the estimated annual loss by the corresponding annual sorghum acreage. It is estimated that in 2014 the SCA caused a total economic loss to farmers in the LRGV of about $21.87M ($12.59M, $31.27M). In 2015 the economic loss was calculated to be equal to $17.13M ($10.76M, $25.40M). Therefore, after its appearance in 2013 the overall reduction in profits due

to the SCA infestation in the LRGV was estimated at $39.00M ($23.35M, $56.67M). The aggregated economic loss represents about 18.75 percent of the total value of sorghum production in the LRGV during the years 2014 and 2015 (Salinas and Robinson, 2015).

Empirical results also indicate that farmers' control efforts contributed to reduce the economic loss caused by the SCA outbreak. Particularly, it is estimated that those growers who sprayed to control the pest, on average, were able to protect $107.04/acre in revenues at a cost of $23.63/acre. Thus, for every dollar expended controlling the pest, farmers were able to save $4.53. Regarding prevented profit losses on sprayed fields, it is estimated that control efforts aimed to mitigate the damage caused by the SCA lessened profit losses by $93.68/acre and $33.10/acre in 2014 and 2015, respectively. When considering both sprayed and non-sprayed fields, prevented profit losses were estimated at $80.61/acre in 2014 and $16.54/acre in 2015 (Table 3). Lastly, at the aggregate-level the total prevented loss attributed to control efforts in the LRGV was equal to $25.57M and $5.13M in 2014 and 2015, respectively.

Region-wide Economic Impacts

Induced agricultural income losses outweighed the positive impacts of additional spending on aphid control. Overall losses in the LRGV economy were greater in 2014, totaling $38.0 million in output, $30.6 million in value-added, and $26.1 million in labor income, as well as 125 full- and part-time jobs (Table 4). Labor income is a component of value added, which is a component of output, so those figures cannot be summed. The $21.9 million in 2014 farm profit loss (Table 3) resulted from lost revenue mitigated by lower harvest costs as well as increased pesticide costs due to aphid damage. In this case, lost profits constituted lost output in the region as well as lost household income. Overall, the lost farm profits resulted in $27.4 million in lost labor income and $40.6 in lost output throughout the LRGV economy. Additional pesticide expenditures in the

economy outweighed reduced harvest costs, resulting in an additional $2.6 million in output and 51 full- and part-time jobs across the regional economy.

In 2015, economy-wide losses in Cameron, Hidalgo, Starr and Willacy counties totaled $32.8 million in output, $25.9 million in value-added, $22.0 million in labor income, and 160 jobs (Table 4). Farm profit losses were reduced relative to 2014 due to mostly lower pesticide costs; however, the agriculture support, pesticide, and surfactant sectors were negatively impacted with reduced harvest expenditures overwhelming mildly increased pesticide use. Employment losses were more severe in 2015 due to decreased spending on pesticide- and harvest-related costs relative to 2014. On average, regional losses totaled $35.5 million in output, $28.4 million in value-added, $24.1 million in labor income, and 144 jobs.

Observed losses in the LRGV economy were substantial. However, they would have been greater had farmers not taken measures to control the SCA. Without control efforts, the regional economy would have faced an additional $36.5 million in direct losses and $67.0 million in output, $52.3 million in value added, $44.2 million in labor income, and 396 jobs across the entire LRGV economy in 2014 (Table 5). Most prevented losses were due to preserving farm-level sorghum revenue, but aphid control also limited crop abandonment and prevented additional harvest losses in the agriculture support sector.

Aphid control efforts protected $16.4 million in output, $12.8 million in GDP contribution, $10.8 million in labor income, and 101 jobs in 2015. On average, control measures preserved $41.4 million in output, $32.3 million in value added, $27.3 million labor income, and 247 full- and part-time jobs. Farmer’s efforts to control aphids mitigated more economic losses than were incurred in 2014 (i.e., prevented losses were greater than observed losses for both farmers and the overall economy). A favorable climate in 2015 limited aphids so farmers and the

economy experienced a larger share of total possible losses, although they experienced fewer losses than expected with no control efforts. Still, on average the losses farmers prevented were greater than realized losses.

SUMMARY AND CONCLUSIONS

The sugarcane aphid has become the most important pest in sorghum since its detection in 2013. This aphid is capable of causing substantial damage to sorghum growers and local economies. However, little work has been conducted to assess and better understand the economic implications of the SCA outbreak. The objective of this study was to estimate the economic impact of SCA in the Lower Rio Grande Valley, Texas, where about 11.5 percent of the state production is located. To this aim, fourty-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 reduction in growers' profit associated to the SCA infestation, as well as the economic value of the prevented loss attributed to control efforts. Aggregated farm-level economic loss estimates were then used to assess the total economic impact of the SCA outbreak in the LRGV economy.

