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Adaptation of 5 varieties of quinoa (*Chenopodium quinoa W.*) to the warm climate of Peru

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Abstract

Cultivation of quinoa (*Chenopodium quinoa Willd.*), Andean grain, was a cultivated plant of the Incas now at present there are varieties improved by the institute of genetic improvement INIA in Puno, Peru. Studies were carried out to adapt and evaluate 5 varieties of quinoa to warm climates during 2022-2023 at the quinoa experimental site of the National University of Piura, located in the city of Piura, Coastal Region, Peru. Longitude: W 80°37'Latitude: S 5°11' in the north. Its height is 55 meters above sea level. An experimental project was used to determine the agronomic yield components of the best variety for warm climates. Climatic conditions on average are as follows: Average temperature in city of Piura. The average annual temperature is 30°C in Piura. The rainy season lasts for 3 months, from December to April. The annual amount of precipitation in Piura is 272 mm. The characteristics of the soil of the experimental plot of the National University of Piura in depth of 0-30 cm, is of sandy textural class. The method applied was random blocks. The results of comparison of box means showed that the Salcedo variety is the most stable variety in its yields because it presents a mean, with asymmetric data in the upper limit and the lower limit with a normal distribution. (population genetics). finally, the "Salcedo" variety has a physiological maturity at 140 days.

Keywords: Warm Clima; Genetic Population; Quinoa; Adaptaccion; Yield Components

Introduction

The selection of new lines provides the option for the agronomic characteristics of the plant to adapt to certain environmental conditions, making it a potential crop for the agricultural sector García [1]. Shape and size of starch granules: Diameters of the quinoa starch granules ranged from 0.4 and 2.0 µm . The granules are smaller than those of most other plant starches. Quinoa starch granules were mostly polygonal and irregular. The variation in the shape and size of the starch granules it is small Jiang [2]; Li & Zhu [3]; López-Fernández [4]; Valdez-Arana et al., 2020). The outer layer of the starch granules was homogeneous and the granules have a hilum Tang [5]. Interpretation and comparability of survey data. proximate composition of quinoa. The observations recorded above showed that the variations in the composition of quinoa grains from different studies varied considerably Craine & Murphy [6], Encina-Zelada [7], Filho [8] ; Li [9], Nowak [10], Valencia-Chamorro [11]. Different studies used quinoa samples from different batches or collected from different locations. The plant genetics, growing locations environmental factors and agronomic practices (e.g., intercrop and irrigation methods) for the quinoa growing significantly contributed to the variations of the results reported Cole [12]; Craine & Murphy [6], Lee & Sim [13], Matias [14]; Tovar [15]; Walters [16]. The Applications and composition of fertilizers can influence the grain morphology and yield Jorfi [17]. For example, in a field study, Jorfi [17] showed that high quinoa grain production was determined by the genotype and the use of suitable levels P2O5 and ZnSO4 of foliar application Jorfi [17]. The tolerance of quinoa may be increased using biostimulants Benaffari [18]. For example, Benaffari [18] showed that combined applications arbuscular mycorrhizal fungi and vermicompost increased the adaptability of quinoa to drought conditions. Different regions have different soils and environmental conditions. This can lead to variations in the grain yield and quality for the same quinoa genotype. Overall, optimization of the agronomic practices could lead to reasonable production quantity of quinoa grains.

For example, the treatment of intercrops (clover/ medic or fescue/clover) affected the Mn manganese concentration and protein content in the quinoa Walters [16]. Three different

varieties of quinoa were grown in three different countries (Spain, Chile and Peru) Reguera [19] The composition of amino acids, proteins, phytates and minerals was affected by the interactions between the varieties and the growing locations, whereas the contents of fibers or saponins were much less influenced by the interactions Reguera [19]. Matias [14] showed that heat stress decreased the contents of total lipids and carbohydrates and the quinoa grain in the Mediterranean area, while increased those of fiber and protein. The response to heat stress was dependent on the quinoa variety Matias [14]. Tovar [15] showed that relatively short periods (11 days) of heat spells during anthesis significantly change the contents of many elements in the seeds. Due to its nutritional properties and the increase in global demand, the cultivated area and its production in the Andes region have increased Gamboa [20]. There are studies of the main exports and production of Peruvian quinoa during the period 2012 - 2020. The studies are of a quantitative type, using descriptive statistics based on the information obtained from competent institutions, which handle the information of quinoa. It has been determined that the prospects for growth in exports in Peru C. Quispe [21]. The aim of the study is to evaluate 5 promising varieties of quinoa *(chenopodium quinoa Willd.)* coming from Puno, Peru to achieve their and introduction in the climatic conditions of the coast, Piura, Peru. The research work is to identify the most outstanding variety by means of the yield of each plant and the ontogenic cycle.

