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ECONOMIC EVALUATION, ENERGETIC AND ENVIRONMENTAL OF TECHNOLOGIES OF WEED CONTROL IN THE SUGARCANE (*Saccharum* spp. Hybrid)

Evaluación económica, energética y ambiental de tecnologías de manejo de arvenses en el cultivo de la caña de azúcar (*Saccharum* spp. híbrido)

Frank J. Viera Barceló[1]✉ and Luis Escobar Cruz[2]

ABSTRACT. The research was carried out in areas of production from Majibacoa Sugar Enterprise, Las Tunas province, to make an economic, energetics and environmental evaluation of technologies of weed control in spring cane plant, in a fluffed brown soil. In the experimental area, parcels were traced, according to a random blocks design with four replications. Nine technologies were evaluated, where the mechanical control and the chemist were combined with the manual cleaning, the animal traction and the mechanical cultivator was used and as means of application of herbicides, sprayer machine and backpack. To the different technologies it was determined economic utilities, energetic efficiency, loads pollutant towards the atmosphere and effects on the compaction of the soil through the resistance to the penetration. It was obtained that the most effective technologies were those which included the Isoxaflutole herbicide, where it was used smaller quantity of agricultural implements passes and applications of herbicides.

Key words: sugarcane, weed control, herbicides, environment, energy

RESUMEN. La investigación se desarrolló en áreas de producción de la Empresa Azucarera Majibacoa de la provincia Las Tunas, para hacer una evaluación económica, energética y ambiental de tecnologías de manejo de arvenses en caña planta de primavera, en un suelo Pardo mullido carbonatado. En el área experimental se trazaron parcelas, según un diseño de bloques al azar con cuatro réplicas, se evaluaron nueve tecnologías, donde se combinaron el control mecánico y el químico, se utilizó la limpia manual, la tracción animal, el cultivo mecanizado y como medios de aplicación de herbicidas, maquina y asperjadora manual. A las diferentes tecnologías se les determinó utilidades económicas, eficiencia energética, carga contaminante hacia la atmósfera y efectos sobre la compactación del suelo a través de la resistencia a la penetración. Se obtuvo que las tecnologías más efectivas resultaron aquellas que incluyeron el herbicida Isoxaflutole, donde se utilizó menor cantidad de pases de implementos agrícolas y aplicaciones de herbicidas.

Palabras clave: caña de azúcar, control de malezas, herbicidas, medio ambiente, energía

INTRODUCTION

Weeds severely affect sugarcane production which demands an integrated control using all available means at the right time; it should be done immediately after planting or after harvest taking into account the edaphoclimatic conditions, weed characteristics and available resources. Competition in the first four months causes major reductions in sugarcane yields which is known as the critical period. In this stage, three to four weeding operations are commonly needed[A].

The same conditions favoring extensive sugarcane growing can be favorable for weed development. Weed control can account for 18-28 % of the crop cost and 5-6 % of the production cost (1, 2).

The control of weeds considered pests for economic crops can be done by different methods: chemical, mechanical, cultural and biological; there are different variants within these methods. Chemical weed control is more economic than the manual one and together with the mechanical control, shows the best cost-benefit relationship compared to other

[1] Facultad de Ciencias Agrícolas, Universidad "Vladimir I. Lenin". Las Tunas, Cuba, CP 75200.

[2] Empresa Azucarera Majibacoa.

✉ fviera@ult.edu.cu

[A] Rodríguez, L. y Díaz, J.C. *Programa de control integral de malezas en caña de azúcar*, [11], INICA, La Habana, Cuba, 2012, 169 p.

approaches (3). It is mainly because when you manage weeds manually, productivity is very low and more manpower per hectare is needed, manpower is very expensive in most of the countries.

The transit of agricultural machinery is one of the causes of soil compression, they are also an important source of atmospheric contamination because of the emission of diesel gasses. The use of crop technologies including different types of tractors and implements, leads to different energetic balances, mainly because of the fuel consumption (4).

The understanding of energy flows and balances is a basic element to achieve energetic sustainability, it is important because of economic, ecological and social reasons. The knowledge and quantification of energetic efficiency in food production systems should become an essential tool to design agricultural management strategies and take political decisions. That is why it is a priority to take into account the necessary methodology to design sustainable systems for food and energy production. This step will be a decisive step to achieve a more efficient use of available energy sources, both biological and industrial (5).

