

Insect pests and natural enemies in two varieties of quinoa (*Chenopodium quinoa*) at Cusco, Peru

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Abstract: The abundance of insect pests and natural enemies in two varieties of quinoa, *Chenopodium quinoa* (Blanca de Junín and Amarilla de Marangani) throughout the growing season in the Southern Peruvian Andes is described. The quinoa varieties differ, among other traits, in their content of saponins (secondary metabolites associated to plant resistance) late in the season. Whereas Agromyzidae and Cicadellidae were abundant only in the early season, both Chrysomelidae and Aphididae populations showed fluctuations. Likewise, Araneae and Braconidae showed fluctuating numbers during the season. The abundance of Coccinellidae peaked at mid-season whereas that of Syrphidae was high only in the late season. Although the overall abundance of insects was very similar in both varieties of quinoa, there were different patterns depending on the season. In the early season there was a tendency towards greater insect numbers on Blanca, but in contrast, in the late season Amarilla (the high-saponin variety) had a higher load of insect pests. This suggests that saponins do not play a major role in quinoa resistance against insects. In the early season, no significant relationship between pests and natural enemies held across quinoa varieties. In the late season, Aphididae and Coccinellidae were negatively and significantly correlated in both varieties. The temporal population dynamics of Aphididae and both Coccinellidae and Braconidae resembled the traditional predator–prey dynamics.

1 Introduction

Quinoa, *Chenopodium quinoa* Willd. (Chenopodiaceae), has been a staple crop in the Andean highlands since 3000 BC (TAPIA et al., 1979). The exceptionally high nutritional value of this formerly ‘forgotten’ crop of the Incas, which is largely superior to traditional cereals (TAPIA et al., 1979; CUSACK, 1984), has promoted its cultivation in Europe and the US (NATIONAL RESEARCH COUNCIL, 1989). The research on quinoa has mainly focused on nutrition (GROSS et al., 1989; BALLÓN et al., 1990; RUALES and NAIR, 1993a), grain processing, i.e. removal of saponin-bitterness (RUALES and NAIR, 1993b, 1994; CHAUHAN et al., 1999), and breeding (SIMMONS, 1971; JACOBSEN et al., 1996; ORTIZ et al., 1998). Less effort has been devoted, however, to study the insect fauna associated with the crop in the Andes (ZANABRIA and MUJICA, 1977; SÁNCHEZ and VERGARA, 1991). This is of key importance if it is considered that the process of expansion of its cultivation will expose quinoa to new communities of insect species. Quinoa in the Andes is currently attacked by several taxa of herbivorous insects, both native and exotic. Occasionally, populations of some of them can reach levels of economic importance and reduce the yields (SÁNCHEZ and VERGARA, 1991). On the other hand, the presence of several natural enemies associated with the crop has

been observed, including exotic and native species (YÁBAR, personal observation).

As the centre of origin of quinoa, the Peruvian Andes harbour approximately 2000 ecotypes (TAPIA et al., 1979), which exhibit a wide range of variation in morphological, phenological, and physiological traits. In this regard, breeding programmes have been targeted towards a number of agronomic features, with relatively successful results (RISI and GALWEY, 1984; JOHNSON and WARD, 1993). However, there is still a paucity of information on plant traits that could be related to resistance against herbivorous insects.

In the present work, we report on the abundance of insect pests and natural enemies in two varieties of quinoa (Blanca de Junín and Amarilla de Marangani) throughout the growing season in the Southern Peruvian Andes. The quinoa varieties differ in their content of saponins (low versus high, respectively) (CUADRADO et al., 1995). Previous work has shown that saponins may play a role in plant resistance against insects (GERSHENZON and CROTEAU, 1992). Given that the difference in saponin content in these quinoa varieties becomes evident only late in the season (approximately 82 days after planting; MASTERBROEK et al., 2000), part of the analysis of insect abundance was split into early and late season situations.

2 Materials and methods

2.1 Description of quinoa varieties

Blanca de Junín is a Valley ecotype, grown in Andean valleys from 2000 to 3600 m, with a long growth period. It is tall (2.2 m high, 1.6 cm diameter), branched, with triangular leaves (7.5 cm long, 6 cm width) with serrated edges, a lax seed-head (45 cm long), and whitish seed grains (2 mm long) with a low saponin content.

Amarilla de Marangani is an Altiplano ecotype, typical of the highlands close to Lake Titicaca (above 4000 m), with a short growth period. It is small (1.05 m high, 1.7 cm diameter), unbranched, with serrated leaves (6.4 cm long, 5.4 cm width), a compact seed-head (22 cm long), and orange seeds (2.5 mm long) with a high saponin content.

