Improved Agave Cultivars (*Agave angustifolia* Haw) for Profitable and Sustainable Bioethanol Production in Mexico

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Introduction

Agave is a plant with a core used to produce tequila and mescal, both important beverages in Mexico and the world.

Upon new technology developments and global warming, one of the options that has received more importance in the world is energy diversification, with usage of renewable sources of energy.

Mexico looks forward to integrate farmers to grow the raw materials needed to produce clean fuels, mainly bioethanol used as an input to obtain gasoline. The need of an adequate additive is being increasing in Mexico since the last years. The actual additive (MTBE, Methil Ter-Buthil Ether) is a carcinogen.

As an attempt to solve the energy diversification problem, Mexico started producing bioethanol from corn. However, according to the "law for bioenergy promotion and development" national production of corn could not be used to produce biofuels. As a consequence, Mexico decided to use sugarcane for that objective, but to produce sugarcane in Mexico is more expensive than in other countries. Moreover, it requires water and lands with high potential to produce food stuffs. (Government inter-department commission for bio fuels development, 2008).

To contribute to solve that problem, Chapingo Autonomous University undertook the research project: "Improved agaves plantations for bio ethanol production", whose main objective is to obtain bioethanol at a high production rates and at a low cost.

Economic costs and biomass analysis

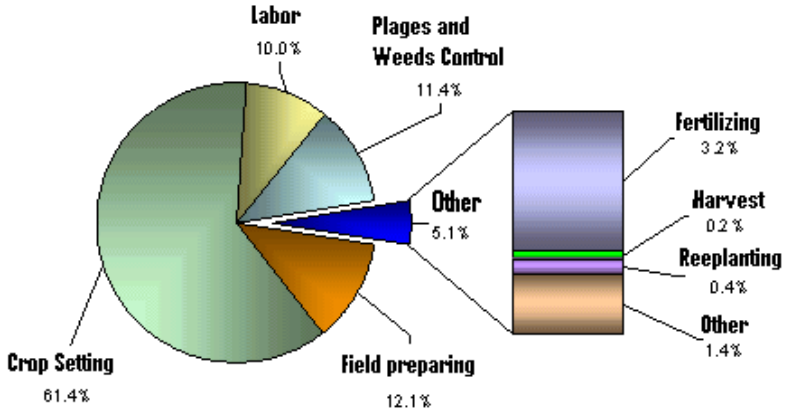
After 30 years of continuous research, Chapingo Autonomous University generated a new improved cultivar of Agave mezcalero (*Agave Angustifolia* Haw), which is a very high yield cultivar. It produces cores of 150 kg, with a population density of 3,500 plants per hectare. Its inulin concentration is about 25% and is able to survive in semiarid areas.

Table 1: Agave Production Cost per Year

Year of Growth *Costs are given in dollars	Concept	Mechanic labors	Workers	Raw materials and supplies	Transport	Other	Total
1	$	234.85	313.64	660.98	193.18	42.42	1,445.1
	%	16.30	21.70	45.70	13.40	3.00	100.0
2	$	90.91	109.09	263.26	41.67	42.42	547.3
	%	16.60	19.90	48.10	7.60	7.80	100.0
3	$	113.64	732.20	339.02	53.03	42.42	1,280.3
	%	8.90	57.20	26.50	4.10	3.30	100.0
4	$	90.91	876.14	255.68	41.67	42.42	1,306.8
	%	7.00	67.00	19.60	3.20	3.20	100.0
5	$	22.73	857.20	304.92	53.03	42.42	1,280.3
	%	1.80	67.00	23.80	4.10	3.30	100.0
6	$	0.00	1,853.41	251.89	647.73	42.42	2,795.4
	%	0.00	66.30	9.00	23.20	1.50	100.0
Total	**$**	**553.03**	**4,741.67**	**2,075.76**	**1,030.30**	**254.55**	**8,655.30**
	%	**6.40**	**54.80**	**24.00**	**11.90**	**2.90**	**100.00**

Source: SAGARPA (2006).

