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EVALUATION OF MIXTURES OF HERBICIDES IN THE WEED CONTROL IN SUGAR CANE FIELD IN THREE TYPES OF SOILS IN MAJIBACOA, LAS TUNAS PROVINCE

Evaluación de mezclas de herbicidas en el control de arvenses en el cultivo de la caña de azúcar en tres tipos de suelos de Majibacoa, Las Tunas

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ABSTRACT. The research was carried out in areas of production from Majibacoa Enterprise, Las Tunas province, to evaluate the effectiveness of mixtures of herbicides in weed control in sugar cane plantations, variety C 86-503 in plant cane spring, in pre-post-emergent applications in three types of soils: reddish brown Fersialitic, fluffed Brown and cromic Vertisol. In the experimental area parcels were traced, according to a Randon Blocks design with four replications, the application of the mixtures was carried out with Super Agro-16 (MATABI) backpack, when some cane stakes had sprouted and small weed existed. Were determined weed species present in the area and those which appeared after application, the percentage of coverage of the same and the toxicity caused by the herbicide mixture and its costs and the number of days it remained clean field. Six mixtures were evaluated: Ametrine + Diuron; Ametrina + 2,4-D and four doses Ametrina + Merlin + 2,4-D. The biggest doses of Merlin (Isoxaflutole): 0,150; 0,200 and 0,250 kg ha^{-1}, this last one was the most effective in the weed control, those that caused a slight toxicity in form of small points in the leaves of the cane, the loamiest soils (Vertisol and Brown) required the biggest doses. With these doses of mixtures obtained Merlin more expensive, however, they maintained a longer period of time clean the cane field, causing the cost per day is less clean.

Key words: herbicides, weed, sugarcane

RESUMEN. La investigación se desarrolló en áreas de producción de la Empresa Azucarera Majibacoa de la provincia Las Tunas, para la evaluación de la efectividad de mezclas de herbicidas en el control de arvenses en plantaciones de caña de azúcar, variedad C 86-503, en caña planta de primavera, en aplicaciones pre-post-emergentes, en tres tipos de suelos: Fersialítico pardo rojizo, Pardo mullido y Vertisol crómico gléyco. En el área experimental se trazaron parcelas, según un diseño de bloques al azar con cuatro réplicas, la aplicación de las mezclas se realizó con asperjadora manual Super Agro-16 (MATABI), 20 días después de la plantación, cuando las yemas de las estacas de caña de azúcar habían brotado, con presencia de algunas arvenses. Se determinaron las especies de arvenses presentes en el área y las que aparecieron después de las aplicaciones, el porcentaje de cobertura de las mismas y la fitotoxicidad provocada por la mezcla de herbicidas, así como sus costos y la cantidad de días que se mantuvo limpio el campo. Se evaluaron seis mezclas: Ametrina + Diurón; Ametrina + 2,4-D y cuatro dosis Merlin + Ametrina + 2,4-D. Las mayores dosis de Merlin (Isoxaflutole): 0,150; 0,200 y 0,250 kg ha^{-1} resultaron las más efectivas en el control de arvenses, provocando una ligera fitotoxicidad en forma de pequeños puntos de color blanco en las hojas de la caña, los suelos más arcillosos (Vertisol y Pardo) requirieron las mayores dosis. Con estas dosis de Merlin se obtienen las mezclas más costosas; sin embargo, ellas mantuvieron un mayor período de tiempo limpio el campo de caña, lo que provocó que el costo por día limpio fuera menor.

Palabras clave: herbicidas, arvenses, caña de azúcar

INTRODUCTION

Within agroecosystems, weeds are a special form of highly successful vegetation that grows under environments disturbed by man without being

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sown; their success can be measured by the quick colonization, the difficulty of removal and the negative effect on productivity of cultivated species (1). Their damage can range from subtle to very severe and, depending on their biology, distribution, dispersal and persistence; they can become a real pest, causing losses of up to 30 % productivity (2).

