In search of Sustainability of the Sugarcane Crop and Sugar Industry: The Role of Preparation and Training of Human Resources

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Abstract

Universidad Veracruzana, Mexico is well known in the Mexican state with the highest sugar production of the country. Therefore, in recent times Universidad Veracruzana began focusing on social, cultural and technological aspects of this significant agro-industry of Veracruz in particular and Mexico as a whole. The Institute for the Improvement of Sugar Production (IMPA), founded in 1949, was the institution that sponsored research in this area, but the entity was terminated in 1990. This event was the main single event that led Universidad Veracruzana, jointly with other research centers, to initiate a program dedicated to train professionals for the sugarcane industry in Mexico. Eleven of the sugar factories in the state are located in the region of Cordoba, where the MS Program 'Management and Use of Sugar Cane Agricultural Systems' was started in 1995. Nine of our graduates are working in sugar mills within the Cordoba region. This paper presents the characteristics of the cited MS Program and its relationship to the sugar agro-industry of Veracruz through research projects and technological improvement. It also presents some of the results from the research done; all this with the purpose of showing that the essential goal of the program is the preparation of highly trained human resources for the sugarcane industry.

1. Introduction

Fifty seven sugar mills distributed throughout 15 states operate in México growing over 650 thousand ha of sugarcane of 4 agro-climatic regions along the coasts of the Pacific Ocean and the Gulf of Mexico-Caribbean Sea, at around 16-21ºN (Marín, 1998; Flores, 2001). Production amounts to over 49 mt of cane and 5 mt of sugar, with cane yields ranging in recent years between 64 and 72 t ha^{-1} and factory recovery around 11% (Manual Azucarero Mexicano, 2008). The industry supports, directly or indirectly, over 3 million people. Veracruz alone generates approximately 41% of the national sugar production in 22 sugar mills, 11 of which are located in the Cordoba region surrounding the Córdoba-Orizaba campus of the state university, Universidad Veracruzana (UV).

UV is a public institution of significant national and international stature. Located in the heart of the Mexican sugar industry, UV has been associated with the sugar industry in the social, cultural and technological fields. Consequently, when the former Institute for the Improvement of Sugar Production (IMPA) closed in 1990, UV, in collaboration with the National Program of Research in Sugarcane Science and Technology and with the Latin America and Caribbean Sugar Exporting Countries Group, initiated a specialized sugarcane program in 1993, which was formalized in June 1995. This experience fostered a strategic alliance between the organisations and enabled the establishment of master's degree (MS) in 'Management and Use of Sugarcane Agro Systems' in December, 1996. The objective of this program was to provide the local sugar industry with highly qualified personnel. To attain this goal, UV counts on its high teaching experience, 56% of the teaching staff having a PhD degree. Other major assets of the program include the Library and Information Services Unit (USBI), the Orizaba High Tech Lab (LATO-UV) and signed collaboration agreements with the Autonomous University of Chapingo (ACH), the National Chamber of Sugar and Alcohol Industries (CNIAA), DGETA, the Veracruz, Oaxaca and Puebla sugar mills, and all from Mexico, the National Sugarcane Research Institute (INICA) of the Ministry of Sugar (MINAZ) of Cuba, the Havana Agricultural University (UNAH), CENGICAÑA, the University of San Carlos and Pantaleon Sugar Mill of Gua-

temala, the Luis de Queiros Higher Agriculture School of the University of Sao Paulo (ESALQ) of Brazil, and the Sugarcane Research and Extension Division (DIECA) of Costa Rica.

The Program goal is to prepare highly qualified human resources which may contribute to the development of a *competitive*, *diversified and sustainable sugarcane agro-industry*, able to design, lead and conduct programs of applied research, training and technological innovation along the sugarcane production chain from an environmentalist perspective.

2. General Characteristics of the Program

The general characteristics of the Program are as follows:

Two years of graduate studies divided into four semesters. The program requires doing research and writing a thesis, except for those cases in which the research project requires a longer period; something which must be certified by the student's advisor and which cannot in any case exceed one calendar year.

The student must submit a thesis title at the beginning of the study program, which, once approved by his/her advisor, can be submitted to the Master's Coordinator. From this moment, the student has a two year period to finish his/her thesis or apply for an extension.

The study plan comprises 19 subjects divided into three categories, viz. Methodological Training, General Agricultural Training, and Specific Sugarcane Training. Fourteen of these subjects are obligatory and one optional which is to be selected from the remaining five. Additionally, the Program includes two activities as Program requirements: the writing of a dissertation or thesis and a final examination. This scheme comprises a total of 1125 h, 585 of which are theory and 540 are practical. Table 1 and 2 highlight the work hours and academic credits associated with the Program as well as the broad curriculum structure.

