Slugs control methods (*Deroceras* sp. Müller) in lettuce and broccoli crops

Métodos de control de babosas (*Deroceras* sp. Müller) en cultivos de lechuga y brócoli

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ABSTRACT

At the Botana experimental farm of Universidad de Nariño, the effect of different management practices of slugs was evaluated, using a randomized block design with five treatments (beer traps, milk traps, sisal bags, metaldehyde, and a control) and six repetitions. The evaluated variables were: captured individuals, affected plants and damage index that were estimated by analysis of variance and Tukey comparison tests. The results show highly significant differences between treatments in different phenological crops stages, the most effective were the metaldehyde and the beer trap with a caught individual number of 89 for lettuce and 126 for broccoli, being the treatments with lower percentages of affected plants. The damage index was evaluated based on percentages and proposed scales to observed crops damage, considering that the treatments described above stood out with mild damage index. This allows involved the beer treatment in an integrated management program for slugs as an alternative for reducing the pest population.

Key words: *Deroceras* sp., gastropod, attracting substances, milk traps, beer traps, metaldehyde.

RESUMEN

En la granja experimental Botana de la Universidad de Nariño, se evaluó el efecto de diferentes prácticas de manejo de babosas. Se estableció un diseño de bloques al azar con cinco tratamientos (trampas con cerveza, trampas con leche, costales de fique, metaldehído y un testigo) y seis repeticiones. Las variables evaluadas fueron individuos capturados, plantas afectadas e índice de daño estimado mediante un análisis de varianza y pruebas de comparación de Tukey. Los resultados señalan diferencias altamente significativas entre tratamientos, en las tres evaluaciones, fueron los más efectivos el metaldehído y la trampa con cerveza con un número de individuos capturados de 89 para lechuga y 126 para brócoli estos obtienen los menores porcentajes de plantas afectadas. El índice de daño fue evaluado con base en porcentajes y escalas propuestas al daño observado estimando que los tratamientos anteriormente descritos sobresalieron con índice de daño leve. Lo que permite involucrar el tratamiento de cerveza dentro de un programa de manejo integrado para las babosas como alternativa para la reducción de la población de esta plaga.

Palabras clave: *Deroceras* sp., gasterópodos, sustancias atrayentes, trampas de leche, trampas de cerveza, metaldehído.

Introduction

In Nariño (Colombia), around 512 ha of vegetable are planted, belonging to cabbage crops (*Brassica oleracea* L. var. *capitata* L), broccoli (*Brassica oleracea* L. var. *Italica* Plenck), lettuce (*Lactuca sativa* L.) and cauliflower (*Brassica oleracea* L. var. *Botrytis* L.), being one of the most important production systems because of its growing contribution to develop agricultural gross domestic product. These areas reported severe damage by slugs, which eat the foliage, reducing yields by holes and secretions left in final product and secondary damage such as rot to the consuming roots; argues that slugs are herbivores of worldwide distribution that acquire economic importance when attacking crops such as: potato (*Solanum tuberosum*), bean (*Phaseolus vulgaris*), corn (*Zea mayz*), soy (*Glycine max*), strawberry (*Fragaria vesca*), pastures, onions (*Allium fistulosum*), cabbage, cauliflower, lettuce among others, being known as garden pests, ornamental plants and vegetables.

In southern Nariño, the most abundant slug species is *Deroceras* sp. Aragón (2003), indicated that this species is native of Europe, is herbivorous, polyphagous, hermaphrodite and nocturnal with few natural enemies allowing it increase its population density during the first months of rainy season, even in absence of their preferred hosts. According to Montero (2001), this mollusk causes economic losses up to 100% to the producers as in case of lettuce, because the yield and planted area are severely affected by their voracious eating habits.

According to Andrews (1987), the control of slugs cost can be a very high factor of particular importance to poor farmers, who are usually facing the highest population densities

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of slugs. The lack of scientific information that allows to incorporate an effective management to the control forced the farmers to use control measures ineffective.

