Determining factors for the use of sorghum as fodder for bovines in Northwestern Mexico

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Abstract:

The objective of the study was to analyze the factors that determine the use of free pollination varieties of sorghum in the north of the state of Sinaloa, in order to characterize the type of producers that use this type of seeds. A discrete choice model was utilized to identify the factors that influence the adoption of sorghum by 199 farmers. Later, adopters (n= 11) and non-adopters (n= 188) of the technology were characterized based on non-parametric tests. The results show that 5.5 % of the producers have adopted sorghum varieties. The number of years with technical assistance and milk production were

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significant (*P*<0.05) for the adoption. Also, the characterization of the farmers showed that those who have more resources—infrastructure, machinery, livestock, land, wages and technical assistance, —were the ones who adopted the varieties of sorghum. It is concluded that the adoption of seeds is low and requires public goods, such as agricultural outreach programs, for the dissemination of its benefits to allow greater appropriation by farmers in the region of study.

Key words: Fodder, Free pollination, Adoption, Technological innovation, Dual purpose, Probit.

Introduction

Sorghum is one of the basic foods consumed by the world's poorest people. From a genetic point of view, this crop adapts well to hot and dry agro-ecological areas where it is difficult to grow other cereals. In many of these areas, sorghum, both as grain and as fodder, is given a high use value[1].

Mexico is the second largest producer of sorghum in the world, with 10% of the world production[2]. In 2017, the area planted with sorghum in Mexico was 1'456,330 ha, with a yield of 4'853,109 t. Within the main producing states is Sinaloa, which occupies the third place nationally in area planted with 109,382.59 ha[3]. In 2017, 1'149,320 hectares were cultivated in Sinaloa, of which the production of vegetables occupied 6.18 % ; grains, 67.52 %; oilseeds, 13.14 %; sugar cane, 0.30 %; fruits, 3.63 %, and other crops, 9.24 %. The production of sorghum amounted to 14.10% of the planted area in the state[3].

The most widely used sorghum varieties in Sinaloa are "free pollination" materials— Costeño-201, Fortuna and Gavatero 203—from the National Institute for Research on Forestry, Agriculture and Livestock (INIFAP), which have been shown acceptance by producers and which, when harvested, can be used for planting without affecting the genetic quality of the grain produced[4]. Despite the fact that the sorghum grain is an important fodder for animals, it is ascribed a low "digestibility" compared to other cereals, due to the presence of condensed tannins. Tannins are generally found in brown sorghum grains, but not in white

sorghum grains, and rarely in red sorghum grains. In Sinaloa, most of the sorghum varieties developed by INIFAP are white or creamy grains[4].

Among the various factors that explain the low adoption of improved seed varieties, the studies identify the lack of adaptation of the materials offered, the high perception of the risk involved in their use due to lack of knowledge of its advantages compared with that of the materials utilized by the producer, and deficient distribution[5]. Some of the varieties generated by INIFAP and currently in demand by producers are Gavatero 203, Costeño 201, Sinaloa, and, to a lesser extent, Perla 101[6,7,8,9]. Gavatero 203 sorghum is the variety most widely accepted by producers; in 2016, seeds of this variety were distributed for the sowing of 70 thousand hectares of rainfed crops in Sinaloa[10].

Gavatero sorghum has an intermediate cycle (61 d at flowering and 110 d at harvest). Its grain is reddish-orange, has a grain yield of 2,849 kg ha^{-1} and a green fodder yield of 35,367 kg ha^{-1}; also, it has 66.4 % digestibility and a 7.3 % protein content[6]. The success achieved by this variety lies in its consistency and good behavior under storm conditions (350-600 mm) and in the acceptance of the fodder by the cattle. In addition, under adverse conditions (drought), the variety is vigorous at the early stages of its development, and its seed can be produced at any time of year.

In the case of Sinaloa, the adoption of sorghum-free pollination varieties for silage or fodder directly used by bovine cattle has been partial, and progress in their use has been made only in the central and southern zone of the state, where evaluations and demonstrations of this crop have been carried out[6]. The present study aims to analyze the factors that determine the use of free pollination varieties of sorghum in the north of the state of Sinaloa, in order to characterize the type of producers who use this type of seeds.

Material and methods

Location of the study area

Sinaloa is located within the northwestern coastal plain, which directly borders the Sierra Madre Occidental. Geographically, it is located in northwestern Mexico, bordering the states of Sonora and Chihuahua to the north, Durango to the east, Nayarit to the south, and the Pacific Ocean and Gulf of California to the west (Figure 1), bounded by the extreme coordinates 22°31' and 26°56' N and 105°24' and 109°27' W of the Greenwich Meridian[11].

