Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Agromorphological Characterization of F1 Progenies of Simple Crosses of Quinoa (Chenopodium Quinoa Willd.), under Greenhouse Conditions

Ernesto, Chura Yupanqui[1], Ángel, Mujica Sánchez[2] , Jessica Pinto Vargas[3,], Betzabé León Tacca[4], Ada Luz Flores Ortega[5]

[1] Universidad Nacional del Altiplano, Puno Perú, ernestochuray@yahoo.com
https://orcid.org/0000-0003-4227-220X
[2]Universidad Nacional del Altiplano, Puno Perú, amhmujica@yahoo.com
https://orcid.org/0000-0002-7013-8780
[3]Universidad Nacional de San Agustín, Arequipa Perú, jessicap12@hotmail.com
https://orcid.org/0000-0002-6090-9131
[4]Universidad Nacional del Altiplano, Puno Perú, betsale@yahoo.es
https://orcid.org/0000-0002-4343-2431
[5]Universidad Peruana Unión, Lima Perú, adaflores1624@gmail.com https://orcid.org/0000-0003-0565-9720
Financiamiento económico: Universidad Nacional del Altiplano Puno Perú
Correo Institucional: rectorado@unap.edu.pe
Dirección: Avda. El Sol No 329 Telef. (051)352206, Telefax (051) 368590 Casilla Postal 291

ABSTRACT

The present research was carried out under greenhouse conditions, whose objectives were: to evaluate the agromorphological characterization of the F1 progenies of eight simple crosses of quinoa (Chenopodium quinoa Willd.), obtaining and evaluating seeds of the F1 progenies; seed from 22 simple crosses whose parents were eight cultivars of quinoa was used, placing one seed per bag. After 50 days flowering began, the panicle was covered with glassine paper bags in order to self-fertilize the flowers and avoid cross-pollination. The variables studied were 9, 2 for morphological characterization and 7 for agronomic evaluation. Analysis of variance (ANVA) was used, with F tabulated at level = 0.05 and Tukey's test at error level = 0.05, (SAS program). The results in the SAS program indicate: Morphological Characteristics; Cross 18 (Chullpi rojo x Pandela) obtained the largest stem diameter (1.65 cm), cross 15 (Chullpi rojo x Pasankalla) obtained the largest panicle length (92. 83 cm); Agronomic characteristics; Cross 7 (Huariponcho x Pasankalla) had the lowest days to emergence with 4.25 days, and cross 13 (Choclito x Kcancolla) had the highest number of days to emergence with 8.67 days. Also, less days to flowering were observed with 58 days, cross 15 (Chullpi rojo x Pasankalla) had the highest height at harvest maturity with 1. 99 cm, cross 2 (Salcedo INIA x Pasankalla) reached the lowest number of days to harvest maturity with 138.75 days, cross 3 (Salcedo INIA x Negra Collana) had the highest grain yield per plant 53.10 g/plant, the highest grain size corresponds to cross 3 (Salcedo INIA x Negra Collana) with 2.12 mm and the lowest grain size for cross 20 (Huariponcho x

Choclito) with 1.66 mm, the lowest number of seeds per gram was observed for cross 20 (Huariponcho x Choclito) with 1.66 mm; the highest grain yield per plant was observed for cross 3 (Salcedo INIA x Negra Collana) with 2.12 mm and the lowest grain size was observed for cross 20 (Huariponcho x Choclito) with 2.12 mm; the highest grain size corresponds to cross 3 (Salcedo INIA x Negra Collana) with 2.12 mm and the lowest grain size was observed for cross 20 (Huariponcho x Choclito) with 1.66 mm; the highest grain yield per plant was observed for cross 3 (Salcedo INIA x Negra Collana) with 2.12 g/plant, the lowest grain size corresponds to cross 3 (Salcedo INIA x Negra Collana) with 1.12 mm and the lowest grain size for cross 3 (Salcedo INIA x Negra Collana) with 2.12 mm, the lowest number of seeds per gram was obtained by cross 3 (Salcedo INIA x Negra Collana) with 373.50 seeds/g, and the highest number of seeds per gram was obtained by cross 9 (Huariponcho x Kcancolla) with 648.46 seeds/g.

Key words: quinoa, self-fertilization, single crosses, seed.

INTRODUCTION

The world food crisis, global warming and the demand for products of high nutritional value, suggest the consumption of products with high nutritional value, forcing to see alternatives to supply a large-scale demand Andean grains have a great opportunity here (FAO, 2011).

Quinoa is a rustic crop that can be planted from sea level to 4000 meters above sea level and in natural regions such as the coast, highlands and even in the jungle. It is also considered as a nutraceutical food in the world, for its nutritional and medicinal quality characteristics and for being a complete and balanced food (Mujica et a*l* 2013).

The protein content of quinoa is higher than milk, meat and fish, rich in vitamins, calcium, iron and phosphorus, has a dozen essential amino acids involved in development, is easily digestible, low in gluten and cholesterol-free (Ayala et al 2004). Therefore, quinoa is a valuable food source that has gained importance in many countries around the world.

On the other hand, (Kuljanabhagavad and Wink 2009), point out that genetic gain as a percentage of the mean was highest for dry weight/plant, followed by seed yield and inflorescence length. Thus, genetic variability translates into morphological characteristics of field crops (Bhargava et al., 2007).

