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QUINOA (*Chenopodium quinoa* Willd.): A PROMISING NEW CROP FOR ROMANIA

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Abstract

This work was undertaken to evaluate the adaptability of quinoa under the South-Eastern Romania's climatic conditions. The trial was carried out in the experimental field of the University of Agronomic Sciences and Veterinary Medicine of Bucharest during the 2024 growing season. For this purpose, two quinoa cultivars sourced from Quinoa Quality ApS, Denmark, were analyzed for growth and seed yield parameters. The experiment was of a monofactorial type and was organized using a Randomized Block Design with four replications. Results showed that in the extremely dry year of 2024, seed yields ranged from 1.000 to 1.917 t/ha. Among the two cultivars, Vikinga yielded the least at 1.000 t/ha, which was 31.44% lower than the control, while the highest yield was recorded for the Puno at 1.917 t/ha, representing a significant increase of 31.43% compared to the control. Both varieties exhibited superior performance across all growth traits, including plant height, maturity, dry weight, and harvest index, all significantly correlated with seed yield. The promising agronomic performance of these cultivars under drought conditions suggests substantial potential for quinoa cultivation in Romania.

Key words: *Chenopodium quinoa, growth traits, seed yield, correlation.*

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is an Andean plant that originated in the Southern Altiplano of Bolivia and the Puno Region in Peru, near Lake Titicaca, at elevations ranging from 3,000 to 4,000 meters above sea level (Espindola, 1986). Due to its recognized nutritional value and ability to adapt to various geographic regions, quinoa cultivation has expanded globally since the 2000s (Didier et al., 2021). Furthermore, because of its high content of proteins, lipids, vitamins, and minerals, along with an excellent balance of essential amino acids, its consumption has been promoted in many countries facing food security challenges. Quinoa is an annual dicotyledonous plant that is predominantly self-pollinated, although cross-pollination can occur at rates of up to 10 to 15% (Rane et al., 2019). It is a C3 crop recognized for its resilience in tough environments and extreme climatic conditions (Ahmadi et al., 2019; Razzaghi et al., 2011). According to Jacobsen et al. (2003), quinoa demonstrates a high degree of resilience to several major adverse factors, including frost, soil salinity, drought, diseases, and pests. This species is increasingly being regarded as a viable alternative to help address water scarcity issues in various regions around the globe (Pathan et al., 2022; Graziano et al., 2022). As a result, quinoa is recognized as one of the world's most sustainable crops due to its adaptability to diverse environments and its relatively low environmental impact compared to many other crops. Despite its advantages, quinoa remains a neglected and underutilized crop in Romania, highlighting a pressing need for extensive scientific research to facilitate its widespread cultivation. One of the primary challenges in adopting quinoa as a viable agricultural product in our country is the limited availability of suitable genotypes for local production. In South America and several European countries, including the United Kingdom, France, Germany, the Netherlands, and Denmark, various cultivars and ecotypes of quinoa have been successfully developed and cultivated, showcasing a diverse genetic pool that can be harnessed to improve agronomic performance. To enhance quinoa cultivation in Romania, it is essential to identify and introduce suitable genetic materials that are adapted to our specific agro-ecological conditions. Research indicates that quinoa yields can vary significantly based on genotype and environmental factors (Miranda et al., 2012). Therefore, comprehensive studies aimed at evaluating the performance of different quinoa genotypes across diverse ecological settings in Romania are crucial. These studies should focus on assessing factors such as adaptability, yield potential, disease resistance, and nutritional quality. By conducting localized trials and optimizing genotype selection, Romania can leverage the agronomic potential of quinoa, ultimately promoting crop diversification, improving food security, and enhancing the resilience of our agricultural systems.

Thus, the objective of this study was to assess the adaptability of quinoa (*Chenopodium quinoa* Willd.) to the climatic conditions of South-Eastern Romania by evaluating two Danish quinoa cultivars for their growth and yield-related parameters. The goal was to provide information about crop management under Romanian conditions and to determine which cultivars are worth keeping for further experimentation.

MATERIALS AND METHODS

Plant material and experimental site

This study used two Danish quinoa cultivars, Puno and Vikinga. The main traits of the quinoa cultivars are presented in Table 1. A field experiment was carried out at the University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania during the 2024 growing season. Bucharest is situated in the south eastern corner of the Romanian Plain (44°26' N latitude, 26°06' E longitude and 90 m altitude above sea level).

The soil characteristics of the experimental plots are included in Table 2. The soil was characterized by a slightly alkaline pH, low humus content, moderate levels of total nitrogen, high levels of mobile phosphorus, and very high levels of mobile potassium.

The soil analyses were conducted in 2023 at the laboratories of the National Institute of Research and Development for Pedology, Agrochemistry, and Environmental Protection in Bucharest, Romania.

Table 1. Quinoa cultivars tested, their origins and main traits

Cultivar	Origin	Traits
Puno	Quinoa Quality ApS, Denmark	Drought and salt tolerant; Resistant to downy mildew; High protein quality; High iron content.
Vikinga	Quinoa Quality ApS, Denmark	Drought and salt tolerant; High protein quality; High iron content; Low saponin, integral grain.

