ADAPTATION AND YIELD POTENTIAL OF DIFFERENT QUINOA VARIETIES IN VAN-TURKEY CONDITIONS

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Abstract. The research was carried out in Van Yüzüncü Yıl University Field Crops Application area between 2020 and 2022 summer growing seasons according to a randomized complete block design with three replications in order to determine different quinoa (*Chenopodium quinoa* Willd.) varieties and populations that can be grown under irrigated conditions in Van region and their important botanical and agronomic characteristics. In the study, nine quinoa varieties (Q-52, Rainbow, Read Head, Sandoval Mix, Cherry Vanilla, French Vanilla, Mint Vanilla, Oro de Valle, and Moqu-Arrochilla) and one genotype (Population China) were used. According to the results of the two-year study, significant differences were found in significant differences in terms of plant height, number of panicle branches, main panicle length, seed yield, biological yield, harvest index, 1000-grain weight, seed protein ratio. However, it was determined that there were no significant differences in terms of the number of days of growth, number of branches and hectoliter weight. The highest grain yield was obtained from the Mint Vanilla variety (3266.7 kg/ha) in 2021 and from the Sandoval Mix variety (2915.4 kg/ha) in 2022, and it was concluded that these varieties could be cultivated in the region.
Keywords: *quinoa, phenotypic characteristics, genotypes, adaptation, efficiency components*

Introduction

Quinoa is an important pseudocereal belonging to the Amaranthaceae family that has been cultivated in South America, including Ecuador for centuries. Quinoa is a plant species with high genetic diversity enhances its capacity to adapt to different environmental conditions. While are reported to be quinoa varieties are resistant to climate change or other stress factors (Ebert and Huerta-Acosta, 2019), the protection of genetic resources is also of great importance for maintaining adaptability. In addition, quinoa is tolerant of different temperatures (-4°C and 38°C) (Bazile et al., 2016; Jacobsen et al., 2005) and rainfall (with satisfactory yield at 100 to 200 mm) (Geerts et al., 2009; Razzaghi et al., 2011), low soil moisture, and salinity (Jacobsen, 2003) throughout its growing period, and it is a plant with high water efficiency. Quinoa also offers important advantages for sustainable agricultural practices. Due to these features, it is considered a future crop for future food security (Jacobsen et al., 2014).

The quinoa plant, which draws attention with its resistance to stress conditions, also stands out with its importance in human nutrition and high nutritional value. The reason for the significant increase in demand for quinoa seeds in recent years is that the seeds can be used both as human food and animal feed due to their high nutritional value (Nowak et al., 2016). Quinoa seeds contain high levels of protein, vitamins and minerals. The amino acid balance of its protein is good. Since it does not contain gluten, it is a safe source of protein and carbohydrates for celiac patients. Since it has a high-quality fiber content, its use for dietary purposes is widespread in the USA and

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European Union countries. The Food and Agriculture Organization of the United Nations (FAO) wanted to draw attention to the fact that quinoa is a beacon of hope for societies experiencing food shortages in the world and therefore declared 2013 as the year of quinoa. In addition, the use of quinoa in the nutrition of astronauts by NASA played an important role in its popularity (Tan and Temel, 2019).

Quinoa has also attracted great interest in Turkey in recent years. It has been determined that quinoa, which has the ability to grow in subtropical climates, can be easily cultivated in our country. (Kır and Temel, 2017). Successful results have been obtained in adaptation studies on quinoa conducted in different regions of our country in recent years (Geren et al., 2014; Kır and Temel, 2017; Üke et al., 2017). However, it is observed that the research conducted on quinoa (plant density, fertilizer dosage, harvest times, adaptation process, planting time, etc.) is insufficient in our country and region.

There are many studies conducted in the world for the purpose of adaptation and cultivation. Basic studies on quinoa, which is new to our country, are insufficient. Undoubtedly, the fact that quinoa has a wide adaptability and can grow in different climate and soil conditions has been effective in attracting attention. Determining high-quality and high-yield quinoa varieties suitable for different regional conditions will only be possible as a result of variety adaptation and other agronomic studies to be carried out according to the characteristics of the regions. In this study, different genotypes of quinoa that have not been tried in Van province conditions before were preferred and the aim was to determine the most suitable quinoa genotypes. Thus, an alternative plant will be introduced to regional agriculture. In addition, this study will play an important role in pioneering scientific studies on quinoa in the region.