Likewise, (Mujica et al 2013) point out that the genetic improvement of quinoa is of enormous importance in the country, since it makes it possible to obtain new varieties with agronomic characteristics desired and longed for by the farmer.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

(Hidalgo, 2003) also points out that genetic variability can be achieved by selection or hybridization; therefore, hybridization is the starting point for obtaining new genetically improved varieties in the future that are tolerant to water stress, low temperatures, salinity with low saponin content and climate change. On the other hand, (Repo Carrasco 2003) points out that the pericarp of the quinoa grain contains saponins, which give it a bitter taste and must be eliminated so that the grain can be consumed.

MATERIALS AND METHODS

This study was carried out in a controlled environment (greenhouse), using seeds from the cross of eight quinoa genitors (Table 1).

Table 1. Cultivars used as parents for the single crosses

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

Source: Own elaboration.

Table 2**.** Single crosses used in the research.

Cross	N° of seed	Cross	N° of seed	Cross	N° of seed	Cross	N° of seed	Cross	N° of seed	Cross	N° of seed	Cross	N° of seed
1x2	4	2x3	17	3x5	4	4x5	12	5x8	2	6x7	9	7x8	17
1x5	4	2x4	6	3x6	2	4x6	6			6x8	7		
1x6	4	2x5	12	3x7	6	4x7	4						
1x8	4	2x6	20	3x8	7	4x8	4						
		2x7	13										
		2x8	17										

Sowing

Sowing was done manually, one seed was placed per bag and then carefully covered. After sowing, a heavy irrigation was given to ensure germination. Subsequently, drip irrigation and sprinkler irrigation were used, being the most frequent irrigations in the early stages of development, two hilling was done, the first was done at 40 days and the second at 65 days after sowing, manually.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Figure 1. Experimental area, sowing and irrigation of self-fertilized F1 progenies for 22 Single crosses in greenhouse.

Figure 2. Self-fertilization of progeny F1 using glassine paper bags

Self-fertilization

The technique consists of isolation prior to anthesis in order to avoid cross-pollination. It is a simple process, however, great care was taken throughout the process, for it were necessary glassine paper to create envelopes of 30 x 40, 10 x 15 and 5 x 10 cm for panicle and glomerulus, small fine-tipped scissors, rubber bar, 32 mm clips; glassine paper bags were placed in all the panicles before the flowers began to open, this happened 50 to 60 days after planting.

Harvesting

Harvesting was carried out 20 days after 100% of the plants reached physiological maturity, when the apical leaves were dry and the stalk was almost dry; at that time the grain had not yet fallen. The harvest was carried out by cutting the plant in two parts so that the main panicle (apical) was taken as the primary harvest and the secondary glomeruli (lower part of the plant) as the second part, it was applied in this way for the safety of self-fertilization.

Statistical analysis

The morphological characters: stem diameter, panicle length; the agronomic characters: days to emergence, days to first flowering, plant height, days to full maturity, seed yield per plant, number of seeds per gram, grain size, were evaluated through the analysis of variance (ANVA) with F tabulated at 0.05 level; to evaluate the significance, Tukey comparison of means between treatments was applied, at 0.05 level. 05 of error, where the treatments were constituted by the 22 crosses, the ANVA analyses (analysis of variance) were made with the SAS program.

RESULTS AND DISCUSSION

Analysis of variance of morphological characters of the F1 progenies of the 22 crosses.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Stem diameter

Table 3 shows the Tukey significance test for stem diameter, showing the largest diameter in cross 18 (Chullpi rojo x Pandela) with 1.65 cm. and the smallest stem diameter in cross 21 (Negra Collana x Pandela) with 1.02 cm. In this regard, (Lopez and Hidalgo, 1994) indicate that the Pandela ecotype comes from the southern highlands are precocious in vegetative cycle, large and bitter grain, grain size 2. 2 mm; then the ecotypes of the southern zone of the Andes have generally thickened stems, a fact that allows them to withstand the strong winds that occur in this part of the altiplano. It also allows us to affirm that this accession is dominant over Chullpi rojo; it also indicates that this genotype has a disadvantage its high susceptibility to mildew, it is not tolerant to drought, the color of grain once it reaches its physiological maturity is white and its yield is 2500 kg/ha. (Gómez and Aguilar, 2016) point out that the diameter of the stem is variable with genotypes, planting spacing, fertilization, growing conditions, varying from 1 to 8 cm in diameter.

Table 3. Stem diameter (cm) for self-fertilized F1 progenies from 22 single crosses

Crosses	Mean (cm)	Tukey					
18	1,65000	a					
2	1,60000	a	b				
4	1,57500	a	b	c			
1	1,50000	a	b	c	d		
11	1,47500	a	b	c	d		
5	1,45882	a	b	c	d		
12	1,45000	a	b	c	d		
13	1,43333	a	b	c	d		
15	1,40833	a	b	c	d	e	
8	1,38000	a	b	c	d	e	
7	1,30833		b	c	d	e	f
16	1,30000		b	c	d	e	f
19	1,30000		b	c	d	e	f
17	1,30000		b	c	d	e	f
9	1,29231			c	d	e	f
20	1,23333				d	e	f
10	1,21176				d	e	f
6	1,20000				d	e	f
3	1,11176					e	f
22	1,07500						f
14	1,07143						f
21	1,02857						f

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Table 4. Analysis of variance corresponding to Stem diameter (cm) for Self-fertilized F1 progenies from 22 single crosses

Sources of variability	Degrees of freedom	Sum of squares	Mean squares		F Calculated
Crosses	21	4.1904169	0.19954366		10.88
Error	159	2.91543945	0.0183361		**
Total	180	7.10585635			

C.V. 10.34 %; Mean: 10.31 cm.