Weed control should be started immediately after planting or harvesting. Competition in the first four months causes the greatest cane and sugar yield reductions, which is known as a critical period. Three to four weedings are commonly required during this stage, (3, 4).

Chemical control plays an important role, among the weeding methods applied to sugarcane cultivation, especially during the rainy season, which permits to treat a lot of areas per workday, favoring sugarcane units lacking workforce. Several types of herbicides are employed in Cuba, some of them have been used for many years, as Ametrine, Diuron, 2,4-D amine salt and Merlin, the latter applied for over a decade in this crop; so, there are not many research papers related to its effectiveness under different soil and climatic conditions, weed species and environments. In other parts of the world, it is mainly applied to maize cultivation.

It is very important to have other weed control choices under the soil and climatic conditions of different sugarcane agroecosystems, taking into account the predominant species, the observations of its effects on environments and application costs.

This paper was aimed at evaluating the effectiveness of pre-post emergent applications of herbicide mixtures on weeding of spring plant cane plantations, variety C 86-503, in three types of soils: reddish brown Fersialitic, loose Brown and gleyed Chromic Vertisol at the production areas from Majibacoa Sugarcane Enterprise, Las Tunas province.

MATERIALS AND METHODS

The research study was conducted at the production areas from Majibacoa Sugarcane Enterprise, located in the central part of LasTunas province, with the objective of evaluating the effectiveness of six herbicide mixtures on weed management: -Ametrine + Diuron; Ametrine + 2,4-D and four doses of Merlin + Ametrine + 2,4-D, applied to spring plant cane plantations, where there is no trash cover and weeds are favored by rainfall. Three experiments were developed in soils with different characteristics, which are plenty in this enterprise and various parts of the country: reddish brown Fersialitic (FsPR), loose Brown (PM) and gleyed Chromic Vertisol (VCG)[A].

Physical and chemical analyses were performed at the Provincial Laboratory of Soils, determining P_2O_5 and K_2O by Machiguin technique (Table I).

At the production fields, plots were laid out through wooden stakes; they consisted of five rows 10 m long, 1.60 m apart, and separated 6.40 m between them.

Experimental conditions

Experimental design: randomized block; 80,00 m^2 plot size; final solution 250 L ha^{-1}; types of soils: reddish brown Fersialitic; loose Brown and gleyed Chromic Vertisol; 10-15 % soil moisture content (gravimetrically determined); pre-post-emergent applications; sett buds had already sprouted at an average height of 18 cm and some weeds 5-10 cm; applications by a (MATABI) backpack with DT 5 flood jet nozzle; a late spring (May) strain, variety C86-503; applications performed 20 days after planting; manual harvesting after 20 months.

Treatments in three soil types

Treatments (kg or L ha^{-1})
Absolute check,
Ametrine + Diuron (2 kg + 4 kg)
Ametrine + 2,4-D (2 kg + 2 L),
Merlin + Ametrine + 2,4-D (0,100 kg + 1,5 kg + 2L),
Merlin + Ametrine + 2,4-D (0,150 kg + 1,5 kg + 2L),
Merlin + Ametrine + 2,4-D (0,200 kg + 1,5 kg + 2L),
Merlin + Ametrine + 2,4-D (0,250 kg + 1,5 kg + 2L).
Ametrine 80 PM: ($C_9 H_{17} N_5 S_1$, 2-ethylamine-4-isopropylamine-6-methylthio-S-triazine).
Diuron 80 PM: $C_9 H_{10} CL_2 N_2 O_1$
3- (3,4-dichlorophenyl) -1,1-dimethylurea.
Amine salt 72 SC 2.4- ammonium dichlorophenoxyacetate.
Merlin 75 WG: Isoxaflutole.

[A] Hernández, A.; Pérez, J. M.; Bosch, D.; Rivero, L. Nueva Versión de Clasificación Genética de los Suelos de Cuba. Primera edición. La Habana: AGRINFOR. 1999. 64 pp.