In Cuba there are several reports on the different weed control methods in sugarcane where evaluations of the technical effectiveness and economic evaluations are predominant, but there are no reports on energetic balances and their influence on the environment. This situation has been reported in Cuba by Funes (5) in agricultural production units, livestock projects and integrated units. If efficient technologies would be applied from the energetic, economic and environmental points of view, it would be possible to attain sustainable productions in sugarcane.

Therefore, the objective of this research has been the testing of technologies to evaluate weed control management from the economic, energetic and environmental point of view in sugarcane growing, in planted spring seeds, on a brown loose soil at the Sugar enterprise of Majibacoa, las Tunas province.

MATERIALS AND METHODS

The research was conducted at the Basic Production Unit "Manduley" of the Sugar Enterprise "Majibacoa", located at the central part of Las Tunas province. The objective was evaluating weed management in sugarcane growing, cultivar C 1051-73, left spring seed, from the energetic, economic and environmental points of view. The experiment took place on a brown loose carbonated soil (6), abundant in this Enterprise and in some other regions of the country.

The soil of the experimental area was submitted to physical and chemical analyses at the Soil Provincial Lab. The P_2O_5 and K_2O were determined by the Machiguin technique, the pH using a pH meter (1:2,5), organic matter by the Walkley Black methodology and the plasticity index by Atterberg (Table I).

Experimental conditions

Experimental design: Random block; using wood poles, strips were laid down on the field. Technologies including the use of ground sprayers, eight sugarcane rows were used, other technologies used five rows, all of them 100 m long and a ridge distance of 1,60 m; the experimental area covered 30 640 m^2. The nine evaluated technologies included treatments shown in Table II and they were applied in four strips considered as replicates.

Cultural practices

Soil preparation was done with a Belarus 1221 tractor and plowing using a MAU-250-C (disking and crossing) and with an MTZ-80 and medium harrow (two loosing operations). This same tractor was coupled with a ridger, the FC-8 cultivator, multiple harrow, a SIMA fertilizer F350 and a sprayer of the brand Máñez Lozano (made in Spain). Harvest was done with a KTP-2M cane cutting machine. Total herbicide applications with Monosodic Methylarsenate were done when sugarcane plants exceeded 60 cm height, the multiple harrowing was used 100 days after planting and the pre-closing herbicide treatment with Amonium gluphosinate was done 130 days after planting. Non-mechanized herbicide applications were done with the hand sprayer Super Agro-16. As fertilizer, 30 kg ha^{-1} of phosphorus and 60 kg ha^{-1} of potassium were applied as carriers in addition to Triple Superphosphate (SFT) and Potassium chloride KCL.

Table I. Chemical and physical chracteristics of the soil at the experimental area

Soil	P_2O_5 (Mg 100 g of soil)	K_2O (Mg 100 g of soil)	pH (H_2O)	Organic matter (%)	Plasticity index (%)
Loose brown carbonated	4,64	41,23	7,00	4,22	35,00

Table II. Evaluated technologies

	Technologies	Number of passes
1	Oxen-drawn cultivator+Hoe	8
2	Ametrine 2 kg ha^{-1}+ 2,4D 2 L ha^{-1} (AM)+ Hoe	2
	MSMA 3 L ha^{-1} + 2,4D 2 L ha^{-1} (AM)+ Hoe	3
3	Ametrine 2 kg ha^{-1}+ 2,4D 2 L ha^{-1} (AM)	2
	MSMA 3 L ha^{-1} + 2,4D 2 L ha^{-1} (AM)	2
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1
4	Cultivator F350 + Hoe	5
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1
5	Cultivator F350 + Ametrine 2 kg ha^{-1}+ 2,4D 2 L ha^{-1} (AM)	2
	MSMA 3 L ha^{-1} + 2,4D 2 L ha^{-1} (AM)	2
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1
6	Merlin 0,200 kg ha^{-1} (AM)	1
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1
7	Merlin 0,200 kg ha^{-1} (M)	1
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1
8	Merlin 0,200 kg.ha^{-1} (AM)	1
	Chemical eradication: Finale 1,5 % v/v + Agrotín 0,15 % v/v (Surf)	2
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1
9	Merlin 0,150 kg ha^{-1}+Ametrina 1,5 kg ha^{-1}+2,4D 2 L ha^{-1} (M)	1
	MSMA 3 L ha^{-1} + 2,4D 2 L ha^{-1} (AM)	2
	Multiple harrow tillage	1
	Pre-closing application: Finale 2 L ha^{-1} (AM)	1