Students must also obtain Level II English and/ or French language as well as demonstrate computer use proficiency before a degree can be awarded.

2.1. Applied research lines in the program

Thesis projects generally focus on current research needs within the local sugar industry but may well relate to any broad area, such as: Sugarcane Breeding and Selection, Sugarcane Agricultural Technology, Sugarcane Byproducts, Biotechnology and Environment, or Sugarcane Plant Protection.

3. Academic Results

3.1. Admission and graduation

A total of 97 students registered in the Program during the period from 1997 to 2008. Fifty two (53.6%) of them have graduated (Table 3). Most Master's graduated are working in various sugar mill plantations and other agro-industrial enterprises in the country, with excellent production and social achievements.

Table 1: Curricular structure of the MS Degree in 'Management and Use of Sugarcane Agro Systems' at UV by training areas

Area of training (4 semesters)	Total number of hours	%	Total number of credits	%ww
Methodological	255	22.7	26	22.8
General agriculture	300	26.7	30	26.3
Sugarcane specific	570	50.6	58	50.9
Sub-total	1125*	100	114*	100
Thesis work			5	
Degree examination			20	
Total			139	
*585 h theory (78 credits) and 540 h practical (36 credits)				

Table 2: Curricular structure of the MS Degree in 'Management and Use of Sugarcane Agro Systems' at UV by subjects

Methodological	Agricultural general	Sugarcane specific
1. Research methodology	1. Edaphology	1. Physiology and biochemistry
2. Statistical methods and experimental design	2. Soil fertility*	2. Applied genetics
3. Company management	3. Agro-ecology	3. Water resources and drainage*
4. Agricultural economics*	4. Biotechnology	4. Agricultural mechanization*
5. Thesis workshop I	5. Seminar I	5. Cropping technology
6. Thesis workshop II		6. Plant protection
		7. Sugarcane by-products*
		8. Seminar II
19 subjects: 14 obligatory, 5 optional* (to select 1) Requirements of the Program: Writing of the thesis and degree examination		

Table 3: Graduated students up to December, 2008					
Generation	Dates		Registered	Graduated	%
1	January, 1997	December, 1998	21	18	85.7
2	January, 2001	December, 2002	19	10	52.6
3	August, 2002	July, 2004	26	13	50.0
4	August, 2004	July, 2006	20	6	30.0
5	August, 2006	July, 2008	11	5	45.5
Total			97	52	53.6

Since 2002, the Master's Degree Program has also been conducting training courses for growers and field technicians in the following subjects: Sugarcane Pest, Disease and Weed Management; Varieties and Seed Sugarcane; Nutrition and Fertilization; Crop Management; Sugarcane Quality; Sugarcane Byproducts; and Crop Harvesting. Up to December 2008, 20 courses were delivered by 22 instructors to 614 students from 57 sugar mills attending them.

3.3. Collaboration with national and international institutions and enterprises

Practical tours have been arranged by the instructors for the students with the support and collaboration of the following institutions and countries:

National Sugarcane Research Institute (INICA) Cuba, in 2002, 2004, 2005 and 2007.

CENGICAÑA, Pantaleón Sugar Mill and the University of San Carlos, Guatemala, in 2001, 2002, 2004 and 2006.# ESALQ and CENA at the University of Sao Paulo, Brazil, in 2005, 2008 and CINCAE of Ecuador in 2005.

DIECA, Costa Rica, in 2007.

CNIAA Breeding Station of Tapachula, Chiapas, México, in 1997, 2001, 2002, 2004 and 2006.

Additionally, the following sugar mills have provided important practice support help to complete student project tasks: Central Motzorongo, San Miguelito, Central Progreso, San José de Abajo, El Potrero, La Providencia, Constancia, La Margarita, Tres Valles, Adolfo López Mateo, El Modelo, Calipam and Huixtla.

3.4. Main research results obtained

Characterization of the main commercial, promising and traditional sugarcane varieties of Mexico. Various student projects have dealt with the botanical and agro-industrial characterization of the most important sugarcane varieties grown in the country: Mex 69-290, CP 72-2086, Mex 79-431, Mex 57-473, Mex 68-P 23, Co 997, Q 96, SP 70-1284, RD 75-11, My 5514, ITV 92-1424, PR 66-2231, CMex 93-45, CMex 93-49, MotzMex 91-207, AteMex 96-40, C86-12, NCo 310, L 60-14, POJ 2878, B 4362 and Co 421 (Hernández, 2004; Patiño, 2005).