Source: https://www.quinoaquality.com/quinoa-seeds

Table 2. Soil characteristics at the study site

Type	Reddish Preluvosol
Texture	Clay-Loam
pH	7.79
Humus content	1.67 %
Total nitrogen	0.166 %
Mobile phosphorus	P_{AL}= 92 mg/kg
Mobile potassium	K_{AL}= 329 mg/kg

Weather conditions

The year 2024 was the warmest year in the history of meteorological measurements in Romania, with an average annual temperature of 12.9916°C, according to the National Meteorological Administration (NMA). Regarding the climatic conditions in Bucharest, the agricultural year 2024 was exceptionally warm with low precipitation throughout the entire growing season (Figure 1). Water stress and heat have had a negative impact on the majority of agricultural crops, leading to a reduction in seed production, both in quantitative and qualitative.

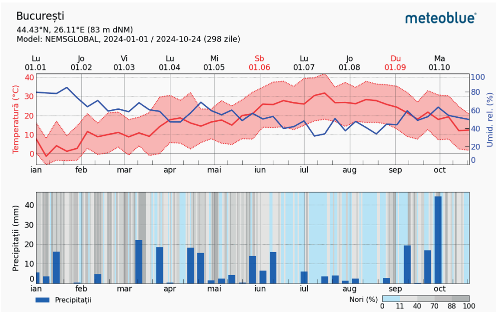

Figure 1. Climate conditions (average temperature and precipitation) in Bucharest - January-October 2024 (Source: https://www.meteoblue.com/ro)

Experimental Protocol and Cultivation Management

In preparation for the soil for sowing spring crops (cultivars of quinoa), plowing was carried out in the fall at a depth of 30 cm. In the spring, to prepare the seedbed (breaking up and leveling the land), on March 11, 2024, work was done with a disc (2 passes) and with a cultivator. The marking of the experimental plot was carried out on March 20, 2024.

The field experiment was of a monofactorial type and was organized using a Randomized Block Design with four replications for each plot/variety (10 m² per plot per replication).

Sowing is a crucial step, as it directly influences seedling emergence, plant density, and ultimately the final yields. Seeds were manually sown on April 9, 2024 and covered to a depth not exceeding 2 cm as recommended by previous research (Hirich et al., 2014).

Plots size was 6 rows of 4 m, with an inter-row spacing of 50 cm, maintaining a density of 100 plants per square meter. However, quinoa is a relatively new crop in Europe, and determining the generally accepted sowing density for its cultivation is challenging (Trotsenko et al., 2023). Different factors, such as local growing conditions, variety of quinoa, and specific farm management practices, may influence the ideal sowing density. Experimentation and observation over time will help refine these practices.

In the spring of 2024, nitrogen (NH_4NO_3) was applied in split applications, at sowing (40 kg/ha) and during the vegetative growth phase before flowering (40 kg/ha). No chemical treatments were used to control weeds or diseases. During the growing season, three mechanical hoeings were carried out to combat weeds. Additionally, two irrigations were applied, one in April after sowing and the second before flowering

Parameters Estimated

a) Plant height was measured in the field at physiological maturity. For this assessment, ten plants from each replication were randomly selected for evaluation.

b) Maturity was recorded in days, calculated from the date of emergence to the date when the crop was deemed ready for harvest.

c) Dry weight (g/plant) refers to the dry biomass above ground for each individual plant.

The sample size consisted of 5 plants, randomly selected from each replication

d) The harvest index is expressed as the percentage ratio of seed yield per plant to the dry weight per plant.

e) Pathogen and insect control: Visual inspections were conducted to assess the presence of pathogen and insect attacks on quinoa plants.

f) Seed Yield: The seed yield from all the plants in each plot was collected and weighed, with the total yield for each plot converted to tonnes per hectare (t/ha). The harvesting was done manually for each replication when the plants reached full maturity (seed moisture at 12%).

Statistical analysis

The collected data underwent statistical processing, where analysis of variance (ANOVA) was conducted for each parameter at a significance level of 0.05. Additionally, correlation analysis was performed to assess the relationships between seed yield and various growth traits, including maturity, dry weight, plant height and harvest index.

RESULTS AND DISCUSSIONS

Phenological observations

Table 3 presents phenological observations that are critical for assessing the days to maturity.

Table 3. Quinoa cultivars tested and phenological data for 2024 cropping season

Cultivar	Sowing date	Emergence date	Harvest date
Puno	09.04.2024	23.04.2024	03.09.2024
Vikinga	09.04.2024	24.04.2024	02.09.2024

Given the drought conditions during the sowing period, the time from sowing to emergence was 15 days for the Puno cultivar and 16 days for the Vikinga cultivar. Similar findings regarding the period from sowing to emergence for quinoa were reported by Domingos and Bilsborrow in 2022. They found that crop emergence began 10 to 14 days after sowing, with stem elongation and inflorescence emergence occurring at the beginning of June, and flowering taking place at the end of June in all analyzed years.