Materials and methods

Location and characterization of experimental area

Van province, where the research was conducted, is located in the Turkey's Eastern Anatolia Region, between 37°-39° north latitude and 43°-45° east longitude, and its altitude is 1.726 m. The study was conducted in 2021-2022, in the Field Crops Department at Van Yüzüncü Yıl University's Faculty of Agriculture. The research carried out during the summer under irrigated conditions. According to the long-term average, the average temperature, relative humidity and total precipitation amounts were measured as 16.9°C, 61.9% and 146.3 mm, respectively. In the years 2021 and 2022 when the research was conducted, the average temperature was 18.7-18.2°C, the average relative humidity was 41.8-48.3% and the total precipitation was 31.3-66.5 mm (*Fig. 1.*) (MGM, 2022). According to these results, the periods when the research was conducted received less precipitation and were drier than the long-term average. When compared in terms of other climate data (temperature and relative humidity), it was seen that the years when the research was conducted were warmer than the long-term average and lower in terms of relative humidity. Before planting, samples were taken from the soil profile (0-30 cm) to represent the research area and according to the analysis results, the soils were found to be in the sandy-clay-loam texture class, salt-free (0.080%), slightly alkaline in character (pH: 7.73), low in organic matter (1.26%), calcareous (18.4%) and low in plant-useful phosphorus (5.3%) (Müftüoğlu et al., 2014). Soil and meteorological data of the trial area were suitable for growing quinoa in irrigated conditions.

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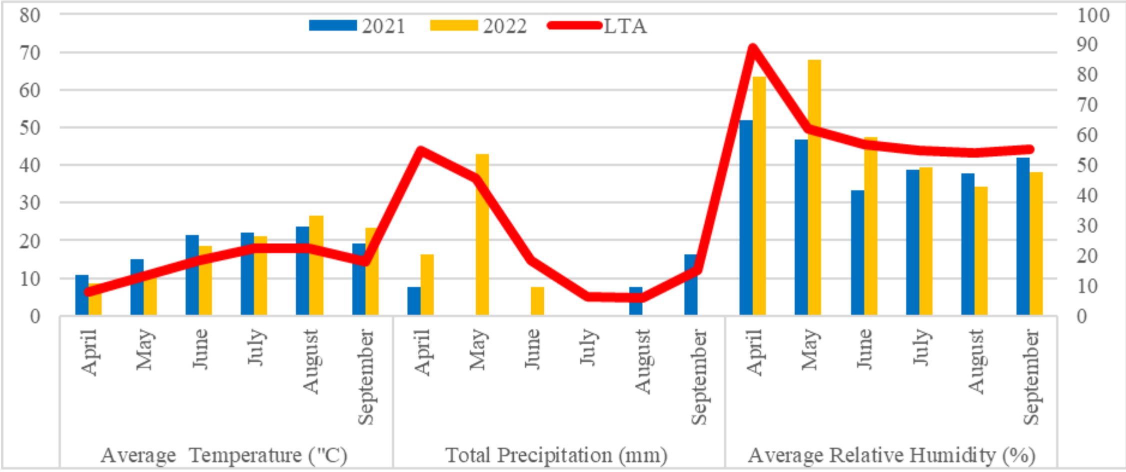


Figure 1. *Some climatic characteristics of the region where the research is conducted*

