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Economic impact of *Melanaphis sacchari* (Zehntner) on *Sorghum bicolor* (L.) Moench, and its management in the Southwestern of Puebla, Mexico

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ABSTRACT

Objective: To evaluate the economic impact of sorghum aphid (*Melanaphis sacchari*) and the sorghum crop profitability in Western Puebla, Mexico, considering the management practices application-index (IAPM), related to the control practices suggested by the State Plant Health Committee (CESAVEG).

Design/Methodology/Approach: Data on socioeconomic aspects of the producer and the production units were collected. The questionnaire was applied to producers affiliated to PROAGRO. Results are shown using descriptive statistics.

Results: The aphid infestation in sorghum had its most relevant effect on yield during 2014-2016. Income obtained from sorghum sales is decreasing due to a downward trend in the purchase price per ton. After the arrival of *M. sacchari*, the primary control strategy was to increase the number of insecticide applications, increasing production costs.

Limitations of the study/implications: Since producers' incomes do not depend solely on sorghum production, the effect of the pest on their economy was relatively minor.

Findings/Conclusions: The management practices application index indicates a moderate use of the recommended practices to manage this pest. The B/C ratio suggests that even after the establishment of *M. sacchari*, sorghum is still a profitable activity.

Keywords: Pest management, injuries, profitability.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is one of the main crops in Mexico; it is a raw material for balanced feed for livestock industry (SAGARPA, 2012). 75.7% of the production of Puebla state is concentrated in 46 municipalities of the Southwestern region (Vargas, 2009; SIAP, 2017). Sorghum yellow aphid [*Melanaphis sacchari* (Zehntner)] represents a phytosanitary problem in this region. In 2013, this pest was detected for the first time in Mexico in the state of Tamaulipas, where infestation levels caused severe damages and losses ranging from 30 to 100%. It is currently present in all states where sorghum is sown (INIFAP-CIRNE, 2015). Damages caused by *M. sacchari* include desiccation, necrosis, delayed seedling growth and panicle appearance. If damage is severe, the plant dies. These damages have an impact on crop yield (Singh *et al.*, 2004; Bowling *et al.*, 2016). In addition, expenses on control tactics are associated with the application of insecticides (Oliveira *et al.*, 2013).

Although there are strategies to control sorghum aphid, their implementation depend on the cultural, physical, biological, technical, social, and economic context in which the crop is grown (Rivas and Sermeño, 2004; Savary *et al.*, 2006a, b).

Production costs have increased due to a greater number of insecticide applications used to control *M. sacchari*. In addition, there has been a continuous reduction in the price paid per ton of sorghum. Nevertheless, this crop is still sown in the region. It is necessary to know the strategies and modifications implemented in the production system to reduce damages caused by sorghum aphid, as well as to analyze the costs and benefits obtained from planting this grain in order to determine the reason for its continued use. For these purposes, the objective of this study was to assess the economic impact of *M. sacchari* and sorghum crop profitability in the Southwestern region of Puebla state, Mexico, considering the Management Practices Application-Index (IAPM) recommended by CESAVEG for sorghum production systems.

MATERIALS AND METHODS

Geographical Framework of the Study

The research was carried out in the Southwestern region of Puebla state, between parallels 18° 00' and 19° 51' N and meridians 97° 49' and 98° 47' W.

Sample Size

A questionnaire containing questions regarding socioeconomic aspects, production process and commercialization of sorghum was prepared. A sample (n) of beneficiary producers of the "PROAGRO PRODUCTIVO" federal program responded the questionair. The sample was estimated with a maximum variance based on the following formula:

$$n = \frac{N Z_{\alpha/2}^2 (.25)}{N d^2 + Z_{\alpha/2}^2 (.25)}$$

Where: $N=1730$ producers who are beneficiaries of "PROAGRO"; $Z_{\alpha/2}^2=1.96$ (value of normal distribution table); and $\alpha=0.05$ (95% reliability).

The sample consisted of 91 producers producers were distributed as follows: Tepexco: 20, Izúcar de Matamoros: 19, Atzizihuacán: 14, Acteopan: 10, Tilapa: 8, Huehuetlán el Chico: 6, Xochiltepec: 7, Atzala: 5, Jolalpan: 1, and Huehuetlán el Grande: 1.