2.2 Experimental procedure

The study was conducted in the Kayra experimental station of the Universidad Nacional San Antonio Abad del Cusco, located in the Southern Peruvian Andes at 3150 m. Both quinoa varieties were sown in a randomized complete block design with three plot/replicates of 10 m². In each plot 10 plants were taken as the sampling unit. Evaluations started 60 days after sowing, and were then carried out 8, 15, 22 (four observations = early season), 44, 51, 57, and 71 (four

observations = late season) days later. In each evaluation the number of individual insects (both pests and natural enemies) in each sampling unit was determined by visual observation.

2.3 Statistical analysis

The analyses were twofold. Firstly, it was evaluated whether there were differences in the overall abundance of insect taxa between quinoa varieties. For this purpose, and to account for the variation due to the season, a *t*-test for dependent samples on mean values ($n = 8$ observations) was applied for each insect taxon. In the cases where data did not meet the assumptions of parametric tests, a Wilcoxon matched-pairs test was used. Secondly, the particular dynamics of the differences between varieties with time was addressed. Thus, for each time of the season (early and late) and each insect taxon, a multivariate repeated-measures analysis of variance (ANOVA) was performed (independent variable = quinoa variety; dependent variable = insect number; repeated measures factor = time). The resulting four dependent variables (time = evaluations) were grouped in two levels and the significance of the multivariate F-value (Wilk's lambda) was tested. Special attention was given to the significance of the variety-time interaction because this factor would indicate the effect of a plant trait whose difference between varieties changes with time, e.g. saponin content.

