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# Fluctuation of main insect pests and diseases in cañihua (*Chenopodium pallidicaule* Aellen) of the Peruvian Andean Altiplano

Fluctuación de principales insectos-plaga y enfermedades en cañihua (*Chenopodium pallidicaule* Aellen) del Altiplano andino peruano

Flutuação das principais pragas e doenças de insetos em cañihua (*Chenopodium pallidicaule* Aellen) do Altiplano Andino peruano

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## Abstract

The Andean crop germplasm bank, of the Camacani Experimental Center of the Universidad Nacional del Altiplano de Puno, has around 400 accessions of cañahua (*Chenopodium pallidicaule* Aellen), and 27 of them have been agronomically characterized. Given the importance of this crop for the inhabitants of highlands of the Peruvian Andes, the objective of this research was to assess the population fluctuation of insect pests and the severity of diseases in the mentioned accessions, along with three commercial varieties. The evaluations were carried out in three phases of the crop development, including the grain yield. It was found that the accessions and varieties of cañahua were tolerant to the attack of most pests and diseases. The most important pest was *Eurysacca quinoae* Povolny, especially in the accession 03-21-26 and the Ramis variety, in which up to 5.5 and 4.5 larvae were found per plant, respectively; however, the pest did not exceed the economic threshold of 6 larvae per plant during the phenological phases. In regards to diseases, it was confirmed that *Peronospora* sp. (mildew) is the main pathology that occurred during the agricultural season. Accessions 03-21-03 and 03-21-24 were not affected by the disease, while accessions 03-21-267, 03-21-218, 03-21-124, 03-21-26 and 03-21-64 were the most affected, showing the highest severity and area under the disease progress curve. When evaluating one season, the accessions and varieties of cañihua showed resistance to insect-pests and diseases, without appreciably decrease of their grain yields.

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## Resumen

El banco de germoplasma de cultivos andinos, del Centro Experimental Camacani de la Universidad Nacional del Altiplano de Puno tiene alrededor de 400 accesiones de cañihua (C*henopodium pallidicaule* Aellen), 27 de ellas han sido caracterizadas agronómicamente. Dada la importancia que representa este cultivo para los pobladores del altiplano peruano debido a su alto valor nutricional, el objetivo de esta investigación fue evaluar la fluctuación poblacional de las principales plagas insectiles y la severidad de enfermedades en las mencionadas accesiones, junto con tres variedades comerciales. Se realizaron evaluaciones en tres etapas fenológicas y en la cosecha. Se encontró que las accesiones y variedades de cañihua son tolerantes al ataque de la mayoría de las plagas y enfermedades. La plaga más importante fue *Eurysacca quinoae* Povolny (Lepidoptera, Gelechiidae), especialmente en la accesión 03-21-26 y la variedad Ramis, en las cuales se registraron 5,5 y 4,5 larvas por planta, respectivamente, sin sobrepasar el umbral de daño económico de 6 larvas por planta en ninguna de sus fases fenológicas. En el caso de las enfermedades, *Peronospora* sp. (mildiu) resultó ser el principal fitopatógeno que se presentó durante la campaña agrícola. Las accesiones 03-21-03 y 03-21-24 no fueron afectadas con la enfermedad, mientras que las accesiones 03-21-267, 03-21-218, 03-21-124, 03-21-26 y 03-21-64 fueron las más afectadas con altos valores de severidad y área bajo la curva de progreso de la enfermedad. En la evaluación de un ciclo de cultivo, las accesiones y variedades estudiadas, mostraron tolerancia a insectos-plagas y enfermedades, sin afectarse sensiblemente los rendimientos.