Economic Impact of *M. sacchari* on Sorghum Production

The following topics were covered in the questionnaire: producers' perception of the impact of sorghum aphid on sorghum yields, their knowledge of the damage it causes, the first cycle with infestation, the varieties planted, the insecticides applied, and the technical assistance received.

Changes Implemented into Agricultural System to Manage Sorghum Aphid Populations

Producers were sought to represent the changes in sorghum production system, and other activities developed to reduce losses due to sorghum aphid.

Management Practices Application-Index (IAPM, for its Spanish Acronym)

The IAPM, derived from the one proposed by Damián-Huato *et al.* (2019), was calculated, and applied to compare the recommendations set out in *M. sacchari* Management Guide by CESAVEG (2017), with practices implemented by producers. A value of 100 points was assigned to the total number of recommendations and these were weighed according to their impact on *M. sacchari* management: 10 points if they know how to locate and identify it, 5 points if they know the damage, 10 points if they identify beneficial fauna, 15

points if they eliminate infestation sources, 5 points if they use a certified seed, 10 points if they use seeds treated with insecticide, 15 points if they check the crop frequently, 10 points if they protect and allow beneficial fauna to act, and 20 points if they apply recommended products at the proposed dosage. Each weighted value was divided by two, where the first quotient represented the use recommended practice, and the second one to the practices actually carried out. The IAPM was calculated with the following equation:

$$IAPM = \sum_{i=1}^k [(pi)(PAPi / PGMi)]$$

Where: Management Practices Application-Index (IAPM); K =Number of Best Practices contained in Sorghum Aphid Management Guide prepared by CESAPEG (2017), where $\max K=9$; P_i : Weighing given to the i -th element the recommendation; PAP_i =Practices applied for the i -th recommendation element; $i=1,2,\dots,k$; where $\sum_{i=1}^k K_i = 1(p_i) = 100$, $i=1, 2,\dots, K$; PGM_i : Practices of the management guide for the i -th component of the recommendation; $i=1,2,\dots, K$, where (PAP_i/PGM_i) =Ratio of practices applied against those recommended.

Once the IAPM has been calculated, the typology of producers was prepared by grouping them according to the value obtained: low (<33.33) medium (33.34 to 66.66) and high (>66.66).

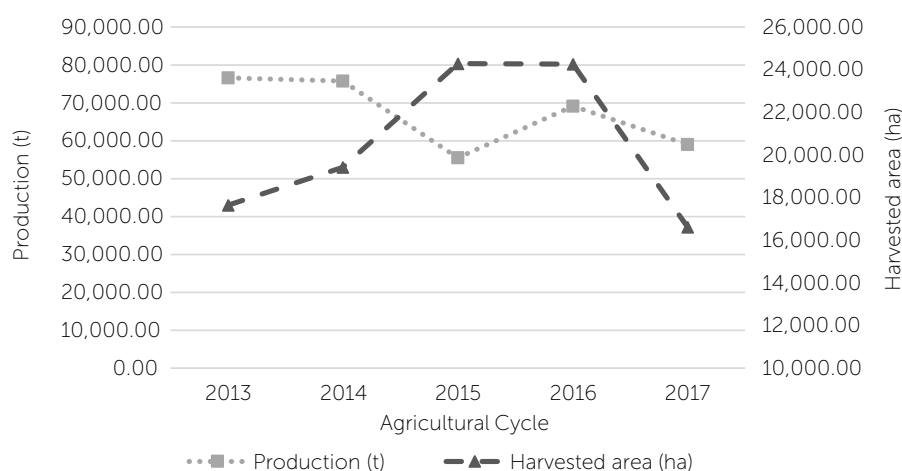


Figure 1. Sorghum production in the Southwestern region of Puebla state. (Prepared from SIAP data, 2019).