(M): sprinkler machine
(AM): manual sprinker
Surf: surfactant
Merlin (Isoxaflutole), 2,4 D (Ácido 2,4- diclorofenoxiacético), Ametrine (2 etilamino 4 isopropilamino 6 metiltio S triazina, Finale (Glufosinato de amonio), MSMA (Metilarsenato monosódico). As surfactant Agrotin was used (polyvinyl alcohols, nonifenols, silicones, pH regulators and polysaccharides)

Evaluations

Input technology (EI): input technology (Input)=Direct energy (ED)+Indirect energy (EID), ED = fuel consumed and EID = energy related to fertilizers, herbicides, seeds, human and animal energy, mechanical energy (tractors and KTP-2M cane cutting machines). (MJ ha^{-1})

Techn: technologies, (M): sprayer machine, (AM): Hand sprayer, Surf: surfactant Merlin (Isoxaflutole), 2,4 D (2,4- D dichlorofenoxiacetic acid), Ametrine (2 ethylamine 4 isopropilamine 6 metiltio S triazine, Finale (Amonium gluphosinate), MSMA (Monosodic Methylarsenate). Agrotín was used as surfactant (Polyvinil alcohols, noniphenols, silicones, pH regulating substances and polysacharids)

Output energy (EE): the output energy is the one provided by the sugar produced and by-products of the industrial process (MJ ha^{-1}).

Energetic efficiency (EE): EE= EE/EI (MJ.ha^{-1}). in order to determine the energetic costs of all technologies, the methodology suggested by Hetz and Barrios (7), was applied and the procedure proposed by Paneque *et al***.** (8) was also used, under Cuba's conditions. It includes all the energy consumed in the execution of each technology. The energetic coefficients of different resources were also used (Table III).

Resistance to penetration: resistance to penetration (RP), is the capability soil has to withstand the penetration of a rigid body. The magnitude of this pressure is measured in megapascals (MPa). RP depends on soil features like texture, structure, moisture content. The drier the soil, the highest will be the value of this variable, its value can reduce root growth in most of the crops until stop it completely at values close to 3 MPa (11).

Table III. Reference energetic values for different resources[B] (9, 10)

Concept	Unit	Energy (MJ/ Unit)
Phosphoric fertilizer	kg	14,00
Potassium fertilizer	kg	9,68
Man power	hour	1,90
Oxen pair work	hours	2,10
Herbicides	kg	418,00
Diesel	L	47,80
Seeds	t	15,60
Sugar	kg	15,80
Alcohol	kg	26,80
Electricity	kW.h	10,32
Biogas	m^3	360,00
Agricultural wastes (RAC)	t	80,00

[B] Ander-Egg, A.; Donato, L.; Hilbert, J.; Huerga, I.; Martin, F. y Medina, J. *Principales insumos para la producción de biocombustibles*, [PSA 028/07], INTA, Buenos Aires, Argentina, 2008, 251 p.

In order to determine the soil resistance to penetration an impact penetrometer was used; penetration reached 30 cm, the area where most of the sugarcane roots develop. Fifty evaluations were performed for each of the replicates for the different technologies.

Contaminating load to the atmosphere: This variable is very important from the environmental point of view since it reflects the quantity of contaminating gasses received by the atmosphere including the greenhouse effect gasses due to the use of tractors. The point of departure is the functioning of the internal combustion engine (MCI) that after burning 1 kg of Diesel (supposing a complete combustion) releases contamination to the atmosphere expressed in kg (12).

$$Gt = (1 + \alpha l_0)\ nC,\ kg\ ha^{-1}$$

Gt_ contaminating load generated by the burned Diesel to perform all tasks.

α_ filling coefficient for Diesel, considered at 1,40.

l_0_ quantity of necessary air to burn 1 kg of fuel: 15,10 kg

nC_ quantity of kg of fuel consumed per hectare in each technology.

