

DOI 10.7764/rcia.v46i2.2142

RESEARCH PAPER

## Agronomic characterization of quinoa (*Chenopodium quinoa* Willd.) progeny from close and distant self-fertilized $s_5$ simple crosses

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### Abstract

**E. Chura, Á. Mujica, B. Haussmann, Karl Smith, S. Flores, and A.L. Flores. 2019. Agronomic characterization of quinoa (*Chenopodium quinoa* Willd.) progeny from close and distant self-fertilized  $s_5$  simple crosses. Cien. Inv. Agr. 46(2): 154-165.** The present research was carried out at the research and production center (CIP) of Camacani. The objective was to agronomically characterize the self-fertilized  $S_5$  progeny originating from simple crosses that were genetically distant and close. We worked with six genetically distant simple crosses, Huariponcho  $\times$  Kancolla, Salcedo INIA  $\times$  Huariponcho and Pasankalla  $\times$  Kancolla, and three genetically close crosses, Salcedo INIA  $\times$  Pink Pandela, Negra Collana  $\times$  Kancolla and Salcedo INIA  $\times$  Negra Collana. Seeds were obtained from a plant breeding program by hybridization, and molecular markers were used to estimate genetic distances for the generation of new cultivars. The results show that the highest plant height occurred for the cross Pasankalla  $\times$  Kancolla, with 93.39 cm, followed by Salcedo INIA  $\times$  Pandela Rosada, with 88.88 cm, and the lowest height was presented by the cross Negra Collana  $\times$  Kancolla, with 69.50 cm. The largest diameter of the stem occurred for the Pasankalla  $\times$  Kancolla cross, with 14.49 mm, followed by the cross Salcedo INIA  $\times$  Pandela Rosada, with 13.49 mm; the cross Negra Collana  $\times$  Kancolla presented the smallest stem diameter, with 9.70 mm. The longest panicle length was recorded for the cross Pasankalla  $\times$  Kancolla, with 28.45 cm, followed by Salcedo INIA  $\times$  Pandela Rosada, with 27.49 cm, and the shortest panicle length occurred for the cross Salcedo INIA  $\times$  Negra Collana, with 24 cm. The largest panicle diameter was presented by the cross Pasankalla  $\times$  Kancolla, with 8.73 cm, followed by Salcedo INIA  $\times$  Pandela Rosada, with 7.73 cm, and the smallest panicle diameter was presented by the cross Negra Collana  $\times$  Kancolla, with 5.75 cm. The best 1,000 grain weight was presented by the cross Salcedo INIA  $\times$  Negra Collana, with 3.80 g and a grain diameter of 2.20 mm, followed by the cross Salcedo INIA  $\times$  Huariponcho, with 2.48 g and a grain diameter of 1.78 mm and the lowest 1,000-grain weight was presented by the cross Negra Collana  $\times$  Kancolla, with 2.09 g and a 1.64 mm grain diameter. The best yield was obtained by the cross Huariponcho  $\times$  Kancolla, with 5,099.28 kg ha<sup>-1</sup>, followed by the cross Salcedo INIA  $\times$  Huariponcho, with 5,064.71 kg ha<sup>-1</sup>; the lowest yield was presented by Collana Negra  $\times$  Kancolla, with 2,836.55 kg ha<sup>-1</sup>.

**Keywords:** Crosses, genetic improvement, progeny self-fertilization, quinoa.

## Introduction

Quinoa (*Chenopodium quinoa* Willd.), is a native species of the Andes and has been domesticated and cultivated by different indigenous cultures for many years (Delgado *et al.*, 2009). Quinoa has since been cultivated in a wide range of environments in South America, North America, Europe and Asia, Bhargava and Srivastava (2013). Underutilized cultivation of this species has recently gained attention because of its ability to adapt to extreme environmental conditions (Geerts *et al.*, 2009).

Quinoa adapts well in response to stressful environmental factors such as drought, salinity and frost (Suracheth, 2014). It is for these reasons why this species is being revalued as an alternative crop species for the production of food in several countries and worldwide, reaching great importance in international markets such as those in the USA, Japan, and Europe (Mujica *et al.*, 2013). In this context, quinoa has undergone various selection processes to obtain desirable

traits, for cultivation and for consumption by people in different cultures and territories in South America (Bazile *et al.*, 2014).