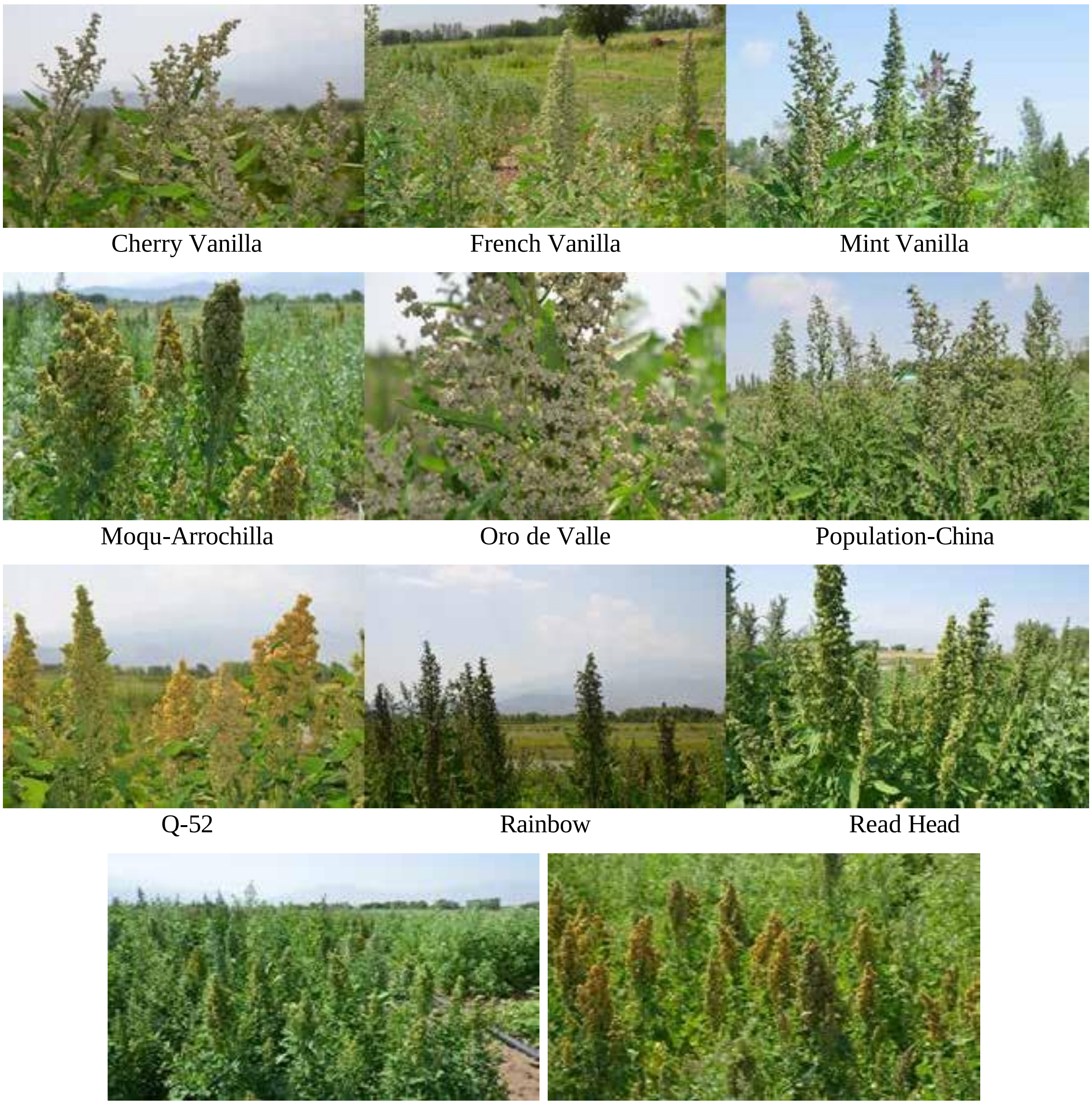
Experimental design and installation of field research

In the study, the characteristics of 10 quinoa (*Chenopodium quinoa* Willd.) genotypes (1 population and 9 varieties) related to grain yield were investigated. The materials used in the study and their origins are shown in *Table 1*. The materials used in the study and their origins are shown in *Table 1*.

Table 1. *Origins and phenotypic seed colors of quinoa used in the study*

Genotypes	Origin	Phenotypic seed color
Population	China	Light brown
Q-52	Denmark	Whitish-yellow
Rainbow	USA	White
Read Head	USA	White
Sandoval Mix	England	Whitish
Cherry Vanilla	USA	White
French Vanilla	USA	White-cream
Mint Vanilla	USA	Bright-white
Oro de Valle	USA	Golden-brown
Moqu-Arrochilla	Peru	Whitish

Field experiments were carried out on 20 April 2021 in the first year and 3 May 2022 in the second year, with 35 cm row spacing and 150-200 g of seed per decare, according to a randomized block design with three replications. Sowing was done manually on the lines marked with markers at a depth of 1.5-2.0 cm (Katwal and Bazile, 2020). In the experiment, the plot length was determined as 4 m and the width was 2.1 m (5 rows × 0.35 m), and each plot area was 8.4 m². Before sowing, 8 kg/da N (ammonium sulfate 21%) and 10 kg/da P_2O_5 (triple superphosphate 39-41%) were applied to the plots (Tan and Yöndem, 2013; Geren et al., 2015). Seed harvests were carried out based on the period when the seeds in the clusters reached harvest maturity, dried out, turned dark brown and started to fall when touched. During the harvest period, 0.5 m sections from the plot heads and one row on the edge were discarded as edge effect and the harvest and all measurement operations were carried out in the remaining 4.2 m² area (3 m × 1.4 m). The first year's harvest was carried out on September 03, 2021 and the second year's on September 17, 2022. Within the scope of the study, some parameters which were shown to have a significant and positive relationship with seed yield by previous studies were examined. These parameters were determined as growth period (days), plant height (cm), seed yield (kg/ha), panicle length (cm), biological yield (kg/ha), harvest index (%), thousand seed weight (g) and hectoliter weight (kg) (Jacobsen and Stolen, 1993; Bhargava et al., 2007; Mc Elhinny et al., 2007; Stikic et al., 2012). Crude protein (%) contents of seeds were determined using the micro-Kjeldahl method (AOAC, 1997). During the period when the seeds were harvested, all observations were determined from 10 plants randomly selected from each plot. Images of the quinoa genotypes used as plant material in the study are given in *Figure 2*.



