# Possibilities of the Alternative Management of Mollusk Pests in Agricultural Crops. A Review

# Posibilidades de la gestión alternativa de las plagas de moluscos en los cultivos agrícolas. Una revisión.

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**Cristian David Quintero Santos**
Universidad de Pamplona. Pamplona (Colombia)
cquintero216@gmail.com

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

**Wlda Margarita Becerra-Rozo**
Universidad de Pamplona. Pamplona (Colombia)

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**Abstract**

**Introduction—** Mollusks are important pests of agricultural crops, for which chemical molluscicides are used in many cases that pollute the environment and crops.

**Objective—** To assess updated information on alternatives for the management of species of mollusk pests in agricultural crops in Colombia and in the world.

**Methodology—** A descriptive documentary research was carried out where the units of analysis were the articles collected in a bibliographic search on information related to the pest mollusk species and alternative control methods during the period 2010 to 2021.

**Results—** From the last decade articles were obtained on alternatives for the control of mollusk pests in all continents. From Colombia only 7 articles, of which 3 correspond to the use of diatomaceous earth, 3 to vegetable extracts and 1 to agroecological management, while, at the international level of the 54 articles located, 21 were related to vegetable extracts, 17 biological control, 6 with essential oils, 5 with barriers, 3 with agroecological management and 2 with biopesticides.

**Conclusions—** Alternatives with the use of plant extracts predominated, followed by biological means such as insects, nematodes, microorganisms and others, natural products such as lime and diatomaceous earth, as well as different materials such as repellents or barriers, depending the type of recommended alternative, on the mollusk species and its size, the phytogenetic resources present and the reported bioregulators, which should be taken into account in Colombia.

**Keywords—** Biological control; plant extracts; snails; slugs; insects; nematodes; barriers

**Resumen**

**Introducción—** Los moluscos son importantes plagas de los cultivos agrícolas, para los que se utilizan en muchos casos molusquicidas químicos que contaminan el medio ambiente y los cultivos. Objetivo— Evaluar la información actualizada sobre las alternativas para el manejo de las especies de moluscos plaga en los cultivos agrícolas en Colombia y en el mundo.

**Metodología—** Se realizó una investigación documental descriptiva donde las unidades de análisis fueron los artículos recolectados en una búsqueda bibliográfica sobre información relacionada con las especies de moluscos plaga y métodos alternativos de control durante el periodo 2010 a 2021.

**Resultados—** De la última década se obtuvieron artículos sobre alternativas para el control de moluscos plaga en todos los continentes. De Colombia solo 7 artículos, de los cuales 3 corresponden al uso de tierra de diatomeas, 3 a extractos vegetales y 1 a manejo agroecológico, mientras que, a nivel internacional de los 54 artículos localizados, 21 estaban relacionados con extractos vegetales, 17 con control biológico, 6 con aceites esenciales, 5 con barreras, 3 con manejo agroecológico y 2 con bioplaguicidas.

**Conclusiones—** Predominaron las alternativas con el uso de extractos vegetales, seguido de medios biológicos como insectos, nematodos, microorganismos y otros, productos naturales como cal y tierra de diatomeas, así como diferentes materiales como repelentes o barreras, dependiendo el tipo de alternativa recomendada, de la especie de molusco y su tamaño, de los recursos fitogenéticos presentes y de los biorreguladores reportados, que deben ser tenidos en cuenta en Colombia.

**Palabras clave—** Control biológico; extractos vegetales; caracoles; babosas; insectos; nematodos; barreras

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## I. Introduction

Agriculture plays a fundamental role in the economy of a country. It not only provides raw materials and food, but also job opportunities to a considerable percentage of the population. Crop protection is of great importance when presenting pest problems, among which are terrestrial mollusks [1]. These can eat up more than 30% of your weight in 24 hours [2]. They have an unfavorable impact on some vegetables, fruit trees, tubers, ornamentals, legumes and legumes, both bark, leaves and fruits [3], [4], [5].

Species such as the giant African snail *Achatina fulica* Bowdich feed on any organic material, including carcasses and feces of various organisms, up to humans. If in contact with *Rattus norvegicus* Berkenhout rats, they can acquire parasites of medical and veterinary importance [6], [7]. Additionally, they are intermediate hosts of nematodes such as *Strongyloides* spp., *Trichuris* spp., *Schistosoma mansoni* Sambo, *Hymenolepis* spp., *Angiostrongylus cantonensis* Chen and *Aelurostrongylus* sp. [8], [9], [10].