Agricultural production needs to increase according to the growth of the global population, which occurs concurrently with increasingly low water availability. In areas with water restriction, species or genotypes capable of production under stress conditions must be selected (Garrido, 2013). Therefore, via the descriptors of characterization and evaluation of quinoa proposed by Bioersivity International (2013), the agronomic and morphological characteristics of the progeny of self-fertilized S5 quinoa lines were evaluated. The selected lines of self-fertilized S5 progeny from simple crosses (those genetically distant and close) are not characterized for six quinoa (*Chenopodium quinoa* Willd.) cultivars. Based on the above, this research aims to agronomically characterize the progeny from self-fertilized S5 plants from simple crosses that are genetically distant and close.

**Table 1.** Cultivars used as parents for simple crosses.

GENITORS	Salcedo INIA	Huari poncho	Choclito	Chullpi rojo	Pasan kalla	Negra Collana	Kanco lla	Pandela
CODE	1	2	3	4	5	6	7	8

**Table 2.** Single crosses of six quinoa varieties from self-fertilized S5s.

Genetic distance	Simple crosses	No. lines	Parents	Experimental unit
Distant	Huariponcho (HUA) × Kancolla (KCA)	196	Huariponcho Kancolla	198
	Salcedo INIA (SAL) × Huariponcho (HUA)	196	Salcedo INIA Huariponcho	198
	Pasankalla (PAS) × Kancolla (KCA)	196	Pasankalla Kancolla	198
	Salcedo INIA (SAL) × Pandela (PAN)	196	Salcedo INIA Pandela	198
Nearby	Negra Collana (COL) × Kancolla (KCA)	196	Negra Collana Kancolla	198
	Salcedo INIA (SAL) × Negra Collana (COL)	196	Salcedo INIA Negra Collana	198
Total experimental units				1188

## Materials and Methods

This research was carried out at the Center for Research and Production (CIP), Camacani, Faculty of Agrarian Sciences National University of the Altiplano – Puno, and was located between the following coordinates: 15° 14' 36" south latitude, 72° 28' 30" west longitude.

### Genetic material

Six parents were used (Table 1), and six progeny of self-fertilized S5 lines were evaluated (Table 2). The seeds were obtained from plant breeding program by hybridization. The genetic distances for the generation of new cultivars were estimated via molecular markers with the aim of creating relatively high genetic variability and a relatively high heritability coefficient in the search for hybrid vigor. We worked with three genetically distant crosses, Huariponcho × Kancolla, Salcedo INIA × Huariponcho and Pasankalla × Kancolla, and three genetically close crosses, Salcedo INIA × Pandela Rosada, Negra Collana × Kancolla and Salcedo INIA × Negra Collana.

### Planting

For planting, envelopes were prepared with 5 g of seed for each furrow and were sown with a continuous jet applicator at a density of 10 kg ha<sup>-1</sup> prior to the application of decomposed sheep manure at the bottom of each furrow. The distance between the furrow was 0.50 m, each line was 5 m long. At the time of the sowing, the seeds were not more than 2 cm in depth. Agricultural work was carried out in accordance with the crop requirements. For phytosanitary control, nothing was above the threshold of economic damage; only some larvae of *Eurysacca quinoae* Povolny were observed in the phase of physiological maturity. There was also an infestation of green aphids (*Myzus persicae*). As for disease, *Peronospora variabilis* Güss

was present at low severity and low incidence, so there was no need for any control.

### Characterization

Agronomic characterization was carried out according to the descriptors of Bioversity International (2013). One agronomic variable evaluated included the height of the plant (cm). These data were recorded at the physiological maturity of the crop, taking 10 plants at random per furrow. The measure was established from the base of the stem to the apex of the central panicle (Rojas and Padulosi, 2013). The diameter of the stem was evaluated from the middle part of the main stem with the help of a vernier caliper, evaluating 10 plants per furrow. When the diameter of the panicle was measured, the data were taken from the middle part of the panicle at the stage of physiological maturity, taking 10 plants per furrow; similar to determining the length of the panicle, the measurements were taken from the base to the apex of the panicle with the help of a tape measure, and 10 plants per furrow were measured.

Harvest was carried out manually according to the physiological maturity of each line with a moisture content of 12% and then was proceeded by the threshing of the panicle of the 10 evaluated plants; finally, we proceeded to separate the grains from the remaining plant material and the seeds were stored inside manila envelopes previously labeled with the name of the cross and replication. The grain yield per hectare was subsequently determined per plant for the 10 plants evaluated in each furrow; after cleaning the seeds of any impurities, they were weighed on an analytical balance. It was observed that this variable is strongly dependent on the genotype and, at the same time, on the variable components, including the diameter of the stem, plant height, the length and diameter of the panicle, and the diameter of the grain, among others. Statistical analysis of the data obtained was carried out

using the multivariate analysis was performed using the conglomerate technique.