Figure 1: Location of the study area
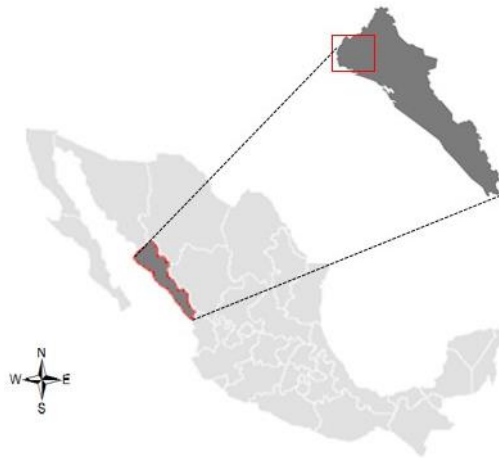
Data collection

The analyzed information comes from a personal and face-to-face survey, conducted in 2015, on a sample of 214 producers of the dual-purpose cattle system (PSBDP, Spanish acronym) in the dry tropics of Sinaloa. The surveys were conducted in northern Sinaloa, a region that has three municipalities with favorable climatic and geographic conditions for sorghum production: Ahome, El Fuerte and Guasave.

The selection of producers was made by non-probability sampling[12]. The following inclusion criteria were used: (a) ownership of livestock, (b) no previous participation in agricultural extension programs, and (c) agreement to respond to the initial diagnostic survey of their livestock production unit.

The survey consisted in collecting data from each producer through a questionnaire with information structured in ten sections, with closed and open questions, which was tested before its final application. The variables included in the questionnaire were divided into the following sections: 1) General aspects of the productive unit, 2) Social and economic characteristics of the producer, 3) Type of ownership of the agricultural area, 4) Level of available resources (number of animals in possession, agricultural land, pasture, water sources), 5) Available facilities (infrastructure, machinery and equipment), 6) Aspects of animal reproduction, 7) Type of feeding and supplementation of livestock, 8) Aspects related to the livestock health of the herd, 9) Aspects related to the management of milking and finally, 10) Issues related to the market for livestock products. The analysis of the information identified 15 surveys with atypical data (e.g. repeated surveys and out-of-average data), so

only 199 surveys with reliable information were considered for the study. This survey was part of a project that aimed to characterize livestock production systems in northern Sinaloa, the results of the characterization, as well as the description and calculation of the index of infrastructure, machinery and equipment are described in Cuevas-Reyes and Rosales-Nieto[13].

Probit model

The Probit model is a discrete choice model, which is characterized by the fact that the dependent variable takes only two values; 0 and 1[14], which correspond to each of the two possible alternatives (in this study: 1 adopts and 0 does not adopt sorghum free pollination varieties). The model uses a normal Cumulative Distribution Function (CDF), according to Gujarati[15] the decision to choose an alternative depends on an unobservable convenience index I_i, determined by one or several explanatory variables (X_i), the index I_i can be expressed as follows: $I_i = \beta_0 + \beta_k X_i$.

With the assumption of normality, the probability (P_i) that I_i^* is less than or equal to I_i is calculated from the standard normal FDA as:

$$P_i = P[Y = 1|X] = P(I_i^* \leq I_i) = P(Z_i \leq \beta_0 + \beta_k X_i) = \varphi(\beta_0 + \beta_k X_i) \qquad (1)$$

Where $P[Y = 1|X]$ signifies the probability of an event occurring, given the value of X_i, Z_i is the standardized normal variable; i.e., $Z_i \sim N(0, \sigma^2)$ and $\varphi(X_i \beta)$ represent the cumulative distribution (CDF) of a standard normal variable [15].

Information regarding I, as well as β_0 and β_k, is obtained using the equation (1):

$$I_i = \varphi^{-1}(I_i) = \varphi^{-1}(P_i) = \beta_0 + \beta_k X_{ki} \qquad (2)$$

Where:
I_i= dichotomous dependent variable reflecting the difference between the use and non-use of a technology (1 if the sorghum variety is adopted, 0 if not).
φ^{-1} is the reverse of the normal CDF.
β_0 = is a constant.
β_k, k = 1, 2 ... n are the coefficients of the independent variables to be estimated.
X_{ki} = vector of exogenous variables that explain the adoption of sorghum varieties.

Once the model (1) has been estimated, the following equation will result from the partial derivative [14]:

$$\frac{\partial \phi}{\partial X_k} = \phi(x_k^i \beta)\beta_k \qquad (3)$$

Thus, the equation (3) represents the effect of the change (marginal probability) of a X_{ki} unit on the likelihood that I = 1.

The model estimation was done by the maximum likelihood method, which provides consistent, asymptotically efficient estimators. The individual significance of the parameters was contrasted using Wald's test, whose statistic Z follows a standardized normal distribution. The overall goodness of fit was evaluated using McFadden's R^2, and the LR statistic or likelihood ratio. The results of the econometric model were obtained with the Data Analysis and Statistical Software (Stata), version 12.