Resistance to biotic stress

In terms of quinoa cultivars' resistance to biotic stress, both cultivars experienced aphid infestations during their growth and development, although the level of pest pressure was not deemed significant. From the perspective of pathogen attacks, particularly concerning *Peronospora farinosa* f.sp. *chenopodii* (downy mildew), a notably incidence of infection was observed in the Vikinga cultivar, which demonstrated susceptibility to this pathogen. In contrast, the Puno cultivar exhibited a minimal response to the pathogen. The response to downy mildew infection involves visually assessing the severity of the disease, which is determined by the proportion of leaf tissue affected by lesions caused by the pathogen (Danielsen et al., 2004). Zala and Szilagyi (2024) found that the disease severity index recorded an intensity of 6.6% for the Vikinga cultivar and 0.65% for the Puno cultivar.

Plant height and Dry weight

In terms of plant height, there was a significant difference between the two quinoa cultivars. Thus, Puno had the highest measurement at 164.20 cm, while Vikinga measured 114.18 cm (Table 4).

The differences in plant heights among the cultivars may be attributed to their genetic structures and varying responses to the environment. T

he comparison of the dry weight trait between the two varieties is statistically insignificant. Dry weight ranged from 29.03 to 28.07 g/plant, with a mean of 28.55±1.17 (Table 4).

Table 4. Plant height and Dry weight of 2 quinoa cultivars

Cultivars	Plant height (cm)	Dry weight (g/plant)
Puno	164.20	29.03
Vikinga	114.18	28.07
Mean ± S.E*.	139.19±1.78	28.55±1.17
$LSD_{0.05}$**	2.69	3.02

*S.E. - standard error;
**LSD - least significant difference; P ≤ 0.05%.

Maturity and Harvest index

Maturity ranged from 132 days (Vikinga) to 134 days (Puno). The difference between the two cultivars is not significant.

Quinoa is classified as a short-day plant, meaning that it initiates flowering and matures as the length of daylight decreases during the summer months. This photoperiod sensitivity is crucial for its growth cycle.

Results show that the harvest index ranged from 49.27% to 51.33%, with an average of 50.30±3.01, with Puno exhibiting the highest value (51.33%) (Table 5).

Table 5. Maturity and Harvest index of 2 quinoa cultivars

Cultivars	Maturity (days)	Harvest index (%)
Puno	134.00	51.33
Vikinga	132.00	49.27
Mean±S.E.*	133.00±2.13	50.30±3.01
$LSD_{0.05}$**	4.04	5.89

*S.E. - standard error;
**LSD - least significant difference; P ≤ 0.05%.

Seed yield

The mean seed yield values are presented in Table 6. The performance of quinoa varied significantly between the two cultivars under Romanian conditions. Seed yield ranged from 1.000 to 1.917 t/ha, with Vikinga showing the lowest yield at 1.000 t/ha, which was 31.44% lower than that of the control.

The highest seed yield was exhibited by Puno, at 1.917 t/ha, representing a significant increase of 31.43% compared to the control (Mean of experiment).

Table 6. Seed yield of quinoa cultivars

Cultivar	Seed yield (t/ha)	Relative yield (%)	Difference±CT* (t/ha)
Puno	1.917	131.43	+0.4585
Vikinga	1.000	68.56	-0.4585
Mean±S.E**	1.4585±0.256	100	CT
$LSD_{0.05}$***	0.4025	-	-

*CT - Control - Mean of the experiment;
**S.E. - Standard Error;
***LSD - least significant difference; P ≤ 0.05%.

Correlation Analysis

The correlation coefficients are included in Table 7. Seed yield showed a significant positive correlation with all key factors, including plant height, maturity, dry weight, and harvest index. This suggests that taller plants, those that reach maturity later, and those with higher dry weights and harvest index tend to produce greater seed yields. Understanding these relationships can assist in the selection and breeding of plant varieties that maximize seed production.

The plant height was associated with the duration of maturity, and generally, shorter varieties exhibited earlier traits.

Similar results have also been reported by Tan and Temel (2018).

Regarding the significant positive association between quinoa seed yield and plant height, dry weight, and harvest index, comparable findings have been documented by Bhargava et al. (2007) and Szilagyi et al. (2014).

Table 7. Correlation coefficients among five traits in quinoa cultivars

Traits	Maturity	Plant height	Dry weight	Harvest index	Seed yield
Maturity	x				
Plant height	0.425**	x			
Dry weight	0.143	0.321*	x		
Harvest index	0.081	0.218*	0.418**	x	
Seed yield	0.462**	0.429**	0.633**	0.518**	x

Level of significance: *P = 0.05, **P = 0.01

CONCLUSIONS

Based on the data collected during the first year of testing the Puno and Vikinga cultivars, we can conclude that quinoa has the potential to be a viable alternative crop with favorable characteristics for cultivation in the pedo-climatic conditions of Romania. However, it is essential to test earlier sowing dates (specifically, the end of March) in the coming year. By selecting the optimal sowing time, the plants are likely to develop more robustly, leading to increased seed production capacity and an earlier harvest (starting in early August). Additionally, it is important to identify the most effective treatments for combating downy mildew.

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