**Palabras clave:** banco de germoplasma, cultivos andinos, variación fluctuacional, resistencia varietal.


## Resumo

O Banco Andino de Germoplasma de Culturas, do Centro Experimental Camacani da Universidad Nacional del Altiplano de Puno, possui cerca de 400 acessos de cañihua (*Chenopodium pallidicaule* Aellen), sendo que 27 deles já foram cultivados e caracterizados agronomicamente. Dada a importância desta cultura para os habitantes do altiplano andino peruano, devido ao seu alto valor nutritivo, o objetivo desta pesquisa foi avaliar a flutuação populacional dos principais insetos-praga e severidade de doenças nos citados acessos, em conjunto com três acessos variedades comerciais. As avaliações foram realizadas em três fases do desenvolvimento da cultura, incluindo sua produtividade. Os acessos e variedades Cañihua foram considerados tolerantes ao ataque da maioria das pragas e doenças. A praga mais importante foi *Eurysacca quinoae* Povolny, especialmente no acesso 03-21-26 e na variedade Ramis, na qual foram registradas até 5,5 e 4,5 larvas por planta, respectivamente; isto é, em nenhum momento a praga excedeu o limite de dano econômico estabelecido de 6 larvas por planta. No caso das doenças, *Peronospora* sp. (míldio) acabou sendo o principal patógeno ocorrido durante a safra agrícola. Os acessos 03-21-03 e 03-21-24 não foram afetados pela doença, enquanto os acessos 03-21-267, 03-21-218, 03-21-124, 03-21-26 e 03- 21-64 foram os mais afetados com a maior gravidade e área sob a curva de progresso da doença. Ao avaliar um ciclo de cultura, os acessos e variedades de cañihua estudados mostraram resistência a pragas e doenças, sem afetar significativamente a produtividade.


**Palavras-chave**: banco de germoplasma, flutuação populacional, severidade.

## Introduction

Cañihua (*Chenopodium pallidicaule* Aellen), from the Amaranthaceae family (Caryophyllales), is an Andean species of great importance in the diet of the inhabitants of this region for thousands of years. However, it was relegated to the background for several decades, but has regained its importance in human nutrition due to the quality of its protein and better biochemical components than most known cereals, given that cañihua proteins have a balanced composition of essential amino acids similar to the composition of casein, the milk protein, and its fatty acids are similar to those of corn germ oil (Repo *et al.*, 2003). It is a crop originally domesticated by inhabitants of the Tiahuanaco culture in the highlands of Peru and Bolivia, where the largest cultivated area and diversity of ecotypes are found (Rojas *et al.*, 2010). Due to its wide diversity, it can tolerate frost, high temperatures, drought and saline soils (Rodríguez *et al.*, 2020; Rollano-Peñaloza *et al.*, 2021).

In Peru, the largest production of this species is concentrated in the Puno region, and on a smaller scale it is produced in the highlands of Ayacucho, Arequipa and Cusco. Among the pests and diseases that attack it, the Kcona-kcona moth (*E. quinoae*) is reported in the flowering and grain formation stage, as well as damage by mildew (*P. variabilis* Gäum.) in the early stages of development of the crop (Apaza, 2010).

The cañihua is one of the least studied species of the altiplano in terms of its insect-plagues and diseases. Some authors have detected mildew infections in the seeds of the plant, as well as in the leaves, where chlorosis, necrosis and sporulation occur (Rollano-Peñaloza *et al.*, 2021; Testen *et al.*, 2014). However, Rodríguez *et al.* (2020) indicated that no insects or diseases have been reported that could significantly affect the development and growth of the crop.

Jager *et al.* (2010) pointed out that there is a considerable risk in Andean grain and tuber crops, due to climate change in the highlands, referring to the lack of information on pest and disease problems in crops such as cañihua, and recommend expanding studies on native varieties that mitigate such risks under the concept of resilience. A similar concept is shared by Tonconi (2015), who pointed out that climatic variables in Puno, referring to average maximum temperatures, have negative effects on the yield of potato, broad bean and corn crops, while quinoa (*Chenopodium quinoa* Willd) and cañihua still do not show such effects. In this regard, Benique (2019) mentioned that cañihua tolerates critical anomalies of the agroclimatic variables of the region, referring to the increase in insect populations that can interfere with yields and concludes by pointing out that this high Andean grain adapts to climate change in the región of high plateau of Puno.

Mamani (2013) molecularly characterized 26 cañihua accessions from the germplasm bank of Camacani UNA-Puno and determined that they do not have genetic similarities with each other, so the duplication of accessions is ruled out. For their part, Bravo *et al.* (UNA-Puno, Peru, unpublished data) characterized the same accessions together with three varieties, and observed that the variety INIA-406 and the accessions 03-21-07 and 03-21-315 were the ones with the greatest stability of characters and higher average performance.

In this context, the objective of this work was to evaluate the population fluctuation of the main insect pests and the severity of the diseases recorded in different stages of development of 27 accessions and 3 varieties of cañihua during the 2019-2020 agricultural campaign in Puno, Peru.