Chemical control, globally and locally, is the most used technology (Bailey, 2002; Hommay, 2002; Mastronardi, 2006; Salvio *et al.,* 2008). This is based on the use of granulated toxic bait formulated with a food attractant and an active ingredient (a.i.) metaldehyde as a molluscicide for example, or carbaryl. Aragón (2004) explains that in some cases these applications cause ecological imbalances by the pesticides accumulation in soil and water sources contamination. Other studied method is the use of beer as an attractant; this liquid is used in pitfall traps allowing capturing large numbers of individuals in strawberries and vegetables crops (Torres and Yánez, 1998). It's also important to mention the use of non-chemical procedures based on manual destruction during the day and the use of shelters as traps to become in economic practices and higher in yields compared to other evaluated.

Due to lack of information, the damage caused, the high control cost, among others, this research was raised in order to evaluate four slugs management practices *Deroceras* sp. on lettuce and broccoli in Nariño department.

Methodology

Location: This study was carried out in Botana experimental farm at Universidad de Nariño, at an altitude of 2,800 meters, with an annual average temperature of 12°C, rainfall of 850 mm and a relative humidity of 73% (IDEAM, 2007).

Experimental design: A randomized block design was used with five treatments and six replications for each crop, with a total of 60 experimental units.

Experimental unit: Corresponded to 4 m^2 plots planted with: lettuce (*Lactuca sativa* L.) CoolGuard Variety and broccoli (*Brassica oleracea* L. var. *italica* Plenck), with Legacy hybrid, a distance of 0,4 x 0,4 m between plants, with a total of 25 plants per plot.

Experimental Area: The total planted area was 630 m^2 distributed in two blocks for each vegetable species. The block comprised 30 experimental units. The streets between treatments estimated an area corresponding to 1,5 m and 1 m between repeats.

The treatments were beer pitfall traps as an attractant, which consisted in 2 thermocol cups of 10 ounces with 20 cm^3 of liquid that were previously sealed and provided with four holes of 1 cm diameter where the pest came in and a lid to prevent mixing with irrigation water or rain, or substantial loss by evaporation. Milk pitfall traps, sisal bags were set in two pieces of 25 x 30 cm, were folded, moistened and placed as traps. Poisoned bait traps, commercial metaldehyde pellets were used and located in two random sites inside the experimental unit in doses of 5 g/site and a plot without observation, which corresponded to the control.

In order to determine the presence and maintain in each plot a pest uniform population, two infestations of slugs were carried with a previous installation of treatments in each block. A sampling was carried out in each plot, was done with help of a quadrant of 1 x 1 m, placed randomly in each experimental unit. This area soil was removed to a depth of 10 cm, carefully examined and the number of individuals found in each quadrant was counted. This process allowed establishing the approximate number of slugs present in each experimental unit. In the same population found in this procedure a sample was taken to identify the gender of the slugs in the investigation. This was carried out in the Entomology Laboratory at the Universidad de Nariño, with a stereoscope helps.

Monitoring and evaluation. The treatments were evaluated during the entire crop growth cycle; three phases of evaluation were stood out:

First evaluation: Period from 1 to 20 d after vegetable transplanting that included a vegetative state more susceptible to pest attack; evaluations and monitoring were carried every 24 h in the morning. The baits change of different treatments was carried once the data was collected for the variables evaluated.

Second evaluation: Period from 21 to 80 days after transplantation (dat), physiologically comprises the broccoli flowering phase formation and head lettuce formation, monitoring and evaluations are carried twice a week and in the same proportion treatments baits were changed once data was collected from evaluations.

Third evaluation: Was carried during the period of 81 to 90 dat that comprised the harvest stage, observing pest traces in the broccoli inflorescence and consumption of the lettuce leaf area.

Captured individuals number per experimental unit: captured individuals living and dead were counted and after each count were "eliminated".

Percentage of plants affected by pest: In the three evaluation phases counts of plants damaged by slugs was carried during the entire crop vegetative state.

Damage index: Was defined quantitatively and qualitatively, for which we rely on crop phenology, where data of 10 plants randomly marked were registered inside the experimental unit. The first evaluation phase includes the damage degree, considering the foliar sprout of the 6th, 8th and 10th leaf, for the two crops each leaf was assigned with a percentage to facilitate the data register. The visual damage estimated of the leaf tissue was measured using the missing area percentage of the foliar limb consumed by pest.

