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PRELIMINARY AGRONOMIC EVALUATION OF *Chenopodium quinoa* Willd. UNDER CLIMATIC CONDITIONS OF ROMANIA

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Abstract

During the 2013 growing season.the trial was carried out in the experimental field of University of Agronomic Sciences and Veterinary Medicine of Bucharest to explore the potential for quinoa growing in climatic conditions of South Eastern Romania. Four quinoa varieties provided by the University of Copenhagen were evaluated for seed yield and some morphological traits. Under irrigated conditions, with nitrogen fertilization, seed yield ranged from 1.70 to 2.96 t/ha Jason Red showing the lowest yield (1.70 t/ha).Highest seed yield was exhibited by Jacobsen 2 (2.96 t/ha), followed by Mixed Jacobsen (2.53 t/ha) and Jørgen 37 (1.84 t/ha). Out of four quinoa varieties, only two showed above average seed yield (2.25 t/ha). These two varieties Jacobsen 2 and Mixed Jacobsen also exhibited above average performance for all morphological traits: plant height, maturity, dry weight and harvest index. All morphological traits showed significant positive association with seed yield. The agronomic performances recorded by these varieties suggest that can be extended commercial cultivation of quinoa in the Romania.

Key words*: Chenopodium quinoa, seed yield, harvest index, maturity, correlation.*

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is native to Andean mountains of Peru, Bolivia, Ecuador and Colombia where it was domesticated some 3.000 to 5.000 years ago. Quinoa is in fact not technically a cereal grain at all, but is instead what it calls a "pseudo-cereal" – the name for foods that are cooked and eaten like grains and have a similar nutrient profile. Quinoa is a highly nutritious food with protein quality and quantity in the seed that is superior to those of more common cereal grains, for example it contains more lysine than the wheat and the amino acid content of quinoa seed is considered well-balanced for human and animal nutrition, as good as to that of the casein. Unlike other grains and cereals, quinoa provides a complete protein, containing all the essential amino acids, making it an ideal food for all diets. Botanically, quinoa is related to beets and spinach. It is an annual dicotyledonous plant, grows to 0.5-3.0 m (1.0-1.5 m in average) and is predominantly self-pollinated. Cytological evidence has shown that quinoa is an allotetraploid species with chromosome number 2n = 4x = 36. Quinoa seeds, and to some extent its leaves, are traditionally used for human and livestock consumption in the Andean region and have exceptional nutritional qualities (Repo-Carrasco et al., 2003; Stikic et al., 2012). In recent times, quinoa has become an interesting species for research, production and consumption in United States, Europe, Asia and Africa. Its cultivation has spread to more than 70 countries. Quinoa was introduced to England in the 1970s, after which studies were started on the crop in Denmark. In 1993, a project was approved in the European Union, titled “Quinoa—A multipurpose crop for EC’s agricultural diversification,” with field trials in England, Denmark, the Netherlands, and Italy, in addition to laboratories in Scotland and France (Jacobsen, 2003). Additional countries have recently shown interest in the crop, including Sweden, Poland, Czech Republic, Austria, and Greece, who are all participating in the American and European Test of Quinoa, and Finland (Iliadis et al., 1997, 2001; Keskitalo, 1997; Ohlsson, 1997). In Romania, quinoa is almost unknown, being one crop yet unexploited by the researchers and growers,

despite its advantages. It is sold in our country, especially in organic or natural foods stores. Quinoa has been selected by the Food and Agricultural Organization of the United Nations (FAO) as a good candidate to offer food security in the next century, especially in the face of the predicted future world scenario of increasing salinization and aridity (Karina et al., 2013). This is why the FAO declared 2013 to be the International Year of Quinoa. Quinoa has an amazing ability to adapt to adverse conditions of climate and soil where other crops cannot grow, especially at high altitudes (over 4000 m). This species is adaptable to different photoperiods, indeed there are even short-day and day-neutral cultivars (Bertero et al., 1999; Bertero, 2001; Casini, 2002). For European conditions the most suitable genotypes are those originating in Chile (0-500 m above sea), with short growth season, unramified habitus, long and compact inflorescence and big white or yellow seeds with low content of saponins. Quinoa exhibits high level of resistance to several predominant adverse factors, like frost, soil salinity, drought, diseases and pests (Jacobsen et al., 2003). It can tolerate soil pH from 4.8 to 9.5 because of mycorrhizal associations, thus maximizing the use of scarce nutrients (Tapia, 1979; Mujica, 1994). Quinoa can be sown from the end of April when soil temperature reaches 7-10°C. Earlier sowing can slow germination and cause bad competitive ability against weed. Number of plants in range from 100 to 500 plants per square meter is the most appropriate and does not affect significantly the yield. The most suitable soils for quinoa cultivation are sandy to sandy-loam. Heavy clay soils are not desirable. It can be successfully grown in poor soils also. Experimental results show that yields can be increased by preparing the soil well, applying 80-40-00, fractionated nitrogen during sowing and earthing up. The aim of this study was to evaluate four quinoa varieties for potential seed yield under climatic conditions from South Eastern of Romania; therefore to provide information about crop management and to determine whether some of varieties are worth-keeping for further experimentation and cultivation.