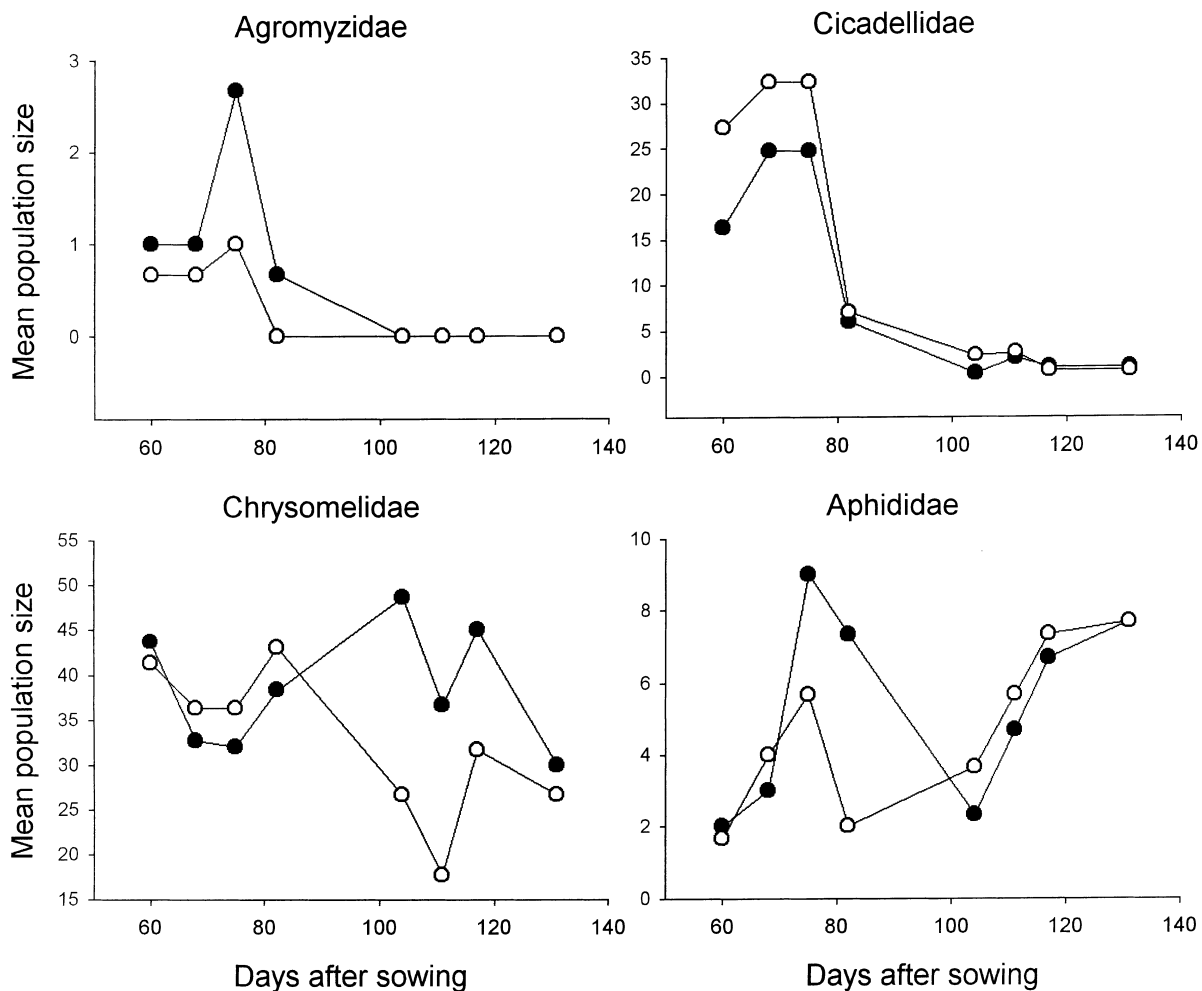


Fig. 1. Population size of insect pests throughout the growing season of quinoa varieties *Amarilla de Marangani* (filled circles) and *Blanca de Junín* (empty circles) in Peruvian Andes. Each point represents the mean of three observations (sampling unit = 10 plants). The first four points correspond to early season, and the last four to late season, as analysed in the text. See Results for the species comprising each family of insects