Crop Profitability both Under Traditional Farming and No-Till Farming Systems

Crop profitability was examined for 2017 cycle, under both systems implemented within the area: traditional farming and no-till farming. In both cases, production costs per hectare were determined based on the type of technology used by an average producer. Land preparation, inputs, contracted services, and indirect production costs were considered. Benefit-cost ratio was used as a profitability indicator, calculated according to Sobrado (2005):

$$C/BR = (SI) / (CH)$$

Where: C/BR =Cost-benefit ratio; SI =Sales Income; CH =Cost per hectare.

If the C/BR index is higher than 1.0, the portion in which it exceeds the unit will indicate the level of profitability of the crop.

RESULTS AND DISCUSSION

Impact of *M. sacchari* on Sorghum Production in the Southwestern Region of Puebla state

Majority (98.9%) of producers responded that their crops have been adversely affected by sorghum aphid. According to these producers, this pest causes the following issues: it dries up the plant (83.5%), lowering grain weight (13.2%) and growth of panicle (3.3%). Not all producers coincided with the initial infestation of the aphid: 56% of producers remember that it took place in 2015, but 44% said it was in 2014. The arrival of sorghum aphid to the region adversely affected crop yield: although 1775 additional hectares were sown in 2014 compared to 2013, the yield was 1.1% lower. This worsened in 2015, when production was 28% lower, although the area sown was larger. Besides the difference of areas sown between 2013 and 2017 is 1040 ha, the yield for the first cycle was 28.1% higher (Figure 1).

In the region, the average sorghum yield was 3.9 t ha^{-1} in 2014, and in 2015, 2.28 t ha^{-1} . These cycles were considered of greater infestation, with yields lower than those in 2013 (4.34 t ha^{-1}) (SIAP, 2017). In 2014

and 2015 nine varieties were sown (ACA506, ACA6001, ACA642, AMBAR, ANZU310, ARGOS, DEKALB, EL CAMINO and GALIO). DEKALB, the variety sown to a greater extent (57.1 % of producers), is classified as a hybrid tolerant to *M. sacchari* (SAGARPA-INIFAP, 2017). The use of plant resistance is part of a strategy to reduce damages caused by sorghum aphid to grain sorghum crops (Haar et al., 2019).

In 2014 and 2015 cycles, 87.9% of the producers applied insecticides. Imidacloprid (imidacloprid) was the most used product (84.1%), followed by Curacron (profenofos, 4.9%), Folidol (parathion, 3.7%), Disparo (chlorpyrifos-ethyl, 1.2%), and Malathion (malathion, 1.2%); while 3.7% of producers applied a mix of two or more of these insecticides and 1.2% applied alternative methods such as soap or ammonia. A low number (12.1%) of producers did not implement any control strategy, since they did not know the pest.

Yield distribution for 2014-2017 cycles is shown in Table 1. In 2014 and 2015 cycles, the yield observed is lower than 3 t ha⁻¹ for a higher percentage of producers, as opposed to what was recorded in 2016 and 2017, when yields were higher than 3 t ha⁻¹ for most of them.

Purchase price per ton has been falling in the region. In 2015, average purchase price was MX\$3337.91, which was the highest price detected (Figure 2).

Due to a reduction in purchase price, combined with less production, revenues were lower than 2013, the cycle previous to the arrival of *M. sacchari* to the Southwestern region of Puebla state. The lowest income was obtained during 2014 and 2015 cycles (Table 2).

Changes Implemented into Agricultural System to Manage Sorghum Aphid Populations

The strategies implemented to control *M. sacchari* are an increased frequency of insecticide application (44%); crop inspection (21%); and change of

Table 1. Distribution of sorghum yields by 2014-2017 sorghum growing cycle.

Cycle	Yield (t ha ⁻¹)					
	< 1 t	1 a 1.9	2 a 2.9	3 a 3.9	4 a 4.5	NS
	Percentage of producers within range					
2014	14.28	31.87	49.45	1.10	3.30	0.0
2015	15.39	29.67	27.47	16.48	4.40	6.59
2016	0.0	7.69	31.87	36.26	21.98	2.20
2017	0.0	1.10	8.79	43.96	46.15	0.0

NS=Producer did not seed. Developed by author.