Table I. Chemical and physical soil characteristics at the experimental area

Soils	P_2O_5 (mg 100 g de suelo)	K_2O (mg 100 g de suelo)	pH (H_2O)	Organic matter (%)	Plasticity index
Reddish Brown Fersialitic	3,15	31,12	6,80	3,15	15,00
Loose Brown	4,65	41,25	7,00	4,20	35,10
Gleyed Chromic Vertisol	5,00	42,30	6,85	5,10	45,25

Weed cover percentage was determined 45, 60 and 75 days after herbicide application (DAA). 5 % cover was the top value established to consider clean fields; then, from this value on, weed control methods are applied in this enterprise, taking into account Maltsev scale (1962), widely used in Cuba (5). The visual method was used to determine cover percentage, with the help of a wooden frame of 0.50 m x 0.50 m (0.25 m^2), according to the methodology proposed by this author.

Phytotoxicity was determined 35 days after herbicide application by EWRS scale (European Weed Research Society) (6).

Crop yield was calculated by weighing the cane from both central rows of each plot using a dynamometer coupled to a Yumz-6KM loader.

For the economic appraisal, the cost of each treatment (CT) was determined according to the price of different herbicides and their doses, as well as the days that fields remained clean (DL) with the types of soils; then, the cost per clean day (CPDL) was calculated with these data.

$$CPDL = CT/DL$$

Data were subjected to a variance analysis and Tukey test was performed to compare means at 0.05 significance. Shapiro Wilks (modified) goodness-of-fit test was applied to percentage data, so as to assess if they have to be changed. Thus, "Infostat" statistical package from the National University of Córdoba, Argentina, version 1 was employed.

RESULTS AND DISCUSSION

Weeds emerging during the investigation are very often in Cuban cane plantations (Table II), but species from Magnoliatae class did not appear after applying herbicide mixtures; however, from Liliatae class, just *Leptochloa panicea* Retz did not emerge after applications, which is a seed-propagated species. *Rottboellia cochinchinensis* Lour is reported as a resistant species to several herbicides, which yields lots of very viable seeds; other species that survived after applications, in addition to botanical seeds, have other propagating forms, making them resistant to herbicides, because it is not germination but sprouting that occurs, which is an example of these structures, rhizomes, bulbs and stolons (4).

These weeds along with others, *Digitaria adscendens* Kunth, *Rhynchosia minima* L, *Dichanthium annulatum* Forsk, *Croton lobatus* L, *Rhynchosia minima* L and *Chamaesyce hyssopifolia* L, prevail in the cane growing fields from Majibacoa Sugarcane Enterprise, generally causing economic losses from 5 to 10% agricultural yield[B].

Sugarcane fields affected by weeds have fewer yields; also weeds make harvest difficult (7). Therefore, weed control is essential to attain an economical crop production. Weeds reduce yields by competing for moisture, nutrients and light during sugarcane growth (8).

Cover percentage and phytotoxicity

In general, weed cover percentage was greater at the absolute check in the loamiest soils (Table III). Very high values, above 44%, were observed since the first evaluation, due to no herbicide application, also to soil moisture because of rainfall and to the absence of trash cover, as it is a (spring) plant cane strain; this is an ecological and economical cover of weed control.

In general, weed cover percentage 75 days after herbicide application (DAA) was higher in the loamiest soils. Regarding Fersialitic soils, the best results were achieved by higher Merlin doses than 0,100 kg ha^{-1}, whereas by 0,200 kg ha^{-1} in Brown soils and 0,250 kg ha^{-1} in the Vertisols.

The application of these products did not assure that a weed-free sugarcane field reached its pre-closing stage; thus, a multiple weed harrowing was necessary 120 days after planting to control weeds and to cover row depression, which makes the plough cut cane stalks high; Finale was also applied at 2 L ha^{-1} after five months.

[B]Rodríguez, L. 2006. Evaluación del Merlin (Isoxaflutole) GD 75 y sus mezclas con efectos pre y post-pre- emergentes en el control de malezas en el cultivo de la caña de azúcar. [Tesis de Maestría]. Universidad Vladimir Ilich Lenin, Las Tunas. 2006. 84 pp.