MATERIALS AND METHODS

Experimental site and set up

The trial was carried out in the experimental field of University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania, during the 2013 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 of trial site is chromic luvisol with medium alkaline pH and clay-loam texture. The experimental design was a randomized block, in three replications (10 m^2/plot). Plots size was 6 rows of 4 m, with an inter-row spacing of 0.5m and 3 cm sowing depth. Sowing date was 9 May 2013. During the season, plants were treated against weeds. Nitrogen (NH_4NO_3) was supplied at sowing (40 kg/ha) and again during vegetative growth before flowering (40 kg/ha). Harvest by hand on 23 September – 2 October 2013 was done at physiological maturity, which was defined as the date when seeds from the main panicle become resistant when pressed (Bertero et al., 2004).

Materials

Four quinoa varieties provided by the University of Copenhagen were evaluated for seed yield and morphological traits (Table 1).

Table 1. Quinoa varieties tested, their origin and phenotypic seed color

Varieties	Origin	Phenotypic seed color
Jason Red	France	Purple
Jacobsen 2	Denmark	Yellow
Mixed Jacobsen	Denmark	Mixed (red, white, yellow)
Jørgen 37	Denmark	Yellow

Parameters estimated

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

b) Maturity was taken (in days) from date of emergence to the date when the crop was ready for harvesting.

c) Dry weight (g/plant): dry above-ground biomass per plant.

d) Harvest index: percentage ratio between seed yield per plant and dry weight per plant.

e) Seed yield: the seed yield of all the plants of each plot were bulked and weighed and the seed yield/plot was converted to tonnes per hectare (t/ha).

Statistical analysis

The data collected was subjected to statistical processing following analysis of variance (ANOVA). The least significant difference (L.S.D.) for each character was calculated at 0.05 level of probability. Correlation analysis was performed to evaluate the relationships between seed yield and morphological traits.

RESULTS AND DISCUSSIONS

Weather conditions

Bucharest has a transitional climate, with both continental and subtropical influences (Köppen climate classification *Cfa/Dfa/Cfb/Dfb*). Winter temperatures often dip below 0°C, sometimes even to -20°C. In summer, the average temperature is 23°C (the average for July and August). Temperatures frequently reach 35 to 40°C in mid-summer. Average precipitation and humidity during summer are low. During spring and autumn, daytime temperatures vary between 17 to 22°C, and precipitation during this time tends to be higher than in summer with more frequent yet milder periods of rain.

The weather conditions for the period over wich the study was conducted are summarized in Figure 1. The quantity and distribution of rainfall were highly variable throughout the growth period. Temperature was not limiting for quinoa growth; the values recorded over the active growth period (from initiation of flowering to pod filling between June – July) were relatively favorable in the 2013 growing season. Two additional irrigations were made, one in May after sowing for emergence and second before flowering.

Morphological parameters and seed yield

In Table 2 are shown phenological observations that are important for determining the days to maturity.

The mean values for morphological and seed yield traits are presented in Table 3. Performance of quinoa varied greatly between varieties in Romanian conditions. Seed yield ranged from 1.70 to 2.96 t/ha with Jason Red showing the lowest yield (1.70 t/ha).