Cherry Vanilla | French Vanilla | Mint Vanilla
Moqu-Arrochilla | Oro de Valle | Population-China
Q-52 | Rainbow | Read Head
Sandoval Mix | Titicaca

Figure 2. *Quinoa genotypes used in the experiment*

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Statistical analysis

One-way analysis of variance (CoStat 6.303) was used to test the significance of the values obtained as a result of the research and the differences between the means were compared and grouped according to the LSD (0.05) test.

Findings and discussion

Number of days of growth and plant height

When the findings obtained regarding the number of days of growth of the Quinoa genotypes examined in the study were examined, it was determined that it was not statistically significant in both years. The average number of days of growth of the genotypes were determined between 122.33 days (Mint Manilla) and 124.83 days (Rainbow). In 2021, the longest number of days of growth period was measured in Rainbow and Sandoval Mix varieties (123.67 days), the least in Population China and Orode Valle (120.33 days), the highest in Mogo Arrochila, Read Head and Orode Valle varieties (126.33 days) in 2022, and the least in Mint Vanilla variety (124.00 days) (*Table 2*).

Quinoa is a short-day plant. It blooms and matures with the shortening of the days in summer. Early maturation is important for protection against frost events that occur towards the end of the season. Kır and Temel (2016), who reported that the late or early ripening of the varieties due to their genetic structures may cause differences between harvest maturity periods, reported that the ripening periods of quinoa genotypes varied between 124.75 - 147.50 days, Katwal and Bazile (2020) 100-197 days, Maamri et al. (2021) 136-164 days. Similarly, Szilagyi and Jornsgard (2014) in Romania, Tan and Temel (2018) in Erzurum and Iğdır provinces reported that the harvest maturity of quinoa varied greatly between varieties. Plant height findings between quinoa genotypes were statistically significant in 2021 ($p \leq 0.01$) and 2022 ($p \leq 0.05$). In 2021, the longest plant height was measured in the Cerry vanilla variety (100.23 cm), while the lowest was measured in the Mogo Arrochila variety (75.53 cm); in 2022, the longest was measured in the Population-China variety (79.73 cm), and the lowest was measured in the Mogo Arrochila variety (55.47 cm) (*Table 2*). Differences in plant heights of genotypes may be due to ripening time (Tan and Temel, 2018), genetic structures (Maamri et al., 2021) and different responses to the environment. Because the different characteristics of the varieties, the soil structure and climate of the region where they are grown can significantly affect plant height. Therefore, when the plant heights obtained as a result of studies conducted with quinoa in different ecological conditions were examined, it was reported that the plant heights of the varieties and genotypes were different and similar results were obtained (Kaya et al., 2017; Tan and Temel, 2018; Temel and Şurgun, 2019; Altuner et al., 2019; Çağlayan and Kökten, 2021; Önkür and Keskin, 2019; Temel and Keskin, 2019; Katwal and Bazile, 2020).

Branch number

It was determined that the branch numbers of the quinoa genotypes were not statistically significant in both years. In 2021, the highest number of branches was measured in Population-China (5.67 pieces), the lowest in French Vanilla (3.55 pieces), and in 2022, the highest was measured in Titicaca (5.25 pieces), and the lowest in Sandoval Mix and Q-52 (4.20 pieces) (*Table 2*). Stating that different branch numbers may occur due to different heights and genetic structures of plants, Kır and Temel

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(2016) reported that the average number of branches in the plant they obtained from the quinoa varieties they used in their studies in 2016 under dry conditions was 13.90 and 22.11 under irrigated conditions (Kır and Temel, 2017). In another study, Curti et al. (2012) determined the average number of branches as 8.7. The data of both years of the study we conducted were close to the data of the researchers, and as stated by the researchers mentioned above, this may be due to the different varieties used in the experiment and their different responses to ecological conditions.

Number of branches in the bunch

It was determined that the bunch branch number values of the quinoa genotypes were not statistically significant in 2021, but were significant in 2022 ($p \leq 0.05$). In 2021, the highest bunch branch number was measured in the Titicaca variety (11.27 pieces), the lowest in Population-China (7.51 pieces); in 2022, the highest was measured in the Orode Valle variety (10.50 pieces), and the lowest in the Mogo Arrochila variety (6.53 pieces) (*Table 2*). In different quinoa studies, it has been reported that the number of branches in the bunch varies between 11.67-141.55 pieces (Bhargava et al., 2007) and 7.00-19.33 pieces (Basra et al., 2014). As a result of our study, it is seen that the values we obtained are within the range of the values obtained by these researchers.

Main bunch length

When the findings obtained for the main bunch length were examined, it was determined that it was statistically significant ($p \leq 0.05$) in both years. In 2021, the maximum main bunch length was measured in the Orode Valle variety (18.40 cm), the minimum in the Q-52 variety (10.60 cm), and in 2022, the maximum in the Orode Valle variety (13.73 cm), and the minimum in the Mogo Arrochila variety (10.27 cm) (*Table 3*). Spehar and Santos (2005) stated that the average bunch length in quinoa in Brazilian conditions varied between 11-26 cm, and Basra et al. (2014) stated that the main bunch length in quinoa grown in Faisalabad Pakistan ecological conditions varied between 12-29 cm. The values we obtained are in accordance with the values of the researchers mentioned.

