Allelopathic effect of sugar cane straw (Saccharum spp. hybrid) on the arvensis Achyranthes aspera, var. Indica L., under controlled conditions

Efecto alelopático de la paja de caña de azúcar (híbrido de Saccharum spp.) sobre la arvensis Achyranthes aspera, var. Indica L., en condiciones controladas

DOI: http://doi.org/10.17981/ingecuc.18.2.2022.13

Artículo de Investigación Científica. Fecha de Recepción: 27/07/2021. Fecha de Aceptación: 03/11/2021.

Walfrido Terrero Matos
Universidad de Cienfuegos Sede "Carlos Rafael Rodríguez". Cienfuegos (Cuba)
wterrero@ucf.edu.cu

Leónides Castellanos González
Universidad de Pamplona. Pamplona (Colombia)
lclcastell@gmail.com

To cite this paper:
W. Terreno Matos & L. Castellano González, "Allelopathic effect of sugar cane straw (Saccharum spp. hybrid) on the arvensis Achyranthes aspera, var. Indica L., under controlled conditions", *INGE CUC*, vol. 18, no. 2, pp. 169–176. DOI: http://doi.org/10.17981/ingecuc.18.2.2022.13

Abstract

Introduction— Allelopathic properties of cane straw are reported, however, information on the effect on some weed species is incomplete.

Objective— To evaluate the allelopathic effect of sugarcane straw (*Saccharum* spp. Hybrid) on germination and initial growth of weed (*Achyranthes aspera* var. Indica L.) under controlled conditions.

Methodology— An experiment was carried out using a completely randomized design with six treatments, including a control and five ratios of straw, 25%, 50%, 75%, 100%, 125%, with four repetitions. The doses used corresponded to the proportion of dry straw biomass/m^2 in a cane field. Weed seeds were placed at a depth of 1.0 cm, and germination, dry mass, stem length and radicle length were evaluated.

Results— It was evidenced that germination was influenced at 10 days by the different treatments, as well as the dry mass, the length of the stem and the length of the radicle at 7 and 10 days after starting the experiment.

Conclusions— The results of the study indicate that the sugarcane straw exerts a negative allelopathic effect on the germination and initial growth of *Achyranthes aspera*, being the 75% dose the one with the best results.

Keywords— Weed control; germination; dry mass

Resumen

Introducción— Se han reportado propiedades alelopáticas de la paja de caña, sin embargo, la información sobre el efecto sobre algunas especies de malezas es incompleta.

Objetivo— Evaluar el efecto alelopático de la paja de caña de azúcar (*Saccharum* spp. Híbrido) sobre la germinación y el crecimiento inicial de la maleza (*Achyranthes aspera* var. Indica L.) bajo condiciones controladas.

Metodología— Se realizó un experimento utilizando un diseño completamente aleatorizado con seis tratamientos, incluyendo un control y cinco proporciones de paja, 25%, 50%, 75%, 100%, 125%, con cuatro repeticiones. Las dosis utilizadas correspondían a la proporción de biomasa de paja seca/m^2 en un cañaveral. Las semillas de malas hierbas se colocaron a una profundidad de 1.0 cm, y se evaluó la germinación, la masa seca, la longitud del tallo y la longitud de la radícula.

Resultados— Se evidenció que la germinación fue influenciada a los 10 días por los diferentes tratamientos, así como la masa seca, la longitud del tallo y la longitud de la radícula a los 7 y 10 días de iniciado el experimento.

Conclusiones— Los resultados del estudio indican que la paja de caña ejerce un efecto alelopático negativo sobre la germinación y crecimiento inicial de *Achyranthes aspera*, siendo la dosis del 75% la que mejores resultados obtuvo.

Palabras clave— Control de malezas; germinación; masa seca

I. Introduction

Today, agriculture faces immense challenges, given the need to increase food production and the growing concern about environmental problems and climate change. Satisficing future demand for food will depend first and foremost on continued growth in crop yields and caring of the environment [1].

Allelopathy is a plant interference mechanism, mediated by the addition of phytotoxins to the environment. Different chemical compounds with allelopathic potential are present in numerous plant species distributed in different tissues. Under suitable conditions, they can be released, generally in the rhizosphere, in sufficient quantities to affect neighboring plants [2].

