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EVALUATION OF THREE PLANT EXTRACTS FROM THE AGAVACEAE FAMILY FOR THE MANAGEMENT OF SLUGS IN POTATO.

EVALUACIÓN DE TRES EXTRACTOS DE PLANTAS DE LA FAMILIA AGAVACEAE PARA EL MANEJO DE BABOSAS EN PAPA.

[1]López-Flórez Carlos Antonio, [2]Castellanos-González Leónides, [3]Ramón-Valencia Jarol Derley

*[*1] Agronomic Engineer Trabajador independiente. Finca La María. Vereda Chichira. Pamplona. Colombia antonio.lopez@unipamplona.edu.co. https://orcid.org/0009-0008-5827-0501*

[2] Agronomic Engineer. PhD. Facultad de Ciencias Agrarias. Universidad de Pamplona. Vía Bucaramanga Km 1. Pamplona. Colombia leonides.castellanos@unipamplona.edu.com, http://orcid.org/0000-0001-9285-4879

[3] Environmental Engineer PhD. Facultad de Ingenierías y Aquitectura. Grupo de Investigación Agua, Aire y Suelo (GIAAS). Semillero de Investigación Variabilidad y Cambio Climático (SIVCC). Universidad de Pamplona. Via Bucaramanga Km 1. Pamplona. Colombia. jarol.ramon@unipamplona.edu.co https://orcid.org/0000-0002-4929-8544

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ABSTRACT

Slugs are an important pest of crops in many ecosystems worldwide and in Colombia too. This research aimed to evaluate the molluscicide activity of three Agavaceae extracts; *Agave americana, Furcraea bedinghausii* and *F. andina*, as alternatives to control slugs in Creole potato, obtained by two extraction methods, juice and fraction. An experimental investigation was carried out in a field trial at a potato cultivation. Three treatments consisted of the juices of the three mentioned plants at 20% and another three with aqueous extracts of the chopped leaves of the plants at 4kg/10L of water, a treatment with Diatomaceous Earth as production standard, and a control without treatment. The vegetable extracts of *Furcraea andina*, both in juice and in pieces, got more than 60% of technical efficacy in Creole potatoes with statistical difference with the control and similar results to the standard production witness, Diatomaceous Earth. The treatments that achieved greater stability for reducing damage by slugs in potatoes were the plant extracts of *Furcraea andina,* both in the form of juice and in fractions.

Key words: *Solanum tuberosum* mollusk pest, natural product, phytopesticide, diatomaceous earth

RESUMEN

Las babosas son plagas importantes de cultivos en muchos ecosistemas a nivel mundial y también en Colombia. Esta investigación tuvo como objetivo evaluar la actividad molusquicida de tres extractos de Agavaceae; *Agave americana, Furcraea bedinghausii* y *F. andina*, como alternativas para el control de babosas en papa criolla, obtenidas por dos métodos de extracción, jugo y fracción. Se realizó una investigación experimental en un ensayo de campo en un cultivo de papa. Tres tratamientos consistieron en jugos de las tres plantas mencionadas al 20% y otros tres con extractos acuosos de las hojas picadas de las plantas a 4kg/10L de agua, un tratamiento con Tierra de Diatomeas como estándar de producción y un testigo sin tratamiento. Los extractos vegetales de *Furcraea andina,* tanto en jugo como en trozos, obtuvieron más del 60% de eficacia técnica en papa criolla con diferencia estadística con el control y resultados similares al testigo de producción estándar, Tierra de Diatomeas. Los tratamientos que lograron mayor estabilidad para reducir el daño por babosas en papa fueron los extractos

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*Autor a quien debe dirigirse la correspondencia Jarol D. Ramón Valencia
E-mail: jarol.ramon@unipamplona.edu.co

Palabras clave: *Solanum tuberosum,* moluscos plagas, productos naturales, fitoplaguicidas, tierra de Diatomeas,

INTRODUCCTION

Mollusks belong to the kingdom Animalia, Philo Mollusca, Class Gastropoda. Within this class are snails and land slugs, which, because they are very related to agriculture, often become important pests of crops (Matamoros, 2014; Castellanos and Baldovino, 2021).