## Materials and methods

Twenty seven accessions and 3 varieties of cañihua (*C. pallidicaule*) were studied in a trial installed at the Centro Experimental Illpa, of the Facultad de Ciencias Agrarias of the UNA-PUNO, on an area of 1,378 m$^2$, with 30 plots in two blocks. The 27 accessions came from the "José Luis Lescano" germplasm bank of the Centro Experimental Camacani, and the varieties were INIA-206, Cupi and Ramis (table 1), the vast majority of them selected because they have been shown to have no genetic similarities between after its molecular characterization (Mamani, 2013).

**Table 1. Codes assigned to the cañihua (*Chenopodium pallidicaule*) accessions and varieties evaluated during the 2019-2020 period.**

| N° Accesión | Code | N° Accesión | Code | N° Accesión | Code |
|---|---|---|---|---|---|
| 1 | 03-21-02 | 11 | 03-21-124 | 21 | 03-21-231 |
| 2 | 03-21-03 | 12 | 03-21-130 | 22 | 03-21-246 |
| 3 | 03-21-64 | 13 | 03-21-140 | 23 | 03-21-267 |
| 4 | 03-21-07 | 14 | 03-21-146 | 24 | 03-21-296 |
| 5 | 03-21-23 | 15 | 03-21-156 | 25 | 03-21-301 |
| 6 | 03-21-24 | 16 | 03-21-196 | 26 | 03-21-315 |
| 7 | 03-21-26 | 17 | 03-21-204 | 27 | Puka |
| 8 | 03-21-27 | 18 | 03-21-215 | Variety 1 | INIA-406 |
| 9 | 03-21-37 | 19 | 03-21-218 | Variety 2 | Cupi |
| 10 | 03-21-117 | 20 | 03-21-230 | Variety 3 | Ramis |

**Crop management**

Sowing was held on November 12, 2019, with the use of organic fertilizer based on cattle manure (31 % organic matter), using 8 kg.ha$^{-1}$ of seed to continuous jet at the bottom of furrows separated 50 cm from each other, which originated an average population density of 55,000 plants.ha$^{-1}$. During the growth and development of the crop, agronomic tasks of desuck, weeding and hilling were carried out. The harvest was carried out between May 5 and 8, 2020.

**Insect pest evaluation**

The insect-pest evaluation was carried out by counting the number of phytophagous insects (larvae or adults) in two consecutive plants and in two representative points of each of the 30 plots under study (Bravo, 2010). Insects were common with the quinoa crop and identified in the Laboratorio de Entomología of the Universidad Nacional del Altiplano de Puno. During the development of the investigation there was no application of insecticides. The evaluations were carried out in the vegetative, flowering and maturation stages of the crop (figure 1 A, B, C).

**Disease evaluation**

The methodology described by Leon-Ttacca *et al.* (2018) in the cultivation of quinoa for mildew was used. Three evaluations of disease severity were made during the agricultural campaign, the first was carried out 52 days after sowing (DDS), which coincides with plant branching, the second, 63 DDS during the formation of the inflorescence, and third, 85 DAS in flowering. For each evaluation, 10 plants were randomly chosen from the three central rows per plot and 3 leaves were randomly selected from each plant, one from each third (upper, middle and lower) where the percentage of severity (average of the 3 readings) of the mildew of each leaf using the graphic evaluation scale proposed by Danielsen and Ames (2003) in quinoa, with values of 0, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80 , 90, 95 and 100 % of the area of the leaves affected by mildew.

Based on the severity measurements, the value of the area under the disease progress curve (AUDPC) was calculated, in order to describe the development of the disease throughout the crop season. The formula for calculating this variable was as follows:

$$AUDPC = \sum_{i}^{n-1}(y_i + y_{i+1})/2x(t_{i+1} - t_i)$$

where $n$ is the number of evaluations, $y$ is the severity and $t$ is the number of days after sowing in which the evaluation is made. There was no application of fungicides.

**Grain yield evaluation**

The harvest was carried out when the grain reached physiological maturity. Ten plants were randomly chosen from the three central rows in each experimental unit and proceeded to cut them at ground level; subsequently, they were placed in paper envelopes and taken to the plant health laboratory to dry under shade at room temperature for two months to facilitate threshing; This was done manually and allowed to separate the grains from the brush. Finally, venting was carried out to eliminate impurities present in the seeds, to then be weighed and determine the yield.