One way to use allelopathy in agriculture is through the use of natural products such as bioherbicides. This approach to weed management is safe for the environment compared to synthetic herbicide [3]. Some plants release allelopathic compounds that, although they have practically no effect on the plant species that live with them in their communities of origin, are highly efficient inhibiting the plant species in the invaded communities [4].

Weeds interfere with the development of the crop through competition and allelopathy, which reduces the vigor of plants, yields or productive capacity of the crop; in effect, the availability of water, nutrients, light and CO^2 is reduced, as well as essential elements for the development of plants [5]. In addition, many serve as a host for other pests or as a source of inoculum for pathogens [6].

An alternative method in weed control is the application of allelochemical compounds before or together with synthetic herbicides to increase the effect of the two products and therefore reduce the amounts of synthetic herbicide application [7].

Sugarcane is a plant characterized by being very efficient in the photosynthetic process, and by having a high capacity to produce large amounts of biomass. The agricultural residues that it generates can be used for animal feed, recycle nutrients and in the form of organic matter within the agroecosystem, as a vegetal cover of the soil to maintain humidity and prevent erosion [8].

The extracted straw remains on the ground in the form of a protective covering that performs an important function of conserving humidity, prevents erosion and contributes to the fight against weeds. Only for this concept, reductions in herbicide consumption of 35% and up to 50% are reported [9], which is important to use all possible alternatives in the integrated management of weeds in the crop [10]. Furthermore, in studies carried out on straw in Cuban sugarcane varieties, phenols and tannins with potential allelopathic effect against weeds have been identified [11].

Plants have their own defense mechanisms, and allelochemicals can be natural herbicides (in fact, they are). However, allelopathy includes numerous complex processes, where different chemicals influence allelopathic effects. Furthermore, both crops and wild plants show these effects; cultivated plants are more interesting since they can be used in the future as material for the production of natural herbicides [12].

Achyranthes áspera L. (Amaranthaceae) is a plant known in Cuba with the common name of prickly cat tail (rabo de gato espinosa). It can measure up to a meter in height, with little branched, hairy, quadrangular stems. It has ovate leaves 4 cm - 20 cm long, opposite with petioles up to 2.5 cm long, small and insignificant flowers, with fine terminal spikes up to 30 cm long [13].

A. aspera is common in the sugarcane fields of Cuba [14] and has been included by the scientific community in the national list of invasive plant species in Cuba as results of the project "Plantas invasoras presentes en la República de Cuba - estrategia para la prevención y manejo de especies con mayor nivel de agresividad" [15].

To date, there is no reference to studies that have been carried out on the allelopathic effect of sugarcane straw on the weed A. aspera in order to make recommendations on the use of this residue for the benefit of the management of this weed. Therefore, the present work aimed to evaluate the allelopathic effect of sugarcane straw (*Saccharum* spp. *Hybrid*) on the germination and initial growth of the weed *Achyranthes aspera, var. Indica* L., under controlled conditions.

II. Methodology

The research was carried out in the Plant Physiology laboratory of the Faculty of Agrarian Sciences of the University of Cienfuegos in collaboration with the Central University of Las Villas in the period from January to December 2017. It had the purpose of determining the effect of six doses of sugarcane straw (*Saccharum* spp. *hybrid*) under controlled conditions on the germination and initial development of cattail weed (*Achyranthes aspera var. Indica* L.

A soil was used, according to the classification of Cuban soils, belongs to the grouping of sialitic brown, brown genetic type (P), fluffy brown subtype, carbonate fluffy brown genus [16].

A completely randomized design was used with six treatments (0%, 25%, 50%, 75%, 100%, 125% of cane straw) and four repetitions, the in vitro experiment in containers with dimensions mentioned above, in sterile soil to test the allelopathic influence of the residues on the seed germination and de development of the *A. aspera* seedlings.

The experiment was carried out with equal conditions of light and humidity, in homogeneous containers with an upper diameter of 8 cm, a lower diameter of 6 cm and a height of 10 cm with a volume of 450 cm^3 of which 400 cm^3 were used by using soil as substrate. sterile. The soil was sterilized at a temperature of 120°C and 1.5 atm of pressure for 30 minutes in a stainless-steel autoclave brand LDZY-50KAS. then they were mixed to look for a homogeneous substrate. Soil and plant weighing were carried out on an OHAUS mechanical scale with a precision of 0.1 g, verified by the Territorial Office of Standardization of Cienfuegos.