Materials and Methods

Adaptability study of quinoa *(Chenopodium quinoa Willd.)*. carried out at the quinoa experimental site of the National University of Piura, located in the city of Piura, Costa Region, Peru from 2020 to 2023. MT S 5°11' N Latitude; 80°37' Longitude: W. Its height is 55 meters above sea level. The 5 varieties were selected from cold climates of the city of Puno to evaluate their introduction and possible adaptability to warm climates of northern Piura. The main components of quinoa yield will be studied are: Plant panicle per m2. Weight of 1000 seeds, (g) . Yield per plant, (g). Vegetative cycle, (days). Panicle size (cm). Panicle maturation, (days). As the main variable the yield of the experimental plot. Therefore An experimental project with random blocks we obtained the yield of each variety. The data obtained were subjected to statistical analysis using analysis of variation (ANOVA) The comparison of mean values with the statistical box model was also used (graph) and Duncan's Multiple Range with software: Statistical Package S.A.S. (Statistical Analysis System) trial version. Critical differences were worked out using LSD at 5% level of significance in order to determine the statistical difference between varieties. The sowing was carried out with soil at field capacity managed and with the management of the crop and the necessary geotechnics, therefore the depth of 3 to 5 cm, the distance of 20 cm long and 60 cm wide and 20 cm between plants. The number of seeds was added to the sample: 10 kg/ha. from 5 to 8 seeds per stroke; with rain watering. we use natural humus fertilizer 6%. The application of chemical fertilizers was not used in order to achieve the expressions of the phenotypic and genotypic characteristics in the new climatic environment and compare it with the place of origin of Puno- Peru. The characteristics of the soil of the experimental plot of the National University of Piura in depth of 0-30 cm, is of sandy textural class, characteristic to be taken into account for the distribution of water and fertilization of the Quinoa crop. It also has an adequate pH 7.06, close to neutrality; its % CaCO3 0.14 is low, the level of organic Matter (MO) 0.10 is extremely low, which responds to the non-existent level of Nitrogen; levels of available phosphorus (ppm) P 6.00 and K 56.00 ppm also low; levels of Ca++ 2.06, Mg++071 and Na 0.12 low. Climatic conditions on average are as follows: Average temperature in city of Piura. The average annual temperature is 30°C in Piura. The rainy season lasts for 3 months, from December to April. The annual amount of precipitation in Piura is 272 mm.

Result

The results showed the yield of the 5 varieties of quinoa *(Chenopodium quinoa Willd)*. There were statistically significant differences of varieties where variety 4, name: "Blanca de Juli" showed the highest average agronomic yield of 26.21 g. and variety 5, name:, showed the lowest average agronomic yield of 13.6 g. (Table 1). The data the box and whiskers (Figure 1). the statistical results to recognize the best variety with adaptability is the one with the most variance and a stable mean the 5 varieties. Therefore the Salcedo variety is the most stable variety in its yields because it presents a mean, with asymmetric data in the upper limit and the lower limit with a normal distribution. the adaptation of a variety is studied with population genetics and the most stable variety is the one with a normal curve with variance in grain yield.

The components of agronomic yield were studied. (Table 2) it was determined the mature grains of quinoa are the result of the interactions between genotype of each variety and the interaction of the warm climate, the phenological stages are also described Figure 2. where it is divided into three phases: the vegetative phase, the reproductive phase and the maturation phase. The results of comparison of box means showed that the Salcedo variety is the most stable variety in its yields because it presents a mean, with asymmetric data in the upper limit and the lower limit with a normal distribution, therefore there is variance in the data. In the case of the Altiplano variety, the median indicates that these data are asymmetric, in the normal distribution, the altiplano does not present, therefore there is no variance in the data. In the "Kancolla" variety the data contain a mean skewed to the third quartile and with normal distribution presenting great variance. In the variety "Blanca de Juli" the data contain a mean skewed to the first quartile and without normal distribution therefore they do not present variance. In the case of the "Negra Collana" variety there is a mean, therefore the data are asymmetric and it only has an upper limit and no normal distribution.