Seed yield

The difference between quinoa genotypes in terms of seed yield was found to be statistically significant ($p \leq 0.01$) in both years. The response of genotypes to differences in climate values was different in both years. In 2021, the highest seed yield was measured in the Mint Vanilla variety (3266.7 kg/ha), while the lowest was measured in the Mogo Arrochila variety (2386.4 kg/ha), and in 2022, the highest seed yield was measured in the Sandoval Mix variety (2915.4 kg/ha), while the lowest was measured in the Read Head variety (2445.4 kg/ha). The average seed yield of the genotypes were determined between 3042.5 kg/ha (Mint Manilla) and 2466.9 (Mogo Arrochila) (*Table 3*). When the results of the studies conducted with quinoa plants in different ecologies are examined, it can be seen that there are significant differences in seed yields according to varieties. Accordingly, in Iğdır, the lowest seed yield in dry conditions was obtained from the Population China variety (1017.7 kg/ha), the highest seed yield was obtained from the Titicaca variety (2100.3 kg/ha) (Kır and Temel, 2016). In the same ecology, in irrigated conditions, the lowest seed yield was obtained from the French Vanilla variety (1767.3 kg/ha), and the highest seed yield was obtained from the Titicaca variety (4120.3 kg/ha) (Kır and Temel, 2017).

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Table 2. *Values of number of days of growth, plant height, branch number and number of branches in the bunch determined in the study*

Varieties	Number of days of growth (day)			Plant height (cm)			Branch number (pieces)			Number of branches in the bunch (pieces)		
	2021	**2022**	**Average**	**2021**	**2022**	**Average**	**2021**	**2022**	**Average**	**2021**	**2022**	**Average**
Mogo Arrochila	122.00 ± 1.53	126.33 ± 2.33	124.16 ± 1.93	75.53 ± 2.85c	55.47 ± 1.68b	65.50 ± 2.27	3.73 ± 0.09	4.63 ± 0.44	4.18 ± 0.26	10.73 ± 0.49	6.53 ± 0.68b	8.63 ± 0.58
Read Head	122.00 ± 1.53	126.33 ± 1.33	124.16 ± 1.43	93.00 ± 3.86ab	74.00 ± 3.48ab	83.51 ± 3.67	4.43 ± 0.67	4.23 ± 0.13	4.33 ± 0.40	9.83 ± 1.33	9.80 ± 0.96a	9.81 ± 1.14
Rainbow	123.67 ± 1.33	126.00 ± 1.53	124.83 ± 1.43	94.20 ± 4.00ab	79.20 ± 4.56a	86.70 ± 4.28	5.47 ± 0.23	4.87 ± 0.37	5.17 ± 0.30	9.80 ± 1.53	8.90 ± 0.44a	9.35 ± 0.98
French Vanilla	123.00 ± 1.15	126.00 ± 1.53	124.50 ± 1.34	88.95 ± 1.88ab	74.83 ± 0.55ab	81.89 ± 1.22	3.55 ± 0.20	4.53 ± 0.03	4.04 ± 0.11	9.95 ± 0.32	8.57 ± 0.79a	9.25 ± 0.55
Sandoval Mix	123.67 ± 1.33	124.67 ± 0.33	124.16 ± 0.83	91.50 ± 4.14ab	77.73 ± 1.75ab	84.61 ± 2.94	3.67 ± 0.62	4.20 ± 0.12	3.93 ± 0.37	10.27 ± 1.00	9.53 ± 0.48a	9.90 ± 0.74
Q-52	121.33 ± 0.33	125.67 ± 1.76	123.50 ± 1.05	82.90 ± 1.39bc	69.57 ± 2.82ab	76.23 ± 2.11	4.00 ± 0.06	4.20 ± 0.17	4.10 ± 0.11	9.70 ± 0.12	9.10 ± 0.57a	9.40 ± 0.34
Titicaca	122.00 ± 1.53	125.00 ± 0.58	123.50 ± 1.06	90.60 ± 0.45ab	76.90 ± 2.08ab	83.75 ± 1.26	4.10 ± 0.20	5.25 ± 0.14	4.61 ± 0.17	11.27 ± 0.49	9.35 ± 0.03a	10.30 ± 0.26
Cerry vanilla	121.67 ± 0.67	124.33 ± 0.33	123.02 ± 0.50	100.23 ± 0.24a	74.85 ± 1.07ab	87.54 ± 0.65	4.63 ± 0.33	4.60 ± 0.35	4.61 ± 0.34	10.37 ± 0.47	10.05 ± 0.14a	10.20 ± 0.31
Mint Vanilla	120.67 ± 0.33	124.00 ± 0.58	122.33 ± 0.46	84.87 ± 2.86bc	72.10 ± 3.75ab	78.48 ± 3.31	4.27 ± 0.43	4.40 ± 0.06	4.33 ± 0.24	7.87 ± 1.87	9.25 ± 0.20a	8.55 ± 1.03
Population China	120.33 ± 0.33	125.67 ± 1.67	123.00 ± 1.00	93.26 ± 3.61ab	79.73 ± 4.50a	86.49 ± 4.06	5.67 ± 1.88	4.27 ± 0.59	4.97 ± 1.23	7.51 ± 0.71	9.37 ± 0.48a	8.43 ± 0.59
Orode Valle	120.33 ± 0.33	126.33 ± 1.33	123.33 ± 0.83	88.41 ± 4.83ab	76.27 ± 2.27ab	82.33 ± 3.55	5.27 ± 1.38	4.27 ± 0.34	4.77 ± 0.86	8.27 ± 0.98	10.50 ± 0.75a	9.38 ± 0.86
F-Value	**ns**	**ns**		**	*		**ns**	**ns**		**ns**	*	
CV (%)	**1.23**	**1.83**		**5.56**	**6.25**		**29.43**	**11.05**		**18.36**	**10.19**	
LSD	**2.55**	**3.92**		**4.42**	**7.94**		**2.22**	**0.84**		**3.00**	**1.55**	