For the selection of the doses, it was considered that the amount of straw in reed beds harvested without burning varies from 10 to 30 t ha^{-1} [17]. Therefore, straw productions of 15 t ha^{-1} were assumed, already corroborated by the authors in Cuba (11 t ha^{-1} - 15 t ha^{-1}), 100% of the dose corresponded to the average dry biomass per m^2 at a depth of 0.20 m, which was considered equivalent to 7.5 g/kg of soil.

The treatments used were the following:

1. Control (0%).
2. Treatment at 25% (1.875 g/kg of soil).
3. Treatment at 50% (3.75 g/kg of soil).
4. Treatment at 75% (5.625 g/kg of soil).
5. Treatment at 100% (7.5 g/kg of soil).
6. Treatment at 125 % (9.375 g/kg of soil).

To evaluate the allelopathic effect of the straw residues, it was selected in the field, taken to the laboratory and chopped to a size of up to five millimeters then it was manually applied to the sterile soil used as substrate in the containers, incorporating it into a depth of 0 cm to 10 cm.

Subsequently, 20 seeds were placed in each one 1 cm deep. The germination percentage was determined for a total of 120 seeds and they were incubated in a germination chamber at a temperature of 30ºC ± 0.1ºC for 16 hours of light and 25ºC ± 0.1ºC for eight hours. Humidity was maintained by applying distilled water 3 ml to 6 ml per day per container depending on the water needs and maintaining the soil at 80% of the field capacity.

The germination count was carried out 5 and 10 days after sowing. After emergence, stem and root lengths were measured with a ruler at 7 and 10 days, taking advantage of these moments to calculate the percentage of DM.

To evaluate the amount of DM, at seven and ten days, 10 complete plants or at least those with leaves and stems were taken, their organs were separated and weighed separately and the weight was recorded (fresh weight of the sample), for which the organs were placed in a porcelain capsule and placed in the stove at a temperature of 100 degrees for one hour to kill the enzyme systems. After this time the stove was set to 70 degrees, for 72 hours until reaching a constant weight. The samples were placed in a drying chamber until cool, they were weighed and their value was recorded, and the percentage of dry mass was determined for each sample as follows:

Percentage of dry mass = Dry weight of the sample × 100 / Fresh weight of the sample.

The data obtained on germination percentage (transformed into 2 arc sin √p) to achieve normality, dry mass, stem size and radicle were processed by analysis of variance. The means were compared by the Tukey test ($P < 0.05$), using the statistical program SPSS for Window version 21 [26].

III. Results and Discussion

A. *Effects of the different doses of sugarcane straw (Saccharum spp. Hybrid) on the germination of Achyranthes aspera var. Indica.*

The sugarcane plant residues at different proportions did not show influence on the germination of *A. aspera* at 5 days after sowing, however, at 10 days at the highest doses of 100 and 125% a negative allelopathic effect was evident, showing a delay in the germination percentage with a significant difference in relation to the control (Table 1).

Table 1.
Percentage of germination of Achyranthes aspera var. Indica L. (prickly cat tail) at 5 and 10 days.

Treatments (% or normal doses and g/kg of soil	Germination (%)	
	5 days	10 days
1. Control (0%)	8.75^{a}	83.75^{c}
2. Treatment at 25% (1.875 g/kg of soil)	15.00^{a}	68.75^{bc}
3. Treatment at 50% (3.75 g/kg of soil)	7.50^{a}	57.50^{bc}
4. Treatment at 75% (5.625 g/kg of soil)	8.75^{a}	51.25^{abc}
5. Treatment at 100% (7.5 g/kg of soil)	6.25^{a}	45.00^{ab}
6. Treatment at 125 % (9.375 g/kg of soil)	5.00^{a}	27.50^{a}
Typic Error of Experimental Error	0.22 ^{NS}	0.04***
Coefficient of variation (%)	3.3	8.3

$^{a, b, c}$ Values in columns with different superscripts differ for $P < 0.05$ (Tukey). ^{NS} –Not Significant.
Source: Authors.

The germination result obtained after 5 days may be justified by the lack of concentration of metabolites released to exert their action, since the decomposition of the straw was still very incipient. For the first applied treatment (25%), a certain positive allelopathic effect could be observed relative to increasing the germination percentage after five days, although without statistically significant difference.