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Table 1: Descriptive Statistics of the agronomic yield.

	N	Minimum	Maximum	Mean	Std. Deviation
Altiplano 01	10	14,25	35,10	238,820	637,906
Salcedo 02	10	14,16	27,35	185,910	406,578
Kancolla03	10	8,80	39,53	221,320	875,776
B.Juli 04	10	14,07	44,64	262,190	1,051,897
N.collana 05	10	11,00	18,00	136,000	263,312
Valid N (listwise)	10				

Note: The descriptive statistics show the lowest yield was obtained by the" Kancolla" variety with a result of 8.8 grams / plant and the highest yield was obtained by the "Blanca de juli" variety with a result of 44 grams / plant. Most importantly the mean where it showed an average agronomic yield of 26.21g.

Table 2: The yield components of Quinoa cultivation in warm climate.

Name of the variety	Yield per plant, (g)	Panicle. per m2	Weight of 1000 seeds, (g)	Panicle Size (cm)	Vegetative period, (days)
"Altiplano"	23.8	20	3.7	40	145
"Salcedo"	18,5	20	3.3	34	140
"Kancolla"	22,1	16	2,7	28	164
Blanca juli	26,2	20	2,0	34	166
"Negra collana"	17,4	16	2,0	33	165

Note: In adaptation, genetic improvement is to identify the optimal characteristics of the phenotype. that will allow to choose the desired potential development of the variety for the best genotype.

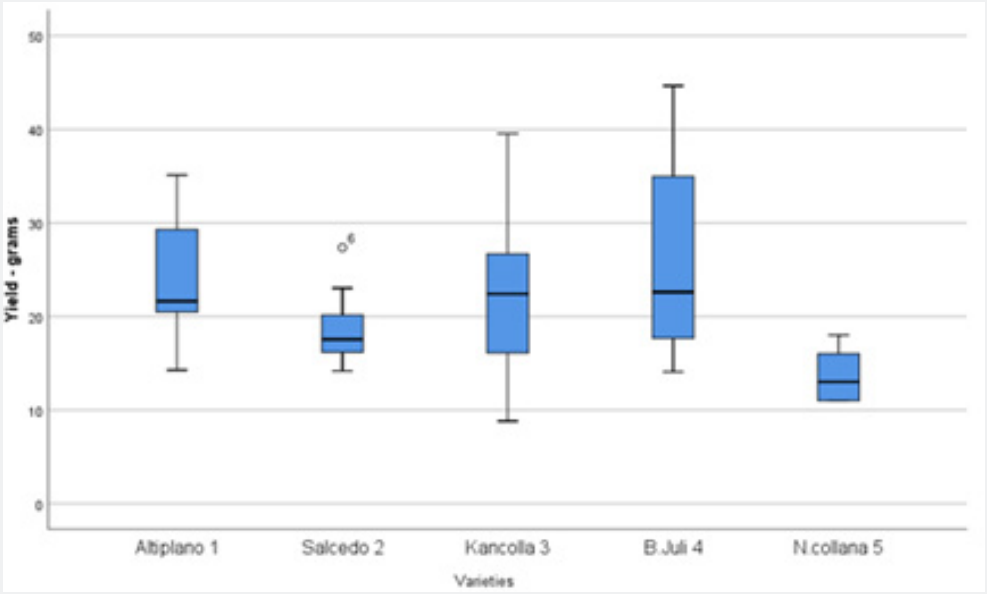

Figure 1: In the method statistical the box and whiskers the 5 varieties.