Once the factors that determine the use of the sorghum varieties were identified, the producers who use (or adopt) the sorghum varieties were characterized in comparison with those who decided not to adopt them. Descriptive statistics were used to analyze the identified groups, and the Mann-Whitney U test was applied to the ordinal variables, as when the (Kolmogorov-Smirnov) normality test was performed on the quantitative variables, they failed to meet the requirements of the test for establishing the normality of the data (P<0.05). The information was processed with SPSS®, version 21 (IBM Corp).

Results and discussion

Factors that determine the use of sorghum varieties

Table 1 shows the results obtained from the binary probabilistic model. The value of X^2 was used to contrast the global significance of the model; its null hypothesis is that all the coefficients of the equation, except the constant, are null. 96.98 % of the cases were correctly classified, the LR $Ji^{2(9)}$ statistic was 40.04, and the associated probability was less than 0.05; therefore, the null hypothesis was rejected, and the global model was statistically significant. The z statistic applied to the model's coefficients shows that two variables (technical assistance and milk production) were significant (*P*<0.05) to explain the probability of adopting sorghum varieties in the study region.

Table 1: Variables that influence the probability of adopting sorghum varieties

Variable	Coefficient	z	*P>z*	dy/dx
Index of machinery and equipment, %	0.0057	0.47	0.639	0.00008
Infrastructure Index, %	0.0346	1.65	0.100	0.0004
Technical assistance, years	0.2149	2.47	0.013*	0.0030
Age, years	-0.0167	-0.91	0.361	-0.0002
Schooling, years	-0.1470	-1.19	0.234	-0.0020
Distance to the municipality, km	-0.0073	-0.28	0.779	-0.0001
Number of adult cows	0.0379	1.42	0.155	0.0005
Agricultural area, ha	-0.0224	-1.07	0.238	-0.0003
Milk production, L	-0.0306	-2.46	0.014*	0.0004
Constant	-1.6908	-1.50	0.134	

dy/dx is the marginal effect of variable x on the dependent variable, and Level of significance dy/dx: $P<0.05$*. Number of observations (n): 199. LR $Ji^2(9) =40.04$; Prob $>Ji^2=0.0000$; Pseudo $R^2=0.4706$, Correctly classified = 96.98 %.

The marginal effects of the significant variables were small; the PSBDP who have technical assistance have a 0.3 % probability of adopting new sorghum varieties, while the probability of adopting this technology by producers who wish to engage in milk production is as low as 0.04 %.

The results obtained in the technical assistance variable in this study are consistent with those found by other authors[16-19], who point to the existence of a positive relationship between technical assistance and the adoption or use of technology.

A relevant factor in the adoption of new varieties is the price of the seeds; price is an extrinsic attribute that affects the farmer's decision to buy[20]. In the case of Gavatero 203 sorghum, the purchase price during 2018 was $12.00 per kg, which was the same as that of the commercial "milon" sorghum variety (generation F2 or F3 of fodder hybrids Silo Miel, Cow Vittles, and others) used by producers. However, when comparing both types of sorghum, it was observed that Gavatero sorghum exhibits a better quality, with 90 % of complete and viable seeds, compared to 75 % of the "milon". It also has a higher germination viability (85 to 90 %) in contrast to the 75-80 percent of other sorghum varieties[4].

An additional advantage of the open-pollinated varieties is their low price compared to sorghum hybrids. In this regard, in the study region there are seeds of hybrid sorghum for silage with a price of sale to the producer of approximately $63.00 pesos per kilo; this price is 425 % higher than the price ($12.00 per kg) of the recommended free pollination varieties in the study area.

Studies on the adoption of corn varieties generated by INIFAP found that in the state of Veracruz, the variables associated with the producer's decision to use a seed were: proximity to the place of purchase, knowledge of INIFAP seeds and, to a lesser extent, preference for planting improved seeds to replace the native variety[21]. On the other hand, in the Yucatan Peninsula, in spite of knowing about INIFAP's improved seeds, the adoption process is interrupted by factors such as the scarce availability of these seeds in the market, or the lack of economic resources on the part of the producer to acquire the seeds[22].

As in Yucatan, one of the factors limiting the adoption of sorghum in Sinaloa is the limited availability and knowledge of these materials by the users. Therefore, in order to improve adoption, the available resources and the decisions of producers must be considered.[23] In addition, the reproduction of these seeds must be promoted through producers' organizations that grow or offer more than one type of seed and receive constant training on production technology, processing, distribution, packaging and marketing of open-pollinated varieties[24].