When the analysis of variance was carried out, a CV of 10.34% was obtained with high statistical significance. (Alegría and Espíndola 1967) indicate that the diameter of the stem is affected by the distance between rows, that is to say that at a greater distance or at a low density the diameter will be greater than at a high density or at a smaller distance between rows. However, (Mujica 1983), points out that the development of stem diameter depends on the variety, which is verified by the catalog of commercial varieties of quinoa in Peru. (INIA, 2013) shows parameters for stem diameter (Table 5)

(Gómez and Aguilar 2016), note that the stem at the junction with the root collar, is cylindrical and as it moves away from the ground it becomes angular in the areas of birth of leaves and branches. The bark is firm and compact formed by strong and lignified tissues. When the stems are young the pith is soft, when the stems mature the pith is spongy and dry and at harvest it falls out and the stem is hollow or empty. For his part, (Zamudio, 2013) points out that the stem is cylindrical at the neck of the plant and angular from the ramifications, since the leaves are alternate giving an exceptional configuration, the thickness of the stem is also variable being greater at the base than at the apex, depending on the genotypes and areas where it develops. There are widely branched genotypes (valley quinuas) even from the base (sea level quinuas) and others with a single stem (highland quinuas), as well as intermediate genotypes, depending on the genotype, planting density and availability of nutrients, the coloration of the stem is variable, from green to red, often has streaks and also pigmented red or purple axils.

Table 5. Stem diameter (cm) for parents used to obtain single crosses.

GENITOR CODE	1	2	3	4	5	6	7	8
STEM	1,9-2,3	2,0-2,2	2,1-2,5	1,0-1,1	1,3-1,7	1,1-1,3	1,1-1,2	2,4-2,5

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

DIAMETER (cm)								

In Table 5, for greater stem diameter and smaller diameter, the Pandela genitor is found in both crosses, being a dominant allele, when crossed with Chulpi red, expressed in stem diameter for cross 18 (Chullpi red x Pandela) and recessive in cross 21 (Negra Collana x Pandela).

Panicle length

Table 6 shows the Tukey significance test for panicle length, showing the greatest length for cross 15 (Chullpi rojo x Pasankalla) with 92.83 cm. This does not differ statistically with cross 8 (Huariponcho x Negra collana) with 81.55 cm, but with the rest of the crosses, obtaining the smallest panicle length in cross 4 (Salcedo INIA x Pandela) with 43.00 cm, In contrast to these results, (Grace, 1985 and Tapia, 1994) mention that the Pasankalla cultivar is distinguished for being a plant with red stem and white stem, the seed color is lead, the plant height reaches up to 1.40 m and grain yield is 2,510 kg/ha, this fact allows us to deduce that the panicle length is closely related to the yield, and also note that the saponin content are traces (sweet).

Table 6. Panicle length (cm) for self-fertilized F1 progenies from 22 single crosses.

Crosses	Means (cm)	Tukey
15	92,83300	a
8	81,55000	a b
9	77,07700	b
10	76,29400	b c
2	74,25000	b c d e
13	73,16700	b c d e f
16	69,33300	b c d e f g
12	68,00000	c d e f g
7	66,50000	c d e f g
14	65,85700	c d e f g
22	65,41200	c d e f g
5	65,05900	c d e f g
17	65,00000	c d e f g
18	63,25000	d e f g
19	62,50000	e f g
11	60,50000	f g
21	60,00000	g h
1	58,50000	g h

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

3	58,25000	g h
6	56,50000	g h
20	48,88900	h
4	43,00000	h

The CV was 8.49 %, which gives a reliability of the data obtained and a mean of 69.21 cm. The analysis of variance shows statistical differences, this is due to some characteristics of the Pasankalla accession, so the dominance is of this accession. (Grace, 1985 and Tapia, 1994) indicate that the vegetative cycle (days, average) is 144 days, the response to biotic and abiotic factors is susceptible to frost (-2°C) and hail; tolerant to mildew (Peronospora variabilis) and susceptible to bird attack (granivorous) and the uses given are for roasted flour, expanded, grained, ideal for cakes.

Table 7. Analysis of variance for panicle length (cm) for self-fertilized F1 progenies from 22 single crosses self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees of freedom	Sum of squares	Mean squares	F Calculated
Crosses	21	21876,73142	1041,74912	30,12
Error	159	5499,29068	34.58673	**
Total	180	27376,02210		

C.V. 8,49 %, Mean: 69,20 cm.

Table 8. Panicle length (cm) for parents used to obtain single crosses.

GENITOR CODE	1	2	3	4	5	6	7	8
PANICLE LENGTH (cm)	34-40	35-30	33-80	25-30	30-35	30-35	30-20	37-42

With respect to this character, (Mujica, et al 2013) mentions that panicle length is variable, depending on genotypes, types of panicle, place where it develops, distances, planting densities, fertility conditions, these interacting make variations in length. Meanwhile (Bonifacio, 1995). He points out that according to the shape of the panicle they can be Glomerulate or Amarantiform. In this research under greenhouse conditions, it was found that of the 181 plants evaluated, 48 plants (26.52%) were glomerulate and the rest 133 plants (73.48%) were amarantiform, proving that this variable is dominated by the place where it develops.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Analysis of variance of agronomic traits of F1 progenies of the 22 crosses.