The optimal characteristics are marked with green color in the Table 2. In the yield component of weight per plant the best weight was obtained by the "Blanca juli" variety with 26.2 g. In second the "Altiplano" variety 23.8 g. In the yield component called panicle size the best was obtained by the Altiplano variety with 40 cm per plant. In second place the variety "Salcedo" with 34 cm. Another important yield component is the weight of 1000 grains first of all the variety "Altiplano" with 3.7. In second place the variety "Salcedo" with 3. The figure shows that the vegetative period of the 5 varieties that the Salcedo variety and the altiplano

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variety reached their physiological maturity at 140- 145 days. The phenology of quinoa can be described by well-marked phases. Seed Germination (V0). Emergency (V1). Appearance of true leaves (V2). Four true leaves (V3). Six true leaves (V4). The Branching (V5). The following phases form the number of flowers and the quality of the grain. Which will determine the phenotypic and genotypic expression of the performance components. Beginning of flowering (R6). When the apical flower opens showing the separated stamens. Panicle formation (R7) The type of amarantiform or glomerulate panicle can be appreciated. Flowering (R8). When 50% of the inflorescence flowers are open and the plant begins to remove the lower leaves. Quinoa has flowers with gyneceo and androceo (perfect flower), pistillate flowers (imperfect flower) and androsterile flowers. Milky Grain (R9). When the fruits that are in the glomeruli of the panicle, when pressed, they explode and let out a milky liquid. Pasty grain (R11). When the fruits, when pressed, present a pasty white consistency. Physiological maturity R12) Physiological maturity R12) begins the starch process within the seed and this depends on the genetics of each variety. each variety matures on different days.

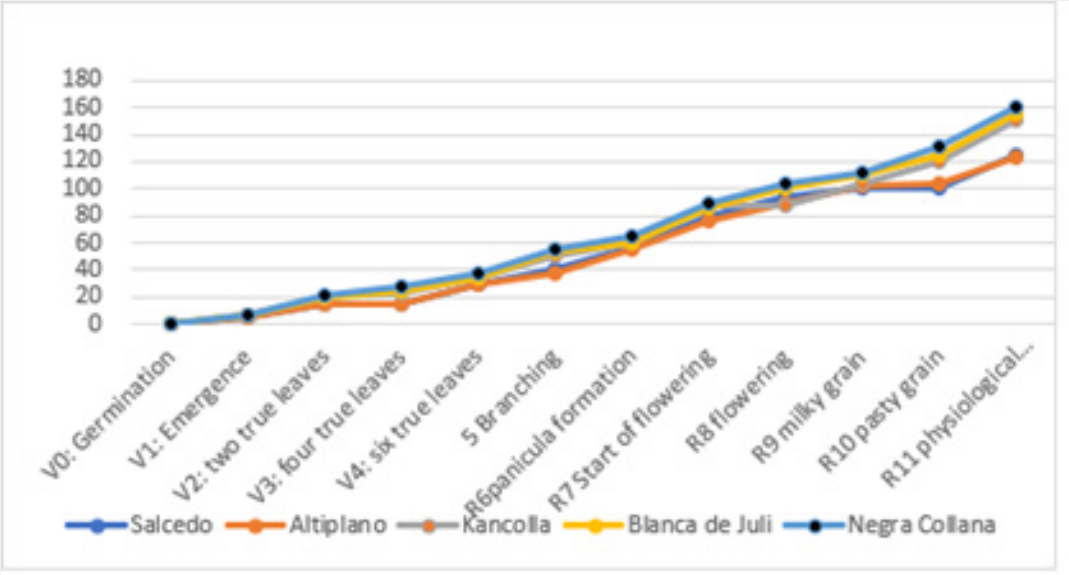

Figure 2: Phenology the varieties of quinoa in Piura , Peru

Discussion

The five varieties obtained from the INIA Peru research center the Salcedo variety is the most stable with an average and in a symmetrical box with normal distribution. Therefore it is the most suitable for hot climates and with a deficit of water and low nutrient soil. Evaluating the yield components of the Quinoa crop are basic to examine the adaptation. Each variety highlights the "Altiplano" variety but in the for the highest individual yield but is not the most productive variety. The productive success of quinoa cultivation in the face of the adversity of the new climate quinoa with high temperatures 30°C 35°C depends on the genetics of a stable populations and not on the individual yield of a variety, and also not for the highest yield per plant variety B. July 44.4 g. The vegetative cycle of the varieties was described in number of days, being the Salcedo variety the most important early variety to adapt to climates with short rainy periods or drought climates. The work can be used for the methodology of plant selection so we recommend repeating the tests in warm climates.

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