Parasitoids of Quinoa Moth: *Eurysacca Melanocampta* Meyrick (Lepidoptera: Gelechiidae) in Eight Locations of Cusco, Peru

Erick Yábar-Landa and Juan F. Costa

Abstract — The presence of six genera of parasitoid insects of quinoa moth larvae: *Eurysacca melanocampta* Meyrick (Lepidoptera: Gelechiidae) in eight locations of Cusco is reported. The genera recovered are: *Apanteles*, *Bassus*, *Bracon* and *Macrocentrus* (Hymenoptera: Braconidae), *Diadegma* (Hymenoptera: Ichneumonidae) and *Phytomyptera* (Diptera: Tachinidae). The species *Apanteles* sp. and *Phytomyptera* sp. were found in all the visited location. The greatest diversity (Simpson 1-D) was observed in Izcuchaca (Anta province) followed by Quiquijana and Marangani (Canchis province). The structure of the parasitoid communities is different for each evaluated location.

Index Terms — Quinoa, biological control, ecology, community of parasitoids.

I. INTRODUCTION

Quinoa is a food crop by excellence; the plant is fully used and has a wide adaptation to various agroecological conditions. It is considered the most complete food for human nutrition [1]. One of the most important pests in the cultivation of quinoa is the "quinoa moth": *Eurysacca melanocampta* Meyrick (Lepidoptera: Gelechiidae). Two species of the genus *Eurysacca* are known for attacking the quinoa crop in Peru and Bolivia: *E. melanocampata* and *E. quinoae* Povolny (Lepidoptera: Gelechiidae), which cause considerable economic losses [2].

Several studies were conducted on pests and their natural enemies in different countries. In Cusco (Peru), *Phytomyptera* sp. (Diptera: Tachinidae) was reported as one of its most important parasitoids, together with *Apanteles* sp. and *Earinus* sp. (Hymenoptera: Braconidae), *Diadegma* sp. (Hymenoptera: Ichneumonidae) and an undetermined Chalcididae, in addition, differences in the percentage of parasitoidism were found in two locations: Quiquijana (Canchis province) and Izcuchaca (Anta province) [3]. Additionally, for the center of Peru, both species of *Eurysacca* were reported as main pest of quinoa crop, and an undescribed species of *Phytomyptera* were reported as its most important parasitoid. Significant differences were found in the levels of parasitoidism between Puno (southern Peru) and Huancaayo (central Peru) [4]. In a study carried out at several locations in Bolivia, several species were reported

as natural enemies of quinoa moth, including *Phytomyptera* sp. (Tachinidae: Diptera), a robber fly (Asilidae: Diptera), two species from Carabidae (Coleoptera), parasitoid wasps from Encyrtidae, Ichneumonidae and Braconidae (Hymenoptera) by [5]. Several parasitoid species on *E. quinoae* larvae are also mentioned: *Copidosoma* sp., *Deleboea* sp. and *Diadegma* sp., *Phytomyptera* sp., *Meteorus* sp., and *Apanteles* sp. in all regions where quinoa is grown, with different levels of parasitoidism [6]. The natural enemies associated with the quinoa crop, in Tucumán (Argentina), were reported, for example: *Chrysoperla externa* and *C. argentina* (Neuroptera: Chrysopidae), *Eriopsis connexa*, *Eriopsis* sp., *Hippodamia convergens* (Coleoptera: Coccinellidae), and parasitoids such as *Copidosoma* sp. (Hymenoptera: Encyrtidae), and one of both undertermined Ichneumonidae and Tachinidae. The species studied are distributed differentially throughout the crop cycle [7].

In Cusco, it has been found that two varieties of quinoa show marked interactions with different species of pests and natural enemies, possibly due to the content of saponins; the species *Aphidius* sp. and *Lysiphlebus* sp. (Hymenoptera: Braconidae), *H. convergens* and *E. connexa*, Araneae and an undetermined Syrphidae, showed fluctuations during the growing season [8].