Days to emergence

The values of days to emergence obtained in Table 9 show the Tukey significance test, with the lowest number of days to emergence for cross 7 (Huariponcho x Pasankalla) with 4.25 days, and the highest number of days to emergence for cross 13 (Choclito x Kcancolla) with 8.67 days. The results of the Tukey test show that the Huariponcho accession has influenced Pasankalla. (Alvarez, 2009) in this regard mentions that it is a cultivar more resistant to hailstorms and frost, it was collected in the district of Taraco (Puno), it began to be planted in small plots this quinoa is bitter and is usually more defensive against the attack of birds, it can only be planted in fertile areas, it is resistant to hailstorms, grain size 1.8 mm; for their part (Gomez and Aguilar 2016) state that quinoa seeds in suitable conditions of humidity, oxygen and temperature can germinate very quickly. Water is essential for the initiation of the process and the maintenance of proper metabolism. Soil temperatures are equally important for the initiation of the process.

Table 9. Days to Emergence (days) for self-fertilized F1 progeny from 22 single crosses.

Crosses	Mean (days)	Tukey
3	8.66670	a
5	8.16670	a
8	8,00000	a b
	8,00000	a b
0	7,77780	a b c
	7,53850	a b c d
	7,47060	a b c d
9	7,00000	a b c d e
0	6,11760	b c d e f
2	6,05880	c d e f
6	6,00000	c d e f
2	6,00000	c d e f
	5,85000	d e f

1	5,75000	e f
7	5,50000	e f
	5,50000	e f
	5,50000	e f
	5,33330	e f
1	5,28570	e f
4	5,14290	e f
	5,00000	f
	4,25000	f

Table 10. Analysis of variance for Days to Emergence (days) for self-fertilized F1 progenies. From 22 single crosses.

Sources of variability	Degrees o freedom	Sum of square	Mean squares	F Calculated
Cruzas	21	254,8493075	12,1356813	16,79
Error	159	114,8965489	0,7226198	**
Total	180	369,7458564		

C.V. 13,26 %, Mean: 6,41 días

Table 11 shows the days to emergence for the parents; when compared with the crosses, the days to emergence are shorter, with parameters ranging from 4.25 to 8.67 days, with the environmental conditions present in the greenhouse having a great influence, such as the amount of light, humidity and temperature. According to the catalog of commercial quinoa varieties in Peru (INIA, 2013), in Table 11, the parents with the longest days to emergence are Pasankalla and Negra Collana, both with 9 days, with Pasankalla being found as a recessive when crossed with Huariponcho for days to emergence, resulting in Huariponcho being dominant and reaching the shortest days to emergence with cross 7 (Huariponcho x Pasankalla) with 4.25 days.

Table 11. Days to Emergence (days) for parents used to obtain simple crosses.

GENITOR CODE	1	2	3	4	5	6	7	8

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

EMERGENCY DAYS	7	7	7	7	9	9	7	7

Days to flowering

The values of days to flowering obtained are presented in Table 12, which shows that the cross that reached the lowest number of days to flowering is cross 7 (Huariponcho x Pasankalla) with 58 days, while the cross 13 (Choclito x Kcancolla) obtained the highest number of days to flowering with 79.67 days. In the glomeruli, flowering begins in the apical part and continues to the base. In each part of the glomerulus the hermaphrodite flowers open first and then the female flowers. Each flower is open from 5 to 13 days. From the opening of the first flower, the other flowers open within 15 days. Thus, the total flowering phase of a panicle takes 3 to 4 weeks. (Gómez and Aguilar, 2016) point out that this phase starts with the opening of the flowers. Hermaphrodite and pistillate flowers open at the same time and can be observed with the naked eye, especially hermaphrodite flowers with intense and bright yellow anthers. The opening of the flowers, in some varieties, begins in the hermaphrodite flower at the apex of the glomerulus and the flowers located in different parts of the glomerulus, in any part of the inflorescence. In other varieties the flowers open simultaneously in different glomeruli along the entire panicle.

Table 12. Days to flowering (days) for self-fertilized F1 progenies from 22 single crosses.

Crosses	Mean (Days)	Tukey
13	79,66700	a
1	76,75000	a b
14	75,71400	a b c
15	74,66700	a b c d
17	72,00000	b c d e
19	71,50000	b c d e f
11	69,50000	c d e f g
18	68,75000	c d e f g
8	68,70000	c d e f g
6	68,33300	d e f g
16	67,83300	d e f g
3	67,25000	e f g h
22	66,76500	e f g h i
4	66,00000	e f g h i j
21	64,71400	f g h i j k
5	63,11800	g h i j k
9	63,07700	g h i j k
20	63,00000	g h i j k
12	60,50000	h i j k
10	60,11800	i j k
2	59,50000	j k

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

7	58,00000	k

Table 13. Analysis of variance for days to flowering (days) for self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees of freedom	Sum of squares	Mean squares	F Calculated
Crosses	21	5520,954105	262,902576	26,73
Error	159	1563,985122	9,836384	**
Total	180	7084,939227		

C.V. 4,71 %, Mean: 66.54 days

The catalog of commercial varieties of quinoa in Peru (INIA, 2013), in days to flowering (Table 14), shows for the Huariponcho genitor 100 days, Pasankalla 116 days, with Pasankalla remaining recessive in the cross with Huariponcho (cross 7), dominating the earliness of Huariponcho. For cross 13 (Choclito x Kcancolla) with 79.67 days with more days to emergence and flowering, this cross is not showing good characteristics according to earliness. On the other hand, (Gómez and Aguilar, 2016) indicate that the flowers are sessile or pedicellate and are grouped in glomerules. The position of the glomerulus in the inflorescence and the position of the flowers within the glomerulus determine the size and number of grains or fruits.

Table 14. Days to flowering (days) for parents used to obtain single crosses.

GENITOR CODE	1	2	3	4	5	6	7	8
DAYS TO FLOWERING	95	100	97	98	116	90	116	90

Plant height.