B. *Effects of sugarcane straw (Saccharum spp. Hybrid) on the initial growth of Achyranthes aspera var. Indica L.*

Seven days after the start of the experiment, the cane straw at the proportions of 75%, 100% and 125% showed a negative allelopathic effect on the initial growth of the length of the cat's tail in comparison with the control and the proportions lower residue. Similar results were observed at 10 days when a significant statistical difference was observed between these treatments and the control and the cane straw at 25% and 50% (Table 2).

Table 2.
Stem length of spiny cattail (Achyranthes aspera var. Indica L.) at 7 days and 10 days.

Treatments (% or normal doses and g/kg of soil	Stem length at 7 days (mm)	Stem length at 10 days (mm)
1. Control (0%)	25.00^{a}	29.75^{a}
2. Treatment at 25% (1.875 g/kg of soil)	26.25^{a}	28.50^{a}
3. Treatment at 50% (3.75 g/kg of soil)	21.00^{b}	23.25^{ab}
4. Treatment at 75% (5.625 g/kg of soil)	16.75^{c}	19.50^{c}
5. Treatment at 100% (7.5 g/kg of soil)	15.50^{c}	19.25^{c}
6. Treatment at 125 % (9.375 g/kg of soil)	15.25^{c}	17.75^{c}
Typic Error of Experimental Error	0.33	1.24
Coefficient of variation (%)	6.81	10.79

$^{a, b, c}$ Values in columns with different superscripts differ for $P < 0.05$ (Tukey). Source: Authors.

The ANOVA performed with the data obtained on the length of the radicle showed that the straw exerted a positive allelopathic effect both at 7 and 10 days. At seven days, all the treatments used showed a significant difference compared to the control, not showing any difference between them, while at ten days a significant difference was observed compared to the control only for the 75 and 100% doses, the The rest of the treatments were intermediate between these and the control from the statistical point of view (Table 3).

Table 3.
Length of spiny cattail radicle (Achyranthes aspera var. Indica L.) at 7 days and 10 days.

Treatments (% or normal doses and g/kg of soil	Length of the radicle at 7 days (mm)	Length of the radicle at 10 days (mm)
1. Control (0%)	14.00^{b}	16.75^{b}
2. Treatment at 25% (1.875 g/kg of soil)	20.00^{a}	23.25^{ab}
3. Treatment at 50% (3.75 g/kg of soil)	20.00^{a}	21.00^{ab}
4. Treatment at 75% (5.625 g/kg of soil)	21.00^{a}	24.25^{a}
5. Treatment at 100% (7.5 g/kg of soil)	20.75^{a}	25.77^{a}
6. Treatment at 125 % (9.375 g/kg of soil)	19.00^{a}	19.75^{ab}
Typic Error of Experimental Error	0.65	1.65
Coefficient of variation (%)	6.61	15.20

^{a,b} Values in columns with different superscripts differ for $P < 0.05$ (Tukey).
Source: Authors.

Phenolic acids can reduce or increase the concentration of IAA. Ferulic, p-coumaric, vanillic and coumaric acids inhibit gibberellin-induced growth [18]. This explains why a positive allelopathy is seen for the radicle, while for the stem it is negative, as a result of a break in the balance between the plant hormones auxin and kinetics.

In the analysis of variance carried out on the percentage of dry matter, a negative allelopathic effect was observed in comparison with the control both at seven and ten days (Table 4).

Table 4.
Percentage of dry matter of Achyranthes aspera var. Indica L. (spiny cat tail) at 7 days and 10 days.

Treatments (% or normal doses and g/kg of soil	Dry matter at 7 days (%)	Dry matter at 10 days (%)
1. Control (0%)	11.58^{c}	15.49^{cd}
2. Treatment at 25% (1.875 g/kg of soil)	11.15^{c}	18.74^{c}
3. Treatment at 50% (3.75 g/kg of soil)	7.69^{b}	12.30^{bc}
4. Treatment at 75% (5.625 g/kg of soil)	6.77^{ab}	10.04^{ab}
5. Treatment at 100% (7.5 g/kg of soil)	6.34^{a}	7.55^{ab}
6. Treatment at 125 % (9.375 g/kg of soil)	6.36^{a}	7.49^{a}
Typic Error of Experimental Error	0.08	0.14
Coefficient of variation (%)	13.64	20.00

$^{a, b, c, d}$ Values in columns with different superscripts differ for $P < 0.05$ (Tukey).
Source: Authors.