Table II. Weed species before and after applications

Weeds	Fersialitic (FsPR)	Loose Brown (PM)	Vertisol (VCG)
Rottboellia cochinchinensis Lour	_	+**	+**
Dichanthium annulatum Forsk	+**	+**	+**
Leptochloa panicea Retz	+	+	+
Cynodon dactylon L.	+**	+**	+**
Cyperus rotundus L.	+**	+**	+**
Ipomoea trífida Kunth	+	+	+
Euphorbia heterophylla L.	+	+	+
Bidens pilosa L.	+	+	+

** weeds emerged after herbicide application

Table III. Weed cover percentage and phytotoxicity caused by herbicide mixtures

Treatments (kg or L ha^{-1})	Reddish Brown Fersialitic				Loose Brown				Gleyed Chromic Vertisol			
	45 dda	60 dda	75 dda	FT	45 dda	60 dda	75 dda	FT	45 dda	60 dda	75 dda	FT
Absolute check	44,65 d	77,63 d	91,71 d	-	45,53 e	82,73 e	92,89 e	-	52,65 d	82,65 d	93,80 e	-
A+ D (2+4)	11,15 b	23,65 c	32,21 c	2	14,90 c	26,34 c	33,44 cd	2	18,38 c	24,44 c	37,73 d	2
A+ 2,4-D (2+2)	14,35 c	27,33 c	32,54 c	1	18,55 d	31,43 d	35,19 d	1	17,85 c	27,78 c	37,78 d	1
M+A+2,4-D (0,100+1,5+2,0)	10,15 b	16,85 b	19,42 b	1	9,65 b	17,65 b	27,53 bc	1	13,05 b	16,68 b	34,78 cd	1
M+A+2,4-D (0,150+1,5+2,0)	4,08 a	11,80 ab	15,58 a	1	6,19 a	16,33 b	25,26 b	1	8,88 ab	16,83 b	27,61 bc	1
M+A+2,4-D (0,200+1,5+2,0)	4,03 a	11,25 a	16,04 a	2	3,90 a	9,80 a	16,33 a	2,5	8,09 a	15,09 ab	26,05 b	2,5
M+A+2,4-D (0,250+1,5+2,0)	4,09 a	10,13 a	15,86 a	2,5	3,67 a	9,65 a	16,59 a	2,5	4,15 a	10,23 a	16,44 a	2,5
ES	0,49	1,10	0,66		0,73	0,98	1,47		1,02	1,04	1,57	

A: Ametrine D: Diuron M: Merlin

A high effectiveness of Merlin is reported with pre-emergent doses of 0.200 and 0.250 kg ha^{-1} applied to light, medium and heavy soils from Ciego de Avila and Las Tunas provinces, without differing from the check Diuron at 4.8 kg ha^{-1}, causing between 1 and 2.12 degrees of phytotoxicity, according to EWRS scale in variety C87-51[B].

Concerning every treatment, sugarcane phytotoxicity was low in the three types of soils, whose values did not affect agricultural yields, according to EWRS; the highest values were obtained by mixtures with Diuron and those containing the highest Merlin doses of 0.200 and 0,250 kg ha^{-1}.

Ametrine and Diuron may cause phytotoxicity in some susceptible varieties (9). Merlin is a pre-emergent herbicide that may damage sugarcane plant, so top rates are not recommended to apply in these types of soil during the dry period (4).

Agricultural yield

The lowest agricultural yields were recorded at the absolute control in all three soil types, with a reduction of over 50 % compared to most treatments, due to cane competition with weeds (Table IV).

In general, the lowest yields were obtained in Fersialitic soils, perhaps because they have fewer nutrients than the other two soils tested (Table I). The highest values were attained by Merlin dose (0.150 kg ha^{-1}).

With regard to the Brown and Vertisol, very similar values were reached, but it is important to note that with Merlin doses of 0.200 and 0.250 kg ha^{-1}, the highest values were mathematically obtained, since there were no statistically significant differences.