## Results

### *Agronomic characterization*

The highest plant height was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 93.39 cm, followed by Pasankalla (PAS), with 89.84 cm, Salcedo INIA × Pandela Rosada (SAL × PAN), with 88.88 cm, Pandela (PAN), with 85.67 cm, Salcedo INIA (SAL × HUA), with 77.45 cm, Salcedo INIA (SAL), with 73.06 cm, Huariponcho × Kancolla (HUA × KCA), with 71.44 cm, Salcedo INIA × Negra Collana (SAL × COL), with 70.41 cm, Negra Collana × Kancolla (COL × KCA), with 69.50 cm, Kancolla (KCA), with 69.46 cm, Huariponcho (HUA), with 68.98 cm, and Negra Collana (COL), with 62.92 cm (Figure 1). The crosses showed great variation in terms of plant height. In addition to being a characteristic of each genotype, this variation occurred according to soil fertility and climatic conditions.

On the basis of the plant height of the parents and the results obtained from the crosses, we could conclude that the genotype-environment factor quoted by Kaisser (1968) was achieved in the data collected in this research. The same author

pointed out that the height of quinoa plants is strongly dependent on variety, with strong effects of locality and year.

### *Stem diameter*

The largest stem diameter was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 14.49 mm, followed by Pasankalla (PAS), with 14.49 mm, and pink Pandela (PAN), with 14.49 mm, Salcedo INIA × Padela Rosada (SAL × PAN), with 13.49 mm, Salcedo INIA, with 12.53 mm, Salcedo INIA × Huariponcho (SAL × HUA), with 12.50 mm, Salcedo INIA × Negra Collana (SAL × COL), with 10.75 mm, Kancolla (KCA), with 10.57 mm, Huariponcho × Kancolla (HUA × KCA), with 10.50 mm, Huariponcho (HUA), with 10.43 mm, Negra Collana (COL), with 9.74 mm, and Negra Collana × Kancolla (COL × KCA), with 9.70 mm (Figure 2). The crosses showed great variation in terms of stem diameter, which varied according to the characteristics of each genotype.

### *Panicle length*

The greatest length of the panicle was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 28.45 cm, followed by Salcedo INIA ×

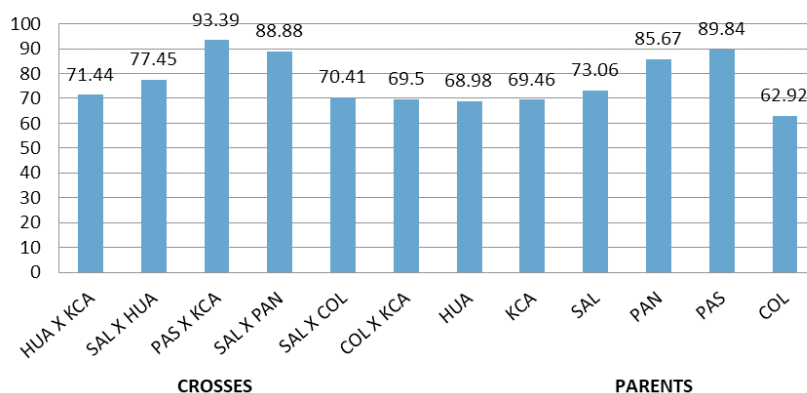


Figure 1. Plant height of crosses compared to that of the parents.

Pandela Rosada (SAL × PAN), with 27.49 cm, Salcedo INIA × Huariponcho (SAL × HUA), with 26.48 cm, Pandela Rosada (PAN), with 26.47 cm, Pasankalla (PAS), with 26.47 cm, Huariponcho × Kancolla (HUA × KCA), with 25.49 cm, Salcedo INIA (SAL), with 25.46 cm, Huariponcho (HUA), with 24.63 cm, Negra Collana × Kancolla (COL × KCA), with 24.46 cm, Kancolla (KCA), with 24.45 cm, Salcedo INIA × Negra Collana (SAL × COL), with 24.0.0 cm, and Negra Collana (COL), with 21.81 cm. These results indicate that the increase in plant height contributes to the increase in panicle length.