Farmers often depend on synthetic molluscicides for the defense, prevention and control of the attacks of mollusk pests on their crops. This originates a series of environmental impacts [11], that go from the economic, social and ecological one. To mitigate or reduce the adverse effects produced by these organisms, different control methods can be used, however, the information is not always organized and available in a systematic way. Taking the above into consideration, the objective of this research was to assess updated information on alternatives for the control of mollusk species pests in agricultural crops with potential for use in Colombia.

## II. Methodology

A descriptive documentary research was carried out where the units of analysis were the articles collected in a bibliographic search on works carried out with species of mollusks pests and alternative control methods during the period from 2010 to 2021. The articles published in the period mentioned above were included. of the following journals: ABC of Biodiversity, Technical Advances, Colombian Biota, Scientific Bulletin, Museum of Natural History University of Caldas, CIDISAV, Agricultural Science and Technology, Distancia al Día, INGE CUC, Environmental magazine, water, air and soil, Magazine Bistua, Centro Agrícola Magazine, Plant Protection Magazine, Infometric Magazine, MVZ Córdoba Magazine. Also foreign journals, some of them with access through the catalog of databases of the digital libraries of the University of Pamplona (Organic Agriculture, Applied Ecology and Environmental Research, Asia-Pacific Journal of Science and Technology, Avances en Biomedicina, Biocatalysis and Agricultural Biotechnology, BioControl, Biodiversity and Environmental Sciences, Bioinvasions Records, Biolife, Biological Control, Biotemas, Chilean journal of agricultural & animal sciences, Crop Protection, Egyptian Journal of Aquatic Biology and Fisheries, Egyptian Journal of Biological Pest Control, Egyptian Journal of Plant Protection Research Institute, Environmental Science: Water Research & Technology, Florida Entomologist, Environment, and Biotechnology, Horticulture, Revista INIA, Insects, International Journal of Agricultural Science and Research, International Journal of Biological and Medical Research, International Journal of Biological Innovations, International Journal of Botany Stud ies, Journal Entomology and Zoology Studies, Journal of Agricultural Science and Technology, Journal of Economic Entomology, Journal of Helminthology, Journal of helminthology, Journal of Integrated Pest Management, Journal of Invertebrate Pathology, Journal of medicinal plants Research, Journal of Negative & No Positive Results, Journal of nematology, Journal of Pest Science, Journal of Pest Science, Journal of Phytopathology and Pest Management, Journal of Plant Protection and Pathology, Molecules, Nematology, New York Science Journal, Pest Management Science, Pesticidi i phytomedicine, PLOS ONE, Research on Crops, Revista Centro Agrícola, Revista Científica Agroecosistemas, Revista da Sociedade Brasileira de Medicina Tropical, Revista do Instituto de Medicina Tropical de São Paulo, Revista Ecuatoriana de Medicina y Ciencias Biológicas, Tropical biomedicine, Sanidad Vegetal, Spanish Journal of Agricultural Research, The Canadian Entomologist, The Egyptian Journal of Hospital Medicine. With the information, a review, compilation and update monograph was created.

## III. Results

According to the information consulted, a total of 60 articles published for the period 2010 to 2021 were collected, distributed as follows: national 7 articles; of which 5 correspond to the municipality of Pamplona. At an international level, 53 articles from 27 countries were found (Germany, Saudi Arabia, Brazil, Canada, Chile, Korea, Croatia, Cuba, Ecuador, Egypt, Slovenia, United States, Philippines, India, Ireland, Italy, Japan, Lithuania, Morocco, Nigeria, Panama, Pennsylvania, Portugal, United Kingdom, Czech Republic, Thailand and Venezuela) (Table 1).

Table 1.
List of articles according to the country, control method and publication date.