The plant height values obtained at harvest are shown in Table 15, with the greatest height in cross 15 (Chullpi rojo x Pasankalla) at 1.99 m., and the lowest height in cross 21 (Negra Collana x Pandela) at 1.40 m. In Table 8, for panicle length, the greatest length was found for cross 15 (Chullpi rojo x Pasankalla) with 92.83 cm, as in Table 15, with the greatest plant height in the aforementioned cross, in this regard we note that there is a relationship between these characteristics. Plant development is a consequence of growth and differentiation processes that take place in the apical meristem, through the successive differentiation and growth of primordia or groups of lateral meristematic cells.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Table 15. Plant height (m) for self-fertilized F1 progenies from 22 single crosses.

Crosses	Means (m)	Tukey
15	1,99750	a
18	1,79500	a b
8	1,78850	a b
16	1,77330	a b
4	1,75000	a b
19	1,73500	a b
17	1,69250	a b
12	1,68000	a b
5	1,65940	a b
9	1,65850	a b
6	1,65500	a b
10	1,65350	a b
1	1,65000	a b
11	1,64750	a b
2	1,64750	a b
7	1,63420	a b
13	1,54830	b
14	1,52570	b
3	1,47000	b
20	1,46670	b
22	1,44590	b
21	1,40710	b

Table 16. Analysis of variance for plant height (m) for self-fertilized F1 progenies from 22 single crosses self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees of freedom	Sum of squares	Mean squares	F Calculated
Crosses	21	3,80060959	0,18098141	4,91
Error	159	5,85789097	0,03684208	**
Total	180	9,65850055		

C.V. 11,62%, Mean: 1,65 m

Plant height in quinoa is strongly dependent on the variety, with strong effects of localities and the behavior of the agricultural year; in addition to the genotype - environment interaction. (Kaiser, 1968) points out that the characteristics such as the greater number of hours of light, temperature, solar radiation, drip irrigation, favorable factors, directly influence the development of the plants. The catalog of commercial varieties of quinoa in Peru (INIA, 2013) for plant height for genitors and in mentioning the results obtained in the crosses we can conclude that the genotype-environment factor cited by (Kaisser 1968) would be fulfilled in data taken in greenhouse.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Table 17. Plant height (m) for parents used to obtain single crosses.

GENITOR CODE	1	2	3	4	5	6	7	8
PLANT HEIGHT (m)	1,5-1,7	1,8-1,9	1,5-1,6	0,9-1,0	1,3-1,4	1,2-1,3	1,0-1,1	1,6-1,8

For their part, (Gómez and Pando, 2016) point out that plant height, from the base of the stem to the apex of the inflorescence, varies from 0.5 m to more than 3 m; it depends on the variety, planting density, nutrition and environment. Generally, valley varieties are taller than those of the Altiplano.

6. Days to full maturity (harvest).

The values for days to full maturity are presented in Table 18, which shows that the cross that reached the lowest days to full maturity is Cross 2 (Salcedo INIA x Pasankalla) with 138.75 days. The cross 13 (Choclito x Kcancolla) with 175.33 days was the one with the longest day to maturity. (Grace, 1985 and Tapia, 1994) indicate that the vegetative cycle (days, average) of the Pasankalla accession is 144 days, it responds to biotic and abiotic factors, and is susceptible to frost (-2°C) and hail, tolerant to mildew (Peronospora variabilis) and susceptible to bird attack. Therefore, the performance of the Salcedo INIA accession is recessive against Pasankalla.

Table 18. Days to Harvest Maturity for Self-fertilized F1 progenies, From 22 single crosses

Crosses	Means (days)	Tukey						
13	175,33300	a						
18	170,00000	a	b					
15	169,33300	a	b					
17	168,00000	a	b	c				
11	166,00000	a	b	c	d			
16	164,66700	a	b	c	d	e		
14	163,14300	a	b	c	d	e		
20	159,22200	a	b	c	d	e	f	
19	158,00000	a	b	c	d	e	f	g
8	156,00000		b	c	d	e	f	g
22	154,94100		b	c	d	e	f	g
4	153,75000		b	c	d	e	f	g
9	151,84600		b	c	d	e	f	g
6	149,50000			c	d	e	f	g
21	148,85700				d	e	f	g
5	148,76500				d	e	f	g
3	148,50000				d	e	f	g
7	146,66700					e	f	g
12	143,00000						f	g
1	142,50000						f	g

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

10	140,76500	f g
2	138,75000	g

Table 19. Analysis of variance for days to harvest maturity for self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees of freedom	Sum of squares	Mean squares	F Calculated
Fuentes de variabilidad	Grados libertad	Suma de cuadrados	Cuadrados medios	F Calculada
Cruzas	21	15824,72488	753,55833	10,80
Error	159	11091,02097	69,75485	**
Total	180	26915,74586		

C.V. 5,41 %, Mean: 154,41 days

The duration of the crop cycle and of each of its stages is strongly linked to genetic factors. Consequently, there are long, intermediate and short cycle varieties. The catalog of commercial quinoa varieties in Peru (INIA, 2013), as mentioned the vegetative cycle for Salcedo INIA is 150 days for the Altiplano; 135 days for Valles Interandinos; 120 days for Costa, Pasankalla with a vegetative cycle of 144 for the Altiplano; 120 days for Valles Interandinos; 105 days for Costa, Kcancolla with a vegetative cycle of 170 days and Choclito with a vegetative cycle of 150 days for the Altiplano; 140 days for Valles Interandinos; 130 days for Costa.

Table 20. Days to Harvest Maturity for parents used to obtain single crosses.