*Panicle diameter*

The largest panicle diameter was presented by the cross Pasankalla × Kancolla (PAS × KCA) ,with 8.73 cm, followed by Pasankalla (PAS), with 8.55 cm, Pandela Rosada (PAN), with 8.55 cm, Salcedo INIA × Padela Rosada (SAL × PAN), with x 7.73 cm, Salcedo INIA × Huariponcho (SAL × HUA), with 6.76 cm, Salcedo INIA (SAL), with 6.45 cm, Negra Collana × Kancolla (COL × KCA), with 5.75 cm, Salcedo INIA × Negra Collana (SAL × COL), with 5.75 cm, Huariponcho × Kancolla (HUA × KCA), with 5.74 cm, Negra Collana (COL), with

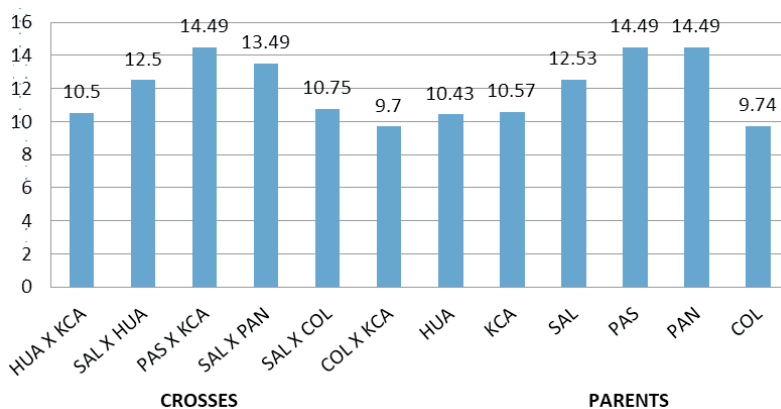


Figure 2. Stem diameter of crosses compared to that of the parents.

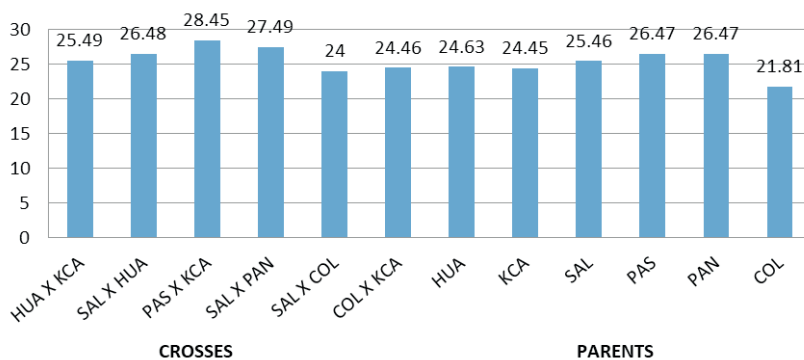


Figure 3. Panicle length of crosses compared to that of the parents.

5.53 cm, Huariponcho (HUA), with 5.48 cm, and Kancolla (KCA), with 5.43 cm. Figure 4 shows that the crosses have a greater panicle diameter than do the parents.

*Thousand-grain weight and grain diameter*

The best 1,000-grain weight was presented by the cross Salcedo INIA × Negra Collana (SAL × COL), with 3.80 g and a grain diameter was 2.20 mm, followed by Negra Collana (COL), with a 1,000-grain weight of 2.95 g and a grain diameter of 1.96 mm, Salcedo INIA (SAL), with a 1,000-grain weight of 2.86 g and a grain diameter with 1.94

mm, Pandela Rosada (PAN) and Pasankalla (PAS), with a 1,000-grain weight of 2.52 g and a grain diameter 1.80 mm, Salcedo INIA × Huariponcho (SAL × HUA), with a 1,000-grain weight of 2.48 g and a grain diameter 1.78 mm, Pasankalla × Kancolla (PAS × KCA), with a 1,000-grain weight of 2.47 g and a grain diameter of 1.82 mm, Salcedo INIA × Pandela Rosada (SAL × PAN), with a 1,000-grain weight of 2.38 g and a grain diameter of 1.78 mm, Huariponcho (HUA), with a 1,000-grain weight of 2.37 g and a grain diameter of 1.72 mm, Huariponcho × Kancolla (HUA × KCA), with a 1,000-grain weight of 2.32 g and a grain diameter of 1.67 mm, Kancolla (KCA), with a 1,000-grain weight of 2.28 g and a grain