**Results analysis**

The presence of insect pests was evaluated by preparing graphs with quantitative data on the amounts of phytophagous insects found in each accession or variety by plant phenological phase. For this,


**Figure 1. Phenological stages of cañihua (*Chenopodium pallidicaule*) cultivation in Puno, Peru (2019-2020 agricultural campaign). A: Vegetative, B: Flowering, C: Maturation.**

taxonomic keys were used at the level of order and family, with identification of species represented by common insects in a wide variety of Andean crops. The graphs allowed comparisons between the phenological phases according to the number of individuals collected in it, as well as a regression test between these and the plant yield. The presence of diseases was graphed by their severity in each accession or variety for each phenological phase of the plant. Likewise, a regression test was performed between AUDPC and crop yield. All analyzes were performed using the Statistix V.8 program.

## Results and discussion

In this section, as well as in the tables and figures, the accessions were identified only by their last digits with the intention of facilitating the reading of the document.

**Population density of pest-insects**

The results of the evaluations in three phenological stages of the crop allow determining that the registered species only reached the level of secondary and occasional pests. These species were aphids: *Macrosiphum euphorbiae* Thomas and *Myzus persicae* Sulzer (Hemiptera-Aphididae), jumping fleas: *Epitrix yanazar* Bechyne (Coleoptera-Chrysomrelidae) and thrips (*Frankliniella* spp. Thysanoptera- Thripidae), which had already been mentioned by Bravo (2010) and INIA (2020). Aphids reached a general average of 10.44 ± 0.04 individuals per plant, which is a relatively low value, considering the behavior of these insects to form very numerous colonies of individuals (between nymphs and adults) per plant in annual crops. (Bravo, 2012). The other two species were found in a range of 1 to 3 individuals per plant, which allows us to conclude that they do not represent an important risk for the crop.

The low population densities of phytophagous insects observed in the crop could, in part, be attributed to the structure and conformation of the plants, which have greater vegetative cover compared to similar crops, such as the case of quinoa, whose growth is erect. The population of these insect species had slight increases at times of decreased rainfall, which is considered a natural response (Bravo, 2010) as a possible combination between the resistance of the insect and the climatic condition.

The main pest species found, due to the damage it produces and the size of its population, was the kcona kcona moth (*E. quinoae* Povolny Lepidoptera-Gelchiidae), whose larva feeds directly on the grains and had slightly higher populations (between 1 and 6 individuals per plant) than the aforementioned occasional insects (figure 2). Similar result was found by Campos *et al.* (2012) in the cultivation of quinoa who reported this moth as a very important direct damage pest, while mentioning other minor secondary and occasional pests. The damage caused by this insect has a negative influence on crop yield, since it is a pest that directly affects the grains that are in formation in the small glomeruli during the flowering and maturation stage (Ochoa-Vizarreta and Franco-Navia, 2013).

However, the level of affectation found in this study was low, since the average insect population did not exceed the economic damage threshold (EDU) of six larvae per plant, as reported by Apaza (2010), Bravo (2010) and INIA (2020). In the flowering stage, a slight increase in the population density of the insect was observed, but without reaching the EDU.

The population density of *E. quinoae* in accession 26 remained stable in the three phenological stages with a range of 4.75 ± 0.5 to 5.50 ± 1 larvae.plant$^{-1}$; the same was observed in the Ramis variety with average ranges from 3.25 ± 1 to 4.50 ± 1 larvae.plant$^{-1}$. On the contrary, accession 230 had varied fluctuations in the three evaluations, reaching the highest peak in the flowering stage (5.75 ± 1 larvae.plant$^{-1}$) to later drop to only 1.25 ± 0.25 larvae. plant$^{-1}$ in the maturation stage (figure 2).

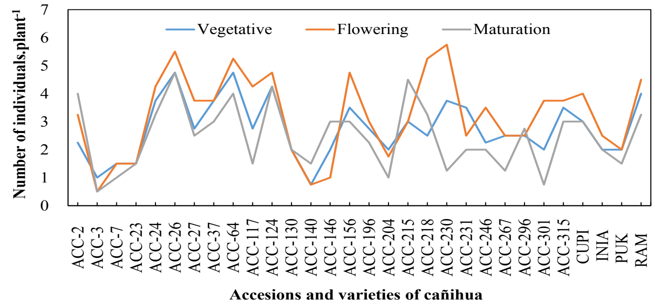


**Figure 2. Population of *Eurysacca quinoae* in cañihua (*Chenopodium pallidicaule*) accessions and varieties in Puno, Peru (2019-2020 agricultural season). Vegetative growth phases, and maturation. The varieties are INIA-406, CUPI and RAMIS.**