Characterization and control of the most common weeds present in sugarcane fields in the region. Various student thesis projects have accomplished the descriptive characterization, distribution, propagation and integrated control of the 50 most important common weeds by their level of hazard to sugarcane. These include the following number of weeds by families: Poaceae, 17; Cyperaceae, 2; Amaranthaceae, 4; Compositae, 8; Commelinaceae, 1; Portulacaceae, 2; Solanaceae, 1; Papaveraceae, 1; Malvaceae, 2; Leguminosae, 3; Convolvulaceae, 1; Acanthaceae, 1; Cucurbitaceae, 1; Euphorbiaceae, 3; Fabaceae, 1; Araceae, 1; and Boraginaceae, 1. (Ordóñez, 2002; Vilaboa, 2003; Illescas, 2004; García, 2008).

Neither sugarcane yield nor sugar recovery in the factory responded to either split or non-split nitrogen fertilization of sugarcane in the cropping area of San José de Abajo and San Miguelito Sugar Mills under the prevailing rain-fed conditions. In the second ratoon cycle under rain-fed conditions, in San Miguelito Sugar Mill, nitrogen fertilization positively influenced sugarcane yield and through this, the pol or sucrose yield ha^{-1} (Table 4) in non-split application but not in a split application. An optimum rate of 140 kg ha^{-1} was found (Figure 1) (Escarola, 2003; Norato, 2004).

Sugarcane potassium fertilisation on Cambisol soils, of San Miguelito Sugar Mill, Córdoba, Veracruz, México. At planting of trials, due to inadequate monoculture and crop agronomic management, losses of soil nitrogen (0.11%), organic matter (1.55%) and potassium (16.5 K_2O 100 g^{-1}) had taken place, producing changes in the category of these components (Tables 5 and 6).

Application of 150 and 225 kg of potassium ha^{-1} at fixed levels of 167 and 0 kg ha^{-1} of nitrogen and phosphorus, respectively, resulted in significantly higher tonnes cane ha^{-1} $month^{-1}$, percentage of pol $cane^{-1}$ and tonnes sugar ha^{-1} $month^{-1}$ in plant cane while, in first ratoon, only the treatment of 225 kg potassium ha^{-1} was higher (Table 7 and 8) (Arreola, 2002; Niño, 2007; Colorado, 2008).

Influence of sugarcane residue management at harvest, on sugarcane yield at El Potrero Sugar Mill.

The following residue management treatments were evaluated: 1) Sugarcane pre-harvest and post-harvest residue burnings

Table 4. Yield (tonnes cane/ha), Pol % cane and tonnes pol ha^{-1} at harvest, second ratoon cycle, in the locality of Tapia, San Miguelito Sugar Mill, Córdoba, Veracruz

No	Treatments	Mean values and formation of groups by LSD								
		tonnes cane ha^{-1}				Pol % cane	tonnes Pol ha^{-1}			
1	00-00-00	87.7	-	-	c	17.47	15.23	-	-	c
2	177-85-85	119.1	a	-	-	18.01	21.34	a	b	-
3	00-60-120	93.6	-	b	c	17.98	16.83	-	b	c
4	50-60-120	111.1	a	b	-	17.82	19.88	a	b	c
5	100-60-120	114.3	a	-	-	17.82	20.35	a	b	c
6	150-60-120	109.6	a	b	-	18.02	19.83	a	b	c
7	200-60-120	113.1	a	b	-	18.96	21.46	a	b	-
8	1502-60-120	114.3	a	b	-	18.61	21.28	a	b	-
9	1503-60-120	121.5	a	-	-	18.64	22.65	a	-	-
10	1504-60-120	116.5	a	-	-	18.57	21.68	a	b	-
LSD (p=0.05)		20.60				3.03	5.39			

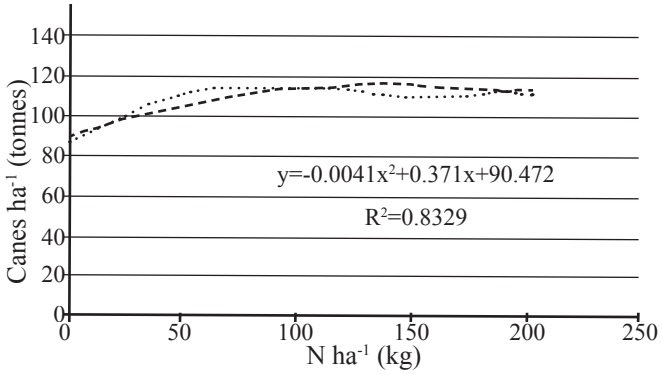

Figure 1: Results of cane yield under various nitrogen dosages in a 12 months old, second ratoon cycle, at San Miguelito Sugar Mill (inflexion point: 140 kg N ha^{-1}, expected yield 115 t cane ha^{-1})

(PHRB), 2) Sugarcane pre-harvest burning, without post-harvest residue burning (WPHRB), 3) Green sugarcane harvesting, without pre-harvest and without post-harvest residue burning (GCWPHRB), and 4) Green sugarcane harvesting, without pre-harvest but with post-harvest residue burning