The physical and chemical characteristics of these soils were not a limiting factor for this crop (Table I): the available contents of P_2O_5 and K_2O of Fersialitic soil are average, whereas in the others they are considered high, pH was neutral, organic matter content in Vertisol was high and average in the others, according to plasticity index, Fersiallitic is considered slightly plastic, the Brown is plastic and Vertisol is very plastic.

To perform these assessments, soil analysis interpretation tables were taken into account[C]. It is important to point out that these soils were chemically fertilized according to this Sugarcane Enterprise, following what is established by the Fertilizer and Amendment Service (SERFE).

Sometimes there are creeping weeds after cultural practices, which are able to climb sugarcane plants, decrease the amount and quality of millable stalks as well as make manual and mechanized harvests difficult (10); in this research study, *Ipomoea trifida* Kunth has these characteristics.

Economic appraisal

Herbicide mixtures with the highest Merlin doses (0.150, 0.200 and 0.250 kg ha^{-1}) were the most costly, but they kept sugarcane field clean for a longer time, in some cases for more than 20 and 25 days compared to other mixtures; during this period of time cleaning is performed twice, increasing the economic costs and possible environmental damage, according to the type of weed control method and quality (Table V).

[C]Martín, N. J. Tabla de interpretación de análisis de suelo. Primera edición. La Habana: Universidad Agraria. 2004. 17 pp.

Table IV. Agricultural yield in three types of soils

Treatments (kg or L ha^{-1})	Fersialitic (FsPR) (t ha^{-1})	Loose Brown (PM) (t ha^{-1})	Vertisol (VCG) (t ha^{-1})
Absolute check	37,38 a	37,55 a	40,68 a
A+ Diuron (2+4)	81,38 c	82,10 b	81,61 b
A+ 2,4-D (2+2)	70,73 b	81,75 b	81,43 b
M+A+2,4-D (0,100+1,5+2,0)	71,21 b	83,50 bc	81,83 b
M+A+2,4-D (0,150+1,5+2,0)	82,41 cd	83,73 bc	84,13 bc
M+A+2,4-D (0,200+1,5+2,0)	84,30 d	84,43 c	85,05 c
M+A+2,4-D (0,250+1,5+2,0)	84,30 d	83,83 c	85,55 c
ES	0,58	0,45	0,67

Table V. Economic appraisal in three types of soils

Treatments (kg or L ha^{-1})	Clean days (DL)			Total cost (CT) USD ha^{-1}	Cost per clean day (CPDL) USD		
	(FsPR) soil	(PM) soil	(VCG) soil		(FsPR) soil	(PM) soil	(VCG) soil
Absolute check	-	-	-	-	-	-	-
A+ Diuron (2+4)	35	35	33	39,70	1,13	1,13	1,20
A+ 2,4-D (2+2)	30	30	33	24,40	0,81	0,81	0,74
M+A+2,4-D (0,100+1,5+2,0)	35	38	35	35,58	1,02	0,94	1,02
M+A+2,4-D (0,150+1,5+2,0)	50	42	40	43,05	0,86	1,02	1,08
M+A+2,4-D (0,200+1,5+2,0)	50	55	40	50,51	1,01	0,92	1,26
M+A+2,4-D (0,250+1,5+2,0)	50	55	49	57,97	1,16	1,05	1,18

In the Fersialitic soil, sugarcane field remained clean with 0,150 kg ha^{-1} Merlin for many days, in the Brown soil with 0,200 kg ha^{-1} and Vertisol with 0,250 kg ha^{-1}. The lowest costs for clean days were achieved with these Merlin doses along with the mixture of Ametrine + 2,4-D in the Fersialitic and Brown soils, whereas in the Vertisol costs were very similar, with the lowest value in Ametrine + 2,4-D. It is important to state that with mixtures involving these Merlin doses, the highest crop yields were obtained, even though there were no significant differences between most of them.

The costs of these herbicides are: Diuron ($6.19 kg^{-1}), Ametrine ($7.47 kg^{-1}), Amine salt ($4.73 L^{-1}) and Merlin $149.25 kg^{-1} (4). The latter is the most expensive, but it does not increase the implementation costs so much, as it is applied in very low doses compared to the others.