At the other extreme, the accessions with the lowest populations of this pest were 03, 140 and 301 with average population density ranges between 0.5 ± 0.15 and 1.5 ± 0.25 larvae.plant$^{-1}$, which would allow suggesting the use of these accessions in genetic improvement works. The INIA-406 variety showed populations that ranged between 2 ± 0.5 and 2.5 ± 0.25 larvae.plant$^{-1}$, that is, relatively low values that ratify it as not very susceptible to pest attack (INIA, 2020).

The moth damage was observed in the three stages of crop development, however, it stands out that the largest number of individuals occurred in the flowering phase (figure 3). Tapia *et al.* (1979) reported that in strong attacks the insect performs the postures in the inflorescences, leaves and young shoots, and when feeding destroys the ovary of the flowers.

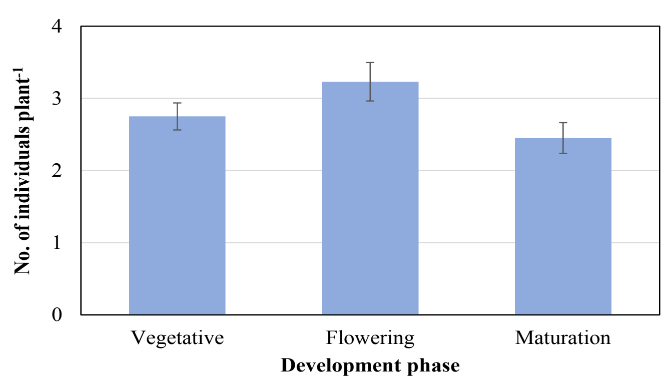


**Figure 3. Mean values of the population of *Eurysacca quinoae* depending on the development phase of cañihua (*Chenopodium pallidicaule*) cultivation in Puno, Peru (2019-2020 campaign).** The vertical bars above the columns indicate the standard error.

Although, in general, the intensity of the insect attack was relatively low, if the population of the pest during the flowering phase is taken as a reference, that is, the moment in which the largest number of individuals of the insect was detected in the crop, it is observed that 27.3 % of the decrease in grain yield was significantly explained by the presence of the insect (p = 0.0031) (figure 4). In general terms, the results obtained ratify the hypothesis that phytophagous insects are common in the crop, but not in high population densities, as pointed out by Bravo (2010) and INIA (2020).

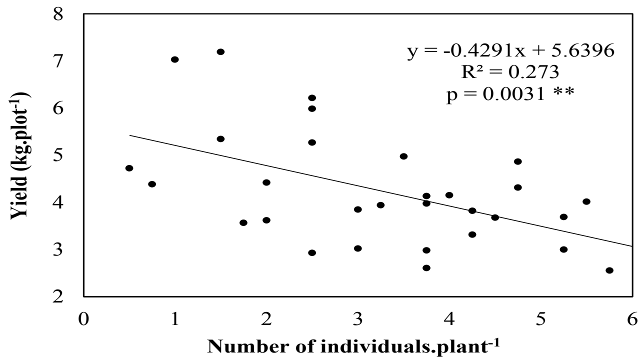


**Figure 4. Regression analysis between the number of *Eurysacca quinoae* larvae per plant and grain yield in cañihua (*Chenopodium pallidicaule*) cultivation in Puno, Peru (2019-2020 agricultural season).**

**Presence of diseases**

The main disease detected by its symptoms and signs was downy mildew (*Peronospora* sp.). Irregular chlorotic spots were observed on the upper leaves that increased in size until presenting the plant with a general discoloration, with a higher incidence on the basal leaves, as reported by Plata *et al.* (2014). According to Danielsen and Munk (2004), if the attack occurs in the early stages of plant development, production can be completely lost. This pathogen was first described in Peru in 1947 and since, has been reported in different countries around the world, but it is noteworthy that despite being endemic in the southern Andean cone, it was not confirmed until recent years, existence through molecular tests in countries bordering Peru such as Bolivia (Rollano-Peñaloza *et al.*, 2021) and Chile (Rosales *et al.*, 2017).