Agricultural yield: Agricultural yield was determined by weighing the sucarcane of the two central rows of each replicate with a scale coupled to a MTZ80 – 6KM hoisting machine and expressed in t ha^{-1}.

Economic evaluation: The economic evaluation was made by determining the cost of each weed management technology, according to the price of the different herbicides, rates, wage expenses and fuel cost. The total cost (CT) included the previous cost plus the rest of the labors: soil preparation, planting, fertilization and harvest. The income derived from sales was calculated through the agricultural yield plus the price of the sugarcane tonne (IV).

Profits = IV- CT (CUP ha^{-1})

Statistical processing. Data were submitted to the analysis of variance to compare means. The Tuckey's test at 0,05 of significance was applied. The statistical software packagage "InfoStat", versión 1 was also used (13).

RESULTS AND DISCUSSION

Energy inputs

The highest energy inputs were true for technologies 5, 3, 2 and 4 (Table IV), technology 5 recorded high values in four herbicide applications, much manpower was also needed since five hand hoeing were practiced. Machinery also recorded high expenses since the cultivator FC8 was used repeatedly.

Technology 3 recorded the highest energy inputs for the use of herbicides that were applied five times. Technology 2 also used herbicides five times and hand hoeing, so manpower use was also present.

Technology 4 required much energy since herbicides were applied four times and five cleaning passes were done with the FC8 and hand hoeing, so a considerable quantity of fuel and manpower were needed.

In technologies 1 and 2 for weed control, no tractors were used, so there were not fuel expenses; technology 1 did not include herbicide applications, but a lot of human and animal energy were needed since hand hoeing and cultivation with oxen were used eight times. Technology 2 used chemical control and hand hoeing five times.

The lowest energy inputs were reached with technology 1 in spite of its high human and animal use, but it neither included herbicides nor machinery; technologies 6, 7, 8 and 9 showed a good performance because the inclusion of Isoxaflutole had a long residual effect on sugarcane fields with a low percentage of weeds, so less cultural practices were needed.

Table IV. Energy input

Technologies	Fuel (MJ ha^{-1})	Machine (MJ ha^{-1})	Human and Animal (MJ ha^{-1})	Herbicides (MJ ha^{-1})	Seed (MJ ha^{-1})	Fertilizers (MJ ha^{-1})	Input (MJ ha^{-1})
1	12 623,50	2 937,84	585,66	0	14 306,97	1000,80	31 454,77
2	12 913,65	2 937,84	301,45	3 762,00	14 306,97	1000,80	35 222,70
3	13 620,61	3 131,86	177,13	4 598,00	14 306,97	1000,80	36 835,37
4	14 815,13	3 907,94	296,17	836,00	14 306,97	1000,80	35 163,01
5	14 191,82	3 519,90	179,51	4 598,00	14 306,97	1000,80	37 797,00
6	13 131,14	3 131,86	166,96	919,60	14 306,97	1000,80	32 657,32
7	13 403,60	3 181,36	164,17	919,60	14 306,97	1000,80	32 976,49
8	13 840,01	3 131,86	168,86	836,00	14 306,97	1000,80	33 284,50
9	13 915,06	3 181,36	177,73	2173,60	14 306,97	1000,80	34 755,51

With all these technologies, high agricultural yields above 90 t.ha^{-1} contributed to save fuel and manpower at harvest time. Once yield surpasses 40 t.ha^{-1}, the number of times the sugarcane cutting machine has to pass by the same rows is lower, so truck and trailers filling time is also lower which leads to fuel and human energy saving. It also has an important incidence on the quality of the roads and the speeds of hauling vehicles (14).

Energy ouput

The highest energy outputs were recorded by technologies 8, 9, 5 and 4 and the lowest value was for technology 1 (Table V). These outputs were directly related to agricultural yields by applying each technology (Table VIII). Out of every tonne of sugarcane, the Majibacoa industry, at that time, produced sugar 110,0 kg, alcohol 11,0 L, electricity 20 kW.h, biogas 1 m^3 and sugarcane residues (RAC) 0,2 t.