| Country | Control methods | Authors |
|---|---|---|
| Germany | Essential oils for control of *D. reticulatum.* | [12] |
| Saudi Arabia | Methomyl and cardenolide extracts of *Calotropis procera* (Aiton) Dryand and *Adenium arabicum* Balf.f. to control *Monacha cantiana* Montagu. | [13] |
| Brazil | Popular knowledge: impacts and control methods *A. fulica* in Valença. | [14] |
| | Hydroalcoholic extracts of *Jatropha gossypiifolia* L., in *Biomphalaria glabrata* Say. | [15] |
| | Prototype kit of natural molluscicide based on lyophilized *E. milii.* | [16] |
| Canada | Ground beetles (Coleoptera: Carabidae) for slug control. | [17] |
| Chile | Saponin-rich plant extracts to control gray slug *D. reticulatum.* | [18] |
| Korea | Tobacco extract and caffeine solution in combination with alcohol. | [19] |
| Croatia | Nematode *Phasmarhabditis hermaphrodita.* | [20] |
| Cuba | Agroecological management of mollusks. | [21] |
| | Plant extracts for the control of *P. griseola.* | [22] |
| | Plant extracts of three species of Agavaceae against *P. griseola.* | [23] |
| Ecuador | *Agdestis clematidea* Moc. and Sessé., control of *Subulina octona* Bruguière. | [24] |
| | Nematode *Phasmarhabditis hermaphrodita* Schneider as a mollusk biocontroller. | [25] |
| Egypt | *Citrus aurantifolia* (Christm.) Swingle, *Citrus limon* L., *Citrus paradisi* Macfad., and *Citrus sinensis* (L.) Osbeck essential oils. | [26] |
| | Effect of some rotifers on land snails and slugs. | [27] |
| | Thymol toxicity in the epidermis and digestive gland of *L. maximus*, and *Lehmannia marginata* Müller. | [28] |
| | Thymol compound on the epidermis of *Limax maximus* L. | [29] |
| | Nematode pathogenicity against the snails *Monacha cartusiana* Müller and *Eobania vermiculata* Müller and the slug *Limax flavus* L. | [30] |
| | Microbial biopesticides for *M. cartusiana* Müller. | [31] |
| | Active compounds from the stems of *Adenium obesum* (Forssk.) Roem. and Schult. | [32] |
| | Nematode *Phasmarhabditis* sp. on the snail *Eobania vermiculata* Müller. | [33] |
| | *Megaselia scalaris* Loew as a biocontrol agent for *E. vermiculata.* | [34] |
| Slovenia | Barrier of wood ash, sawdust, hydrated lime and diatomaceous earth. | [35] |
| | Efficacy of *Fallopia japonica* (Houtt.) Ronse Decr., *F. x bohemica* (Chrtek and Chrtková) Bailey, *Solidago canadensis* L., *Solidago gigantea* Aiton, *Rhus typhina* L., *Ailanthus altissima* (Mill.) Swingle. | [36] |
| USA | Nematode *P. hermaphrodita* in *D. reticulatum*, D. laeve and *Lehmannia valentiana* Férussac. | [37] |
| | Essential oils for eggs and juvenile snails *Cornu aspersum* Müller. | [38] |
| | Evaluation of barrier materials for the control of *L. floridana.* | [39] |
| | Nematode *P. hermaphrodita* in *D. reticulatum.* | [40] |
| | Lethality of four species of *Phasmarhabditis* sp., In slug *D. reticulatum.* | [41] |
| | *Theba Pisana* Müller exposed to the nematodes *Phasmarhabditis californica* n. sp., P. *hermaphrodita* and *Phasmarhabditis papillosa* Schneider. | [42] |
| Philippines | *Euphorbia tirucalli* L. latex extract, to control *Pomacea canaliculata* Lamarck. | [43] |

| Country | Control methods | Authors |
|---|---|---|
| India | Physical method (electrical discharge of cattle urine) with copper and zinc electrode. | [44] |
| | Biogenic Silica and Botanical Pesticides. | [45] |
| | Action of essential oils (terpenes). | [46] |
| | Plants like molluscicides. | [47] |
| | *Solanum surattense* Burm. fil., to control *Lymnaea acuminata* Brongniart. | [48] |
| Ireland | *Tetanocera elata* Fabricius biocontroller of *P. hermaphrodita*. | [49] |
| Italy | Artificial barriers for arionid slugs. | [50] |
| Japan | Predator of L. *maximus*. | [51] |
| Lithuania | Saponins from *Quillaja saponaria* Molina control *Arion vulgaris* Moquin-Tandon - *Arion lusitanicus* Mabille. | [52] |
| Morocco | *Helioscopy euphorbia* L., control of *Theba pisana* Müller and *Arion hortensis* Férussac. | [53] |
| | Plastic mulching film with Cade's oil for slugs. | [54] |
| Nigeria | Ethanolic extracts of papaya leaves *Carica papaya* L., and *Terminalia catappa* L. | [55] |
| | Aqueous and ethanolic extracts of lemongrass *Cymbopogon citratus* (DC.) Stapf., to control the different stages of *Biomphalaria pfeifferi* Krauss. | [56] |
| Panama | Larva *Cratomorphus signativentris* Olivier control of *Veronicella cubensis* Pfeiffer. | [57] |
| Pennsylvania | Management in no-till field crops with emphasis on the mid-Atlantic region. | [58] |
| Portugal | Four essential oils of Apiaceae control from *Radix peregra* Müller. | [59] |
| United Kingdom | *P. hermaphrodita* as a biological molluscicide. | [60] |
| | Conidia and volatile organic compounds (VOCs) of the *Metarhizium brunneum* Petch fungus. | [61] |
| | *P. hermaphrodita* exposed to the slug *Deroceras invadens* Reise, Hutchinson, Schunack and Schlitt. | [62] |
| Czech Republic | *Alloionema appendiculatum* Schneider effect on A. vulgaris. | [63] |
| Thailand | *Camellia oleifera* Abel seed extract and *Garcinia mangostana* L. pericarp, evaluated on *P. canaliculata*. | [64] |
| Venezuela | *Euphorbia laurifolia* Juss extracts to control snail *B. glabrata*. | [65] |
| Colombia | Pinion seeds *J. curcas*, for and leaves of pink guayacán *T. rosea* for the control of *A. fulica*. | [66] |
| | Plant extracts and substances of common access for the control of *A. fulica*. | [67] |
| Pamplona-Colombia | Efficacy of diatomaceous earth against *H. aspersa* under "in vitro" conditions. | [68] |
| | Diatomaceous earth and lime on arionides and agriolimacids. | [69] |
| | Organic alternatives for pests and diseases in strawberry. | [70] |
| | Baits with extracts of eucalyptus *Eucalyptus globulus* Labill and *Eucalyptus camaldulensis* Dehnh. | [71] |