In Colombia, slug's pest is found in different attitude, mainly in places with relative humidity higher than 80 %. That mollusks cause damage to the foliage, tubers and roots of plants (ICA, 2012). One of the most important cases occurs in the cultivation of coffee, where these mollusks cause damage in the nurseries and younger plants lesions, the same as perforations in the fruits, producing grain losses (Constantino, 2013). Slug attacks also occur in many vegetables, including creole potato, cabbage, cauliflower, lettuce, spinach and chard. Damage in this crop are caused by slugs as *Deroceras reticulatum* (Müller, 1774), *Limax marginatus* and *Milax gagates* (Draparnaud, 1801) has been reported (ICA, 2010).

The municipality of Pamplona, Norte de Santander, has a great vocation for horticultural and fruit production as it has adequate agroecological conditions for both fruit and vegetable production (Gualdrón et al., 2017). A large part of the crops in Pamplona, such as potatoes, strawberries, peas and lettuce, show damage caused by slugs and snails, in the specific case of potatoes with significant defoliation (Castellanos and Serrano, 2020), which requires treatments with chemical products, like metaldehyde.

Traditionally, at the international level, the control of mollusk pests is done through chemical baits (Salvio et al., 2008), since the culture of farmers prefer quick results, while few studies focus on evaluating biological control. or alternative, obtaining little information in this regard (Camacho *et al.,* 2020; Bonilla *et al*., 2021). It is suggested that metaldehyde-based formulas work mainly through ingestion and contact, many times they no longer have the desired efficacy against slugs such as *Deroceras reticulatum*, which depends on the concentration of the product, its attractants and soil moisture (Salvio *et al.,* 2008).

During the last years, new alternatives in molluscicide control have been searching, one of them with the extracts of plants of the Agavaceae family. Internationally, several authors have reported encouraging results, demonstrating that it is a product that is friendly to the environment and human health, reflecting great molluscicide action on slugs by *Agave americana* and *Furcraea hexapetala* (Nodarse *et al.,* 2019).

Species of the Agavaceae family and related constitute a group of monocotyledonous plants of American origin that include 10 genera and 340 species, whose history has been linked to different Mesoamerican civilizations that have used them as fiber and beverages (De la Torre *et al.,* 2018; Guerrero *et al*., 2021). In particular, fique (*Furcraea* spp.) is the most widely used source of natural hard fiber in Colombia for multiple artisanal uses; it is cultivated in smallholdings of low-income farmers who generally live in marginal areas, despite this, about 70,000 families subsist from its production, mainly in the departments of Cauca and Nariño (Ortiz, 2022). In the area of Pamplona, Norte de Santander, Colombia, plants of many species of Agavaceae are abundant. Locally in Pamplona, researches for the control of slugs have been carried with agricultural lime and diatomaceous earth (Méndez and Castellanos, 2019), eucalyptus extracts (Castellanos and Mora, 2020; Niño Rondón *et al*., 2021) seeking solutions in strawberry cultivation, but there is little information on the Creole potatoes crop, a topic that is addressed in the present work.

Then the following question arises: What will be the level of efficacy and the repercussion on foliar damage of the extracts of three plants of the Agavaceae family *Agave americana, Furcraea bedinghausii* and *F. andina* obtained by different extraction methods on slug populations, in Creole potato (*Solanum tuberosum* Phureja group).

Therefore, the objective of the research was to evaluate the molluscicide activity of three Agavaceae extracts; *Agave americana, Furcraea bedinghausii* and *F. andina*, as alternatives to control slugs in Creole potato, obtained by two extraction methods, juice and fraction.

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MATERIALES Y MÉTODOS

An experimental research was carried out with a field trial in a Creole potato crop, at the Villa María farm, Chíchira village, in the municipality of Pamplona, coordinates 7°21'41''N and 72°36 '32' 'W, Norte de Santander, Colombia. It was carried out in a plot of Creole potatoes at 60 days age with a planting distance 1.0 m between rows and 0.30 m between plants.

A randomized block design of eight slug control treatments was used, with 4 replicates, that is, 32 plots of 20 m^2 each, 5 m long by 4 m wide. The eight treatments used are shown in Table 1.

Table 1. Treatments developed in the experiment.

	TREATMENTS
1	Juice of *A. americana* at 20%
2	Juice of *F. andina* at 20%
3	Juice of *F. bedinghausii* at 20%
4	Extract fractions of *A. americana* 4Kg/10L of water
5	Extract fractions of *F. andina* 4Kg/10L of water
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water
7	Diatomaceous Earth 10kg/ha
8	Control without treatment

The Diatomaceous Earth used came from the Agropuli Company, certified by the ICA with a concentration of 55.55% Silicon Oxide at Grupo (Méndez and Castellanos, 2019).