The production of sorghum for fodder in the region of study constitutes an important alternative as, since it is a variety of free pollination, the same producer can store seeds for the following cycles. However, in order to maintain its genetic quality, controlled production of this type of seed is required. In the region of study, the Produce Sinaloa Foundation is the only institution that has developed a production scheme for some of the free pollinated sorghum varieties released by INIFAP. However, the greatest effort is currently being made by individual producers who, on their own initiative and at their own risk, are engaging in this activity to meet the demand of the PSBDP across the state.

Characterization of adopters and non-adopters of sorghum varieties

The results obtained are consistent with previous studies that indicate that the adoption of free pollination varieties by producers is low[5,21,22]. In this regard, only 5.5 % of the producers in this study adopted new varieties of sorghum. The following is a description of the adopting and non-adopting producers in terms of social and productive aspects and types of products obtained.

Social aspects

The social variables analyzed among the group of adopters and non-adopters were the same in both groups ($P>0.05$), so from the social point of view they are families with similar characteristics (Table 2). These results differ from those found by other authors[25], who point out that social characteristics are variables that differentiate the users of technological innovations.

Table 2: Social variables between adopters and non-adopters (median)

Variable	Adopters	Non-adopters	*P**
Age, yr	55.0	47.5	0.497
Schooling, yr	3.0	3.0	0.389
Dependents aged over 18 yr (#)	1.0	1.0	0.224

* Mann-Whitney U.

Availability of productive resources

Significant differences ($P<0.05$) between adopters and non-adopters were identified for six productive variants: infrastructure index, machinery and equipment index, type of employment (casual or hired), number of animal units, total agricultural area and number of years that technical assistance has been provided. In other words, producers who adopt sorghum seeds have more productive resources (agricultural area, number of animal units), more infrastructure and equipment, and also salaried labor and technical assistance (Table 3).

Adopters held a larger number of hectares (median of 15 ha) than non-adopters (median of 8 ha); it seems that the availability of land together with other productive resources makes the producers less adverse to risk and, therefore, they may venture to plant new varieties.

Table 3: Productive variables between adopters and non-adopters (median)

Variable	Adopters	Non- adopters	*P**
Infrastructure index, %	36.36	18.18	0.000
Index of machinery and equipment, %	40.00	20.00	0.006
Daily wage (0= casual; 1=hired)	1.00	0.00	0.010
Total number of adult cows, #	20.00	13.50	0.102
Stocking rate, #	34.30	21.30	0.027
Agricultural area, ha	15.00	8.00	0.029
Technical assistance, years	4.00	0.00	0.000

* Mann-Whitney U.

Technology adoption is positively associated with larger plot sizes and higher incomes[26]. However, farmers usually tend to face any innovation with uncertainty and preconceptions regarding how it will affect them[27]. The results obtained with respect to the variables of farm size and contact with technical assistance services coincide with various studies conducted on the use of rice and wheat varieties by small producers[28,29].

Types of products obtained: milk and meat

The explanatory milk production variables were significant at 1% (*P*= 0.000) for non-adopters and 5% (*P*=0.005) for calf production in the group of adopters. This result indicates that the group of adopters of new sorghum varieties are inclined to produce calves. Adopters had a median of 0 and non-adopters had a median of 30 L of milk. In contrast, adopters' calf production had a median of 2 and non-adopters had a median of 0. Seemingly, then, the use of new varieties of sorghum has to do with the possibility of having more fodder to improve the production of calves for fattening.

The use of sorghum free pollination varieties in the study area has several advantages over other materials and hybrids, including: 1) Better yield in grain and fodder, 2) Low price compared to commercial sorghum, 3) Produces even under drought conditions, 4) The producer can "harvest" its seed for the next sowing cycle. However, the varieties are little known by the producers. In this regard, Kaliba *et al*[30] mention that greater adoption of seeds of sorghum varieties requires linking research, extension services, and decision makers in order to promote appropriate agricultural technology that is up-to-date and easily accessible by producers in the face of production, the market, and information access constraints.

Conclusions and implications

In the study region, only 5.5 % of the producers decided to use free pollinated varieties of sorghum as fodder for cattle. Technical assistance and milk production were the significant variables that determined the adoption of new sorghum varieties. By characterizing the analyzed groups, it was possible to identify that producers who have technical assistance and more resources, such as land and livestock, are more willing to innovate with new technological alternatives. The results of the research allow us to conclude that free pollinated varieties are not so rapidly adopted due to the low availability of new sorghum materials and to the lack of dissemination actions and technology transfer to the producers of the dual-purpose cattle system. Schemes must be designed for the reproduction and dissemination of

freely pollinated sorghum seeds. Other public goods, such as agricultural extension, are also required to enable the dissemination and transfer of these technological innovations as well as a greater adoption by livestock producers in northern Sinaloa and in regions with similar characteristics and issues.

Acknowledgements

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