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 $61.88/acre between 2014 and 2015. The major share of the loss was due to the decrease in yields, which reduced revenues by $52.14/acre. The total cost to control the aphids was estimated at $15.54/acre, including insecticide, surfactant and application costs. The SCA also caused a reduction on the variable harvesting cost of $5.80/acre. In terms of annual losses, it was estimated that the SCA reduced profit by $68.96/acre in 2014

and by $55.25/acre in 2015. The difference in losses between years is attributed to a higher infestation rate in 2014, caused by optimal weather conditions that favored a rapid growth and spread of the aphids. Results also suggest that after it appearance in 2013, the SCA has caused a total economic loss to farmers in the LRGV of about $39.00M. Namely, farmers' profits were reduced in $21.87M and $17.13M in 2014 and 2015, respectively. The aggregated economic loss represents about 18.75 percent of the total value of sorghum production in the LRGV in the same period of time.

Control efforts aimed to mitigate the negative effects of the pest contributed significantly to reduce the economic impact caused by the SCA infestation. Namely, empirical results suggest that for every dollar expended controlling the SCA, farmers were able to protect $4.53. Results also indicate that the profit loss in treated fields was reduced in $93.68/acre and $33.10/acre in 2014 and 2015, respectively. Overall, LRGV's sorghum producers were able to protect $25.57M in 2014 and $5.13M in 2015.

Farmers' profit losses were magnified in the regional economy. Additional local spending on insect control was dwarfed by losses in farm revenues (output) and reduced harvest expenditures. Regional value added was decreased by $30.6 million in 2014 with severe aphid infestations and $25.9 million in 2015 with a climate more favorable to natural aphid control (average of $28.4 million). Job losses were more severe in 2015 with reduced pesticide application and harvest expenditures (160 full- and part-time jobs in 2015 as compared to 125 in 2014, average of 144). Regional losses would likely have been worse in 2015 if farmers had not planted fewer sorghum acres.

In 2014 and on average, farmers prevented greater losses to themselves and the economy they experienced. Despite control efforts, aphids inflicted $38.0 million in lost output, $30.6

million in lost value added, $26.1 million in lost labor income, and 125 lost jobs in 2014. However, farmers' control efforts prevented losses of $67 million in output, $52.3 million in value added, $44.2 million in labor income, and 396 jobs. On average, the LRGV economy experienced aphid-related losses of $28.4 million in value added and 144 jobs, but farmers prevented additional losses of $32.3 million in GDP and 247 jobs. These loss calculations are short-term in nature and do not consider the impacts of farmers switching from sorghum production to other crops or of new aphid-resistant varieties or new aphid control measures becoming available.

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
Yield Penalty:			
Sprayed Fields	%	-10.00	-5.00
Non-sprayed Fields	%	-49.60	-22.80

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)
Farm size (Acres)	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	
Farm 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	

Table 3. Sugarcane aphid estimated and prevented economic impacts.

	2014	2015	Average
Economic Loss ($/acre)			
Revenue Loss	51.76	52.50	52.14
Additional Insecticide Application Cost	22.57	8.96	15.54
Insecticide	9.33	3.83	6.49
Surfactant	3.33	0.96	2.11
Application	9.92	4.16	6.95
Reduced Variable Harvesting Cost	5.37	6.21	5.80
Total Profit Loss	68.96	55.25	61.88
Total Profit Loss for LRGV ($)	21,874,897	17,127,788	19,528,590
Prevented Economic Loss ($/acre)			
Revenue Saving	115.12	28.92	70.60
Additional Insecticide Application Cost	22.57	8.96	15.54
Increased Variable Harvesting Cost	11.94	3.42	7.54
Total Profit Saving	80.61	16.54	47.52
Total Profit Saving for LRGV ($)	25,568,578	5,128,646	15,465,933

Note: Each value represents the estimated mean over sprayed and non-sprayed fields.

Table 4. Observed Economic Impacts of Sugarcane Aphid Outbreak in South Texas.