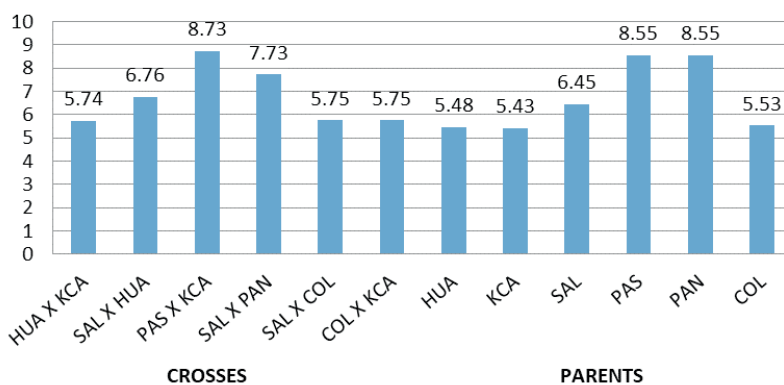


Figure 4. Panicle diameter of crosses compared to that of the parents.

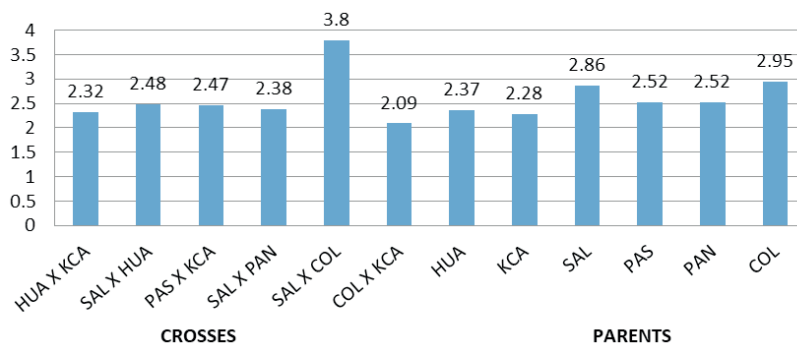


Figure 5. Thousand-grain weight and grain diameter of crosses compared to those of the parents.

diameter of 1.69 mm, and the cross Negra Collana × Kancolla (COL × KCA), with a 1,000-grain weight of 2.09 g and a grain diameter of 1.64 mm. Compared with their parents, no significant differences were found; therefore, there was no genetic gain for this variable.

#### Grain yield per hectare

The best grain yield per plant was presented by the cross Huariponcho × Kancolla (HUA × KCA), with 17 g, which therefore presented the best yield, with 5,099.28 kg ha<sup>-1</sup>, followed by Salcedo INIA × Huariponcho (SAL × HUA), with 16.88 g and a yield of 5,064.71 kg ha<sup>-1</sup>, Pasankalla × Kancolla (PAS × KCA), with 15.05 g and a yield of 4,514.24 kg ha<sup>-1</sup>, Salcedo INIA × Pandela Rosada (SAL × PAN), with 15 g and a yield of 4,499.84 kg ha<sup>-1</sup>, Huariponcho (HUA), with 13.32 g and a yield of 3,995.78 kg ha<sup>-1</sup>, Pasankalla (PAS) and Pandela Rosada (PAN), with 13.21 g and a yield with 3,960.90 kg ha<sup>-1</sup>, Salcedo INIA, with 12.25 g and a yield of 3,675.45 kg ha<sup>-1</sup>, Salcedo INIA × Negra Collana (SAL × COL), with 11.79 g and a yield of 3,597.82 kg ha<sup>-1</sup>, and Kancolla (KCA), with 11.79 g and a yield of 3,535.05 kg ha<sup>-1</sup>. The lowest yield was presented by the cross Negra Collana × Kancolla (COL × KCA), with 9.46 g and a yield of 2,836.55 kg, and its female genitor Negra Collana (COL), with 9.04 g and a yield of 2,711.40 kg ha<sup>-1</sup>.