Energetic efficiency

The highest energetic efficiencies were reached with technologies 8, 9, 6 and 7, mainly due to the low energy inputs (Table VI) and high agricultural yields, mainly for technologies 8 and 9. Technology 1 had an enegetic efficiency higher than the rest of the technologies in spite of having a lower output value, but also had the lowest input.

As irrigation was not practiced in this research, input energy values were not so high; they could be reduced if organic fertilizers would have been applied to reduce the quantity of chemical fertilizers. In Iranian agricultural farms, the highest energy expenses fall upon irrigation, fuel, machinery and fertilizers, with a total value of 148,02 GJ ha^{-1}; the energy produced was 112,22 GJ ha^{-1}, so there is a relationship of 0,76. In order to improve these results, the efficiency of irrigation systems should be higher, organic fertilizers should be applied and tractors' power optimized (10).

Table V. Energy output

Tecnologies	Sugar (MJ ha^{-1})	Alcohol (MJ ha^{-1})	Electricitry (MJ ha^{-1})	Biogás (MJ ha^{-1})	RAC (MJ ha^{-1})	(Output) (MJ ha^{-1})
1	15 4143,22	26 145,81	18 305,62	31 928,40	1 419,04	155 562,26
2	16 3111,30	27 666,98	19 370,64	33 786,00	1 501,60	164 612,90
3	16 3250,34	27 690,56	19 387,15	33 814,80	1 502,88	164 753,22
4	16 9385,48	28 731,21	20 115,74	35 085,60	1 559,36	170 944,84
5	18 0387,02	30 597,29	21 422,26	37 364,40	1 660,64	182 047,66
6	16 3771,74	27 779,00	19 449,07	33 922,80	1 507,68	165 279,42
7	16 3771,74	27 779,00	19 449,07	33 922,80	1 507,68	165 279,42
8	18 5409,84	31 449,26	22 018,75	38 404,80	1 706,88	187 116,72
9	18 1551,48	30 794,81	21 560,54	37 605,60	1 671,36	183 222,84

Table VI: Energetic efficiency

Tecnologies	Inputs (MJ ha^{-1})	Outputs (MJ ha^{-1})	Energetic efficiency (MJ ha^{-1})
1	31 454,77	155 562,26	4,94
2	35 222,70	164 612,90	4,67
3	36 835,37	164 753,22	4,47
4	35 163,01	170 944,84	4,86
5	37 797,00	182 047,66	4,82
6	32 657,32	165 279,42	5,06
7	32 976,49	165 279,42	5,01
8	33 284,50	187 116,72	5,62
9	34 755,51	183 222,84	5,27

Contaminating load to the atmosphere and soil penetration resistance

The contaminating load (CC) of the different technologies for weed management showed significant differences among them (Table VII), with the highest values for technologies 4 and 5 and the lowest ones for technologies 1 and 2. These results directly depended on fuel consumption (Table IV).

The lowest values were reached with those weed management technologies that did not use tractors to perform cultural practices and also in those with less involvement. Contaminating loads were not higher because light tractors with a low fuel consumption were used and their technical status was good.

The Cuban Ministry of Higher Education has proposed itself to consume less fuel to reduce the contaminating load to the atmosphere, mainly of CO_2 that amounts to 328 tonnes per year. It contributes to an increased greenhouse effect. The service sector consumes 54 % of the Diesel allocated to the enterprise for mechanized weed control (15).

In relation to the contaminating load / agricultural yield, the highest values were reached with technology 4 and the lowest ones with technologies 8 and 9, the rest had rather closer results.

The highest soil penetration value (RP) was reached with technology 4, without significant differences with 7 and 9; it was possibly due to the fact that technology 4 included several operations with tractors, 5 passes of the FC8, multiple harrow cultivation and fertilization with SIMA F350- Technologies 7 and 9 did not use FC8, but Isoxaflutole was applied with a ground sprayer including the weight of the tractor and the sprayer with an initial capacity of 800 L of water.

Soil compression is a direct consequence of transit intensity, especially in labors requiring the repeated load use. One of the measurements to evaluate induced compression on the soil mass is resistance to penetration (RP), that mainly depends on soil properties. Its value is an indicator of the soil-roots interaction; RP values above 2 MPa are considered restrictive to roots development (16).