Figure 1: Agave Production Cost Distribution



Source: OEIDRUS-MORELOS, 2008

Sugar cane production costs are that we would have as point of comparison (Table 2).

Table 2. Sugar cane Production Costs per Year

Concept *Costs are given is USD	**Mechanic labor**	**Workers**	**Raw materials and supplies**	**Transort**	**Other**	**Total**
Cane with automatic irrigation	626.21	402.27	1,452.27	238.64	297.73	3,017.12
Cane, irrigation by dripping	443.07	438.41	827.12	424.24	336.92	2,469.76
Cane, water season only	640.15	377.2	761.81	424.24	228.63	2,432.12

Source: SAGARPA (2006)

Tables 1 and 2 indicate that the cost of sugarcane production in Mexico is far more expensive than that of agave mezcalero. Nevertheless, there are other important concepts before deciding whether agave is the best option or not.

Comparing agave mezcalero with sugarcane in terms of cost, biomass production, and ethanol obtaining potential (Table 3).

Table 3: Sugarcane (Automatic Irrigation) Comparison to Agave Mescalero

Crop	Sugar cane*	Improved agave Angustifolia Haw
Years to harvest	1	6
Production Tons/hectare * year	77	87.5
Raw materials (Kg) /Ethanol(liter)	15	8
Ethanol (liter)/hectare a year	5,113	10,937
Sugar (%)	8-12%	27%
Cost per liter of ethanol (USD), in terms of raw materials only.	0.47	0.13

Sources: Self elaboration with data from Madrigal (2009), SAGARPA (2006) and Becerra (2009).
*Cane under Water season only.

Agave produces more ethanol per hectare even when biomass production is lower, thanks to its high inulin concentration.

What about both plants physiological needs? Table 4, presents a comparison, from a physiological perspective, between Agave and Sugarcane.

Table 4: Agave *Versus* Sugarcane Needs

Crop / Characteristic	Improved Agave (*Angustifolia Haw*)	Sugar cane
Water needs	Very low, no need to irrigate in places where there are about 500mm of precipitation.	Very high, it requires water during all year, so irrigation is mostly needed when planted in Mexico.
Fertilizing needs	No need to fertilize, but if done, low concentrations of Nitrogen are needed.	Needs nitrogen, potassium, and minor elements to ensure a fine growing.
Light needs	Needs to be directly under sunlight, but grows fine if light shadow.	Needs to be directly under sunlight.
Climate needs	Semi desert areas are the minimum requirement to have a satisfactory growth. But doesn't tolerate very humid places.	Tropical to semitropical only. Needs lots of water and light soils.

Sources: Self elaboration with data from Infojardin.com, 2002 and CONAFOR-CONABIO (2001).

Agave crop production has a significant advantage with respect to sugarcane produced in Mexico, but, it necessary to compare it with yellow corn production in the United States, because Mexico could find imported MTBE cheaper than bioethanol produced in national lands.

Once taken a look at this data, the next context (Table 5) represents the cost and production average values for sugar cane and "agave mescalero"; besides, it gives some important points of comparison not only for sugar cane, but for yellow corn. It can even be used at the same time to reforest semidesert areas with erosion problems, having a positive impact on ecological issues. It could help to fulfill the national bioenergy demand, and also improve the environment in Mexico (CONAFOR, 2009).