Source: Consulted articles. Own Elaboration.

### A. *Control of mollusk pests*

In Cuba, an agroecological management of mollusks was proposed, with methods such as sanitation, which consists of keeping the orchards, farms, plots, and other agricultural systems in order and care and thus not favoring the development of snails and slugs. It also includes physical methods, where it recommends collecting snails and slugs in the morning, spreading sawdust covers on roads and in nurseries, protecting plants with copper sheets, leaving crushed eggshells around affected plants, in addition to employment of botanical pesticides such as *C. frutescens* chili, *S. globiferu* spiny güirito, *A. indica* neem, *J. curcas* pinion, *Solanum mammosum* L. cow udder, as well as mineral products such as lime, vegetable by-products such as ash and caffeine [21].

Some authors affirm that secondary metabolites such as alkaloids, saponins, cardiac glycosides and essential oils (terpenes), allow the plant to exert a natural control over mollusks [46]. It is proposed that the extracts of the plant *Solanum surattense* Burm. fil., have molluscicidal properties, which can be used to control snail pests [48].

In Brazil, the use of a prototype molluscicide kit is proposed, based on lyophilized *E. milii*. According to the author, MolusSchall is a natural, effective and inexpensive molluscicide with lower environmental toxicity than existing molluscicides for *Biomphalaria* spp. [16]. In Nigeria, the molluscicidal effects of ethanolic extracts from the leaves of two medicinal plants from Nigerian indigenous communities, *Terminalia catappa* almond and *Carica papaya*, were evaluated. The results of the lethal concentration values showed that *T. catappa* seems to be the best plant molluscicide for *Biomphalaria pfeifferi* Krauss and *C. papaya*., For *Bulinus Globosus* Morelet [55]. In that country, the molluscicidal activity of the aqueous and ethanolic extracts of *C. citratus* leaves against adults, youthful and egg masses of *B. pfeifferi* was also investigated. The result obtained shows that *C. citratus* is a promising plant molluscicide candidate since the ethanolic extract of *C. citratus* in its 50% and 90% lethal dose for eggs was 42.85 ppm and 113.20 ppm respectively. The authors mention that it deserves more studies to identify and characterize its molluscicidal components [56].

In the United States it was found that the use of essential oils of cinnamon *Cinnamomum verum* J. Presl, clove bud *Syzygium aromaticum* (L.) Merr. & Perry, Garlic *Allium sativum* L., Limonaria *Cymbopogon citratus*, Peppermint *Mentha piperita* L., Pine *Pinus* sp. and spearmint *Mentha spicata* L., cause 100% mortality of both the eggs and the juveniles of *Cornu aspersum* Müller [38].

From Brazil, the potential use of biomoluscicides of the essential oils of bitter fennel *Foeniculum vulgare* var. vulgare Mill, parsley *Petroselinum crispum* (Mill.) Fuss, cumin *Cuminum cyminum* L., and dill *Anethum graveolens* L., against the freshwater snail *Radix peregra*. The results showed that the essential oils and compounds were variable and visibly dependent on the stage of development of the mollusk, the molluscicidal effectiveness was achieved in at least 16 h of exposure for most of the treatments [59].

Information was collected on plant extracts used in some regions of Colombia with molluscicidal effects, recommending the families Bignonaceae, Euphorbiacea, Apiaceae or Fabaceae, plant families that contain anthraquinones and polyphenols in organs such as leaves, seeds or stem, it also suggests the extract of pink guayacán *T. rosea* as control alternatives [67].

The methomyl and cardenolide extracts of *C. procera* and *A. arabicum* were evaluated to control the land snail *M. cantiana*, resulting in the benzene extract being the most effective material, followed by the *C. procera* extract. The authors conclude that these individual compounds should be tested in other snail species [13].