Sugarcane harvest during the dry period favors soil against deterioration of its physical properties and keep its surface without geometrical alteration. A research conducted in Colombia, on a fine-texture soil with 23 % of average moisture content; resistance penetration values of 3,5 MPa were reported pre-harvest and of 4,0 Mpa post-harvest (17).

Studies conducted on the use of minimum tillage on clay soils of Villa Clara province, showed that in the ridge area where agricultural machinery move, soil structure was somewhat altered; however, on the sugarcane row, compression was lower so there was a better aeration because of a higher organic matter content (18).

Economic evaluation

Technology 8 reached the highest agricultural yield, followed by technologies 9, 5 and 4, the lowest value was reached with technology 1, significantly surpassed only by the other two. The rest of the values were very similar (Table VIII).

The chemical and physical characteristics of this soil were not a restrictive factor to the crop (Table I), the assimilable contents of P_2O_5 and K_2O were high, the pH was neutral, the organic matter content was medium as the plasticity index. These evaluations took into account the interpretation charts for soil analysis[C].

[C] Martín, J.N. *Tabla de interpretación de análisis de suelo*, Universidad Agraria de La Habana, La Habana, Cuba, 2004, 17 p.

Table VII. Contaminating load to the atmosphere (CC), its relationship with agricultural yield (RA) and soil penetration resistance (RP)

Tecnologies	CC (kg ha^{-1})	Relationship CC/RA kg t^{-1}	RP (MPa)
1	5 262,21 a	59,33	1,52 a
2	5 383,16 b	57,36	1,51 a
3	5 677,86 e	60,45	1,51 a
4	6 176,01 i	63,37	1,56 b
5	5 915,33 h	56,99	1,52 a
6	5 473,77 c	58,09	1,52 a
7	5 587,55 d	59,30	1,53 ab
8	5 769,27 f	54,08	1,51 a
9	5 799,94 g	55,52	1,53 ab
ES	2,45		2,45

Incomes for sales directly depended on the agricultural yield, selling price of sugarcane tonne that was 104,00 CUP.

The most expensive weed management technologies were 2, 1 and 4 mainly due to the salary expenses for hoe cleaning that was repeatedly used. The lowest costs were reached with technologies 7, 6 and 8, where Isoxaflutole was applied as pre-emergent herbicide without mixing it with other herbicides like technology 9 did.

The highest profits were reached with technologies 8, 9 and 5, with values above 9 510 CUP.ha^{-1}, followed by technologies 7 and 6, the lowest value was achieved with technology 1.

Weeds present at the experimental area were: *Rottboellia cochinchinensis* Lour, *Dichanthium annulatum* Forsk, *Leptochloa panicea* Retz, *Cynodon dactylon* L, *Ipomoea trífida* Kunth, *Euphorbia heterophylla* L, *Bidens pilosa* L and *Cyperus rotundus* L. This latter showed allelopathic properties (19).

Herbicides can show beneficial or negative effects on other organisms and it is not always convenient to practice the “total weed control approach” since preserving certain levels of these plants contribute to reduce the population of grass-living organisms and increase the population of beneficial insects (20).

In this research, herbicide applications in most technologies could contribute to counteract the resistance effects developed by weeds which results in a reduced efficiency of this control method. The economic benefits of using cultural practices and herbicides of different modes of action, mainly the residual ones, vary depending on the crop, so there can be positive and negative results. Of course, agricultural yields have a great influence on the profits. Weed species that have developed resistance to herbicides increase worldwide; a reported example is after several applications of Glyphosate. Sugarcane cultivars also show different tolerance degrees to herbicides so if the phytotoxicity is high, agricultural yields might be damaged (21).

Herbicide costs are: Ametrine (2 ethylamine 4 isopropilamine 6 methyltio S triazine) (7,47 CUP kg^{-1}), Salt amine (Ácido 2,4- dichlorophenoxyacetic) (4,73 CUP L^{-1}), Finale (Amonium Gluphosinate) (10,20 CUP L^{-1}) and Merlin (Isoxaflutole) (149,25 CUP kg^{-1}). This latter is the most expensive one, but it does not increase application costs so much since it is used at very low rates compared to the rest. It also maintains the field weed free for a long period of time, so less hand cleaning is needed[A].