According to the above ratings, scales of qualitative damage description were estimated and proposed for broccoli (Tab.1) and lettuce (Tab. 2).

TABLE 1. Damage degree caused by *Deroceras* sp. in broccoli.

Degree	Damage degree	
	Damage (%)	Description
1	0-10	Mild
2	11-15	Moderate
3	16-20	Severe
4	>20	Very severe

TABLE 2. Damage degree caused by *Deroceras* sp. in lettuce.

Degree	Damage degree	
	Damage (%)	Description
1	0-10	Mild
2	11-25	Moderate
3	26-49	Severe
4	>50	Very severe

It's worth mentioning that cut plants in first evaluation were classified with a 100% damage index.

Statistical analysis: Results were analyzed using statistical software SAS V6 through an analysis of variance; treatments that showed significant differences were processed with the Tukey comparison test.

Results and discussion

According to gender identification, was classified as *Deroceras* sp. Vera and Linares (2003) small slugs of 20 to 50 mm long were found, its mantle near the head (Strange *et al.*, 1999) and on its surface, a pattern protrusions as a concentric wrinkles that are originated from the right side near the pneumostome, respiratory pore located on the right rear of the mantle (Crowell, 1977), laterally compressed tail (keeled), its body color is cream with gray marks, the foot is divided in three layers (tripartite foot) with a whitish sole and its mouth is protruding.

According to the analysis of variance, the initial pest population, before the treatments application showed no significant differences ($P \leq 0.05$), which indicates uniformity across the entire experimental area.

Number of captured individuals per experimental unit: The analysis of variance for the captured individual variable, revealed highly significant differences at level $P \leq 0.05$, during the three evaluation stages in two cultures. In broccoli, the total of caught individuals was 126, 95, 83, 68 and 0 for the beer trap, metaldehyde trap, sisal bags, milk trap and the plot without management method, respectively (Tab. 3).

The total of captured individuals during the evaluation period in lettuce was 89, 71, 62, 51 and 0 for the beer trap, metaldehyde trap, sisal bags, milk trap and the plot without management method, respectively (Tab. 4). It was observed that the greatest number of caught individuals for the two crops corresponds to the beer treatment.

According to Tab. 4 for the first and second evaluation stage of lettuce, treatments showed statistical differences

TABLE 3. Average number of captured slugs by different management practices in three evaluation stages in broccoli crop.

Treatment	Evaluation		
	0-20 d	21-80 d	81-90 d
Metaldehyde	13.50 a	4.16 a	3.00 a
Beer	11.30 ab	5.33 a	3.33 a
Sisal bags	8.16 b	4.00 a	3.00 a
Milk	7 b	3.33 a	1.83ab
Control	0 c	0 b	0 b
CM Tx.	159.58**	24.36**	11.30**
CV	37.08%	42.90%	48.22%

Means with different letters indicate significant differences according to the Tukey test ($P \leq 0.05$).
** represent significant differences ($P \leq 0.001$).

TABLE 4. Average number of captured slugs by different management practices in three evaluation stages in lettuce crop.

Treatment	Evaluation		
	0-20 d	21-80 d	81-90 d
Metaldehyde	9.00 a	3.83 a	2.66 a
Beer	8.00 a	3.66 a	1.66 ab
Sisal bags	8.50 a	2.50 a	1.50 b
Milk	5.50 a	2.16 a	1.33 b
Control	0 b	0 b	0 c
MS Tx.	82.95**	14.21**	5.46**
CV	38.67%	49.25%	42.24%

Means with different letters indicate significant differences according to the Tukey test ($P \leq 0.05$).
** represent significant differences ($P \leq 0.001$).

compared to control treatment, in the third evaluation with metaldehyde, sisal bags and milk treatments not differ statistically between them for this stage.

The beer pitfall trap, acted as a real attractive due the high number of captures, contrary to the statement of Van Balen *et al.* (1983); who not attribute to this substance any attractant effect. Besides, for some mechanism, beer doesn't allow to escape to the slugs once they fall into the liquid, in contrast to milk that allows to the slugs to escape out of the pitfall trap. Studies carried out by Angel *et al.* (2004), recommend beer as an effective treatment in slugs capture, because, as well as snails they are attracted to this chemical, result of the fermentation process and high content of yeast, reason why it's one of the most popular baits (Andrews and Sobrado, 1984).