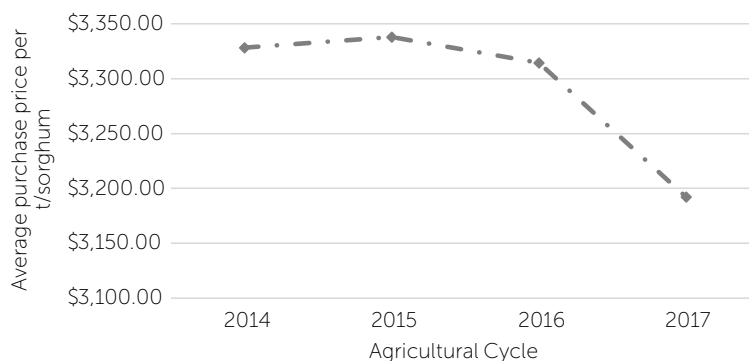


Figure 2. Average purchase price per ton of sorghum in the study region (Developed by author).

insecticide (14%). Due to losses, 9% of producers did not seed in the next cycle, 10% sought advice, and only 2% continued with the insecticide applied in the previous cycle. According to Aguilar (2005), intrusive species reduce crop yield, increase production costs, and the frequency of agrochemical use, which also was observed in this research.

In 91% of the cases, the effect of sorghum aphid on the producer's economy was relatively minor, since their income does not depend solely on sorghum profits. Their primary activities are: sugarcane sowing (35%), amaranth sowing (15%), peanut sowing (12%), corn sowing (11%), onion sowing (2%), stockbreeding (3%), aquaculture (1%); in addition to secondary activities, such as pottery (10%), as well as tertiary activities, such as their small businesses (2%) (grocery store and "huarache" shoe sale). The above agrees with that stated by FAO (2012): family farming represents the main source of income, but it can be supplemented with other non-

Table 2. Average sales revenue for 2013-2017 cycles in the study region.

Agricultural Cycle	2013	2014	2015	2016	2017
Data from SIAP	\$12,558.65	\$8,514.59	\$6,070.97	\$9,154.08	\$11,621.12
Data from surveys	--	\$6,161.57	\$6,178.36	\$9,910.19	\$11,843.46

Prepared with data from survey and data from SIAP 2019.

agricultural activities. In this context, FAO (2001) stated that the effect of pests on producers' economy is mitigated by extra sources of income. However, this effect also depends on the producer's own adaptation, the reconsideration of the productive system, the availability of economic reserves, or even selling or pawning goods.

Management Practices Application Index (IAPM)

Two thirds (65.78%) of producers who use traditional farming showed a medium level in IAPM. In addition, most of the producers with no-till farming (85.7%) showed a medium level in IAPM (Figure 3). According to Damián-Huato et al. (2011), crop yield is the result of multiple factors, including the technological component, which should be used appropriately to be relevant. In both farming types, those with a higher IAPM also obtained a higher yield.

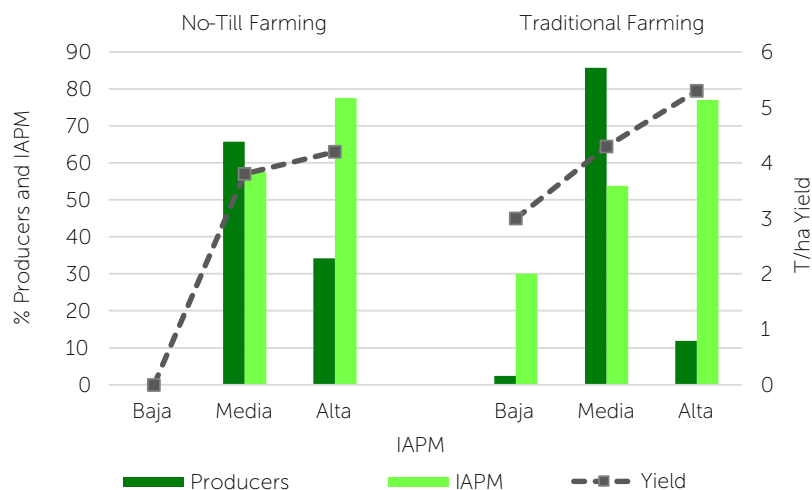


Figure 3. Percentage of producers and yield with respect to IAPM obtained in the Southwestern region of Puebla state.