Evaluations made show how the best results to achieve sustainable productions, were reached with technologies 6, 7, 8 and 9, which included the use of Isoxaflutole; since the highest agricultural yields were attained with the highest energetic efficiencies. In the relationship contaminating load / agricultural yield, technologies 8 and recorded the lowest values. Technologies 8, 9 and 5 stood out profits wise, followed by 6 andy 7. The lowest costs were for technologies 7, 6 and 8; technology 9 had lower values than the others, except 3.

As to soil resistance penetration, very similar values were recorded around 1,5 MPa, with an increasing trend in those technologies where tractors were more active within the field and where herbicides were applied with a ground sprayer. Technology 8 had positive results on agricultural yields, energetic efficiency, economic results and contaminating load to the atmosphere per tonne of sugarcane produced.

Table VIII. Economic evaluation

Tecnologies	Weed control cost (CUP ha^{-1})	Total cost (CUP ha^{-1})	Sales income (CUP ha^{-1})	Profits (CUP ha^{-1})	Agricultural yield (t ha^{-1})
1	782,08	1611,76	9223,76	7612,00	88,69 a
2	789,57	1624,71	9760,40	8135,69	93,85 b
3	300,96	1149,41	9768,72	8619,31	93,93 b
4	568,76	1439,71	10135,84	8696,13	97,46 c
5	424,60	1283,81	10794,16	9510,35	103,79 d
6	238,71	1077,95	9799,92	8721,97	94,23 b
7	160,20	1004,57	9799,92	8795,35	94,23 b
8	281,19	1133,78	11094,72	9960,94	106,68 e
9	304,41	1158,41	10863,84	9705,43	104,46 d
ES					0,30

CONCLUSIONS

The most efficient weed management technologies from the energetic and environmental points of view (the contaminating load to the atmosphere and soil compression, were evaluated by the soil penetration resistance) were: 6, 7, 8 and 9; those including the pre-emergent herbicide Isoxaflutole, with the best results for technology 8, where it was applied at the rate of 0,200 kg ha^{-1} with a hand sprayer, two chemical eradication practices with Amonium gluphosinate 1,5 % v/v, multiple harrow tillage and a pre-closing application with the same herbicide at 2 L ha^{-1}. Technology 1, based on hand hoeing and cultivation with oxen without the use of herbicides, was a good choice to protect the environment, but it is not economic and requires a high consumption of human energy.