		2014				2015				Average			
		Employment	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**
Observed Revenue Loss	Direct Effect	0.0	($21,874,900)	($21,874,900)	($21,874,900)	0.0	($17,127,800)	($17,127,800)	($17,127,800)	0.0	($19,528,600)	($19,528,600)	($19,528,600)
	Indirect Effect	0.0	$0	$0	$0	0.0	$0	$0	$0	0.0	$0	$0	$0
	Induced Effect	-176.1	($5,495,500)	($10,427,300)	($18,761,500)	-137.9	($4,302,900)	($8,164,400)	($14,690,000)	-157.3	($4,906,100)	($9,308,800)	($16,749,100)
	Total Effect	-176.1	($27,370,400)	($32,302,200)	($40,636,400)	-137.9	($21,430,700)	($25,292,200)	($31,817,800)	-157.3	($24,434,700)	($28,837,400)	($36,277,700)
		Employment	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**
Additional Insecticide Application and Harvest Reduction Costs	Direct Effect	42.3	$992,900	$1,150,600	$1,668,000	-18.5	($425,400)	($409,300)	($569,100)	10.6	$255,600	$340,100	$505,700
	Indirect Effect	1.3	$49,500	$99,100	$184,600	-0.5	($17,800)	($33,500)	($62,200)	0.4	$14,500	$30,200	$56,400
	Induced Effect	7.2	$226,100	$425,600	$766,500	-3.1	($96,200)	($181,000)	($326,000)	1.9	$58,600	$110,200	$198,500
	Total Effect	50.8	$1,268,500	$1,675,200	$2,619,100	-22.1	($539,400)	($623,800)	($957,400)	12.9	$328,700	$480,500	$760,600
		Employment	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**
Total Economy-wide Loss	Direct Effect	42.3	($20,882,000)	($20,724,300)	($20,206,900)	-18.5	($17,553,200)	($17,537,100)	($17,696,900)	10.6	($19,273,000)	($19,188,500)	($19,022,900)
	Indirect Effect	1.3	$49,500	$99,100	$184,600	-0.5	($17,800)	($33,500)	($62,200)	0.4	$14,500	$30,200	$56,400
	Induced Effect	-168.9	($5,269,400)	($10,001,700)	($17,995,000)	-141.0	($4,399,100)	($8,345,400)	($15,016,100)	-155.4	($4,847,500)	($9,198,600)	($16,550,600)
	Total Effect	-125.3	($26,101,900)	($30,626,900)	($38,017,300)	-160.0	($21,970,100)	($25,916,000)	($32,775,200)	-144.4	($24,106,000)	($28,356,900)	($35,517,100)

Table 5. Economic Impacts of Prevented Losses in South Texas.

		2014				2015				Average			
		Employment	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**
Prevented Revenue Loss	Direct Effect	0.0	($32,728,500)	($32,728,500)	($32,728,500)	0.0	($7,905,600)	($7,905,600)	($7,905,600)	0.0	($20,178,900)	($20,178,900)	($20,178,900)
	Indirect Effect	0.0	$0	$0	$0	0.0	$0	$0	$0	0.0	$0	$0	$0
	Induced Effect	-263.5	($8,222,200)	($15,600,900)	($28,070,300)	-63.7	($1,986,100)	($3,768,400)	($6,780,400)	-162.5	($5,069,400)	($9,618,800)	($17,306,900)
	Total Effect	-263.5	($40,950,700)	($48,329,400)	($60,798,800)	-63.7	($9,891,700)	($11,674,100)	($14,686,100)	-162.5	($25,248,400)	($29,797,700)	($37,485,800)
		Employment	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**
Prevented Harvest Loss	Direct Effect	-110.8	($2,567,800)	($2,671,500)	($3,788,000)	-31.0	($718,800)	($747,800)	($1,060,300)	-70.5	($1,633,100)	($1,699,000)	($2,409,100)
	Indirect Effect	-3.1	($115,900)	($224,100)	($417,000)	-0.9	($32,400)	($62,700)	($116,700)	-2.0	($73,700)	($142,500)	($265,200)
	Induced Effect	-18.7	($582,100)	($1,095,800)	($1,973,700)	-5.2	($162,900)	($306,700)	($552,500)	-11.9	($370,200)	($696,900)	($1,255,200)
	Total Effect	-132.7	($3,265,900)	($3,991,400)	($6,178,800)	-37.1	($914,100)	($1,117,200)	($1,729,500)	-84.4	($2,077,000)	($2,538,400)	($3,929,500)
		Employment	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**	**Employment**	**Labor Income**	**Value Added**	**Output**
Total Economy-wide Prevented Loss	Direct Effect	-110.8	($35,296,300)	($35,400,000)	($36,516,500)	-31.0	($8,624,400)	($8,653,400)	($8,965,900)	-70.5	($21,812,000)	($21,877,900)	($22,588,000)
	Indirect Effect	-3.1	($115,900)	($224,100)	($417,000)	-0.9	($32,400)	($62,700)	($116,700)	-2.0	($73,700)	($142,500)	($265,200)
	Induced Effect	-282.2	($8,804,400)	($16,696,700)	($30,044,100)	-68.9	($2,149,000)	($4,075,200)	($7,332,900)	-174.4	($5,439,700)	($10,315,700)	($18,562,100)
	Total Effect	-396.2	($44,216,600)	($52,320,800)	($66,977,600)	-100.8	($10,805,900)	($12,791,300)	($16,415,600)	-246.9	($27,325,300)	($32,336,200)	($41,415,300)