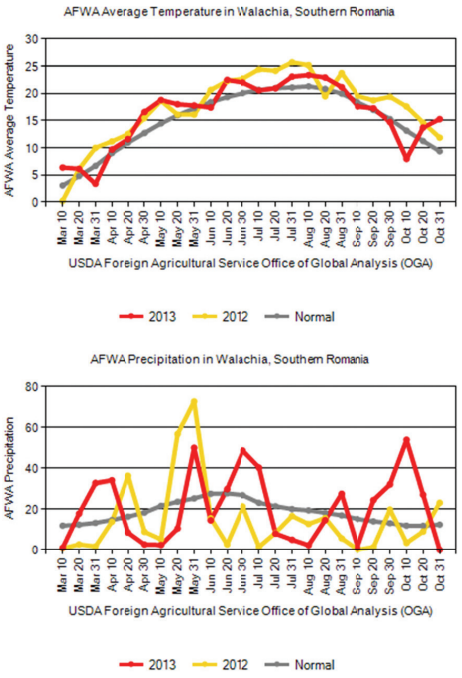

Figure 1. Average temperature and precipitation in Southern Romania, 2012-2013

Table 2. Quinoa varieties tested and phenological data; 2013 growing season

Varieties	Sowing date	Emergence date	Harvest date
Jason Red	09.05	17.05	23.09
Jacobsen 2	09.05	16.05	02.10
Mixed Jacobsen	09.05	17.05	01.10
Jørgen 37	09.05	16.05	27.09

The highest seed yield was exhibited by Jacobsen 2 (2.96 t/ha), followed by Mixed Jacobsen (2.53 t/ha) and Jørgen 37 (1.84 t/ha). Out of four quinoa varieties, only two showed above mean seed yield (2.25 t/ha). These two varieties Jacobsen 2 and Mixed Jacobsen also exhibited above average performance for all morphological traits: plant height, maturity, dry weight and harvest index.

Maturity ranged from 130 to 140 days. Late maturity genotypes, like Jacobsen 2 and Mixed Jacobsen grew taller than the ones that matured early as Jason Red and Jørgen 37, being superior in other yield components.

Results show that harvest index ranged from 44.52% to 57.03% with an average of 50.02±3.40, Jacobsen 2 exhibiting the highest value (57.03%).

Correlation study

The correlation coefficients are presented in Table 4. Seed yield was significant positive associated with plant height, length of the vegetation period, dry weight and harvest index. The maximum value was recorded for maturity (0.863). It is known that selection for lateness has resulted in more productive genotypes, similarly to yield obtained in high latitude (Jacobsen et al., 1996). The minimum value was exhibited for harvest index (0.492). Early maturity genotype as Jason Red, recorded a higher harvest index (50.33%) than Mixed Jacobsen late maturity genotype (48.20%) (Table 3). Harvest index low values for late and high values for early maturity genotypes supported similar findings by Spehar et al. (2005). Similar results have been reported by Bhargava et al. (2007), concerning significant positive association among quinoa seed yield and plant height, dry weight and harvest index.

Table 3. Morphological and yield parameters of 4 quinoa varieties

Varieties	Maturity (days)	Plant height (cm)	Dry weight (g/plant)	Harvest index (%)	Seed yield (t/ha)
Jason Red	130.00	122.50	24.08	50.33	1.70
Jacobsen 2	140.00	166.18	30.07	57.03	2.96
Mixed Jacobsen	138.00	152.33	24.67	48.20	2.53
Jørgen 37	135.00	148.45	20.19	44.52	1.84
Mean±S.E*.	135.75±2.51	147.36±1.03	24.75±1.89	50.02±3.40	2.25±0.24
$LSD_{0.05}$**	5.06	2.09	3.77	6.82	0.54

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

Table 4. Correlation coefficients among five traits in quinoa varieties: seed yield, maturity, plant height, dry weight and harvest index

Traits	Maturity	Plant height	Dry weight	Harvest index
Seed yield	0.863**	0.745**	0.688**	0.492**
Maturity	x	0.960**	0.313*	0.167
Plant height		x	0.251*	0.144
Dry weight			x	0.569**

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

CONCLUSIONS

Seed yield and harvest index of the cultivar Jacobsen 2 and Mixed Jacobsen were much higher than the other quinoa varieties and its have a great potential for cultivation in Romanian conditions.

A growing period greater than 140 days (from May date of sowing to October date of harvest) would be too long under Romanian conditions. However, by choosing the best sowing time (April), different stages of plant growth can better develop that lead to increase of yield and to shorten the vegetative period.

Quinoa could be an alternative crop with favourable features for cropping systems in the climatic conditions of Romania.

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