Beer trap has the advantage of capture and eliminate slugs by drowning, as corroborated by Torres and Yánez (1998), who also affirms that beer can still capturing slugs for a month without a constant vigilance from the farmer for its elimination, but it's a more expensive treatment, while sisal bags eases the collecting work of slugs and has the additional advantage that can be reused.

Metaldehyde treatment proved to be very effective in broccoli and lettuce first evaluation. The high mortality rate is explained by Lange and Sciarone (1952), who affirms that *Deroceras reticulatum* is more susceptible to be attracted to this substance compared to other species (*Milax gagante* and *Limax* sp.). Ester and Geelen (1996) concluded that these toxic baits are characterized to be fast and effective controlling this pest by destroying the mucus-secreting cells, dehydrating the slugs in an irreversible way. However the capture number decreased in the following evaluation stages, the chemical efficiency wasn't the expected possibly due to adverse weather conditions that affected the concentration of the active ingredient of the bait when enter in contact with rainwater.

Respect to treatment with sisal bags, possibly occurred that slugs used it as a refuge during the day and at night went out to eat, since the number of live slugs observed under this type of refuge was high. Therefore there's no statistical difference in relation to other treatments in the second and third evaluation in the two crops tested, is considered as an advantage because it gets as a resource in the farm and it can be used with no cost, however requires more labor force to remove live slugs that take refuge under the trap.

Percentage of plants affected by pest: Results showed differences highly significant between treatments ($P \leq 0.05$) in the three evaluations of both crops.

In the third evaluation stage, sisal bags provided the largest number of affected plants, probably due to prolonged monitoring frequency in the last evaluations, that's the reason why we agree with Andrews (1983) who affirms that slugs find moisture in sisal bags and seek shelter on it, that'll guarantee its permanence and to cause further damage day after day. Using this method as an option to reduce slug's population is unpredictable because they need to be revised periodically and in early hours of the morning, to avoid that these mollusks take refuge and cause further damage.

The general pattern of average affected plants by *Deroceras* sp., was sigmoid type. Apparently the slug's feeding activity is related with environmental conditions such as precipitation, moisture and soil temperature, since in the evaluation period there was constant rain, a favorable condition to the slug growth. The affected plant total percentage was found during the evaluation period in lettuce crop was 87.00 and 81.92% in broccoli, when plants presents any type of control practice (control). Results obtained by Andrews and Mira (1983), affirms that for each active slug/m^2 per night there's a 20% decrease in plants number.

Damage index: Analyses of variance for damage degree, revealed highly significant differences ($P \leq 0.05$) in the three stages of the two crops tested. For the first evaluation stage of broccoli and lettuce treatments with metaldehyde and beer behaved statistically different from other treatments, in the sixth leaf sprout with mild damage in lettuce that then became in a moderate damage during the eighth leaf sprout. Sisal bags and milk treatments are statistically equal, with a moderate damage description, as well in the control, however in the eighth leaf sprout the damage is assumed as serious for both crops. In the tenth leaf sprout, treatments show statistical differences with description ranges of damage to those presented in the eighth leaf, according to Barrat *et al*. (1989), the strong attacks of slugs in crops early stages caused damage that limit their growth because sometimes cause defoliation in young plants resulting in growth deficiencies or death. In this sense, Allard *et al.* (2004) affirms that some researchers estimate the damage caused by these foliage consuming pests could result in 60 to 90% losses which, according to Clement (2006), for the particular case of *Deroceras* sp., can affect from 10 to 80% general production.

In the first evaluation stage of lettuce (control) 29,8% of the foliar limb was affected described as a severe damage index. In beer traps and metaldehyde treatment, a damage reduction was noticed, without significant differences ($P \leq 0.05$), with moderate damage index. Montero *et al.* (1999), evaluated different treatments of impregnated baits with chemicals and beer, saying that yields were three of four times higher than control without any application thus preserving more healthy plants at harvest time with an increase 23,3% compared to the control which only had 6,8% of healthy plants with respect to the entire plants planted. Sisal bags treatment in lettuce was statistically similar to milk tramps treatment, but these percentages are very close to percentages of index damage classified as severe.