GENITOR CODES	1	2	3	4	5	6	7	8
DAYS TO MATURITY HARVEST	150	160	150	140	144	138	170	140

Seed yield per plant

Table 21 shows the Tukey significance test for seed yield per g/plant, obtaining the highest yield in cross 3 (Salcedo INIA x Negra collana) with 53.10 g/plant, and the lowest seed yield per plant in cross 15 (Chullpi rojo x Pasankalla) with 26.27 g/plant. Regarding seed yield, (Lescano, 1994) mentions that it depends on the variety, in addition to the genotype-environment interaction; yield is evidently a complex character, since it is the product of a

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

series of casual factors that act actively or interact with each other, such as soil nutrition, plant density, good water supply, solar radiation, climatic factors, and so on.

Table 21. Seed yield per plant (g/plant) for self-fertilized F1 progenies from 22 single crosses.

Crosses	Mean (g/planta)	Tukey
3	53,10000	a
22	50,77900	a b
19	50,43000	a b
1	46,53200	a b c
6	45,50300	a b c
9	43,80600	a b c d
14	43,19900	a b c d
4	42,32500	a b c d
5	42,25600	a b c d
13	42,17000	a b c d
21	41,68300	a b c d
2	41,47200	a b c d
7	40,92000	a b c d
10	40,24200	a b c d
17	40,20100	a b c d
8	39,82200	a b c d
11	38,30900	b c d e
12	35,26600	c d e
16	34,98700	c d e
18	33,70000	c d e
20	30,49300	d e
15	26,27700	e

Table 22. Analysis of variance for seed yield per plant (g/plant) for self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees o freedom	Sum of square	Mean squares	F Calculated
Crosses	21	6972,12154	332,00579	9,20
Error	159	5739,26603	36,09601	**
Total	180	12711,3875		

C.V. 14,70 %, Mean: 40,86 g/plant

Photoperiod and/or solar radiation influences the vegetative period, but does not influence seed yield. Yield would then be influenced by temperature and more specifically by thermoperiodicity. Plant growth is much higher under a regime of thermal fluctuations than under a constant temperature, a fact known as thermo periodicity. The higher the night

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

temperature, the greater the loss of substances in relation to those acquired photosynthetically during the day. Low temperatures at night will lead on the contrary to a decrease in respiration losses (in the form of CO2); as occurs in the autumn and winter months. In Table 23, in seed yield per plant (g/plant) of parents used to obtain the simple crosses, we can observe that Salcedo INIA is one of the parents with the highest seed yield per plant (g/plant) and according to cross 3 (Salcedo INIA x Negra Collana) with 53.10 g/plant is dominant for seed yield per plant (g/plant) and Negra Collana in a recessive manner. (Gómez and Aguilar, 2016) points out that the seed is an achene of lenticular, ellipsoidal, conical or spheroidal shape, covered by the sepaloid perigonium or the floral sheaths that surround the fruit and are easily detached at maturity; however, in some cases it can remain attached to the grain even after threshing, making harvesting and industrial processing of the grains difficult.

Table 23. Seed yield per plant (g/plant) for parents used to obtain single crosses to obtain single crosses.

GENITOR CODE	1	2	3	4	5	6	7	8
RDTO SEED (g/ptant)	40-49	40-45	30-50	25-28	32-34	27-29	31-35	40-44

Number of seeds per gran

Table 24 shows the Tukey significance test for the number of seeds per gram, where it is observed that the numbers of seeds per gram were presented in a range of 373.50 and 648.46 seeds/g., obtaining the highest number of seeds per gram the cross 9 (Huariponcho x Kcancolla) with 648.46 seeds/g.This cross stands out for seed yield per plant, the results of this variable are directly related to the size of the seeds, both parents have smaller seed size; on the other hand, cross 3 (Salcedo INIA x Negra Collana) with 373.50 seeds/g, this cross has the lowest number of seeds per gram, this is due to the seed size of the Salcedo INIA parent, which is dominant over Negra Collana.

Table 24. Number of seeds per gram for self-fertilized F1 progenies from 22 single crosses.

Crosses	Mean (g/seed)	Tukey

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

9	648,46000	a				
12	623,50000	a	b			
6	621,00000	a	b			
20	615,33000	a	b			
5	602,41000	a	b			
7	598,50000	a	b			
22	597,00000	a	b			
8	586,95000	a	b			
10	572,71000	a	b			
21	572,29000	a	b			
11	563,75000	a	b	c		
13	528,67000	a	b	c	d	
1	506,25000	a	b	c	d	e
18	497,75000	a	b	c	d	e
17	487,50000		b	c	d	e
15	486,92000		b	c	d	e
16	481,83000		b	c	d	e
14	476,57000		b	c	d	e
4	416,50000			c	d	e
19	407,00000				d	e
2	380,25000				d	e
3	373,50000					e

Studies on this variable (seed size) are very little studied, the previously mentioned works indicate yield per hectare; however, there are studies on the color of the grain. In this regard Gómez and Aguilar (2016), point out that the color of the grains depends on the layer (husk) under observation. If the varieties maintain the sepaloid perigonium (tepals of the flowers) the colors are green, red and purple. If the pericarp is observed the colors can be white, cream, yellow, orange, red, pink, purple, brown, gray and black. (Mujica et al 2013), points out that the fruit is an achene, which is derived from a supero unilocular ovary and dorsiventral symmetry, has a cylindrical-lenticular shape, slightly widened towards the center, in the ventral area of the achene, there is a scar that is the insertion of the fruit in the floral receptacle, it is constituted by the perigonium that surrounds the seed completely and contains a single seed, of variable coloration, with a diameter of 1. 5 to 4 mm in diameter, which detaches easily at maturity and in some cases may remain attached to the grain even after threshing, making selection difficult. The moisture content of the fruit at harvest is 14.5% (Gallardo, et al.; 1997).