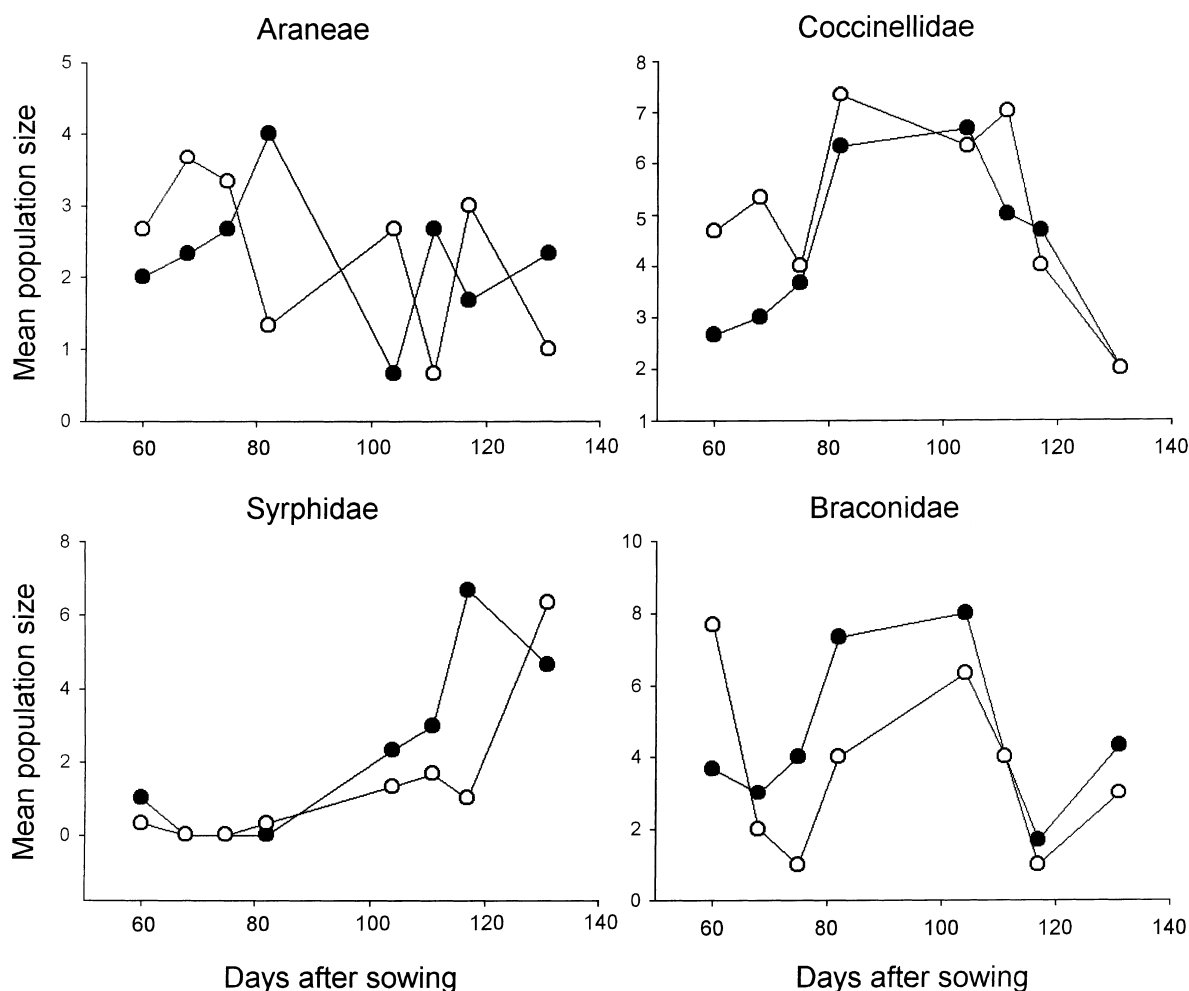


Fig. 2. Population size of natural enemies of insect pests throughout the growing season of quinoa varieties *Amarilla de Marangani* (filled circles) and *Blanca de Junin* (empty circles) in Peruvian Andes. Each point represents the mean of three observations (sampling unit = 10 plants). The first four points correspond to early season, and the last four to late season, as analysed in the text. See Results for the species comprising each family of insects

The significance of the correlations between the abundance of different taxa of insects was determined by a Pearson product-moment correlation analysis. This was carried out for each variety and time of the season.

3 Results

Insect pests belonged to the following taxa: Col., Chrysomelidae (*Diabrotica speciosa* and *D. sicuanica*); Dipt., Agromyzidae (*Liriomyza huidobrensis* and *Liriomyza* sp.); Hom., Aphididae (*Macrosiphum euphorbiae* and *Myzus persicae*); Hom., Cicadellidae (*Empoasca* sp. and *Bergallia* sp.). Likewise, natural enemies were grouped as follows: Hym., Braconidae (*Aphidius* sp. and *Lysiphlebus* sp.); Dipt., Syrphidae; Col., Coccinellidae (*Hippodamia convergens* and *Eriopis connexa*); Araneae (Lycosidae and Salticidae).

Whereas Agromyzidae and Cicadellidae were abundant only in the early season, both Chrysomelidae and Aphididae populations showed fluctuations (fig. 1). Likewise, Araneae and Braconidae showed fluctuating numbers during the season. The abundance of Coccinellidae peaked at mid-season whereas that of Syrphidae was high only in the late season (fig. 2).

The overall abundance of insects was very similar in both varieties of quinoa. The only significant difference was found for Cicadellidae, which were more abundant in Blanca de Junin (Blanca) than in Amarilla de Marangani (Amarilla) (table 1). However, when the statistical analyses were carried out separately for the early and late season, evaluating the change in insect abundance with time, some differences between varieties could be detected. Thus, the results of the multivariate repeated-measures ANOVA indicated that in the early season the Agromyzidae population was greater in Amarilla than in Blanca in a time-dependent way (table 2). This was followed by a sudden decline of the populations (fig. 1). In contrast, both Chrysomelidae and Syrphidae showed a time-dependent superiority in Amarilla only during the late season (table 2).

The correlation matrices show that the relation between the abundance of natural enemies and pests changes with the season and with the quinoa variety (table 3). In the early season no significant relationship between pests and natural enemies held in both quinoa varieties, whereas in the late season Aphididae and Coccinellidae were negatively and significantly correlated in both varieties.

4 Discussion

The insect fauna associated with quinoa was similar to that described in earlier reports. The difference with previous work in the Andean region (ZANABRIA and MUJICA, 1977; SÁNCHEZ and VERGARA, 1991) and other regions of the world (CRANSHAW et al., 1990; BARRIENTOS, 1994) was the absence of noctuid caterpillars (Lepidoptera) and plant bugs (Heteroptera). In general, the cumulative abundance of insect pests was rather similar in the quinoa varieties studied. However, there were different patterns depending on the season. Thus, in the early season there was a tendency towards greater insect numbers in Blanca. In contrast, in the late season Amarilla had a higher load of insect pests. Given that the pests were overall more abundant in the early season, the former patterns can also be seen as a steep (Blanca) versus a gradual (Amarilla) decrease in insect population size with time.