Profitability of Grain Sorghum Cultivation

Production cost using traditional farming for 2017 was \$11,520.44 ha⁻¹. Land preparation represented 24.21% of production costs, supplies 41.48%, hired services

Table 3. Cost of sorghum production in the Southwestern region of Puebla state, 2017 cycle.

Activity	Traditional Farming			No-Till Farming (Zero)		
	Qty.	Cost ha ⁻¹	Total (\$)	Qty.	Cost ha ⁻¹	Total (\$)
Tasks			2789.42			911.76
Fallow	1	968.57	968.57			
Tracking	1	914.28	914.28			
Planting	1	906.57	906.57	1	911.76	911.76
Supplies			4778.83			5654.02
Gesaprim 90				2.5 L	182.15	455.37
Jornal				2	163.84	327.68
DEKALB	19 kg	30.96	588.24	18.9 kg	30.17	570.21
1 st Fertilization	Included in planting		1511.03	Included in planting		1214.81
2 nd Fertilization			749.21			1095.36
Jornal	2	162.81	325.62	2	267.77	535.54
Imidacloprid	0.379 L	686.22	260.70	0.585	691.67	404.62
Jornal	2	159.03	318.06	2	181.71	363.42
Gesaprim 90	1.81 L	188.02	340.31	2.52	127.41	321.07
Jornal	2	162.83	325.66	2	182.97	365.94
Hired services			1501.65			1639.76
Trilla	1	893.74	893.74	1	940.48	940.48
Freight	3.75 t	162.11	607.91	4.46	156.79	699.28
Direct Costs			9069.90			8205.54
Insurance	1	482.12	482.12	1	419.63	419.63
Financing			1968.42			1968.42
Indirect Costs			2450.54			2388.05
Total production cost			11,520.44			10,593.59

Developed by author.

13.03%, and indirect costs 21.27%. With this investment, an average yield of 3.75 t ha⁻¹ is obtained. The cost for no-till farming systems was \$10,593.59 ha⁻¹, where 53.37% represent supplies, 15.47% hired services indirect production costs 22.54%, and land preparation only 8.60% (Table 3).

For traditional farming systems, benefit-cost ratio was lower than that obtained in no-till farming; in the first one, for every peso invested, the profit was only four mexican peso cents, while in the latter, the profit was 33 cents (Table 4). A similar pattern in B/C indicators was reported with 1.14 for traditional farming and 1.40 for no-till farming, indicating profitability (SAGARPA, 2014). With traditional farming, land preparation has a higher cost.

CONCLUSION

A lower sorghum yield in 2014-2016 cycles is a proof of the negative effects caused by *M. sacchari* attack. In addition to a lower yield, the income obtained from grain sales was increasingly smaller due to a downward trend in the purchase price per ton. More frequent insecticide applications were the main control strategy implemented against this pest, which increased production costs. However, the negative effect of *M. sacchari* on the producers' economy was relatively minor since producers have multiple jobs. A medium Management Practices Application Index (IAPM) was obtained for both types of farming types under assessment. However, the higher the IAPM, the higher the yield. Although profits with no-till farming are higher, sorghum cultivation is still considered a profitable activity for the Southwestern region of Puebla state.

ACKNOWLEDGEMENTS

To the National Council of Science and Technology of Mexico for the grant allowed to the first author.

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Table 4. Profitability (in mexican pesos) of sorghum cultivation in the Southwest of Puebla, 2017 cycle.

	Traditional Farming	No-Till Farming (Zero)
Yield (t ha ⁻¹)	3.75	4.46
Cost (\$ ha ⁻¹)	11,520.44	10,593.59
Sale price (\$ t ⁻¹)	3202.63	3,179.76
Sales Revenue (\$ ha ⁻¹)	12,009.86	14,181.72
Net income per ha (\$ ha ⁻¹)	489.42	3588.13
Net income per t (\$ t ⁻¹)	130.51	804.51
Cost-Benefit Ratio	1.04	1.33

Developed by author.

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