At 7 days it could be seen that from 50% the straw begins to exert a negative allelopathic action in a significant way, while at ten days the effect was appreciated from the 75% dose. The best results of the treatments were presented for the 100% and 125% doses, respectively.

The present results coincide with the statements made by other researchers in relation to the fact that the sugarcane straw that remains in the field after harvest can interfere with weed growth [19]. However, the studies should be continued with other types of soils other than the predominantly clayey one, such as the one in the present study, since it is suggested that the allelopathic activity of the sugarcane leachate has been more pronounced in the soil with a lighter texture in comparison. with heavy textured soil [20].

Research on this issue has been carried out, both with cane straw residues and leachates from it, on weeds or weeds, on the sugar cane itself and also on economic crops that could be affected in rotation with the sugar cane. In addition, sterile and biotic soil (not sterilized) has been used and it has been verified that unburned cane straw leachate incorporated into the biotic soil had a greater effect on root growth, which suggests that microbial activity is involved in the interference made by sugarcane straw, observing a higher total phenolic content [19]. These investigations demonstrated that water-soluble phenolics may play a role in inhibiting the growth of *Bidens subalternans* L. and *Brassica campestris* L. seedlings.

The most studied variable in studies of allelopathy of sugarcane straw has been the germination of the seed, for example, it was possible to verify that the allelopathic effects of 2,4-dihydroxy-1,4-benzoxazin-3-one, isolated from sugarcane leaves and its decomposition product completely inhibited the seed germination of wheat (*Triticum aestivum* L.), mustard (*Brassica campestris* L.) and caused a 90% inhibition in mung beans (*Vigna radiata* L.) [21]. However, these results contradict others carried out with different parts of the sugarcane where the germination of the wheat seed was not affected [22].

The negative allelopathy of sugarcane straw residues in the field is demonstrated since germination decreased in three dicotyledonous weeds Ipomoea coccinea L., *Amaranthus retroflexus* L. and *Amaranthus spinosus* L. by 29%, 17.5% and 80.5%, respectively [23], while the best treatment for weed in the present investigation reduced the germination of *A indica* by 32.8%.

In another research the influence of the sowing depth and the amount of sugarcane straw on the emergence of weed species *Luffa aegyptiaca* Miller (Cucurbitaceae); *Mucuna térima* Piper & Tracy (Fabaceae - Leguminosae) and *Ricinus communis* (Euphorbiaceae) were studied. Different responses regarding emergence according to the sowing depth and the amount of cane straw deposited in the soil were showed. For *L. aegyptiaca* and *M. acantima*, no significant differences were observed in the interaction between depth and sugarcane straw, showing the adaptation of these species to the sugarcane system, however for *R. communis*, seeds placed at 0 cm of sugarcane straw were affected, but it is felt that the depth favored the emergence of seedlings [24].

In other studies, it was found that sugarcane bagasse extracts did not inhibit the germination of Chinese kale (*Brassica oleracea* L. *var. Alboglabra Bailey*) and cucumber (*Cucumis sativus* L.), and only inhibited tomato germination (*Solanum lycopersicum* L.), by 13% at the highest concentration (66.7 g / L) [25].

The present results therefore open the way to continue research on the demonstrated allelopathic potential of cane straw on the important weed, *A. aspera* arvensis in sugarcane fields in Cuba, being necessary to continue studies in field conditions in different types of soil to do better weed management with the agroecosystem's own resources [10], in particular with the own residues of the sugar cane.

IV. Conclusions

Sugarcane straw (*Saccharum* spp. Hybrid) at a ratio of 100% and 125% (7.5 - 9.375 g/kg of soil) exerted a significant negative allelopathic effect on the germination of (*Achyranthes aspera* var. Indica L.) at 10 days under controlled conditions.

A negative allelopathic effect of sugarcane straw on shoot growth was shown, but stimulated radicle growth, however, in general it demonstrated a negative allelopathic effect on initial growth of *Achyranthes aspera var. Indica* L. under controlled conditions since a significant reduction in dry matter was observed at doses above 75% of sugarcane straw (5.625 g/kg of soil).