*Significant at the 5% level, **significant at the 1% level, ns: not significant

Table 3. *Main bunch length, seed yield values, biological yield and harvest index values determined in the study*

Varieties	Main bunch length (cm)			Seed yield (kg/ha)			Biological yield (kg/ha)			Harvest index (%)		
	2021	**2022**	**Average**	**2021**	**2022**	**Average**	**2021**	**2022**	**Average**	**2021**	**2022**	**Average**
Mogo Arrochila	15.53±2.10ab	10.27±1.11b	12.90±1.61	2386.4±15.40e	2546.0±15.33ef	2466.9±15.36	7123.3±42.56f	6655.0±37.53h	6889.0±40.04	33.50±0.23	38.26±0.45	35.91±0.34
Read Head	13.77±1.17ab	12.40±0.57ab	13.08±0.87	3248.1±10.43a	2445.4±35.82f	2846.4±23.12	9380.0±15.28b	6945.1±24.51g	8162.5±19.89	34.63±0.12	35.21±0.40	34.90±0.26
Rainbow	14.90±0.61ab	13.47±0.38a	14.18±0.49	3129.8±24.90bc	2636.5±41.00de	2882.3±32.95	8426.7±58.12d	7833.3±60.09d	8129.5±59.51	37.14±0.16	33.66±0.43	35.39±0.29
French Vanilla	11.25±0.38b	11.67±1.10ab	11.45±0.74	3056.2±27.76c	2840.4±23.10abc	2948.9±25.43	7846.7±56.08e	7700.2±40.27e	7773.3±48.17	38.95±0.38	36.89±0.47	37.92±0.42
Sandoval Mix	12.07±1.37b	11.63±0.68ab	11.85±1.02	3164.2±28.32ab	2915.4±40.37a	3039.1±34.34	8333.3±56.11d	7360.0±66.58f	7846.3±61.34	37.97±0.25	39.61±0.38	38.79±0.31
Q-52	10.60±0.12b	12.20±0.40ab	11.40±0.26	3218.9±7.06bc	2604.8±25.35de	2911.6±16.20	7186.7±84.52f	6643.3±29.06h	6914.0±56.79	44.80±0.47	39.21±0.55	42.00±0.51
Titicaca	13.93±1.75ab	11.95±0.32ab	12.94±1.03	3063.2±15.94c	2798.4±56.43abc	2930.4±36.18	8280.3±23.24d	8173.8±17.92c	8226.3±20.58	36.99±0.09	34.24±0.75	35.58±0.42
Cerry vanilla	15.07±1.62ab	12.35±0.09ab	13.70±0.85	2866.6±22.53d	2688.1±19.63cde	2777.7±21.08	7843.3±63.33e	6893.3±14.53g	7368.0±38.93	36.55±0.44	39.00±0.25	37.77±0.34
Mint Vanilla	13.00±0.62ab	11.85±0.03ab	12.42±0.32	3266.7±24.82a	2819.1±51.37abc	3042.5±38.09	8973.3±20.28c	8398.1±36.33b	8685.4±28.30	36.40±0.19	33.57±0.66	34.98±0.42
Population China	16.36±2.16ab	12.27±0.23ab	14.31±1.19	3223.8±34.19ab	2719.1±56.46bcd	2971.4±45.32	9793.3±55.14a	8610.0±51.32a	9201.6±53.23	32.92±0.43	31.58±0.49	32.24±0.46
Orode Valle	18.40±1.55a	13.73±0.46a	16.06±1.01	2923.6±38.17d	2881.9±35.10ab	2902.4±36.63	8986.7±52.07c	8583.3±31.80a	8784.3±41.93	32.53±0.29	33.58±0.35	33.04±0.32
F-Value	*	*		**	**		**	**		**ns**	*	
CV (%)	**15.39**	**8.00**		**1.44**	**2.59**		**1.12**	**0.94**		**1.51**	**2.46**	
LSD	**3.68**	**1.65**		**74.98**	**119.93**		**160.11**	**123.01**		**0.94**	**1.50**	