BIBLIOGRAPHY

1. Edmond, L.M. "Outdoing the weed competition", *Sugar Cane International*, vol. 24, no. 1, 2007, pp. 10-12, ISSN 0265-7406.
2. Conlong, D.E. y Campbell, P.L. "Integrated weed management for sugarcane field verges: *Melinis minutiflora* and *Cynodon dactylon* encroachment.", *Proceedings of the Annual Congress - South African Sugar Technologists' Association*, no. 83, 2010, pp. 276-279, ISSN 1028-3781.
3. Cheema, M.S.; Bashir, S. y Ahmad, F. "Evaluation of integrated weed management practices for sugarcane.", *Pakistan Journal of Weed Science Research*, vol. 16, no. 3, 2010, pp. 257–265, ISSN 1815-1094.
4. Olivet, R.Y.E. y Cobas, H.D. "Balance energético de dos aperos de labranza en un Fluvisol para el cultivo del boniato (*Ipomoea batatas* Lam)", *Revista Ciencias Técnicas Agropecuarias*, vol. 22, no. 2, junio de 2013, pp. 21-25, ISSN 2071-0054.
5. Funes, M.F.R. *Agricultura con futuro: la alternativa agroecológica para Cuba*, edit. Estación Experimental Índio Hatuey, Matanzas, Cuba, 2009, p. 176, ISBN 978-959-7138-02-0.
6. Hernández, A.; Pérez, J.; Bosch, D. y Castro, N. *Clasificación de los suelos de Cuba 2015*, edit. Ediciones INCA, Mayabeque, Cuba, 2015, p. 93, ISBN 978-959-7023-77-7.
7. Hetz, E. y Barrios, A. "Reducción del costo energético de labranza/siembra utilizando sistemas conservacionista en Chile", *Agro-Ciencia*, vol. 13, no. 1, 1997, pp. 41–47, ISSN 0718-3216.
8. Paneque, R.P.; Fernandes, H.C. y de Oliveira, A.D. "Comparación de cuatro sistemas de labranza/siembra en relación con su costo energético", *Revista Ciencias Técnicas Agropecuarias*, vol. 11, no. 2, 2002, pp. 1–6, ISSN 1010-2760.
9. dos Santos, H.P. y Fontaneli, R.S. "Conversão e balanço energético de sistemas de produção de grãos com pastagens sob plantio direto", *Pesquisa Agropecuária Brasileira*, vol. 35, no. 4, 2000, pp. 743–752, ISSN 1678-3921.
10. Karimi, M.; RajabiPour, A.; Tabatabaeefar, A. y Borghei, A. "Energy analysis of sugarcane production in plant farms a case study in Debel Khazai Agro-industry in Iran", *American-Eurasian Journal of Agricultural and Environmental Science*, vol. 4, no. 2, 2008, pp. 165–171, ISSN 1818-6769.
11. Sellés, G.; Ferreyra, R.; Ruiz, R.; Ferreyra, R. y Ahumada, R. "Compactación de suelos y su control. Estudio de casos en el Valle de Aconcagua", *Boletín INIA*, no. 234, 2012, p. 53, ISSN 0717-4829.
12. Mordujóvich, M.M. *Fundamentos termodinámicos y funcionamiento del motor Diésel de tractor. Manual de motores Diésel para tractores*, 1.ª ed., edit. MIR, Moscú, 1996, p. 685.
13. Di Rienzo, J.A.; Casanoves, F.; Balzarini, M.G.; González, L.; Tablada, M. y Robledo, C.W. *InfoStat* [en línea], versión 1998, [Windows], edit. Grupo InfoStat, Universidad Nacional de Córdoba, Argentina, 1998, Disponible en: <http://www.infostat.com.ar/>.
14. Matos, R.N. y García, C.E. "Evaluación técnica y de explotación de los camiones en la transportación de la caña", *Revista Ciencias Técnicas Agropecuarias*, vol. 21, no. 2, junio de 2012, pp. 30-33, ISSN 2071-0054.
15. Herrera, M.I.; Toledo, A. y García, M.P. "Elementos de gestión en el uso del parque de tractores", *Revista Ciencias Técnicas Agropecuarias*, vol. 20, no. 1, marzo de 2011, pp. 20-24, ISSN 2071-0054.
16. Kulkarni, S.S.; Bajwa, S.G. y Huitink, G. "Investigation of the effects of soil compaction in cotton", *Transactions of the ASABE*, vol. 53, no. 3, 2010, pp. 667-674, ISSN 2151-0032.
17. Rodríguez, L.A.; Valencia, J.J. y Bolívar, J.G. "Tráfico de Equipos de Cosecha, Compactación y Efectos Superficiales", *Revista Tecnicaña*, no. 26, 2010, pp. 31-35, ISSN 0123-0409.
18. Betancourt, R.Y.; Cairo, P.; Gutiérrez, M.A.; García, R.I. y García, de la F.C.A.E. "Las propiedades físicas del suelo para definir la zona de aplicación del laboreo localizado en los suelos arcillosos pesados del norte de Villa Clara", *Revista Ciencias Técnicas Agropecuarias*, vol. 19, no. 1, marzo de 2010, pp. 01-08, ISSN 2071-0054.
19. Arévalo, R.A.; Bertoncini, E.I.; Aranda, E.M. y González, T.A. "Alelopatía en *Saccharum* spp.(caña de azúcar)", *Avances en Investigación Agropecuaria*, vol. 15, no. 1, 2011, pp. 51–60, ISSN 0188-789.
20. Kortekamp, A. *Herbicides and Environment* [en línea], edit. InTech, 8 de enero de 2011, ISBN 978-953-307-476-4, [Consultado: 19 de junio de 2015], Disponible en: <http://www.intechopen.com/books/herbicides-and-environment>.
21. Rodrigues, F.R.; Oliveira, F.T.R.; DeLite, F.S.; Azevedo, R.A.; Nicolai, M.; Carvalho, S. de.; Christoffoleti, P.J. y Figueira, A. "Tolerância diferencial de variedades de cana-de-açúcar a estresse por herbicidas", *Bragantia*, vol. 69, no. 2, 2010, pp. 395–404, ISSN 1678-4499.

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