Table 5: Category reached by the various cropping techniques for total nitrogen, organic matter and pH

Samples from 0-20cm depth	Moreno (1978) quoted by López (1998)		Moreno (1978) quoted by López (1998)		Letelier (1967) quoted by López (1998)	
	Total nitrogen		Organic matter		pH	
	%	Class	%	Class	%	Class
Soil without sugarcane during 15 previous years	0.28	Extremely rich	3.35	Rich	5.50	Moderately acid
Soil with sugarcane without harvest burning	0.16	Rich	2.17	Medium	5.70	Moderately acid
Soil with sugarcane with harvest burning	0.17	Rich	1.80	Moderately poor	5.10	Moderately acid

Table 6: Category reached by the various cropping techniques for phosphorus, potassium and cation exchange capacity

Samples from 0-20 cm depth	INICA (1997)				Cottenie (1980) quoted by INICA (1997)	
	P_2O_5 100^{-1} g		K_2O 100^{-1} g		CCC-meq 100^{-1} g	
	Value	Class	Value	Class	Value	Class
Soil without sugarcane during 15 previous years	5.20	High	31.30	High	17.06	Medium
Soil with sugarcane without harvest burning	5.60	High	33.60	High	15.36	Medium
Soil with sugarcane with harvest burning	6.20	High	14.80	Low	16.75	Medium

(GCPHRB). From the analysis of results, it was concluded that the best treatment was No. 3: Green sugarcane harvesting without pre-harvest and without post-harvest residue burning; this treatment produced 24.25 t of sugarcane more than burnt sugarcane, while the lowest yield was in the green sugarcane harvest and subsequent residue burning (Table 9) as reported

Table 7: Results of harvest variables in a 17 months old, plant cane cycle, at San Miguelito Sugar Mill, Córdoba, Veracruz										
No.	Treatments	tonnes cane ha^{-1} month^{-1}			Pol % cane			tonnes Pol % cane ha^{-1} month^{-1}		
1	(00-00-00)	8.38	-	b	12.07	-	b	1.01	-	b
2	(167-75-75)	9.35	a	b	12.77	a	b	1.19	a	b
3	(167-00-75)	8.76	a	b	13.01	a	-	1.14	a	b
4	(00-00-75)	8.58	a	b	12.89	a	b	1.11	a	b
5	(167-00-00)	8.47	a	b	12.62	a	b	1.07	a	b
6	(167-00-150)	9.64	a	-	13.35	a	-	1.29	a	-
7	(167-00-225)	9.52	a	-	13.06	a	-	1.24	a	-
Tukey 0.05		1.13			0.91			0.22		

Tabla 8: Harvest results for variables in a 14 months old first ratoon cycle, at San Miguelito Sugar Mill, Córdoba, Veracruz									
No.	Treatments	tonnes cane ha^{-1} month^{-1}			Pol % cane		tonnes Pol % cane ha^{-1} month^{-1}		
1	(00-00-00)	7.05	-	b	17.47	Not Significant	1.23	-	b
2	(167-75-75)	8.44	a	b	18.00		1.52	a	b
3	(167-00-75)	7.86	a	b	17.90		1.41	a	b
4	(00-00-75)	7.19	-	b	17.82		1.28	-	b
5	(167-00-00)	7.76	a	b	18.03		1.40	a	b
6	(167-00-150)	8.00	a	b	18.34		1.47	a	b
7	(167-00-225)	8.75	a	-	18.51		1.62	a	-
Tukey 0.05		1.49			----		0.33		

Table 9: Yield, tonnes tops ha^{-1} and tonnes trash ha^{-1} at harvest in second ratoon cycle at El Brinco Farm, El Potrero Sugar Mill						
No.	Treatments	Mean values and formation of groups by Tukey				
		tonnes cane ha^{-1}			tonnes cane ha^{-1}	tonnes cane ha^{-1}
1	PHRB	90.38	----	b	29.150	5.4360
2	WPHRB	90.50	----	b	30.846	4.8840
3	GCWPHRB	114.75	a	----	31.730	5.3780
4	GCPHRB	70.25	----	c	28.312	4.1900
Tukey 0.05		20.08			----	----

by Molina (2004).

4. Conclusion

The training program presented in this paper can contribute to improve human capital for sugarcane agro-industry. The success of such program requires collective support from neighboring countries for maximum effect. Many of the courses included in the program are available as distance learning courses, which assist in the admission of students in their own countries and the participation of professors from various countries around the world. Proper training and research are key elements for ensuring the sustainability of the sugar industry around the world. This particular program has made an important impact in the Mexican sugar industry, particularly in the state of Veracruz. *The program is highly encouraging which may have direct impact in sugarcane production and efficient utilization of human resource*.

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