## Discussion

### Plant height

The quinoa plant is erect and can reach heights varying from 30 to 300 cm depending on the type of quinoa, the genotype, the environmental conditions where it grows, and the fertility of the soil. Quinoa plants that grow in valleys are taller than those that grow above the 4,000 m asl and in cold zones. The plants reach relatively high heights in sheltered and fertile areas, their coloration varies with genotype and phenological phase and they are classified as C3 plants FAO (2011). Tapia (2000) reported that, according to the variety, quinoa plants can reach different heights. Benavides and Rodríguez (2007), who worked with lines of simple quinoa crosses in the municipality of Pasto (2,450 meters), reported lines with greater plant height compared to that of their parents; those authors considered medium-sized plants as ideal for selection. Moreover, Kaisser (1968) noted that the height of quinoa plants is strongly dependent on the variety, with strong effects of locality and year; in addition to genotype × environment interactions, characteristics such as maximum hours of light, temperature, solar radiation, and drip irrigation as well as other favorable factors directly influence the development of plants. Gómez and Aguilar (2016) indicated that the plant development is a consequence of growth and differentiation pro-

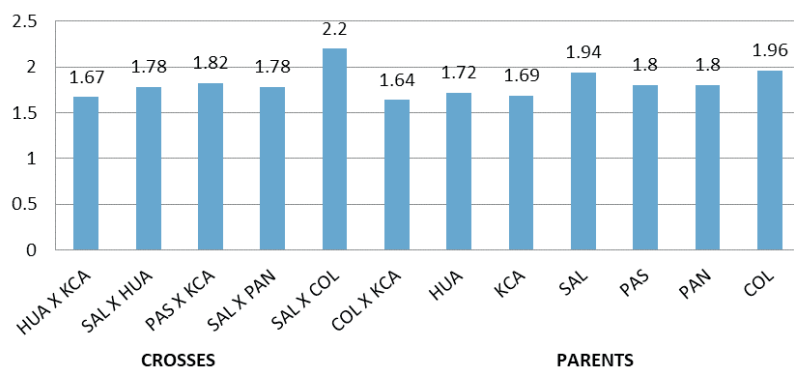


Figure 6. Grain diameter of crosses compared to that of the parents.

cesses that are carried out in the apical meristem by the successive differentiation and growth of primordia or groups of cells in the meristem. It was pointed out that the plant height from the base of the stem to the apex of the inflorescence varies from 0.5 m to more than 3 m depending on the variety, plant density, nutrition and the environment; generally, the varieties of the ecotypes grown in valleys are taller than those of the Altiplano. For improvements, Mujica *et al.* (2013) indicated that the objective of the genetic improvement of quinoa should be precisely to improve the architecture of plants to achieve a high production efficiency via large and thick panicles, thick stems and medium plant height.

*Stem diameter*

Alegria and Espíndola (1967) indicated that the stem diameter is affected by the distance between furrows; i.e., at a relatively great distance or at a low density, the diameter will be greater than that at a high density. However, Mujica (1983) indicated that the development of the diameter of the stem depends on the variety, which was verified by the catalog of commercial varieties of quinoa in Peru. (INIA, 2013). Moreover, Gómez and Aguilar (2016) indicated that the morphological characteristics

of a crop are closely related to the behavior of the natural environment where it develops and that the diameter of the stem varies with genotype, distance from sowing, fertilization, and cultivation conditions, varying from 1 to 8 cm in diameter. Tapia (2000) affirmed that, according to variety, quinoa can produce different stem diameters, affirming what Mujica *et al.* (2013) indicated. In addition, López and Hidalgo (1994) indicated that the ecotypes that originate from the southern Altiplano generally have thick stems, which enables withstanding the strong winds that are present in that part of the Altiplano. Likewise, Gómez and Aguilar (2016) and Zamudio (2013) pointed out that the stem becomes cylindrical and that as its distance from the ground increases, it becomes angular at the nodes of leaves and branches; the thickness of the stem is also variable, as it is greater at the base than at the apex, depending on the genotype and areas where it develops.

*Panicle length*

Gómez and Aguilar (2016) indicated that plant development is a consequence of processes of growth and differentiation that are carried out in the apical meristem; with regard to this characteristic, Mujica *et al.* (2013) mentioned that the length of

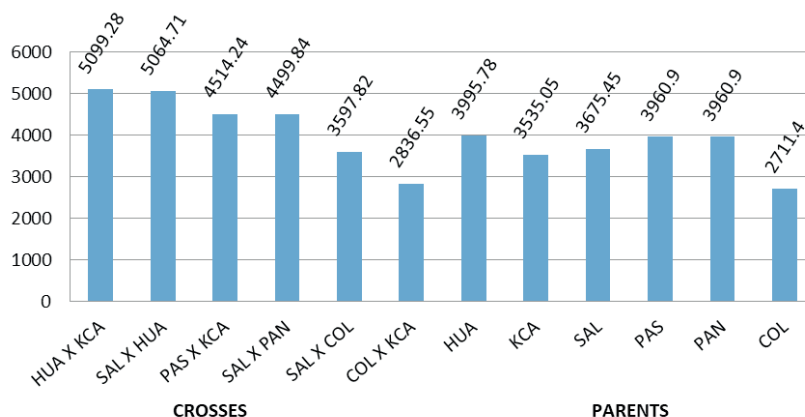


Figure 7. Performance per hectare of crosses compared to that of the parents.