Respect to the area consumed by slugs, during the eighth and tenth leaf sprout, in these stages of lettuce growth, statistical differences ($P \leq 0.05$) between treatments were showed. The control lost the highest percentage of leaf area for the sprout evaluation of the 8th and 10th leaf. For this evaluation, beer and metaldehyde treatments achieved a greater crop protection, obtaining a smaller consumed area, for valuation with 6 leaves and 8 leaves, while in sisal bags and milk treatments are statistically equal in the valuation of the eighth leaf and the sprout of the tenth leaf, are statistically different (Tab. 5).

These values corroborate the results of Montero *et al*. (2000); who carried out observations in which was determined that slugs consumed more foliar limb, 15 d after sowing. In the same way, Raut and Punigrahi (1980) quoted by Fernandez (1982), selected eight vegetable species to determine the food preference of slugs *Laevicauli alte*. Results showed that lettuce was the most accepted vegetable while spinach had lower consumption and food preference. In the second evaluation stage, the damage in the broccoli inflorescence and the head compaction was evaluated, obtaining significant differences between treatments. In broccoli inflorescence, was observed that there was no serious damage however the damage percentage was decreasing because of the individual reduction in field by action of different attractants tested.

For the second evaluation stage, corresponding to the compaction phase of lettuce head, the damage percentage on the head surface with beer treatment reported the lowest percentage, while statistically metaldehyde treatments and sisal bags are the same respect to the affected area by slugs with mild damage. It's worth mentioning that control is not different from the milk trap treatment, being the highest index values at head damage level.

In the third evaluation stage, which includes broccoli harvest stage; the damage index was conserved in relation to the evaluation above described, was observed a light increase in damage percentage of milk traps and the unaffected control, finally a description based on the damage percentage per evaluated treatment. The damage index percentage for beer and metaldehyde treatment was kept. In case of broccoli the mild qualification seriously affects

TABLE 5. Damage degree in the second evaluation stage; Broccoli flowering stage and compaction phase of lettuce head, estimating the damage by *Deroceras* sp.

Treatment	Broccoli flowering stage		Compaction phase of lettuce head	
	Damage (%)	Description	Damage (%)	Description
Control	3.46 a	Mild	19.70 a	Moderate
Milk	2.67 b	Mild	16.50 a	Moderate
Sisal bags	2.37 bc	Mild	8.30 b	Mild
Metaldehyde	1.88 cd	Mild	6.00 bc	Mild
Beer	1.66 d	Mild	3.20 c	Mild
MS treatment	3.07**		298.55**	
CV	24.91%		34.10%	

the final product quality and since this damage despite of being the lower is evident in the vegetable inflorescence affecting its appearance and the consumer purchase final decision. This is evidenced by Montero *et al*. (2000) who indicate that this pest can affect vegetables like broccoli and cauliflower in the inflorescence formation; damage evidenced by a blight presence because the slug transfer on the surface that initially is not observed, but over time is recognized by its brown color (rare), finally affecting quality and price of the product.

In lettuce, control showed a continuous damage and the highest foliar area consumption. Beer and metaldehyde treatments showed a mild increase in damage index percentage, but its description match with the previous evaluation, milk and sisal bags are statistically the same. The decrease of foliar area consumption is attributed to slugs didn't keep a regularity in the amount of daily food consumption, being noted that they can increase the consumption in one period but can decrease it in other, since they can keep their workload to minimum in search of food, thus reducing their energy consumption and staying up to 6 d without eating. This irregular behavior in food consumption was confirmed by Andrews (1987), Andrews and Sobrado (1984), with similar results. Otherwise, Fernández (1982) affirms that slugs also feed on adjacent weed to crops, where they hide and reproduce, which would also explain the reduction of foliar area consumption.

Conclusion

Beer pitfall traps and metaldehyde treatments are consolidate as a good choice for integrated management of slugs, since they were the best treatments to capture slugs and reduce affected plants, especially in early phenological stages of crop because it's considered the most critical attack of this pest to present mild damage index in harvested product.

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