In sugarcane crop, the benefits of a right weed control are known to reduce costs. Some studies show that yields surpassing 80 t ha^{-1} are obtained by those producers that invest more in weed control.

It is inappropriate to evaluate only the expenses per hectare; the best approach is to consider the cost per ton of sugar, which can be reduced with higher yields, as part of an appropriate cultural package (11).

The same conditions that enhance sugarcane growth in large areas are favorable for weed growth. Its management can represent 18-28 % crop cost or 5-6 % production cost (12, 13).

The application of these herbicide mixtures within the early days of plantation kept cane fields clean from weeds between 30 and 55 days, which was very important because competition over these early stages until field closure may cause higher yield losses than 50 % (14).

In this research study, the applications of different herbicide mixtures can help counteract the resistance effects acquired by weeds, which reduces the efficiency of this control method and increases costs. Economic benefits for employing tillage and herbicides of different modes of action, mainly residuals, vary depending on the type of crop, so that there may be positive or negative results; logically, agricultural yields have great influence on profits. All over the world, the number of herbicide-resistant weed species increases, an example is reported by several applications of Glyphosate (15, 16, 17, 18).

Among all herbicides applied, 2,4-D Amine salt is reported as moderately toxic to humans, whereas the others can injure fish slightly, Diuron is reported as moderately toxic; however, every herbicide except Merlin can damage bees (4).

Some weed species show allelopathic properties in sugarcane crop, such as *Cyperus rotundus* L. At present, some researchers are evaluating the influence from these plant extracts on weed control and other pest managements, so as to integrate compatible technologies with the environment, where biological pest control has a key role (19, 20, 21).

Herbicides can show beneficial or adverse effects on other organisms; thus, it is not always convenient to use the method of "total weed control", as the preservation of certain levels of these plants helps reduce herbivore populations and increase beneficial insects (22, 23, 24).

CONCLUSIONS

- Mixtures involving Merlin doses of 0,150; 0,200 and 250 kg ha^{-1} + Ametrine + 2,4-D were the most effective in weed control, with increasing doses of this herbicide at the loamiest soils, causing a slight phytotoxicity to sugarcane.
- The former mixtures, despite having the highest costs, kept sugarcane fields clean for a longer period of time and had the lowest costs per clean days.