Vegetal material

The plant material used in the research was collected in the surroundings of the University of Pamplona, 7°23'12" N and 72°38'54" W. Adult leaves were collected from the lower part of the plant of three species of the family Agavaceae *A. americana, Furcraea bedinghausii, F. andina*, in the month of February 2022, during a dry period.

To evaluate molluscicide activity, two types of extracts were used, the first generated by the juice of the adult leaves of the plants and the other with fractions of the leaves, applied by spraying applications for the control of slugs.

Extraction of juice from the leaves of Agavaceae plants:

The leaves were washed with water and dried with a paper towel; pieces of approximately 4 cm x 4 cm were cut with a knife, without removing the bark. The fragments were passed through a manual grain mill, CORONA brand (composed of two crushing discs and a crank that rotates and drags the stalks towards the discs). The juice obtained was filtered through a plastic sieve with a 1 mm porosity, sterilized and subsequently filtered through eight layers of surgical gauze.

Preparation of extracts from the chopped leaves of Agavaceae plants:

After washing the leaves, pieces of approximately 4 cm x 4 cm in size were cut with a knife without removing their bark. With the material obtained, the extracts were prepared using a proportion of 4 kg of leaves divided by 10 L of water. Subsequently, they were left at rest for 24 hours. They were filtered again and applied directly to the crop in each plot according to treatment.

The treatments were carried out at sunset with a 20-liter Royal Cóndor pump, using a final solution of 350 L/ha estimated from the operator's calibration. This procedure was carried out with the three extracts and juices (*A. Americana, F. bedinghausii,* and *F. Adina*) and with Diatomaceous Earth.

Sampling of populations in traps

To monitor slug populations, 25 cm x 25 cm refuge traps made of cardboard were used. Each experimental unit (plot) was sampled, identifying slugs and damage. Although the plots had an area of 20 m^2 each, that is, 5 meters long x 4 meters wide, the samplings were carried out in the three central furrows, leaving an edge effect of 1 m in each plot to avoid interference from the different treatments.

Slug populations were quantified before starting the experiment to verify whether slug populations and damage were randomly distributed, as the same as the slug species present were identified. Five refuge traps per experimental unit or plot were placed at sunset and evaluated the following morning. To determine the efficacy on the populations, samplings were carried out 3, 5 and 7 days (3D, 5D and 7D after the applications of the products, that is, after the first application and after the second applications.

The traps were placed in the afternoon and sampled the following morning. In each trap, the number of live individuals present in each trap was recorded according to the respective treatments. Slugs were not removed from the trap or from the field. With the population data from the traps. The efficacy of each treatment per plot was determined at 3, 5 and 7 days after each application using the Abbott formula (Ciba Geygi, 1981).

$$\text{Technical efficacy (ET) (\%)} = (A - B)/A * 100.$$

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Where A: Initial population of each treatment. Slugs by traps in the control (average of the four plots)

B Population in each successive sampling, 3, 5 and 7 days of each treatment.

With the technical efficacy data, comparative graphs were made using the Microsoft Excel application.

To determine the damage of slugs, 10 plants were sampled in the center of each plot. The total number of leaves affected by the slug was evaluated for each one. With this information, the affected leaf percentage was determined and from there a degree of damage was assigned, for which the diagrammatic scale proposed by Abbott (Ciba Geygi, 1981) was used. This procedure was carried out 3, 5 and 7 days after each treatment.

The scale used is described below (Ciba Geygi, 1981).

- 0= plant without damage.
- 1= the plant shows damage up to 5% of the leaf area.
- 2= the plant shows damage between 6 - 25% of the leaf area.
- 3= the plant shows damage between 26 - 50% of the leaf area.
- 4= the plant shows damage between 51 – 75% of the leaf area.
- 5= the plant presents damage between more than 76% of the leaf area

To calculate the degree of damage at the plot level in the 10 evaluated plants, the Townsend and Heuberger formula (Ciba-Geigy, 1981) was used.

$\boldsymbol{S} = \ \%\,\text{severity} = \ (\sum (\text{Ax B})/\text{KN} * 100)$.

Where:

$\sum$= summation symbol.

S= Severity of the damage.

A= Scale degree.

B= Number of plants with each degree a of the scale.