Other researchers analyzed tobacco extracts and caffeine solution in combination with alcohol for control of the *L. valentiana* slug. Ethyl alcohol at 10% provided a mortality rate of greater than 90%, while at 3-7% it resulted in a mortality rate of less than 30%. Ethyl alcohol (5-7%) mixed with 0.5% caffeine or tobacco extract increased slug mortality from 50% to 80% [19].

Plant extracts rich in saponins such as *C. oleifera*, *Gleditsia amorphoides* (Griseb.) Taub., And *Q. saponaria* for the control of *Deroceras reticulatum* Müller, were evaluated resulting in the experiment of forced oral injections and histological analysis of the digestive system that the three extracts showed anti-feeding activity and toxicity against the pest, in concentrations between 1 and 4% w/w. All three extracts caused damage to the gastric epithelium of slugs, suggesting that these plants possess membranolytic properties in these mollusks [18]. It is found that the essential oils of thyme *Thymus vulgaris*, lethal concentration 50: 0.148%, presented higher toxicity, followed by spearmint oil *M. spicata* lethal concentration 50: 0.153% and pine *Pinus* sp., Lethal concentration 50: 0, 176% are 100% lethal for the control of *D. reticulatum* [12]. On the other hand, the use of the rhabditid nematode *P. hermaphrodita* in the youthful stage is also recommended for the control of slugs [25], while other authors [41]. Show three species of nematodes lethal to *D. reticulatum* (*P. hermaphrodita*, *Phasmarhabditis califórnica* n. sp. and *P. papillosa* Schneider.

The hydroalcoholic extracts of *J. gossypiifolia* were examined, where the leaves presented the greatest variety of secondary metabolites. Catechins, saponins, triterpenoids, alkaloids, tannins, and steroids. Research results showed that hydroalcoholic extracts from *J. gossypiifolia* leaves are lethal for *Biomphalaria glabrata* Say as it promotes 100% mortality even at the lowest concentration tested, 25 ppm [15]. In Venezuela was is verified that *E. laurifolia* extracts have a powerful lethal activity against snails of *B. glabrata*, considering the best ethyl acetate extract, which presented a mean lethal dose of 5.57 ppm [65].

According to a survey carried out in Brazil [14] the most used methods for the extermination of *Achatina fulica* Bowdich in the Cambota neighborhood, municipality of Valencia, Rio de Janeiro, were: table salt, lime, incineration, and burial of mollusks, while in Colombia, it was proposed to implement the use of the extracts of pink guayacán *T. rosea* and pinion *J. curcas*, in the control programs of the African snail *A. fulica*, due to their low cost and the absence of negative environmental effects [66]. On the other hand, in India biogenic silica from rice husk ash and botanical pesticides obtained from neem *Azadirachta indica* Juss, *Pongamia pinnata* L. *Nicotiana tabacum* L., and *C. procera* have been used for the control of *A. fulica*, registering loss of body fluids and mortality from the plague [45].

Also in India they have ventured with the control of slugs and snails by means of electric shock, and experimenting with *L. alte* and *Macrochlamys* sp., Using two metal plates of copper and zinc, in cattle urine, when the mollusk tries to pass over it and touching the two plates completes the circuit, receiving the discharge releasing a mass of slime that improves electrical conduction, finally the mollusk leaves the station [44].

In Thailand, the molluscicidal activity of camellia seed extracts *Camellia oleifera* Abel and mangosteen pericarp *G. mangostana* was evaluated in the snail *Pomacea canaliculata* Lamarck. loss of cilia, degeneration of columnar epithelial cells, increased vacuoles, mucous cells in the digestive tract and gills, while the digestive gland exhibited an increase in the number of dark granules and basophilic cells in addition to dilation of digestive cells. The muscle cells of the foot showed a loss of texture. The authors indicate that both *C. oleifera* and *G. mangostana* have molluscicidal activity for the species studied [64], while in the philippines evaluated the molluscicidal activity of the *E. tirucalli* extract to control the rice mollusk plague *P. canaliculata*, resulting in a lethal effect on the snail at 8.75 ppm [43].

Experiments with plant extracts of *A. americana* var. Marginata., *A. legrelliana* and *F. hexapetala* for the control of *Praticolella griseola* Pfeiffer, showed that all were effective against this snail seven days after application to the minimum dissolution studied (12.5%), depending on the form of obtaining the extract, so they are good candidates for more in-depth studies [23]. Other results indicate the extracts of the maguey *Furcraea hexapétala* Jacobi, the prickly güirito *Solanum globiferum* L., the hot pepper *Capsicum frutescens* L., and the cardon *Euphorbia lactea* Haw, as alternatives for the control of *P. griseola*. The highest percentages of mortality are reached with extracts of *C. frutescens* and *S. globiferum* 72 hours after application [22].