the panicle is variable, depending on the genotype, type of panicle, place where it develops, distance, plant density, and soil fertility conditions; moreover, the interactions of these factors lead to variation in the length of the panicle. Delgado and Benavides (2000) reported panicle lengths between 22 and 40 cm and relate this component to plant height, specifically increased plant height, and increased panicle length. On the basis of the aforementioned considerations, we conclude that the length of the panicle is variable depending on the genotype, type of quinoa, where it develops and the conditions of soil fertility, reaching from 30 to 80 cm in length and 5 to 30 cm in diameter. These facts are related to the number of seeds per panicle, which range from 100 to 300, large panicles that yield up to 500 grams per inflorescence have been reported.

#### *Panicle diameter*

With respect to the diameter of the panicle, we point out that the inflorescence of quinoa is clustered by the arrangement of flowers in the cluster and is considered a panicle. In this regard, Quisocala (2000) noted that glomerulate inflorescences are considered the primitive form and can be loose or compact; this characteristic is strongly related to crop yield. When observing the diameter of panicles, Tapia (2013) noted that in some panicles, it was possible to observe a sectorial chimera that makes half of the panicle green and the other half red, which is called "Misa quinoa".

#### *Thousand-grain weight and grain diameter*

Similar results were obtained by Inguilan and Pantoja (2007) and Benavides and Rodríguez (2007), who evaluated quinoa accessions in Córdoba and Pasto at heights of 2,800 m asl and 2,710 m asl, respectively. The weight of seed in grams and the grain diameter are closely related to the height of the plant and the diameter of the panicle, which in turn are related to other factors, such as soil type, variety and environmental factors.

#### *Yield per hectare*

According to Bonifacio (2013) yield is the result of genetic, environmental and genetic-environment interactions, where the genetic part, which is inherited, is important from the point of view of improvement, Mujica and Apaza (2002) indicated that performance is obviously a complex characteristic, as it is the product of a series of causal factors such as soil nutrition, plant density, good water supply, solar radiation, and climatic factors that act independently or interact together, However, Hidalgo (2003) indicated that photoperiod and/or solar radiation influences the vegetative period but does not influence grain yield; in our opinion, performance is influenced by temperature and, more specifically, thermoperiodicity. On the other hand, Gallardo *et al.* (1997) pointed out that the growth of plants is much higher under a regime of thermal fluctuations than under a constant temperature, the former of which is known as thermoperiodicity. The higher the night temperature is, the greater the loss of substances in relation to those acquired photosynthetically during the day. In contrast, Ayala *et al.* (2004) indicated that low temperatures at night will lead to a decrease in respiratory loss (in the form of CO<sub>2</sub>, as occurs in the autumn and winter months. The results obtained in the present study indicate that, for the seed yield per plant (g plant<sup>-1</sup>) of the parents used to obtain the simple crosses, Salcedo INIA is one of the parents with a relatively high seed yield per plant (g plant<sup>-1</sup>), and according to cross 3 (Salcedo INIA × Negra Collana), 53.10 g/plant is dominant for yield seed per plant (g plant<sup>-1</sup>), and Negra Collana is considered recessive. These results suggest that crop yields have a close relationship with variety, type of soil, and environmental factors, as indicated by the authors mentioned above.

#### **Conclusions**

The self-fertilized S5 progeny from simple, genetically distant and close crosses were characterized agronomically. Evaluation of the variables showed

the following behavior: The greatest plant height was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 93.39 cm, followed by Salcedo INIA × Pandela Rosada (SAL × PAN), with 88.88 cm, and the lowest plant height was presented by the cross Negra Collana × Kancolla (COL × KCA), with 69.50 cm.

The largest stem diameter was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 14.49 mm, followed by the cross Salcedo INIA × Pandela Rosada (SAL × PAN), with 13.49 mm, and the Negra Collana × Kancolla (COL × KCA) presented the smallest stem diameter, with 9.70 mm.

The greatest panicle length was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 28.45 cm, and Salcedo INIA × Pandela Rosada (SAL × PAN), with 27.49 cm, and the shortest panicle length was presented by the cross Salcedo INIA × Negra Collana, with 24 cm.