K= Maximum degree of the scale =5

N= Total number of plants sampled in the plot

Statistical analysis

Analysis of variance was carried out with the slug population data and the percentage of severity of damage by treatments in the different time samplings (3D, 5D and 7D), once the assumptions of normality were verified by the Kolmodorov Smirvov test, as well as the uniformity of the variances. The means were compared by the Tukey test (P<0.05), using the statistical package SPSS (Statistical Package for the Social Sciences) version 21 for Windows.

RESULTS AND Y DISCUSION

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Comparison of the efficacy on slugs of three Agavaceae extracts in the field.

During the samplings before the applications it was possible to observe the predominance of slugs of the genus *Arion* and to a lesser extent of the genus *Deroceras*, which could be easily recognized by the position of the mantle, in front, in *Arion* sp. and in the center of the body in *Deroceras* sp., in addition to the difference in color and pigmentation characteristic of each genus, In general, no species of other genera of slugs were observed in the traps. These results confirm those of and Rizzo et al. (2019) and Castellanos and Serrano (2020), in relation to the preference of these two genera of slugs in the cultivation of Creole potato in Pamplona conditions.

The result of the ANOVA for the slug populations before making the first application revealed the non-existence of statistical differences by Fisher's test (P<0.05). It was verified that there is no statistical difference between the plots of the treatments, which allowed to be carried out the experiment without risk of a non-uniformity population, which in this case was high, varying between 14.70 and 20.75 slugs/traps (Table 2).

Table 2. Results of the analysis of the comparison of means of the population of slugs present before the first application

N°	Treatments	Slugs/traps
1	Juice of *A. americana* at 20%	16.95
2	Juice of *F. andina al* 20%	16.10
3	Juice of *F. bedinghausii* al 20%	14.70
4	Extract fractions of *A. americana* 4Kg/10L of water	16.15
5	Extract fractions of *F. andina* 4Kg/10L of water	18.50
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water	20.75
7	Diatomaceous Earth 10kg/ha	15.70
8	Control without treatment	17.30

The analysis of variance of the slug populations 3 days (3D) after the first application carried out on 04/22/2022 revealed significant statistical differences between all treatments. The multiple comparison of means showed that the treatment with the lowest population was the extract of *F. andina* 4 kg/ 10 L with 5.25 slugs/trap, although the treatment *A. americana* juice at 20% and Diatomaceous Earth obtained results statistically similar to this. At 5D after the first spray, the population of all treatments differed from the control except *F. bedinghausii* extract 4 kg/10 L. The treatments with the lowest population were *F. andina* juice at 20% (5.90 slugs/trap), *A. americana* juice at 20% (7.10 slugs/trap) and Diatomaceous Earth (7.25 slugs/trap), although the populations of two other treatments did not differ statistically from these, such as *F. bedinghausii* at juice at 20% and *F. andina* extract 4 kg/ 10 L. Already at 7D after the first application again the treatments of smaller populations were *F. andina* juice at 20%, *A. americana* juice at 20% and Diatomaceous Earth that differ from the control and also from the rest of the treatments (Table 3).

Table 3. Results of the analysis of the comparison of means for the slug populations after the first application.

N°	Treatments	Slugs/traps 3D	5D	7D
1	Juice of *A. americana* at 20%	9.15de	7.10 d	14.85 b
2	Juice of *F. andina al* 20%	5.25 e	5.90 d	7.10 c
3	Juice of *F. bedinghausii* al 20%	11.75 bc	9.60 cd	16.70ab
4	Extract fractions of *A. americana* 4Kg/10L of water	11.80 bc	12.60 bc	14.70 b
5	Extract fractions of *F. andina* 4Kg/10L of water	10.05 bc	8.05 cd	8.15 c
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water	13.85 b	14.75 ab	13.60 b
7	Diatomaceous Earth 10kg/ha	9.20 de	7.25 d	7.10 c
8	Control without treatment	18.60 a	18.80 a	21.05 a
	Coefficient of Variation	39.05	39.16	39.75
	Typic Error *	2.85	2.37	2.43

*Unequal letters in the column indicate statistical difference for p<0.05 according to Tukey's test

These results can be justified due to the concentration of saponins and other metabolites with a molluscicide effect reported for *Furcraea andina* and *Agave americana* by Iannacone *et al.* (2013).