Interestingly, the start of the herein-defined late season was coincident with the onset of saponin

Table 1. Mean abundance (standard error¹) of insect taxa in quinoa (*Chenopodium quinoa*) varieties Amarilla de Marangani (Amarilla) and Blanca de Junin (Blanca). $n = 8$ observations during the season. Values shown are the number of insects found in 10 plants = sampling unit

	Amarilla	Blanca	P-value
Pests			
Chrysomelidae	38.4 (2.4)	32.5 (3.0)	0.166*
Aphididae	5.3 (0.9)	4.7 (0.8)	0.484*
Cicadellidae	9.5 (3.7)	13.2 (5.2)	0.036#
Agromyzidae	0.7 (0.3)	0.3 (0.1)	0.068#
Natural enemies			
Braconidae	4.5 (0.7)	3.6 (0.8)	0.316*
Syrphidae	2.2 (0.8)	1.4 (0.7)	0.345#
Coccinellidae	4.3 (0.6)	5.1 (0.6)	0.083*
Araneae	2.3 (0.3)	2.3 (0.4)	0.999*

¹ Given that the statistical tests were paired, the standard error value reflects the variability of data with the season rather than the degree of data dispersion.
* After a *t*-test for dependent samples.
After a Wilcoxon matched-pairs test.

accumulation in quinoa leaves (CUADRADO et al., 1995). However, since the high-saponin variety (Amarilla) was the one with higher abundance of insect pests in the late season, it is suggested that, at least for these quinoa varieties, saponins do not play a major role in plant resistance against insects, as has been described before (GERSHENZON and CROTEAU, 1992). A further experimental approach is needed to verify or negate this preliminary conclusion. If it is validated, then breeding programmes aimed at the development of quinoa varieties with lesser levels of saponins/bitterness (WARD, 2000) would not entail the risk of developing varieties more susceptible to insect pests. This kind of 'dilemma' has been addressed before, in the case of potato glycoalkaloids (see RAMAN et al., 1979). Of course, the quinoa varieties studied do not differ only in their saponin content. The differences in branching, plant height, and growth rate could be partially accounting for the observed patterns of insect abundance. Despite being related to plant resistance less directly than secondary chemistry (but see COLEY et al., 1985 for the relationship between growth rate and herbivory) these plant characteristics deserve further evaluation.

There were no significant negative correlations among the abundance of insect pests. It is therefore unlikely that interspecific competition affects the patterns of abundance of these insect taxa (see DENNO et al., 1995 for a review on the topic). This is also supported by the fact that insect populations were rather low and consequently plants were not a limiting resource. On the other hand, it is more likely that pressure by natural enemies could have a significant impact on pest populations. In this regard, it was found that the sign and magnitude of the relation between the abundance of natural enemies and pests changed with the season and with the quinoa variety. Nevertheless, Aphididae and Coccinellidae showed a consistent negative relationship in the late season. Coccinellids are widely known as predators of aphids (HODEK, 1973) and hence the correlation could imply causality. Moreover, the temporal population dynamics of Aphididae (two peaks, at the beginning and end of the season) and

Table 2. Results of the multivariate repeated-measures ANOVA for the abundance of pests and natural enemies in quinoa varieties Amarilla de Marangani and Blanca de Junin in early and late-season. Independent variable = quinoa variety (*V*); dependent variable = insect number; repeated measures factor = time (*T*). *P*-values associated to values of Wilk's lambda (*d.f.* = 2,3) are shown and those significant are in boldface. See text for further details

	Early season	Late-season
Pests		
Chrysomelidae	<i>V</i> : 0.838 <i>T</i> : 0.297 <i>V</i> × <i>T</i> : 0.829	<i>V</i> : 0.228 <i>T</i> : 0.757 <i>V</i> × <i>T</i> : 0.032
Aphididae	<i>V</i> : 0.480 <i>T</i> : 0.390 <i>V</i> × <i>T</i> : 0.309	<i>V</i> : 0.754 <i>T</i> : 0.031 <i>V</i> × <i>T</i> : 0.912
Cicadellidae	<i>V</i> : 0.123 <i>T</i> : 0.007 <i>V</i> × <i>T</i> : 0.590	<i>V</i> : 0.458 <i>T</i> : 0.461 <i>V</i> × <i>T</i> : 0.609
Agromyzidae ¹	<i>V</i> : 0.556 <i>T</i> : 0.529 <i>V</i> × <i>T</i> : 0.032	–
Natural Enemies		
Braconidae	<i>V</i> : 0.173 <i>T</i> : 0.312 <i>V</i> × <i>T</i> : 0.235	<i>V</i> : 0.147 <i>T</i> : 0.034 <i>V</i> × <i>T</i> : 0.501
Syrphidae	<i>V</i> : 0.604 <i>T</i> : 0.239 <i>V</i> × <i>T</i> : 0.604	<i>V</i> : 0.035 <i>T</i> : 0.024 <i>V</i> × <i>T</i> : 0.009
Coccinellidae	<i>V</i> : 0.503 <i>T</i> : 0.401 <i>V</i> × <i>T</i> : 0.831	<i>V</i> : 0.836 <i>T</i> : 0.083 <i>V</i> × <i>T</i> : 0.649
Araneae	<i>V</i> : 0.558 <i>T</i> : 0.954 <i>V</i> × <i>T</i> : 0.098	<i>V</i> : 0.160 <i>T</i> : 0.738 <i>V</i> × <i>T</i> : 0.909