References

[1] R. Bordón, "Detección de malezas mediante el análisis de imágenes tomadas desde un vehículo aéreo no tripulado", *Tesis magistral*, UAZ, ZAC, MX, 2018. Disponible en http://ricaxcan.uaz.edu.mx/jspui/handle/20.500.11845/1695

[2] J. Weidenhamer, "Distinguishing resource competition and chemical interference: overcoming the methodological impasse", *Agron J*, vol. 88, no. 6, pp. 866–875, Nov. 1996. https://doi.org/10.2134/agronj1996.00021962003600060005x

[3] T. Xuan, E. Tsuzuki, H. Uematsu & H. Terao, "Effect of alfalfa (Medicago sativa L.) pellets on weed control in rice" *Allelopathy J*, vol. 9, no. 2, 195–203, Apr 2002. Available: https://www.allelopathyjournal.com/archives/?Year=2002&Vol=9&Issue=2&Month=4

[4] K. Ledger, R. Pal, P. Murphy, D. Nagy, R. Filep & R. Callaway, "Impact of an invader on species diversity is stronger in the nom-native range than in the native range", *Plant Ecol*, vol. 216. No. 9, pp. 1285–1295, Aug. 2015. https://doi.org/10.1007/s11258-015-0508-2

[5] O. Ordeñana, *Malezas: rol, bioecología, fisiogenética y taxonomía filogénica morfológica molecular.* GUAY, EC: Grafimpac, 2018.

[6] H. Escobedo, C. Alvarado y E. Castolo, "Manejo integrado de malezas. Una introducción", *Rev Enlace*, vol. 8, no. 38, pp. 14–17, Jun. 2017. Disponible en https://idp.cimmyt.org/revista/no-38/

[7] J. Ferguson, B. Rathinasabapathi & C. A. Chase, "Allelopathy: How plants suppress other plants," *EDIS*, no. 3, pp. 1–5, Jan 2009. https://doi.org/10.32473/edis-hs186-2013

[8] C. Barahona & M. Toala, "El abono elaborado del bagazo de caña de azúcar como alternativa para la generación de ingresos para los habitantes del sitio San Carlos", *proyecto de grado*, Fac. Cienc. Economic., UNESUM, JIPI, EC, 2019. Disponible en http://repositorio.unesum.edu.ec/handle/53000/1760

[9] F. Díaz-Casas, "Manejo integrado de malezas en caña de azúcar", *Rev Cuba Caña*, vol. 1, no. 1, pp. 1–14, 1996.

[10] T. Rodríguez, L. Castellanos e I. Rodríguez, *Plagas, enfermedades y malezas de la caña de azúcar y su manejo en la Empresa Azucarera Melanio Hernández.* Ci, CU: Universo Sur, 2018.

[11] W. Terrero, L. Castellanos & L. Vicet, "Potencialidades alelopáticas del residual de paja de la caña de azúcar (Saccharum spp., hybrid) para el manejo de arvenses", *Rev Amb Agua Aire Suel*, vol. 11, no. 1, pp. 1–7, Jul. 2020. https://doi.org/10.24054/19009178.v1.n1.2020.357

[12] F. Macías, A. Torres, J. Molinillo, R. Varela & D. Castellanos, "Potential allelopathic sesquiterpene lactones from sunflower leaves", *Phytochem*, vol. 43, no. 6, pp. 1205–1215, Dec 1996. https://doi.org/10.1016/S0031-9422(96)00392-5

[13] K. Robertson & S. Clemants, "Amaranthaceae", in FNA, *Flora of North America*, vol. 4, NY, USA: OUP, 2003, pp. 405–406. Available: http://floranorthamerica.org/Amaranthaceae

[14] J. Acuña, *Plantas indeseables en los cultivos cubanos.* HAB, CUB: ACC, 1974.