In the first evaluation (branching stage, 52 DAS) the initial symptoms of the disease were observed, with a severity range of 0.17 ± 0.11 to 1.34 ± 0.33 %, the latter in accession 26 (figure 5). In the second evaluation (formation of inflorescences, 63 DAS, the percentage of severity increased markedly and varied from 0.09 ± 0.08 to a maximum of 5.42 ± 3.25 %, corresponding to accession 267. In the third evaluation (flowering, 85 DAS) a reduction in severity was observed, and the range was between 0.05 ± 0.05 and 1.77 ± 0.1 %; this last value corresponded to accession 124.

Particularly susceptible to the disease, manifested mainly in the second evaluation, were accessions 26, 64, 124, 218 and 267, the latter being the one that showed the greatest severity. On the contrary, accessions 3, 24, 27, 37, 156, 215, 231 and 315, together with the Cupi variety, did not show important symptoms in any of the three phases of the crop development cycle (figure 5).

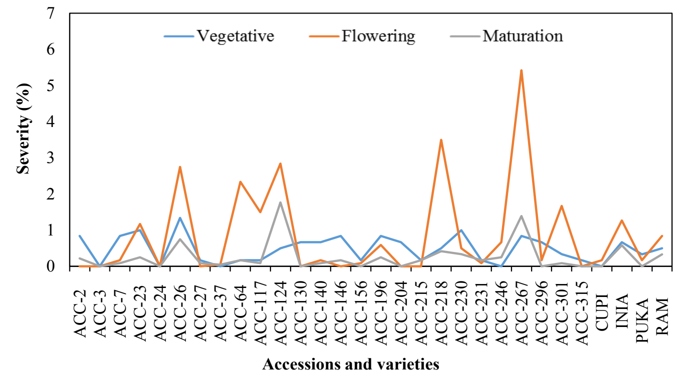


**Figure 5. Fluctuation in the severity of mildew caused by *Peronospora* sp. in accessions and varieties of cañihua (*Chenopodium pallidicaule*) in Puno, Peru (agricultural campaign 2019-2020).** Branching, inflorescence formation and flowering phases. The varieties are INIA, CUPI 406 and RAMIS.

Although the mildew attack was present in the three evaluations carried out, it stands out that the greatest severity was detected in the second evaluation (inflorescence formation) (figure 6). However, when trying to relate the severity of the disease at that time with grain yield, no association was obtained (p = 0.3843), which indicates that not even the highest levels of severity were able to significantly affect crop grain yield (figure 7). Future studies could determine if the high tolerance in the flowering stage is associated with the climatic conditions existing at that time. Cruces *et al.* (2016) and Rodríguez *et al.* (2020) also highlighted the high tolerance of cañihua to the attack of diseases, which is associated with its condition of rustic cultivation and native to highplains.

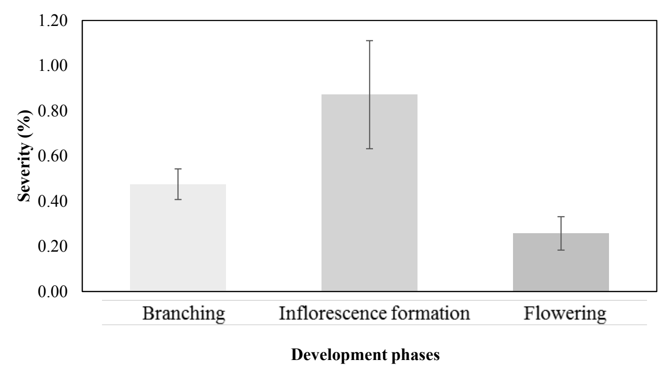


**Figure 6. Mean values of the severity of downy mildew (*Peronospora* sp.) depending on the development phase of cañihua (*Chenopodium pallidicaule*) cultivation in Puno, Peru (2019-2020 campaign).** The vertical bars above the columns indicate the standard error.

Regarding the AUDPC, the detected values were low and ranged from 0 to 173 ± 13.29. Accession 267 was the most affected by the disease followed by accessions 218, 124, 26 and 64 with approximate values of 106 ± 7.33, 102 ± 12.83, 98 ± 21.08 and 67 ± 14.67, respectively. On the contrary, in accessions 3 and 24 the disease did not appear. In the case of the varieties, the AUDPC values fluctuated from 4.58 ± 0.42 to 48.58 ± 11.25 (figure 8). In general, these values represent a low level of pathogen damage when compared to the values of 2,161 (Aguilar *et al.*, 2020) and 442 (Risco and Mattos, 2015) found in control quinoa plants.