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

Table 25. Analysis of variance for number of seeds per gram (seeds/g) for self-fertilized F1 progenies from 22 single crosses (seeds/g) for self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees o freedom	Sum of square	Mean squares	F Calculated
Crosses	21	827315,510	39395,977	8,30
Error	159	754657,054	4746,271	**
Total	180	1581972,564		

C.V. 12,34 %,   Mean: 558,12 seeds/g.

Grain size

The grain size values obtained at harvest are shown in Table 26, where it can be seen that the grain sizes ranged from 1.66 mm to 2.12 mm. The largest grain size corresponds to cross 3 (Salcedo INIA x Negra Collana) with 2.12 mm and the smallest grain size for cross 20 (Huariponcho x Choclito) with 1.66 mm. In view of these results (Mujica and Apaza, 2002), indicate the origin of this cultivar Salcedo INIA, comes from the selection furrow-panicle of the dialelic cross 7 x 7 of the variety "real boliviana x sajama", made in the experimental station of Salcedo Puno, large grain of 1.8 to 2 mm in diameter, white color, glomerulated panicle, vegetative period of 150 days (early), yield 2500 kg/ha-1, resistant to frost. /ha-1, frost resistant (-2°C), tolerant to downy mildew. So, these characteristics influenced the cross with dominance over Negra Collana, hence the larger grain size. (Gómez and Aguilar, 2016) point out that the seed presents three well-defined parts which are: episperm, embryo and perisperm, these layers enlarge the size of the seed. The episperm is the layer that covers the seed and is attached to the pericarp. (Gallardo et al 1997) point out that the embryo, formed by two cotyledons and the radicle, constitutes approximately 30% of the total volume of the seed and surrounds the perisperm like a ring, with a curvature of 320 degrees.

Table 26. Grain size (mm) for self-fertilized F1 progenies from 22 single crosses.

Crosses	Mean (mm)	Tukey
3	2,12000	a
4	2,12000	a
2	2,07500	a b
14	2,01286	a b c
1	2,00750	a b c
19	1,96500	a b c d
11	1,93000	a b c d
17	1,91500	a b c d
18	1,89750	a b c d
15	1,89417	b c d
10	1,87235	b c d e

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

13	1,87000	b c d e
5	1,85059	b c d e
12	1,85000	c d e
16	1,83167	c d e
22	1,79118	c d e
8	1,79000	c d e
7	1,77750	d e
9	1,77154	d e
6	1,75167	d e
21	1,75000	d e
20	1,66333	e

Table 27. Analysis of Variance for Grain Size (mm) for Self-fertilized F1 Progenies
Self-fertilized F1 progenies from 22 single crosses.

Sources of variability	Degrees o freedom	Sum of square	Mean squares	F Calculated
Crosses	21	1,89993087	0,09047290	8,60
Error	159	1,67257189	0,01051932	**
Total	180	3,57250276		

C.V. 5.55%, Mean: 1.85 mm.

Table 28 shows the grain size of the parents used to obtain the simple crosses, in this table we can see that the varieties with the largest grain size (mm) are Pandela with 2.3 mm, Pasankalla with 2.2 mm, Salcedo INIA with 2.0 mm, 0 mm, in the results (Table 28) the largest grain size is cross 3 (Salcedo INIA x Negra Collana), and cross 4 (Salcedo INIA x Pandela), with Salcedo INIA being dominant in cross 3 and in cross 4, both genitors expressed in terms of grain size. As for the smallest grain size, cross 20 (Huariponcho x Choclito) was observed with 1.66 mm, decreasing somewhat in size compared to its parents.

Table 28. Grain size (mm) of parents used to obtain single crosses.

GENITOR CODE	1	2	3	4	5	6	7	8
GRAIN SIZE (mm)	2,0	1,8	1,9	1,8	2,2	1,6	1,8	2,3

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 5, 2021, Pages. 2460 - 2481
Received 15 April 2021; Accepted 05 May 2021.

CONCLUSIONS

In accordance with the objectives set and under the conditions in which the study was carried out, the following conclusions are drawn:

- Morphological characteristics; cross 18 (Chullpi rojo x Pandela) obtained the largest stem diameter (1.65 cm), cross 15 (Chullpi rojo x Pasankalla) obtained the largest panicle length (92.83 cm).
- Agronomic characteristics; cross 7 (Huariponcho x Pasankalla) had the lowest days to emergence with 4.25 days, and cross 13 (Choclito x Kcancolla) had the highest number of days to emergence with 8.67 days; it also had the lowest number of days to flowering with 58 days, cross 15 (Chullpi rojo x Pasankalla) had the highest height at harvest maturity with 1.99 cm, cross 2 (Chullpi rojo x Pasankalla) had the highest height at harvest maturity with 1.99 cm, cross 2 (Huariponcho x Pasankalla) had the highest number of days to emergence with 1.65 cm. 99 cm, cross 2 (Salcedo INIA x Pasankalla) reached the lowest number of days to harvest maturity with 138.75 days, cross 3 (Salcedo INIA x Negra Collana) had the highest grain yield per plant 53.10 g/plant, the largest grain size corresponds to cross 3 (Salcedo INIA x Negra Collana) with 2.12 mm and the smallest grain size for cross 20 (Huariponcho x Choclito) with 1.66 mm, the lowest number of seeds per gram was observed for cross 20 (Huariponcho x Choclito) with 1.66 mm. The lowest number of seeds per gram was obtained by cross 3 (Salcedo INIA x Negra Collana) with 373.50 seeds/g, and the highest number of seeds per gram was obtained by cross 9 (Huariponcho x Kcancolla) with 648.46 seeds/g.
- Regarding the variables of earliness, yield and quality, it was concluded that cross 1 (Salcedo INIA x Huariponcho), cross 3 (Salcedo INIA x Negra Collana), cross 19 (Pasankalla x Pandela) and cross 22 (Kcancolla x Pandela), are the most promising crosses.