Has been observed the toxicity of the thymol extracted from the thyme Thymus vulgaris L., in the epidermis and the digestive gland of the slugs L. maximus, and Lehmannia marginata Müller where the species treated with lethal concentration 90, showed in the mucous membrane erosion of the epithelial cells, hypoplasia of connective tissues with increased mucus secretion from both slugs [28]. Continuing with this study on the toxicity of thymol in the epidermis and digestive gland of L. maximus, this time at a lethal concentration of 50 thymol, it showed certain histological changes in the salivary gland, they appeared with vacuolated cytoplasm and severely affected nuclei including pyknosis. and karyorexis. The lamina that encapsulates the salivary acini appeared with rupture in some regions, observed vacuolated cytoplasm and deformed nuclei in the different types of cells. Slugs after exposure to a lethal 90 concentration of thymol, secretory cells were seen widely separated from each other, highly vacuolated cytoplasm and severely affected nuclei, including pyknosis and karyorexis [29].

Essential oils from *C. aurantifolia*, *C. limon*, *C. paradisi* and *C. sinensis* have been shown to have strong toxicity against adult snail *Theba pisana* Müller [26]. Other researchers evaluated food granules containing roots, stems, leaves and flowers of *Euphorbia helioscopia* against *T. pisana* and *Arion hortensis* Férussac. For both species of mollusks, the activity of the molluscicides resulted in a rupture of their cell membrane and a change in their permeability, concluding that they can be used in the protection of plants against slugs and phytophagous snails [53]. There are publications with other evidence that the essential oil thymol (terpenoids) has molluscicidal activity for snails *Biophalaria alexandrina* Ehrenberg, to control *T. pisana*, thymol is a very effective compound, followed by eugenol and pulegone [15].

The lethality of saponins was evaluated, concluding that these can be a successful tool for slug control, but their concentration should be selected according to the age group of *A. vulgaris*; since this measure is more toxic than expected for white worms, which limits its use [52]. The performance of water glass (sodium silicate) and copper foil as barriers of *A. vulgaris* was also determined, where the water glass barriers applied to the pots reduced the damage events by slugs by 50% [50].

The level of control of Arionidae slugs was determined with plant extracts of *F. japonica*, *F. bohemica*, *S. canadensis*, *S. gigantea*, *R. typhina*, *A. altissima*. The experiments resulted in the plant material of *R. typhina*, *S. gigantea* and *F. japonica* exhibiting stronger anti-feeding and barrier effects against slugs. In the semi-field trial, only 7% of the crop plants treated with *S. gigantea* plant material were attacked by slugs [36].

The molluscicidal activity of the active compounds cerberine and neriifolin from the stems of the desert rose *Adenium obesum* is reported for *Monacha obstructa* Pfeiffer snails, where the mean lethal dose evidenced was 5.39 µg g–1 and 4.3 µg g–1 of body weight [32]. On the other hand, the aqueous extract of stinky sweet potato *A. clematidea* according to the researchers shows repellent and molluscicidal action at concentrations of 50%, 75% and 100% for the snail *S. octona* [24].

In relation to the biological fight in Portugal, information was collected on the nematodes that are associated with terrestrial mollusks as definitive hosts. Resulting in the following Rhabditida families: Agfidae, Panagrolaimorpha: Alaninematidae, Rhabditida: Alloionematidae, Rhabditida: Angiostomatidae, Ascaridida: Cosmocercidae, Diplogastrida: Diplogastridae, Mermithida: Mermithidae, Rhabditida: Rhabditrod], in addition to *P. herbditidae* [60].

The bionomics of the parasitic nematode of the slugs *A. appendiculatum* and its effect on the invasive pest slug *A. vulgaris* were studied, giving as results information on the saproobic life cycle and the natural prevalence of the species, but also showing that, under conditions standard, *A. appendiculatum* has a weak influence on mortality and feeding activity of *A. vulgaris* [63].

In the United Kingdom it was investigated the response of representative mollusks to conidia and volatile organic compounds of the insect pathogenic fungus M. brunneum. As a result, the sensitivity of terrestrial mollusks to 3-octanone and 1-octen-3-ol and the ephemeral nature of these compounds makes them excellent candidates for development as repellants for molluscs or molluscicides [61].