*Significant at the 5% level, **significant at the 1% level, ns: not significant

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Tan and Temel (2018) reported that seed yields varied between 825.0–4004.3 kg/ha in Erzurum and Iğdır, and Pulvento et al. (2010) in Italy, and that these differences were due to the different seed production capacities of varieties with different genetic structures. The results of the researchers (Jacobsen, 2014; Geren et al., 2014; Maamri et al., 2022; Katwal and Bazile, 2020; Oustani et al., 2023 and Snowball et al., 2022) who stated that the yield potential of quinoa under optimum conditions may vary depending on conditions such as climate, soil, planting time, variety, etc., showed that different results can be obtained depending on the cultivation region and variety. In addition, researchers reported that the differences in grain yield between years were affected by the changes in precipitation and temperature in the regions between years, and therefore, the number of plants per unit area and other morphological characteristics were affected. It is thought that our findings are within the range of the findings obtained by many of the researchers mentioned, but the differences obtained may be due to differences in the variety used, agricultural practices (fertilization, irrigation, etc.) and ecological factors of the region (climate, soil, etc.).

Biological yield and harvest index

When the findings obtained for biological yield as a result of the two-year study conducted with quinoa genotypes were examined, statistically significant ($p \leq 0.01$) was determined in both years. The average biological yield of the genotypes in was determined between 6889-9201.6 kg/ha. In 2021, the highest biological yield was measured in the Population China genotype (9793.3 kg/ha), the lowest in the Mogo Arrochila variety (7123.3 kg/ha); the highest in the Population China variety (8610.0 kg/ha), and the lowest in the Q-52 variety (6643.3 kg/ha) in 2022. When the findings obtained for harvest index were examined, it was found that it was statistically significant ($p \leq 0.01$) in 2021 but not significant in 2022. The average harvest index of the genotypes in was determined between 32.24-42%. In 2021, the highest harvest index was measured in the Q-52 variety (44.80%), the lowest in the Orode Valle variety (32.53%), and in 2022, the highest in the Sandoval Mix variety (39.61%), and the lowest in the Population China variety (31.58%) (*Table 3*).

It is an expected result that biological yield varies among quinoa genotypes and ecologies with different characteristics (Tan and Temel, 2018; Kır and Temel 2017; Bertero and Ruiz, 2008; Gesinski, 2008; Bhargava et al., 2007). In fact, when we look at the results we obtained, it can be seen that this explanation is confirmed.

Maamri et al. (2021), Tan and Temel (2018), Kır and Temel (2017), Lavini et al. (2014), and Bhargava et al. (2008) reported that there were generally significant differences in the harvest index of quinoa according to variety and region. This seems consistent with our results.

1000 seed weight (TGW)

When the findings obtained in terms of TGW between genotypes were examined, it was determined that there was a statistically significant ($p \leq 0.05$ and $p \leq 0.01$) relationship in both years. The average TGW values of the genotypes varied between 2.03 g (Mogo Arrochila) and 2.43 g. (Population China). In 2021, the lowest TGW was detected in the Cherry Vanilla (2.07 g), the highest TGW was detected in the Population China and Orode Valle variety (2.54 g), the lowest TGW was detected in the Mogo Arrochila variety (2.25 g), the highest TGW was detected in the Sandoval Mix variety (2.89 g) in 2022 (*Table 4*).