Table 5: Agave, Corn and Sugarcane Bioethanol Production. Impact Comparison

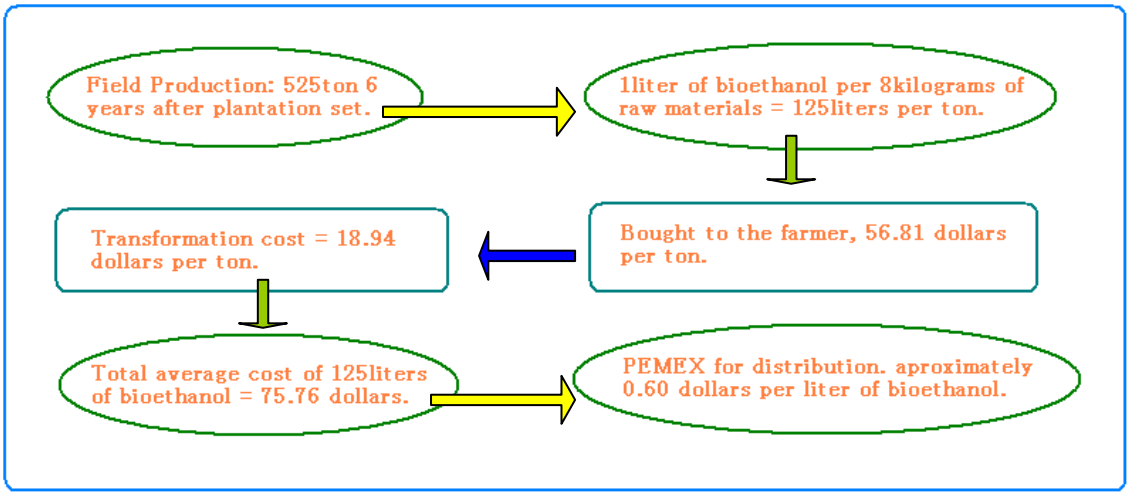
Product/process	Yellow corn (US National Average)	Sugarcane (Mexico, National average)	Improved Agave (Mexico)
Raw material /Ethanol(lt)	3	15	8
Yield (t/hectare)	12	73.18	81.25
Years to harvest	1	1	6
Ethanol (lt/hectare)	3,785	4,	9462
Water needs	High	Very high	Low
Labor Needs	High	High	Low
Environmental impact	Very high	High	Low
Needed as Food	Very high	High	Low
Sugar content (%)	5-11	8-12	25-30
Soil quality needs	Very high	High	Low

Source: Madrigal (2009).

The cost of 120 cents per MTBE gallon in US will be considered as the production cost (ICIS, 2009).

If wanted to compare this costs with agave and sugarcane based bioethanol costs, the whole movement since agave growing in the field, until the final product is ready, must be considered (Figure 3).

Figure 3: Agave movement costs



Source: self elaborated with data from (Madrigal, 2009).

Sugarcane bioethanol is worth for $0.60 dollars per liter when harvested and processed (Becerra, 2008). MTBE cost (120 cents per gallon) means $0.317 USD per liter. It is cheaper than agave and sugarcane bioethanol.

It is very important to invest time and money to ensure a new source of energy for a future era when we will not have enough oil to supply the world. The time to look for an answer to future more severe global crisis is now.

According to the previous results, agave bioethanol production in Mexico would require a subsidy of $0.29 dollar/liter subsidy to agave ethanol refineries to support the transition toward a sustainable economy based on renewable sources of energy.

Even when producing both agave and sugarcane bioethanol have the same cost, agave bioethanol still has some other characteristics over sugarcane plantations. It is sustainable because of being an environmental-friendly plantation and having low production costs. It is profitable, the proposed price paid to farmers after growing improved agave plantations and the costs at which industry transforms raw materials, lets the farmer and the industry have utilities.

Conclusions

The average cost of imported gasoline in Mexico is $0.32 US dollars/liter, which is 48% less expensive than both agave and sugarcane ethanol. This means that it is not profitable to substitute gasoline by ethanol obtained from agave or sugarcane at current market prices. It must be the opposite whether oil barrel price surpasses $100 US dollars or agave ethanol falls 48%.

Therefore, it is required the Mexican government give a $0.29 dollar/liter subsidy to agave ethanol refineries to support the transition toward a sustainable economy based on renewable sources of energy. This is a feasible policy since the United States government subsidies ethanol obtained from corn with approximately $0.28 dollars/liter.

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