From the consulted literature, some fundamental aspects are evident: i) more or less dispersed information about the parasitoid species that attack the quinoa moth larvae (regardless of their taxonomic position), ii) marked differences between the composition of beneficial insects between different locations and varieties, iii) marked differences between the levels of parasitoidism between locations. The objectives of the present study were: a) to update the information on parasitoids of the quinoa moth, and b) to assess the differences between parasitoid communities of the quinoa moth in eight locations of Cusco.

II. MATERIALS AND METHODS

A. Locations

Eight locations were selected, corresponding to five provinces located between 3096 and 3975 meters above sea level (Table I).

B. Sampling

Each location was visited once during the crop development period, especially in the stages corresponding to branching and milky grain. At each visit, 25 plants were evaluated at random, trying to cover the entire field sown.

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Larvae of the quinoa moth (*E. melanocampa*) were collected by shaking the panicles on a plastic tray. The larvae were taken to the laboratory and conditioned in plastic pots with natural food until the emergence of parasitoids [3].

TABLE I: COLLECTION LOCATIONS

Province	Location	Longitude	Latitude	Altitude
Anta	Izcuchaca	-71.4506	-14.0650	3672
	Zurite	-72.2661	-13.4386	3472
Calca	Pisac	-71.8467	-13.4225	3225
Canchis	Quiquijana	-71.5394	-13.8228	3628
	Marangani	-71.1686	-14.3578	3975
Cusco	Kayra	-71.8881	-13.5417	3278
	Perayoc	-71.9781	-13.5183	3392
Urubamba	Ollantaytambo	-72.2633	-13.2547	3096

C. Identification

Specialized taxonomic keys were used for identification [9] - [17], as well as consultations with specialists.

D. Data Analyses

The structure of the insect communities for the studied locations are represented in the form of accumulation bars. The Simpson Index (1-D) for each location (PAST software) was determined. A *t-test* as well as the Pearson correlation coefficient ($\alpha=0.05$) was performed for related samples taking the beneficial insect species as a variable.

III. RESULTS

The wasp *Apanteles* sp. was found in all the locations studied, followed by *Phytomyptera* sp. (Fig. 1).

Fig. 1. Structure of beneficial insect communities in quinoa for the studied locations.

The greatest diversity (Simpson 1-D) for parasitoid insects was observed in Izcuchaca (Anta) followed by Quiquijana and Marangani (Canchis) (Fig. 2).

Figure 2. Simpson diversity index (1-D) for the studied locations.

The analysis of related samples shows that there are marked associations between parasitoid species (Table II).

The correlation analysis shows that there are associations, positive and negative, between parasitoid species but a statistically significant and positive correlation is found only between *Bassus* sp. and *Diadegma* sp. (Table III).

There is a correlation clearly noticeable between *Bassus* and *Diadegma*. The population those species is very similar for each location (Fig. 3a). On the other hand, *Apanteles* and *Phytomyptera* showed a lesser correlation between their populations (Fig. 3b).

IV. DISCUSSION

Results show that the quinoa moth parasitoid complex contains several genera that coincide between locations and countries; among the most important and common genera are *Phytomyptera*, *Apanteles* and *Diadegma* [3], [5], [6], [8], in addition to other genera that could be specific to particular locations.

It should not be overlooked that, in the case of parasitoids, most references are made on genera and not on species, despite the fact that there are comprehensive proposals for biological control based on the natural enemies of the quinoa moth [6], [18].

TABLE II: P-VALUE OBTAINED FROM THE T-TEST FOR RELATED SAMPLES

	<i>Apanteles</i>	<i>Bassus</i>	<i>Bracon</i>	<i>Macrocentrus</i>	<i>Diadegma</i>	<i>Phytomyptera</i>
<i>Apanteles</i>						
<i>Bassus</i>	0.011 n.s.					
<i>Bracon</i>	0.020 n.s.	0.4617 *				
<i>Macrocentrus</i>	0.059 n.s.	0.9160 *	0.4438 *			
<i>Diadegma</i>	2.446 *	0.1017 *	0.2428 *	0.5619 *		
<i>Phytomyptera</i>	0.633 *	0.0786 *	0.0866 *	0.0688 *	0.0990 *	

* the asterisk indicates 95% statistical significance ($\alpha = 0.05$), n.s. = non significative.