The entomopathogenic fungus *Beauveria basssiana* is considered promising for the control of mollusks. For this reason, trials were carried out to evaluate the effectiveness of other biological insecticides; Biozed (*Trichoderma album*) and Biogard (*Bacillus thuringiensis*), using the toxic bait technique. The toxicity index, lethal concentration 50 and the relative potency values reveal the potential activity of Biozed (fungi) than Biogard (bacterial) against *M. cartusiana* snails, Biogard did not cause any mortality among the treated snails at all on the first day of exposition. The mortality percentages appeared after one week and gradually increased with increasing concentrations and the time of the treatments. The highest concentrations of Biozed (0.75%) and Biogard (3.9%) caused 66.6% and 40% mortality, respectively, after 28 days of exposure. Histopathological investigations on the digestive and hermaphroditic glands revealed that the sublethal concentration of Biozed produced tubular changes, vacuolation and excessive luminal secretions in the tissues of the digestive glands. Malformed sperm and oocytes were detected in Biozed-treated ovotestis acini. Biogard, which caused extensive luminal secretions, hemocyte infiltration, and lysis of peripheral cells of the digestive tubules, while hermaphroditic acini showed altered sperm and oocytes vacuolation and excessive luminal secretions in the tissues of the digestive glands. Malformed sperm and oocytes were detected in Biozed-treated ovotestis acini. Biogard, which caused extensive luminal secretions, hemocyte infiltration, and lysis of peripheral cells of the digestive tubules, while hermaphroditic acini showed altered sperm and oocytes vacuolation and excessive luminal secretions in the tissues of the digestive glands. Malformed sperm and oocytes were detected in Biozed-treated ovotestis acini. Biogard, which caused extensive luminal secretions, hemocyte infiltration, and lysis of peripheral cells of the digestive tubules, while hermaphroditic acini showed altered sperm and oocytes [31].

In Japan predation was reported of *Limax maximus* L., by a terrestrial macrophage leech *Orobdella kawakatsuorum* Richardson, which is part of the soil microfauna [51]. In Egypt they analyzed the effects of other members of the microfauna, some rotifers affect the eggs and the adult stage of snails and land slugs. The eggs showed different responses, the stages from a cell to the gastrula appeared opaque and died rapidly during the first days, a mortality rate of 92% was recorded. The reported mortality rates were 90%, 94%, and 94% for the early trocophore, late trocophore, and late trocophore stages, respectively. The mortality rate registered 88%, 82%, 72% and 62% for early veliger, veliger, late veliger and pre-hatch, respectively. In the adult stage, the symptoms were slow, abrasion of the mantle of the slugs and scratches or cracks in the shell of the snails, finally they died due to secondary infection [27].

It is reported in Canada that both female and male of a carabid insect *Carabus nemoralis* Müller prey on *Arion distincus*, the adults could be introduced into greenhouses followed by conservation efforts that allow the larvae to successfully develop to consume young slugs before the slugs larger ones become a major economic damage [17]. On the other hand, it reports the predation of the *Veronicella cubensis* Pfeiffer slug by the larvae of the beetle *Cratomorphus signativentris* in Panama [57]. From Egypt it is reported that the dipteran *M. scalaris* controls the snail *Eobania vermiculata* Müller with better action in the juvenile stage of the snail [34]. Other researchers in Ireland studied the biological control of slugs with the dipteran *Tetanocera elata* Fabricius, exposing them to *P. hermaphrodita*. The authors conclude that there is a potential use of *T. elata* as a biological control agent for pest slugs [49], These being some of the examples of insects as bioregulators of mollusks pests.

Also in Egypt, it is recorded a nematode, *Phasmarhabditis* sp., in *E. vermiculata* eggs, and it is concluded that the parasitic nematode may play a role in the control of different stages of gastropods, including eggs. This makes control more effective in protecting host plants before the pest causes damage. The nematode was more effective against local pest species than non-local ones. Furthermore, the size of the parasite was proportional to the size of the host pest [33].

The nematode *P. hermaphrodita* is reported as a parasite of many slugs and snails and it is suggested that it provides effective control of *Arion lusitanicus* Mabille [20]. The presence of *P. hermaphrodita* is reported for the first time in North America from the corpses of the invasive slugs D. reticulatum, D. laeve and L. valentiana and it is proposed to use it as a biological control in these species [37]. Other authors in the US also refer to the nematode *P. hermaphrodita* predating gastropods [40].

I know exposed the pestiferous slugs *Deroceras invadens* Reise, Hutchinson, Schunack and Schlitt to nine wild strains of *P. hermaphrodita* (DMG0002, DMG0003, DMG0005, DMG0006, DMG0007, DMG0008, DMG0009, DMG0010 and DMG0011 at three doses) and the commercial strain DMG0001 (three doses) (0, 500 nematodes/mL and 1 000 nematodes/mL). All wild strains of *P. hermaphrodita* (other than DMG0010) and *P. hermaphrodita* (DMG0001), applied to 500 nematodes/mL, caused significant mortality of *D. invadens*. Similarly, all *P. hermaphrodita* strains applied to 1000 nematodes/mL caused significant mortality of *D. invadens* [62].