When analyzing the technical efficiencies obtained by the different treatments during this first application (Fig. 1), it can be observed that some treatments reached or exceed the 60% efficiencies established for biological or alternative means (National Center for Plant Health, 2014) like *A. americana* juice (20%) at 3D, *F. andina* juice (20%) at 3D, 5D and 7D, and *F. andina* extract 4 kg/10 L at 7D and Diatomaceous Earth at 5D and 7D. It is shown that the treatment with the most stability in efficacy was *F. andina* juice at 20 %, while the treatments of *F. bedinghausii* in any moment or variants obtained 60% of efficacy, observing a tendency to be more effective extracts from of the juice, than those of chopped.

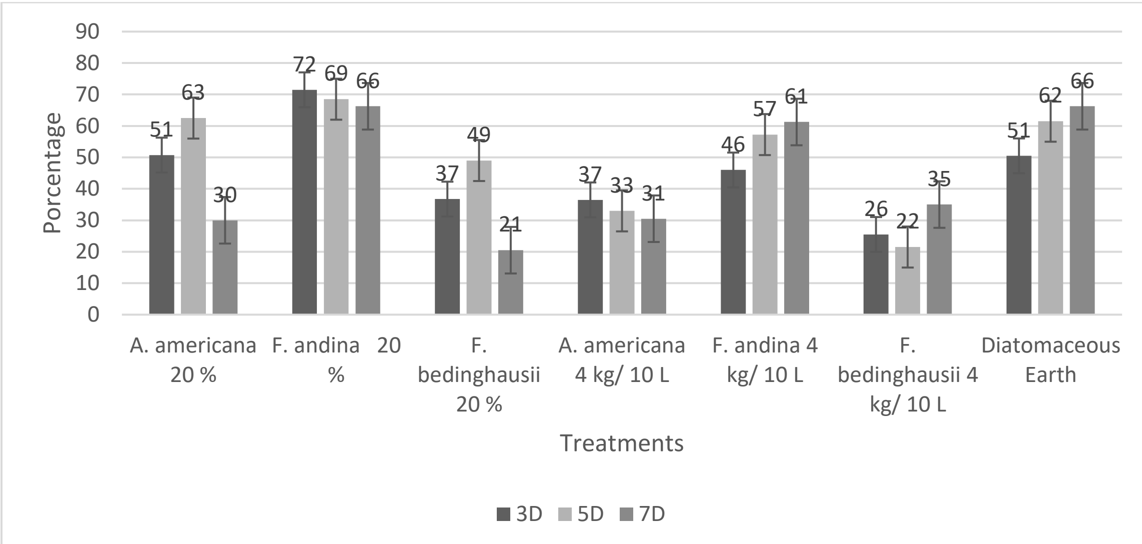

Figura 1. Technical efficacy of the products in each treatment after the first application.

When observing the results of the ANOVA with the second application carried out 15 days after the start the experiment, statistical difference was observed between the treatments. The multiple comparison analysis of means showed significant statistical difference at 3D between all treatments. The treatment with the lowest population of slugs was for *F. andina* juice at 20% (6.90 slugs/trap), which presented a statistically significant difference with the control (18.75 slugs/trap), although without statistical difference with the *F. americana* treatment. 4 kg/ 10 L (9.15 slugs/trap). At 5D after the start the trial, the population of all treatments differed statistically from the control. The treatment with the smallest population was for *F. andina* juice at 20% and only the treatment with *F. bedinghausii* 4 kg/10 L presented a statistical difference with this. At 7D after the second application, again the treatment with the lowest slug population was *F. andina* juice at 20%, without statistical difference with *A. americana* juice at 20% and *A. americana* extract 4 kg/10 L. It is noteworthy that the treatment with *F. bedinghausii* 4 kg/10 L did not differ from the control (Table 4).

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Table 4. Results of the analysis of the comparison of means for the slug populations after the second application.

N°	Treatments	Slugs/traps		
		3D	3D	3D
1	Juice of *A. americana* at 20%	13.95 b	8.80 bcd	7.20 de
2	Juice of *F. andina al* 20%	6.90 d	6.50 d	5.35 e
3	Juice of *F. bedinghausii* al 20%	10.70 bc	8.80 bcd	17.10 a
4	Extract fractions of *A. americana* 4Kg/10L of water	10.80 bc	9.65 bcd	9.60 cde
5	Extract fractions of *F. andina* 4Kg/10L of water	9.15 cd	7.60 cd	10.70 cd
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water	11.00 bc	11.75 bc	16.45 ab
7	Diatomaceous Earth 10kg/ha	12.15 bc	10.40 bcd	12.15 bc
8	Control without treatment	18.65 a	21.60 a	16.75 a
	Coefficient of Variation	35.55	36.66	38.34
	Typic Error *	1.94	2.62	2.28