The largest panicle diameter was presented by the cross Pasankalla × Kancolla (PAS × KCA), with 8.73 cm, followed by Salcedo INIA × Pandela Rosada (SAL × PAN), with 7.73 cm, and the smallest diameter of the panicle was presented by Negra Collana × Kancolla (COL × KCA), with 5.75 cm.

The best 1,000-grain weight was presented by the cross Salcedo INIA × Negra Collana (SAL × COL), with 3.80 g and a grain diameter of 2.20 mm, followed by the cross Salcedo INIA × Huariponcho (SAL × HUA), with 2.48 g and a grain diameter of 1.78 mm; the lowest 1000-grain weight was presented by the cross Negra Collana × Kancolla (COL × KCA), with 2.09 g and a grain diameter of 1.64 mm.

The best performance was by presented the cross Huariponcho × Kancolla (HUA × KCA), with 5,099.28 kg ha<sup>-1</sup>, followed by the cross Salcedo INIA × Huariponcho (SAL × HUA), with 5,064.71 kg ha<sup>-1</sup>; the lowest performance was presented by the cross Negra Collana × Kancolla (COL × KCA), with 2,836.55 kg ha<sup>-1</sup>.

## Resumen

**E. Chura, Á. Mujica, B. Haussmann, Karl Smith, S. Flores, y A.L. Flores. 2019. Caracterización agronómica de la progenie de la quinua (*Chenopodium quinoa* Willd.) de cruces simples autofecundados cercanos y lejanos. Cien. Agr. 46(2): 154-165.** La presente investigación se llevó a cabo en el Centro de Investigación y Producción (CIP) de Camacani. El objetivo era caracterizar agronómicamente a la progenie S5 autofecundada procedente de cruces simples que eran genéticamente distantes y cercanos. Trabajamos con seis cruces simples genéticamente distantes, Huariponcho × Kancolla, Salcedo INIA × Huariponcho y Pasankalla × Kancolla, y tres cruces genéticamente cercanos, Salcedo INIA × Pandela Rosa, Negra Collana × Kancolla y Salcedo INIA × Negra Collana. Se obtuvieron semillas de un programa de mejoramiento de plantas por hibridación y se utilizaron marcadores moleculares para estimar las distancias genéticas para la generación de nuevos cultivares. Los resultados muestran que la mayor altura de la planta se produjo para la cruz Pasankalla × Kancolla, con 93,39 cm, seguido de Salcedo INIA × Pandela Rosada, con 88,88 cm, y la menor altura fue presentada por la cruz Negra Collana × Kancolla, con 69,50 cm. El diámetro más grande del tallo se dio en la cruz de Pasankalla × Kancolla, con 14,49 mm, seguido de la cruz de Salcedo INIA × Pandela Rosada, con 13,49 mm; la cruz de Negra Collana × Kancolla presentó el diámetro más pequeño del tallo, con 9,70 mm. La longitud de panícula más larga se registró para la cruz Pasankalla × Kancolla, con 28,45 cm, seguida del Salcedo INIA × Pandela Rosada, con 27,49 cm, y la longitud de panícula más corta se registró para la cruz Salcedo INIA × Negra Collana, con 24 cm. El mayor diámetro de panícula fue presentado por la cruz Pasankalla × Kancolla, con 8,73 cm,

seguido por Salcedo INIA × Pandela Rosada, con 7,73 cm, y el menor diámetro de panícula fue presentado por la cruz Negra Collana × Kancolla, con 5,75 cm. El mejor peso de 1.000 granos fue presentado por la cruz Salcedo INIA × Negra Collana, con 3,80 g y un diámetro de grano de 2,20 mm, seguido por la cruz Salcedo INIA × Huariponcho, con 2,48 g y un diámetro de grano de 1,78 mm y el peso más bajo de 1.000 granos fue presentado por la cruz Negra Collana × Kancolla, con 2,09 g y un diámetro de grano de 1,64 mm. El mejor rendimiento fue obtenido por el cruce Huariponcho × Kancolla, con 5,099.28 kg ha<sup>-1</sup>, seguido por el cruce Salcedo INIA × Huariponcho, con 5,064.71 kg ha<sup>-1</sup>; el menor rendimiento fue presentado por Collana Negra × Kancolla, con 2,836.55 kg ha<sup>-1</sup>.

**Palabras clave:** Autofecundación de la progenie, cruces, mejoramiento genético, quinua.

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