In the United States it has been shown in laboratory tests that when exposing *T. pisana* to the nematodes *P. hermaphrodita*, *P. californica* sp., and *P. papillosa*, at a lethal dose of 50/cm$^2$ cause significant mortality in these gastropods [42].

In 1999, a molecular identification of some mollusk parasitic nematodes was carried out, obtaining as a result that the *Rhabditella axei* Cobbold nematode can live a dual life (free life and parasitic life) that is, it could be pathogenic only of small adult species of gastropods. like the *Monacha cartusiana* Müller snail (life parasite) and can live on the carcass of large terrestrial gastropods. Finally, it is concluded that the nematode *R. axei* can be used in integrated pest management as a biological control agent for *M. cartusiana* [30].

In Colombia, it was reported that the effect of diatomaceous earth both by contact and by ingestion in spraying and dusting applications against the *Helix aspersa* Müller mollusk is low at doses between 1 kg/ha and 4 kg/ha under «in vitro» conditions [68]. Subsequently, it was reported that the slugs were controlled with diatomaceous earth, thus allowing the incorporation of new alternatives to be validated in the cleaner production of the *F.* × *ananassa* strawberry crop in the conditions of Pamplona, North Santander [69], [70].

Other alternatives evaluated were the extrusion of plastic mulching film with Cade's oil, a plastic mulch film made of 0.1% cade oil, which demonstrated a repellent effect for *H. aspersa* [54].

In Slovenia carried out laboratory studies on the contact and barrier efficacy of different natural substances (wood ash, sawdust, hydrated lime and diatomaceous earth) against slugs of the genus Arion. The results of the study showed that hydrated lime had the best contact efficiency with slugs (100%), both individually and in combination with other substances. Hydrated lime treatments also proved to be the most effective barrier to prevent slugs from feeding on *L. sativa* lettuce. Hydrated lime shows great potential for the control of *Arion* sp. Slugs. [35]. Also in the United States, barriers of lime, sulfur, wood ash sprayed on the foliage, fumed silica have been used to control the snail *Leidyula floridana* Leidy and Binney [39].

In Pamplona North Santander (Colombia), slugs are a big problem and several publications were found, which motivated the study of slug control by means of diatomaceous earth, determining the in vitro effect on the mobility and mortality of *A. distinctus*, observing that the contact effect was higher than that of ingestion, only achieving 100% mortality with dusting treatments at a dose of 4 kg/ha. Efficacy in the field for the control of slugs in strawberry *F.* × *ananassa* crops was achieved with two foliar sprays at a dose of 8 kg/ha and the addition of PEGAL CS pH 18.767 g/L as adherent [69]. In addition, it is reported on the control of slugs through the use of baits with extracts of the leaves of eucalyptus *Eucalyptus globulus* Labill and *Eucalyptus camaldulensis* Dehnh, which are considered potential alternatives for the management of slugs in the conditions of Pamplona (Colombia) [71].

As it has been shown the publications on the alternative management of mollusk pests is very limited in the last decade in Colombia compared to the rest of the world, with many aspects of alternative control that have not been addressed in the country, or at least the results have not been published. It is worth reflecting on this, and reviewing whether or not it is necessary to open lines of research on biological control and the use of plant extracts from mollusck pests, more in tune with the dynamics in the rest of the countries.

## IV. Conclusions

Articles from the last decade on alternatives for the control of mollusk pests were obtained on all continents. From Colombia only 7 articles, of which 3 correspond to the use of diatomaceous earth, 3 to vegetable extracts and 1 to agroecological management, while, at the international level of the 53 articles located, 21 related on vegetable extracts, 17 on biological control, 5 on essential oils, 5 on barriers, 3 on agroecological management and 2 on biopesticides.

Alternatives with the use of plant extracts predominated, followed by biological means such as insects, nematodes, microorganisms and other natural products such as lime and diatomaceous earth, as well as different materials such as repellants or barriers. The recommended alternative type depended to a great extent on the mollusk species and its size, on the phytogenetic resources present and the reported bioregulators. It was verified that in many countries' sources of saponins and essential oils from plants can be found, which could lead in the future to the development of efficient alternatives that are much less aggressive to the environment.

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**Cristian David Quintero Santos.** Universidad de Pamplona. Pamplona (Colombia). https://orcid.org/0000-0002-5071-5755

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

**Wlda Margarita Becerra-Rozo.** Universidad de Pamplona. Pamplona (Colombia)