*Unequal letters in the column indicate statistical difference for p<0.05 according to Tukey's test

An analysis of the technical efficiencies of the different treatments after the second application shows that the treatments that reach or exceed the efficiencies of 60% established for biological or alternative means (CNSV, 2014), were *F. andina* juice (20%) at the 3D, 5D and 7D, and the extract *F. andina* 4 kg/ 10 L at 7D (Fig. 2). It is shown that the treatment with the greatest stability in efficacy was *F. andina* juice 20 %, while the treatments of *F. bedinghausii* in any time and variants overcome 60 % of efficacy, observing a tendency to be more effective extracts from the juice, than those of chopped. In this case, there was a tendency to be greater efficiencies at 5 days compared to 7 days, which can be attributed to the presence of rainy days on those days, but it is also an alert about the possible decrease in efficacy after this moment, considering that no adherent was added to the natural products. In this case, the additive control effect was not observed, indicated by other authors with the use of two consecutive phytopesticide treatments (Peña *et al.,* 2013).

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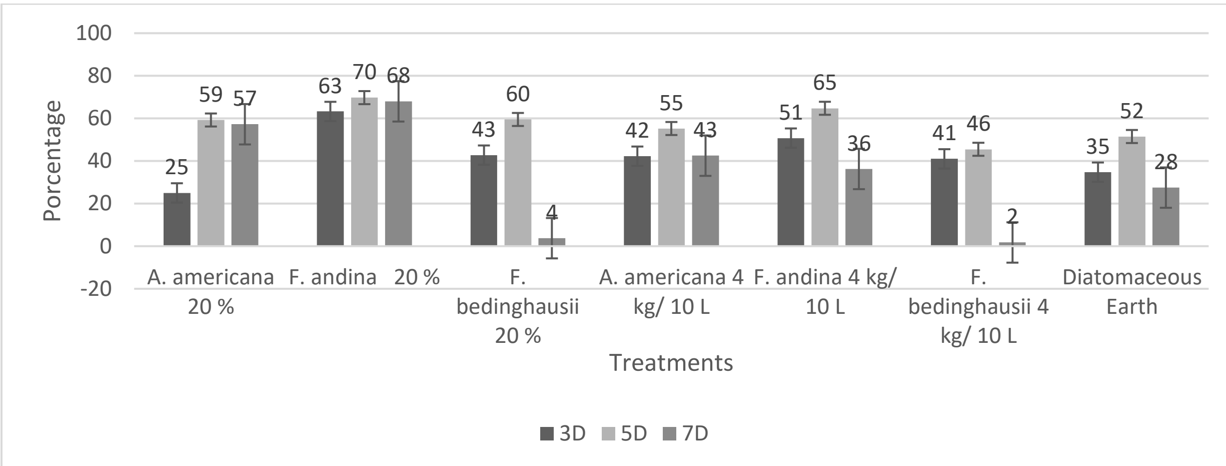

Figura 2. Technical efficacy of the products in each treatment after the second application.

Damage to the foliage of the Creole potato crop with the applications of the three extracts of the Agavaceae

Before starting the treatments, the result of the ANOVA for the severity of the damage by slugs did not show any statistical difference, varied between 54 and 64 % (Table 5). The non-difference between the treatments where the damage percentages guaranteed uniformity of the damage before starting the applications.

Table 5. Results of the analysis of the comparison of means for the damages by slugs present before the first application.

N°	Treatments	Severity of damage (%)
1	Juice of *A. americana* at 20%	56.50
2	Juice of *F. andina al* 20%	56.50
3	Juice of *F. bedinghausii* al 20%	64.00
4	Extract fractions of *A. americana* 4Kg/10L of water	56.00
5	Extract fractions of *F. andina* 4Kg/10L of water	54.50
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water	52.50
7	Diatomaceous Earth 10kg/ha	54.50
8	Control without treatment	54.50 a

Regarding to the statistical analysis of the severity of the damages, after the first application there was statistical difference between the treatments (Table 6), it was possible to verify that at 3D, all the treatments differed from the control (64.50% of damages) and not among them, with the exception of the treatment of the extract of *F. bedinghausii* 4 kg/ 10 L, which did not differ

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from the control, nor from the rest. At 5D after application, the damage of all treatments differed statistically from the control (68.50% damage). The treatment with the lesser damage was the juice of *F. andina* 4 kg/10 (42.00% damage). but only that of *F. bedinghausii* 4 kg/ 10 L presented a statistical difference with it. At 7D after the second application, all the treatments differed from the control (71.00% damage) and not between them, with the exception of the treatment of the extract of the juice of *F. bedinghausii* 4 kg/10 L, which did not differ from the control, nor the rest.