TABLE III: PEARSON'S CORRELATION COEFFICIENT FOR BENEFICIAL INSECT SPECIES IN QUINOA CROP

	<i>Apanteles</i>	<i>Bassus</i>	<i>Bracon</i>	<i>Macrocentrus</i>	<i>Diadegma</i>	<i>Phytomyptera</i>
<i>Apanteles</i>						
<i>Bassus</i>	0.2249					
<i>Bracon</i>	0.6949	-0.1666				
<i>Macrocentrus</i>	-0.5148	-0.1666	-0.1666			
<i>Diadegma</i>	0.1482	0.9826 *	-0.2395	-0.0263		
<i>Phytomyptera</i>	-0.2456	0.5682	-0.2598	0.6920	0.6913	

*statistical significance, t-value

Fig. 3a. Populations of *Bassus* sp. and *Diadegma* sp. in the studied locations.

Fig. 3b. Populations of *Apanteles* sp. and *Phytomyptera* sp. in the studied locations.

In this sense, it seems appropriate to propose to researchers of quinoa cultivation in South America a collaborative project to achieve the identification at a specific level, both of the parasitoids and of the beneficial insects in general, to generate and update the information on, among other aspects, their taxonomy, behavior, and patterns of distribution.

As has been observed in Bolivia and Peru [3] - [5], there were differences in the levels of parasitoidism in different locations have been found, this study supports that the structure of the beneficial insect communities, in this case parasitoids, depends on location.

Regardless of the locations where the respective assessments have been carried out, the areas suitable for the cultivation of quinoa correspond to high Andean areas that have similar ecological and geographical conditions, which could represent large areas for the management of beneficial insect complexes. This aspect draws attention to the current concepts of Integrated Pest Control. Based on existing data, it is not possible to discuss biological control of the quinoa moth in large areas of production of this crop, but rather, the need to perform diagnoses in different locations to design local strategies based on concrete information of the native insects should be considered, thus reinforcing the proposal to use natural enemies as a resource for the management of the quinoa moth [18].

Furthermore, there is also the fact that different varieties of quinoa are used. As has already been demonstrated, quinoa varieties can have effects on pests and their natural enemies due to their architecture and chemical content [8], [19], but additionally, there is the introduction of new varieties to areas where they were not sown previously [7], thus generating increasingly complex interaction mechanisms [20], [21]. A striking aspect in the use of different varieties of quinoa is the fact that females are attracted by a certain variety, but males are more attracted to the smell derived from females than to the volatile compounds of plants [19].

On the other hand, the analyses carried out (t-test and correlation coefficients) show associations between the species of parasitoids studied. It does not seem likely to expect a numerical relationship between the populations of parasitoids but it can be assumed that, as in the case of *Bassus* and *Diadegma*, the high populations found in Anta province may be due to the optimum conditions for quinoa farming and the presence of the quinoa moth in this area, therefore allowing the existence of high populations of these parasitoids. This relationship seems less noticeable in the case of *Apanteles* sp. and *Phytomyptera* sp., both considered as the most important parasitoids of the quinoa moth in all cases reported [2] - [5]. In this case, *Phytomyptera* is clearly more abundant in Izcuchaca (Anta) and Ollantaytambo (Urubamba) which, under the current circumstances, must offer the best conditions for the population development of this genus.

V. CONCLUSIONS

The parasitoids *Apanteles* sp., *Bassus* sp., *Bracon* sp., *Macrocentrus* sp., *Diadegma* sp., and *Phytomyptera* sp. have been reported parasitizing quinoa moth larvae: *E. melanocampa* in eight locations of Cusco.

It has been found that the structure of the parasitoid insect communities of quinoa moths is different for the studied locations. The parasitoid communities could be determined by several factors, some of them can be the associated vegetation, altitude, climatic factors and others.

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