¹ Null abundance at late-season (see fig. 2).

Table 3. Correlations among the abundance of pests and natural enemies in quinoa varieties *Amarilla de Marangani* and *Blanca de Junín* in early and late-season. Values shown are correlation coefficients r (Pearson product-moment correlations). Above the main diagonal: values for the variety *Amarilla de Marangani*. Below the main diagonal: values for the variety *Blanca de Junín*

Early season									
	Cic	Agr	Aph	Chr	Bra	Coc	Syr	Ara	
Cic	1.00	0.05	0.22	-0.41	-0.61*	0.52	-0.15	-0.36	
Agr	0.39	1.00	0.67*	0.18	0.42	0.53	0.08	0.12	
Aph	0.22	0.85***	1.00	0.03	0.22	0.23	-0.06	0.12	
Chr	-0.24	0.01	-0.07	1.00	0.11	0.08	0.58*	0.13	
Bra	0.05	0.17	-0.13	0.31	1.00	0.79**	0.17	0.07	
Coc	-0.57*	-0.31	-0.28	-0.07	-0.29	1.00	-0.16	0.28	
Syr	-0.38	-0.04	-0.28	0.29	0.04	0.18	1.00	-0.57*	
Ara	0.47	0.87***	0.73**	0.03	0.39	-0.37	-0.23	1.00	
Late season									
	Cic	Agr	Aph	Chr	Bra	Coc	Syr	Ara	
Cic	1.00	-	0.23	-0.17	-0.11	0.09	0.03	0.60*	
Agr ¹	-	1.00	-	-	-	-	-	-	
Aph	-0.36	-	1.00	-0.01	-0.47	-0.58*	0.71**	0.47	
Chr	-0.52	-	0.33	1.00	0.34	0.30	0.25	-0.34	
Bra	0.58*	-	-0.64*	-0.18	1.00	0.51	-0.41	-0.11	
Coc	-0.08	-	-0.72**	-0.23	0.25	1.00	-0.23	-0.34	
Syr	-0.46	-	0.38	0.09	-0.17	-0.22	1.00	0.35	
Ara	-0.13	-	-0.09	0.50	0.03	-0.05	-0.38	1.00	

Cic, Cicadellidae; Agr, Agromyzidae; Aph, Aphididae; Chr, Chrysomelidae; Bra, Braconidae; Coc, Coccinellidae; Syr, Syrphidae; Ara, Araneae.

¹ Null abundance at late-season (see fig. 2).

* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

Coccinellidae (one peak, at the mid-season) resemble the traditional predator-prey dynamics (HASSELL, 1978). A similar pattern (one mid-season peak) was found for Braconidae, which are also reported as parasitoids of aphids (MACKAUER and VÖLKL, 1993). Hence, it is suggested that natural enemies could regulate Aphididae populations in these quinoa varieties. Again, an experimental approach is needed to test this speculation.

The present study is a preliminary report on the insect fauna associated with the quinoa crop in Southern Andes. It was found that the quinoa shoots are attacked by sapsuckers (Aphididae, Cicadellidae), leaf miners (Agromyzidae) and chewing insects (Chrysomelidae). No specialist pest species was found. On the other hand, the pool of natural enemies was also rather generalist. It is suggested that these insect species are more relevant to the pest population dynamics than the secondary chemistry (specifically saponins) of the quinoa plant. Both insect pests and natural enemies showed distinct patterns of abundance with regard to the quinoa variety and the time of the season. The latter encourages further research to uncover the main factors that govern the seemingly complex dynamics of the insect taxa studied. In addition, future work – ideally encompassing more quinoa varieties – should address the relative importance of plant architecture and phenology on the abundance of insect pests.

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