Table 6. Results of the analysis of the comparison of means for the damages by slugs after the first application.

		Severity of damage (%)		
	Treatments	3D	5D	7D
1	Juice of *A. americana* at 20%	42.50 b	45.50 bc	46.00 b
2	Juice of *F. andina al* 20%	48.00 b	44.50 bc	46.00 b
3	Juice of *F. bedinghausii* al 20%	44.50 b	51.50 bc	56.50 ab
4	Extract fractions of *A. americana* 4Kg/10L of water	40.50 b	46.50 bc	52.00 b
5	Extract fractions of *F. andina* 4Kg/10L of water	44.00 b	42.00 c	45.50 b
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water	51.50 ab	53.50 b	51.50 b
7	Diatomaceous Earth 10kg/ha	45.50 b	47.0 bc	48.50 b
8	Control without treatment	64.50 a	68.00 a	71.00 a
	Coefficient of Variation	13.51	9.09	12.03
	Typic Error *	3.21	2.43	3.13

*Unequal letters in the column indicate statistical difference for p<0.05 according to Tukey's test

The reduction of foliage damage of the potato with respect to the control after the first application of the treatments varied between 20% and 38%. This is because a high impact on this variable is not possible in a short time, since the damage is maintained for a while, even though the plants are growing.

The ANOVA for the damage to the potato foliage between the different treatments showed a statistical difference by Fisher's test. The analysis of comparison of means of the severity of the damages, after the second application (Table 7) showed that at 3D, all the treatments differed from the control and not between them, with the exception of the treatment with the juice of *F. bedinghausii,* which it did not differ from the control, nor from the rest. The treatment with less severity of damage (44%) was shown by *F. andina* juice, but a group of treatments did not differ from this, such as *A. americana* juice (51.50%), *A. americana* extract 4 kg/10 L, *F. andina* extract 4 kg/ 10 L (48.40 %), *F. bedinghausii* extract 4 kg/ 10 L (55.00 %), and Diatomaceous Earth (50.00 %). At 5D after second application, the treatments with the least damage were the extract of *F. andina* 4 kg/10 L and Diatomaceous Earth, which differed from the control (67.50%), but not from the other four treatments. At 7D, the treatments with less damage were also the extract of *F. andina* 4 kg/10 L and Diatomaceous Earth, which differed from the control (67.00%), and not with four other treatments.

Table 7. Results of the analysis of variance for slug damage after the second application.

	Treatments	Severity of damage (%) 3D	5D	7D
1	Juice of *A. americana* at 20%	46.50 bc	54.40 abc	55.50 abc
2	Juice of *F. andina al* 20%	44.00 c	54.40 abc	48.00 bc
3	Juice of *F. bedinghausii* al 20%	57.50 ab	55.00 abc	56.50 abc
4	Extract fractions of *A. americana* 4Kg/10L of water	51.50 bc	52.50 bc	47.50 bc
5	Extract fractions of *F. andina* 4Kg/10L of water	48.40 bc	45.00 c	43.50 c
6	Extract fractions of *F. bedinghausii* 4Kg/10L of water	55.50 bc	60.50 ab	58.50 ab
7	Diatomaceous Earth 10kg/ha	50.50 bc	44.00 c	45.00 c
8	Control without treatment	68.50 a	67.50 a	67.00 a
	Coefficient of Variation	12.05	10.89	8.81
	Typic Error *	2.89	2.87	2.59

*Unequal letters in the column indicate statistical difference for p<0.05 according to Tukey's test

The evaluation of the damages revealed a high level of damage in the control at 5D and 7D with 67% after the second application. In the plots it was possible to observe losses in leaf, stem and plant area. On the other hand, with the treatment of *F. bedinghausii* extract, plots presented high levels of damage, attributable to the fact that during this stage there were more rainy days than after the first application.