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Table 4. *Values of 1000 seed weight, hectoliter weight and seed protein ratio*

Varieties	1000 seed weight (TGW)(g)			Hectoliter weight (kg/hl)			Seed protein ratio (%)		
	2021	**2022**	**Average**	**2021**	**2022**	**Average**	**2021**	**2022**	**Average**
Mogo Arrochila	2.18±0.20b	2.25±0.49b	2.03±0.34	46.80±1.86	45.47±1.11	46.13±1.48	13.32±0.04bc	13.12±0.79c	13.22±0.42
Read Head	2.33±0.08ab	2.56±0.08ab	2.39±0.08	50.10±1.23	46.10±1.86	48.10±1.54	15.58±0.08a	15.39±0.03a	15.48±0.06
Rainbow	2.31±0.11ab	2.56±0.05ab	2.30±0.08	51.57±1.56	48.90±1.03	50.23±1.29	11.01±0.20d	11.48±0.38d	11.24±0.29
French Vanilla	2.20±0.04ab	2.72±0.09ab	2.25±0.06	50.37±0.60	49.70±1.32	50.33±0.96	14.78±0.57ab	15.05±0.42ab	14.91±0.50
Sandoval Mix	2.21±0.16ab	2.89±0.04ab	2.22±0.10	48.33±1.27	45.67±1.74	47.00±1.50	14.58±0.08ab	14.18±0.09abc	14.38±0.09
Q-52	2.26±0.03ab	2.66±0.06ab	2.38±0.22	50.80±0.84	48.80±2.24	49.80±1.54	13.93±0.38bc	13.22±0.06c	13.57±0.22
Titicaca	2.17±0.13ab	2.48±0.03ab	2.32±0.04	48.67±0.62	46.00±1.07	47.33±0.84	13.53±0.52bc	13.32±0.04c	13.42±0.28
Cerry vanilla	2.07±0.17b	2.64±0.14ab	2.27±0.15	46.77±0.26	44.10±0.91	46.13±0.58	13.63±0.02bc	13.02±0.45c	13.32±0.24
Mint Vanilla	2.27±0.08ab	2.63±0.04a	2.45±0.06	50.43±2.93	47.10±2.03	48.76±2.48	13.01±0.03c	13.61±0.04bc	13.31±0.04
Population China	2.54±0.06ab	2.63±0.07ab	2.46±0.07	51.30±1.71	46.63±2.04	48.96±1.87	12.49±0.51c	13.76±0.21bc	13.12±0.36
Orode Valle	2.54±1.04a	2.74±0.04a	2.18±0.54	48.93±0.43	44.60±0.90	46.76±0.66	13.65±0.38bc	13.78±0.21bc	13.71±0.30
F-Value	*	**		ns	ns		**	**	
CV (%)	**7.79**	**3.95**		**4.58**	**5.94**		**4.24**	**4.45**	
LSD	**0.30**	**0.176**		**3.98**	**4.72**		**0.98**	**1.03**	

*Significant at the 5% level, **significant at the 1% level, ns: not significant

Oustani et al. (2023) determined the TGW values of the genotypes as 1.61-2.68 g, Tan and Temel (2018) as 2.12-2.61 g, and Kır and Temel (2017) as 1.98-2.65 g. It can be seen that thousand grain weights among quinoa genotypes vary due to the different varieties and ecological conditions. Researchers who conducted research in different ecologies in quinoa reported that thousand grain weight varied between 2.18 g and 2.91 g in Argentina (Bertero and Ruiz, 2008), and between 2.25 g and 2.29 g in the Lucknow region of Northern India (Bhargava et al., 2008).

Hectoliter weight and seed protein ratio

When the findings obtained for hectoliter weight were examined, it was determined that it was not statistically significant in both years. The average hectoliter weight of the genotypes was determined between 46.13 kg/hl (Mogo Arrochila and Chery Vanilla) and 50.33 kg/hl (French Vanilla). In 2021, the highest hectoliter weight was measured in Rainbow (51.57 kg/hl), and the lowest in Cerry Vanilla (46.77 kg/hl); in 2022, the highest was measured in French Vanilla (49.70 kg/hl), and the lowest was measured in Cerry vanilla (44.10 kg/hl). The findings obtained for the seed protein ratio were statistically significant ($p \leq 0.01$) in both years. The protein ratio averages of the genotypes varied between 11.24 – 15.48%. In 2021 and 2022, the lowest seed protein ratio was measured in Rainbow (11.08-11.48%); in 2021 and 2022, the highest was measured in Read Head (15.39-15.58%) (*Table 4*). Studies conducted with different genotypes in different regions of the world have revealed that quinoa protein content is between 11.70-21.02%, generally varying depending on the variety and region (Oustani et al., 2023; Snowball et al., 2022; Kır and Temel, 2017). These results are also consistent with our results.

Conclusion

It was thought that quinoa could be grown as an alternative product in high altitude lands in the Eastern Anatolia Region of Türkiye. As a result of this study conducted in

Van, which has a continental climate, it was determined that all quinoa genotypes used could be easily grown for seed production in irrigated conditions. However, the responses of the genotypes varied according to the years. In the study, there was a decrease in grain yield in all genotypes according to the years. However, the highest yield was obtained from Sandoval Mix and Mint Vanilla genotypes and it was determined that they were more stable. In the light of these results, we believe that it would be beneficial to grow these varieties that stand out for the region.

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