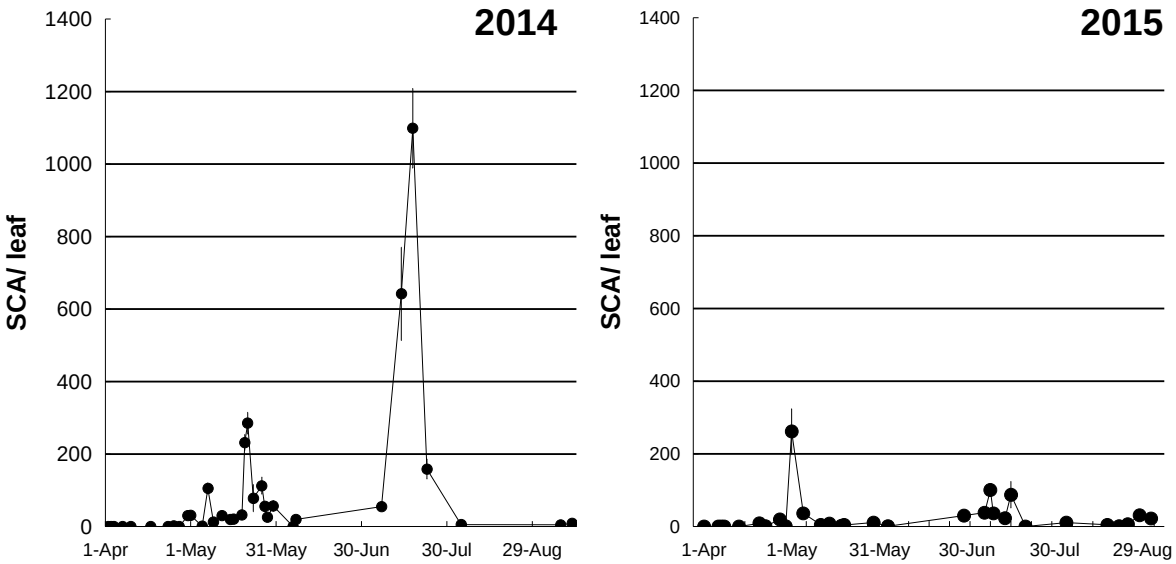

Figure 1. Mean number of SCA per leaf in the Lower Rio Grande Valley by year.

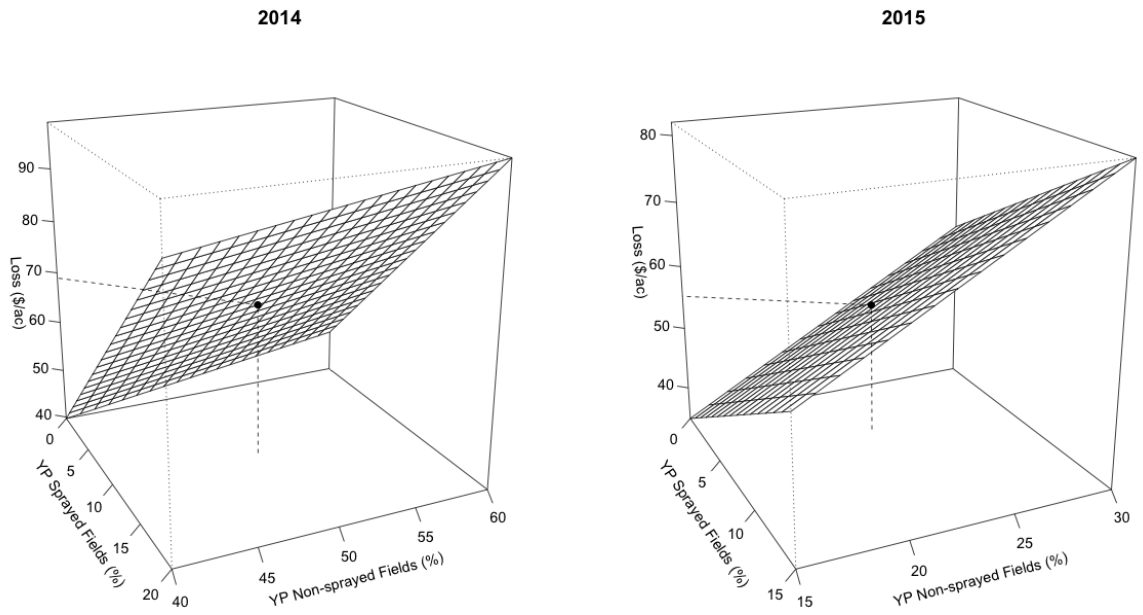

Figure 2. SCA annual economic loss by yield penalty (YP) in sprayed and non-sprayed fields. The dot on the loss response surface denotes the reference scenario.

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