When observing the grain yields of the plants in relation to the AUDPC, it stands out that accessions 23 and 146 showed the highest yield values with 19.25 ± 3.75 and 18.80 ± 7.6 $g.plant^{-1}$, respectively, and the lowest values of AUDPC, which would indicate that they present tolerance to the disease compared to accessions 230, 301 and 64, which showed the lowest yields with 6.20 ± 0.5; 6.35 ± 1.65 and 7.45 ± 1.45 $g.plant^{-1}$, respectively, with AUDCP values close to or greater than 40. Likewise, it was observed that accession 267 was the one that best tolerated the disease, because it presented a greater pathogen attack but a high grain yield about 16.50 ± 0.1 $g.plant^{-1}$ (figure 8).

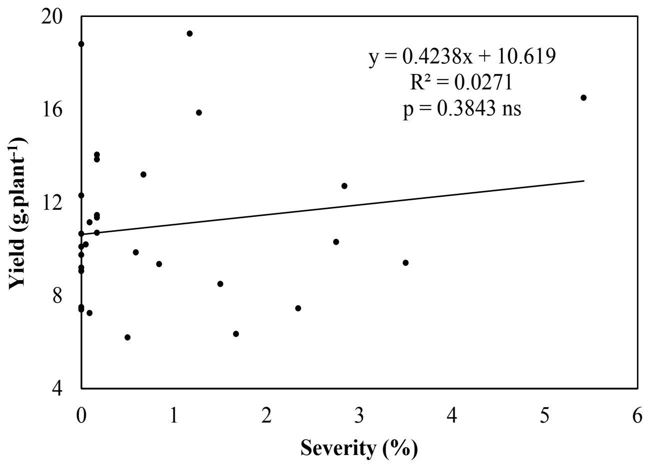


**Figure 7. Regression analysis between severity percentage of downy mildew (*Peronospora* sp.) and grain yield in cañihua (*Chenopodium pallidicaule*) cultivation in Puno, Peru (2019-2020 agricultural campaign).**

The presence of mildew was not significant in the accessions and varieties, because the species C. pallidicaule proved to be a crop resistant to biotic factors, whose grain yield was not affected by the disease, which agrees with what Rodríguez *et al.* to (2020), who reported cañihua as a vigorous and strong crop that does not present insect-plagues or diseases that significantly affect its development and growth.

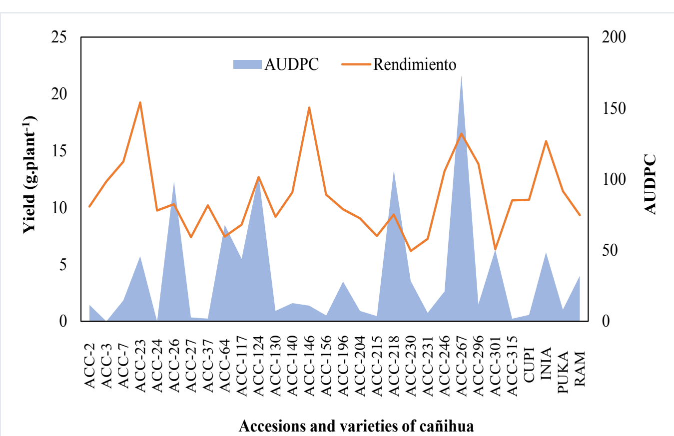


**Figure 8. Grain yield and area under the disease progress curve (AUDPC) caused by *Peronospora* sp. in accessions and varieties of cañihua (*Chenopodium pallidicaule*) in Puno, Peru (agricultural campaign 2019-2020).** The varieties are INIA, CUPI 406 and RAMIS.

## Conclusions

The kcona kcona moth (*Eurysacca quinoae*) is the most important insect pest that appeared in cañihua (*C. pallidicaule*) crop, but without reaching the threshold of economic damage. As secondary and occasional pests are *Macrosiphum euphorbiae*, *Myzus persicae*, *Epitrix yanazara* and *Frankliniella* spp.

The crop showed less severity of downy mildew (*Peronospora* sp.), and even accessions 3 and 24 did not contract the disease. For its part, accession 267 presented the highest severity of infection and the largest area of disease progress, but was tolerant to it by maintaining a high grain yield.

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