REFERENCES

1. Alvarez, R., Castro (2009), Determinación del nivel de tolerancia a sales de accesiones de quinua en la fase de germinación, repositorio.lamolina.edu.pe, Lima Perú.
2. Alegría y Espíndola, G. (1967) Fertilización nitrogenada sobre quinua dos épocas de siembra y dos distanciamientos en el altiplano central. En resúmenes de investigación de quinua. (1962-1999) Universidad Nacional del Altiplano. 22 p.
3. Ayala, G., L. Ortega y C. Morón. (2004). Valor nutritivo y usos de la quinua. In: A. Mujica, S. Jacobsen, J. Izquierdo y JP. Marathee (eds). Quinua: Ancestral cultivo andino, alimento del presente y futuro. FAO. UNA. CIP. Santiago, Chile. pp 215-253.
4. Bhargava et al., (2007). (Stevens et al., 2006; Turner, (2007); Sederberg, 2008; Soliai, 2009; Fuentes et al., 2009b) conservación de la diversidad genética y su uso en el mejoramiento genético de quínoa Departamento de Agricultura del Desierto y

Biotecnología, Universidad Arturo Prat, Casilla 121, Iquique, Chile, (francfue@unap.cl) ** Brigham Young university, Department of Plant & Ani mal Science, 275 WIDB, Provo, UT 84602, USA.

5. Bonifacio, A. (1995). Interspecific and Intergeneric hybridization in Chenopod species. Thesis M.Sc. Brigham Young University. Provo, Utah, USA. 150 p.
6. FAO, (2011). La Quinua: Cultivo milenario para contribuir a la seguridad alimentaria mundial; Alan Bojanic Representante Regional Adjunto Coordinador del Equipo Multidisciplinario para América del Sur.
7. Gallardo, M.; Gonzales, A. y Ponessa, G. (1997). Morfología del fruto y semilla de *Chenopodium quinoa* Willd.(Quinoa). Chenopodiacea. Lilloa 39 (1).
8. Gómez, L. y Aguilar, E. (2016). Guía de Cultivo de la Quinua, ©FAO y Universidad Nacional Agraria La Molina Lima - Perú
9. Gómez y Pando, (2016) Incidencia de aves granívoras y su importancia como plagas en el cultivo de quinua (*Chenopodium quinoa* Willd.) en el altiplano Peruano, Page 2. 140 Volumen 28. UNALM Lima Peru.
10. Hidalgo, R. (2003). Variabilidad genética y caracterización de especies Vegetales En Boletín Técnico Nº 8 Análisis estadístico de datos de caracterización morfológica de recursos Filogenéticos. Instituto Internacional de Recursos Fito genéticos (IPGRI). Cali, Colombia. 89 p.
11. Káiser, O. (1968). Densidad optima de plantas de quinua en el altiplano central. 1ra. Edición. Tesis Ingeniero Agr. Bolivia Universidad de Cochabamba. 43p.
12. Kuljanabhagavad, T. & Wink, M. Phytochem Rev (2009) 8: 473. Biological activities and chemistry of saponins from *Chenopodium quinoa* Willd., June 2009, Volume 8, Issue 2, pp 473–490
13. Lescano, J. L. (1994). Genética y mejoramiento de cultivos altoandinos: quinua, kañihua, tarwi, kiwicha, papa amarga, olluco, mashua y oca. Programa Interinstitucional de Waru Waru, Convenio INADE/PELT – COTESU. pp. 459.
14. López, J. e Hidalgo, M. (1994). Análisis de conglomerados En: Boletín Técnico Nº 8 Análisis estadístico de datos de caracterización morfológica de recursos Filogenéticos. Instituto Internacional de Recursos Fito genéticos (IPGRI). Cali, Colombia. pp. 28 – 34.
15. Mujica A., Suquilanda M., Chura E., Ruiz E., Leon A., Cutipa S., Ponce C., (2013) Producción orgánica de quinua (*Chenopodium quinoa* Willd.). pp 118
16. Mujica Sánchez, Ángel (1983). Selección de variedades de quinua *(Chenopodium quinoa* Willd.*)* en Chapingo, México. Tesis de Maestría en Ciencias. Centro de Genética, Colegio de Posgraduados Centro de Genética. Montecillo México.
17. Mujica, A Apaza, V. (2002). variedad Salcedo-INIA Indican la procedencia de esta variedad, Selección surco-panoja var. “real boliviana x sajama” Puno, Perú.
18. Repo-Carrasco, R., Espinoza, C., and Jacobsen, S. (2003). Nutritional value and use of the Andean crops quinoa (Chenopodium quinoa) and kañiwa (*Chenopodium pallidicaule*). FoodRev. Int. 19, 179–189.
19. Zamudio, J. (2013). Cultivo de la quinua: inclusión social o beneficio para funcionarios, Agencia Agraria. Todos los derechos reservados. Diseñado y desarrollado por Foqus.pe.