[15] R. Oviedo, P. Herrera, M. G. Caluff, L. Regalado, I. Ventosa, J. Plasencia, I. Baró, P. González, J. Pérez, L. Hechavarría, L. González, L. Catasús, J. Padrón, S. Suárez, R. Echevarría, I. Fuentes, R. Angulo, P. Oriol, W. Bonet, M. Villate, N. Sánchez, G. Begué, R. Villaverde, T. Chateloin, J. Matos, R. Gómez, C Acevedo, J. Lóriga, M. Romero, I. Mesa, Á. Vale, A. Leiva, J. Hernández, N. Gómez, B. Toscano, M. González, A. Menéndez, M. Chávez y M. Torres, "Lista nacional de especies de plantas invasoras y potencialmente invasoras en la República de Cuba - 2012", *Bissea*, vol. 6, no. 1, pp. 22–96, Feb. 2012. Disponible en http://repositorio.geotech.cu/jspui/handle/1234/520

[16] A. Hernández-Jiménez, J. Pérez-Jiménez, D. Bosch-Infante y N. Castro, "La clasificación de los suelos de Cuba 2015: énfasis en la versión de 2015", *Cult Trop*, vol. 40, no. 1, pp. 1–31, Mar. 2015. Disponible en https://ediciones.inca.edu.cu/index.php/ediciones/article/view/1504

[17] P. Trivelin, J. Rodrigues & R. Victoria, "Utilização por soqueira de cana-de-açúcar de início de safra do nitrogênio da aquamônia-15N e uréia-15N aplicado ao solo em complemento à vinhaça", *Pesqui Agropecu Bras*, vol. 31, no. 2, pp 89–99, Fev. 1996. Disponível em https://seer.sct.embrapa.br/index.php/pab/article/view/4457

[18] D. Sampietro, "Alelopatía: Concepto, características, metodología de estudio e importancia", *Catedra Fitoquímica*, Fac Biolog Quim Farmac, UNT, 2003. Disponible en https://www.uv.mx/personal/tcarmona/files/2010/08/Sampietro-1.doc

[19] D. Sampietro & M. Vattuone, "Nature of the interference mechanism of sugarcane (Saccharum officinarum L.) straw", *Plant Soil*, vol. 280, no. 1, pp. 157–169, Feb. 2006. https://doi.org/10.1007/s11104-005-2856-5

[20] R. Viator, R. Johnson, C. Grimm & E. Richard, "Allelopathic, Autotoxic, and Hormetic Effects of Postharvest Sugarcane Residue", *Agron J*, vol. 98, no. 6, pp. 1526–1531, Nov 2006. https://doi.org/10.2134/agronj2006.0030

[21] P. Singh, A. Shrivastava, A. Suman, N. Arya, P. Tiwari, R. Rai, J. Singh & A. Singh, "Allelopathic effects of hydroxamic acids from sugarcane leaves on germination and growth of crops", *Allelopath J*, vol. 23, no. 1, pp. 203–212, Jan. 2009. Available: https://www.allelopathyjournal.com/archives/?Year=2009&Vol=23&Issue=1&Month=1

[22] A. Majeed, Z. Muhammad, M. Hussain & H. Ahmad, "In vitro allelopathic effect of aqueous extracts of sugarcane on germination parameters of wheat", *Acta Agric Slov*, vol. 109, no. 2, pp. 349–356, Jul. 2017. https://doi.org/10.14720/aas.2017.109.2.18

[23] C. Webber, P. White, D. Landrum, D. Spaunhorst & D. Wayment, "Sugarcane field residue and bagasse allelopathic impact on vegetable seed germination", *J Agric Sci*, vol. 9, no. 11, pp. 10–16, Aug. 2017. https://doi.org/10.5539/jas.v9n11p10

[24] P. Silva, P. Monquero, F. Silva, N. Bevilaqua & M. Malardo, "Influence of sugarcane straw and sowing depth on the emergence of weed species", *Plant Daninha*, vol. 33, no. 3, pp. 405–412, Jul. 2015. https://doi.org/10.1590/S0100-83582015000300003

[25] C. Webber, P. White, D. Landrum, D. Spaunhorst, D. Wayment & E. Dorvil, "Sugarcane field residue and root allelopathic impact on weed seed germination", *J Agric Sci*, vol. 10, no. 1, pp. 66–72, Oct. 2017. https://doi.org/10.5539/jas.v10n1p66
[26] *SPSS*. (version 21). IBM. [Online]. Disponible en https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-21

Walfrido Terrero Matos. Universidad de Cienfuegos Sede "Carlos Rafael Rodríguez" (Cienfuegos, Cuba). https://orcid.org/0000-0003-4582-1737

Leónides Castellanos González. Universidad de Pamplona (Pamplona, Colombia). http://orcid.org/0000-0001-9285-4879