BIBLIOGRAPHY

1. Rodríguez, J. Las malezas y el Agroecosistema. Departamento de Protección Vegetal, Facultad de Agronomía, Universidad de la República Oriental de Uruguay. [en línea]. 2007. [Consultado: 15-12-2007]. Disponible en: <http:www.pv.fagro.edu.uy/Malezas>.
2. Daehler, C. y Virtue, J. Variable perception of weeds and the implication for WRA. En: International Weed Risk Assessment Workshop (IWRAW). [en línea]. 2007. [Consultado: 10-12-2007]. Disponible en: <http:www.hear.org/iwraw>.
3. Cuellar, I. A.; de León, M.; Gómez, A.; Piñón, D.; Villegas, R. y Santana, I. Caña de azúcar paradigma de sostenibilidad. Primera edición. Ciudad de la Habana: Editorial PUBLINICA. 2003. 175 pp.
4. Rodríguez, L. y Diaz, J. C. Programa de control integral de malezas en caña de azúcar. 11na edición. La Habana: Editorial INICA. 2012. 169 pp.
5. Labrada, R. Métodos para el Estudio de las Malezas y los Herbicidas. Primera edición. La Habana: Ediciones ENPES. 1991. 149 pp.
6. CIBA-Geigy. Manual para ensayos de campo en protección vegetal. Segunda edición. Basilea, Suiza: Editorial CIBA-Geigy. 1981. 205 pp.
7. Reynoso, A. Ensayo sobre el cultivo de la caña de azúcar. Sexta edición. La Habana: Editorial Nacional de Cuba. 1962. 462 pp.
8. Sarwar, S. C.; Bashir, S. y Ahmad, F. Evaluation of integrate weed management practices for sugarcane. *Pakistan Journal of Weed* Science Research, 2010, vol. 16, no. 3, pp. 257-265. ISSN 2225-7942.
9. Rodríguez, F. R. Tolerancia diferencial de variedades de caña de azúcar al stress por herbicidas. *Bragantia*, 2010, vol. 69, no. 2, pp. 395-404. ISSN 1678-4499.
10. Jones, C. A. y Griffin, J. L. Red morningglory (*Ipomoea coccinea*) control and competition in sugar cane. *J. Am. Soc. Sugar Cane Technol*., 2009, vol. 29, pp. 25-35. ISSN 1075-6302.
11. Edmond, L. M. Enhancing Chemical Weed Management. *Sugarcane*, 2007, vol. 24, no. 1, pp. 1-3. ISSN 0265-7406.
12. Edmond, L. M. Outdoing the weed competition. *Sugarcane,* 2007, vol. 24, no. 1, pp. 10-12. ISSN 0265-7406.
13. Conlong, D. E. y Campbell, P. L. Integrated weed management for sugarcane field verges: *Melinis minutiflora* and *Cynodon dactylon* encroachment. *Proc. S. Afr. Sug. Technol. Ass.*, 2010, vol. 83, pp. 276-279. ISSN 0370-1816.
14. Zafar, M. Weed-crop competition effects on growth and yield of sugarcane planted using two methods. *Pakistan J. Bot*., 2010, vol. 42, no. 2, pp. 815-823. ISSN 2070-3368.
15. Bonny, S. Genetically modified glyphosate-tolerant soybean in the USA: Adoption factors, impacts and prospects. *Agronomy for Sustainable Development*., 2008, vol. 28, no. 1, pp. 21-32. ISSN 1773-0155.
16. Boerboom, C. Giant ragweed with suspected glyphosate resistance. *Wisconsin Crop Manager,* 2009, vol. 16, no. 16, pp. 63-64. ISSN 1543-7833.
17. Heap, I. M. The international survey of herbicide resistant weeds. [en línea]. 2009. [Consultado: 23-6-2013]. Disponible en: <http://www.weedscience.org/>.
18. Hurley, T. M.; Mitchell, P. D. y Frisvold, G. B. Weed management costs, weed best management practices, and the Roundup Ready® weed management program. *AgBioForum*., 2009, vol. 12, no. 3, pp. 281-290. ISSN 1522936X.
19. Weihet, M.; Didon, U. M.; Rönnbergt, W. y Bjirkman, C. Integrated agricultural research and crop breeding: Allelopathy weed control in cereals and long-term productivity in perennial biomass crops. *Agricultural Systems*, 2008, vol. 97, no. 3, pp. 99-107. ISSN 0308521X.
20. Arévalo, R. A.; Bertoncini, E. I.; Salgado, G. S. y Rossi, F. Alelopatía de *Cyperus rotundus* L. en *Saccharum* spp. cv. IAC-SP 93-6006. *Revista Fitosanidad,* 2009, vol. 13, no. 3, pp. 193-196. ISSN 1818-1686.
21. Arévalo, R. A.; Bertoncini, E. I.; Aranda, E. M. y González, T. A. Alelopatía en *Saccharum* spp. (caña de azúcar). *Avances en Investigación Agropecuaria*, 2011, vol. 15, no. 1, pp. 51-60. ISSN 0188-7890.
22. Andreasen, C. y Stryhn, H. Increasing weed flora in Danish arable fields and its importance for biodiversity. *Weed Research*, 2008, vol. 48, no. 1, pp. 1-9. ISSN 1365-3180.
23. Nicholls, C. I. y Altieri, M. A. Suelos saludables, plantas saludables: la evidencia agroecológica. *Leisa Revista de Agroecología*, 2008, vol. 24, no. 2, pp. 6-8. ISSN 1569-8424.
24. Andreas, K. Herbicides and Environment. Primera edición. Estados Unidos: Editorial, CC BY-NC-SA. 2011. 746 pp. ISBN 978-953-307-476-4.

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