According to Pérez (2011) the plants of the Agavaceae family are rich in steroidal saponins. These are secondary metabolites that are interesting due to the wide spectrum of biological activities such as molluscicide that have been attributed to them, as well as their structural complexity. In this regard, Osman *et al.* (2011) point out that in *F. selloa* Koch., it presented a high molluscicide activity on the *Biomphalaria alexandrina* snail, due to the fact that the components of the group of steroidal saponins that form complexes with cholesterol and decrease their levels in the plasma and thus reduce the cholinesterase activity or decrease heart rate, significantly affecting snail mortality.

It is known that from the leaves of *F. hexapetala,* six saponins were isolated, among them some better known such as cantalasaponin-1, and furcreastatin, (Pérez, 2011). In a phytochemical screening of the ethanolic-aqueous extracts of *F. hexapetala* (Jacq.), saponins were detected, which were attributed the insecticidal activity on the aphid *Myzus persicae* Sulzer, 1766 (Castellanos *et al.,* 2011). Nodarse *et al.* (2017) also attributed the molluscicides activity of *F. hexapetala* (Jacq.) against the snail *Praticolella griseola* to saponins, including furcrastatin. The effect of the aqueous extract of *F. andina* on the aquatic mollusk *M. tuberculata* (Thiaridae) was also attributed to saponins by Iannacone *et al.* (2013).

Many year ago, it was reported that *F. andina* and *A. americana*, were plants with several ethnobotanical properties, among which the effects as biopesticides stand out (Pino, 2006). *F. andina* is reported with molluscicides activity on *Fossaria viatrix* and *Physa venustula* (Guzmán, 2008). Molluscicide effect has been reported in plant extracts of several Asparagaceae species, extracting steroidal saponins from *A. wightii* Drumm. & Prain and *A. sisalana* (Debnath et al., 2010). Other research results have also explained the molluscicides effects of different substances as saponins or glycosides (González *et al.,* 2013; Alzabib *et al.,* 2019).

Botanical pesticides such as those studied here are considered low risk, traditionally used by human communities, highly specific, and an attractive and environmentally safe alternative to synthetic insecticides for vector and pest control (Isman, 2006). Moreover, plant-derived products are receiving attention for their pesticidal properties and lower impact on the environment (Lina *et al.,* 2013).

These results coincide with others obtained with extracts or essential oils of plants for the control of mollusk pests internationally (Edis *et al.,* 2018; Harmouzi *et al.,* 2018; Adomaitis et al., 2020), and also in Colombia (Garcés *et al.,* 2016; Castellanos and Mora, 2020).

Another aspect to consider is that old leaves were taken, and the Agavaceae plants shed the lower leaves as they develop, so the use of these does not constitute a risk to the plant genetic resource if it is rationally collected in the lower part of the plant.

Efficiency levels greater than 60% obtained with *F. andina* extracts, both in juice and in chopped form, recommended for alternative pesticides (CNSV, 2014), give farmers options to use either of the two methods employed to obtain the extract, in case the farmer does not have a mill, although a second treatment may be made, if necessary.

The percentage of damage to potato leaves caused by slugs showed a relative decrease after the second application in relation to the first, which can be explained because the affected leaves can remain alive on the plant for several days, and also must be into consideration that the extracts can accumulate when applications are made in the same plots twice, as has been pointed out by other authors (Peña *et al.,* 2013).

Despite the low risk that is traditionally posed to humans (Isman, 2006) and that due to the degree of solubility in water, saponins should not remain for a long time on the plants and it would be advisable to carry out more specific studies on the residuals of the extracts in this crop, while on the other hand it would be interesting to test natural substances as adherents when there are rainy periods that can wash the extracts.

These results have great importance, since the potential of fique (*F. andina*) is verified to reduce slug populations and their damage in potato crop, both the sap juice and the extracts from the leaves chopped. This is of great relevance due to the abundance of this plant in many farms and villages in Pamplona and other Andes areas where it is cultivated, and for the ease of obtaining the molluscicide and making treatments with these plant extracts, with similar technical effectivity than Diatomaceous Earth, which many farmers use for this purpose.

CONCLUSIONS

The plant extracts of *Furcraea andina*, both in the form of juice and in fraction, showed a reduction in more than 60% of the populations of slugs in Creole potatoes under the conditions of the La María farm, with similar results to the standard production control of Diatomaceous Earth in terms of technical efficacy, followed by *Agave americana* with encouraging results.
The treatments that achieved greater stability for reducing damage by slugs in creole potatoes were the plant extracts of *Furcraea andina*, both in the form of juice and in

pieces, with similar results than Diatomaceous Earth.

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