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EVALUATION OF THE DEVELOPMENT AND YIELDING POTENTIAL OF *CHENOPODIUM QUINOA* WILLD. UNDER THE CLIMATIC CONDITIONS OF EUROPE

Part Two: Yielding potential of *Chenopodium quinoa* under different conditions

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S u m m a r y

The evaluation of *Chenopodium quinoa* cultivation effects in Poland has been compared with European research results. It was found that the conditions in Europe are favorable to *Chenopodium quinoa* cultivation. Poland has the mean length of the vegetation period. The maximum value of this trait was found in Sweden. The conditions in Bydgoszcz (Poland) are very favorable to the cultivation for green matter and favorable as far as the seed yield is concerned. The most favorable seed yield was recorded in Greece.

Key words: *Chenopodium quinoa*, yielding potential, Poland, Europe

INTRODUCTION

So far *Chenopodium quinoa* has not been popular when establishing human diet (D ę b s k i and G r a l a k , 2001). Its exceptional survival potential and at the same time high nutritive values suggest that in the contemporary world *Chenopodium quinoa* can alleviate hunger in Africa or Middle East. However, not only, as the high nutritive value of both seeds and green matter are the basis of a wide interest, also in highly-developed countries: Denmark (C h r i s t i a n s e n and J a c o b s e n (2006), England (R i s i and G a l w e j , 1989), Sweden (O h l s s o n and D a h l s t a d t , 2000) and others. The main aim is mainly an increase in food biodiversity. This species can play an important role in the diet of people suffering from celiac disease. Nutritive limitations of this group are specially high and the problem of such cases reported is growing. *Chenopodium quinoa* does not include gluten and so it can be introduced as an element of the diet. High protein quality (9 exogenous amino acids) is yet another reason for using this product. Therefore, getting to know the possibility of production of that plant is important not only in Poland, but also in Europe. This species is not very demanding as far as climate and soil conditions are concerned and so it adapts easily.

The aim of the present paper is to reply to the question which of the European countries analyzed show the most favorable conditions for this species to be grown and at the same time its yielding potential will be highest. The comparative analysis of the effects of cultivation in European countries was compared with regional potential and possibilities of the location the species comes from, that is South American countries.

MATERIALS AND METHODS

Experiments being the basis of comparative study of *Chenopodium quinoa* in Poland, as compared with Poland and Europe and South America, are presented based on international research. Test Quinoa was performed in many countries not only in Europe but also America, Asia and Australia (M u j i c a et al. 2001). However, for the purpose of this paper, research centers were chosen as well as European researchers representing Copenhagen (Denmark), Larissa (Greece), Bydgoszcz (Poland), Uppsala (Sweden) and Valdichiani (Italy), and from South America: Buenos Aires (Argentina), La Paz (Bolivia), Brasilia (Brazil), Cajon (Chile), Cusco and Puno (Peru). *Chenopodium quinoa* cultivars analyzed showed a full developmental cycle (G ę s i ń s k i , 2006). They included RU-2-PQCIP, RU-5-PQCIP (England), NL-6-PQCIP (Holland), 02-EMBRAPA (Brazil), BAER-II-U (Chile), E-DK-4-PQCIP, G-205-95-PQCIP (Denmark). Single-factor experiments were established in the randomized block design in four reps.

The plot area for harvest was 7 m^2, the sowing rate 17 kg $\times ha^{-1}$, depth 1 cm, row spacing 40 cm. The mechanical row-sowing technique was used.

The following characters were analyzed: weather conditions (air temperature: minimum and maximum, total rainfall, sun exposure in the months analyzed – daily means); for *Chenopodium quinoa* (vegetation period length, seed yield, green matter yield, seed diameter, reproduction effort – ratio of the seed weight to vegetative parts of the plant).

For the purpose of this analysis, data unitarization was performed concerning the characters of selected *Chenopodium* cultivars characters and the cultivation effects were compared with the multi-factor method – profile analysis (Brzeziński, 2002; Gęsiński, 2004).

This analysis was performed based on own research performed over the period 1989-2000 and the following publications: Mujica et al. 2001; Gęsiński, 2000, 2001; Iliadis and Karyotis, 2000; Ohlsson and Dahlstadt, 2000).

When developing this analysis, Microsoft Word, Microsoft Excel and Statistica were used.

RESULTS

Comparing the multi-character profiles of *Chenopodium quinoa* for Europe and South America and based on the means for the analyzed locations participating in Quinoa Test, it was observed that they are very similar (Fig. 1). A slight difference was observed only in the case of green matter yield. The value of this character is higher in Europe, while the reproduction effect of *Chenopodium quinoa* is higher in South America (Tab. 1).

The mean length of the vegetation period is almost the same in Europe and America. The mean seed yield obtained from the cultivation of *Chenopodium*

Table 1
Value of *Chenopodium quinoa* traits in Bydgoszcz (Poland), Europe and America.

Area of Europe, Poland and Americas	Mean length of the vegetation period (days)	Mean seed yield ($kg \times ha^{-1}$)	Mean biomass ($kg \times ha^{-1}$)	Mean seed diameter (mm)	Mean reproduction effort (%)
Europe	123.8	1058.7	5345.8	1.7	19.5
Poland	128.1	1652.9	17927.1	1.8	9.2
America	125.1	1056.3	3102.4	1.7	41.8

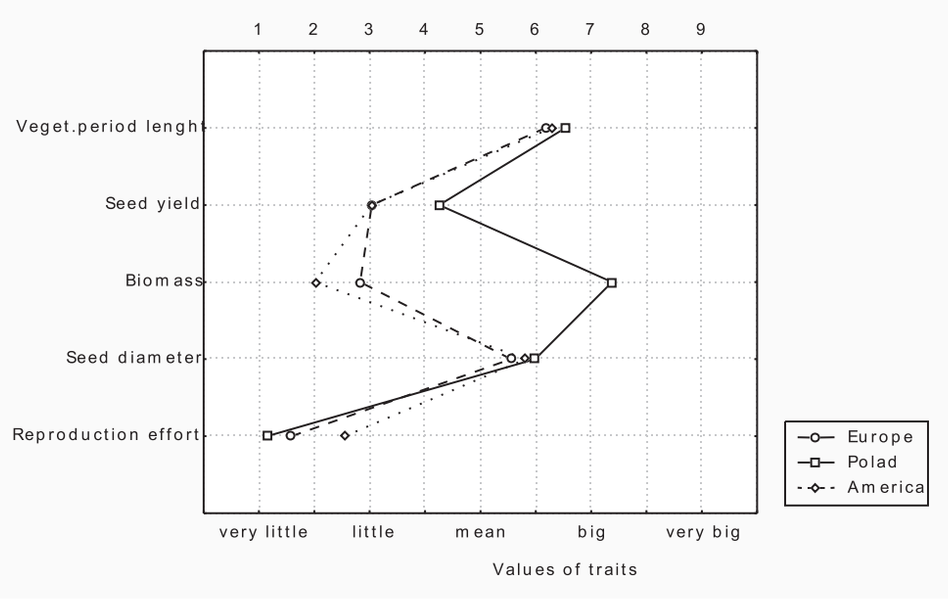

Fig. 1. *Chenopodium quinoa* multi-trait profile for Bydgoszcz (Poland) as compared with the mean values for Europe and America.

quinoa both in Europe and in America is relatively low. Bydgoszcz (Poland), as compared with the means for these continents, was more favorable and the yields reached in our country were average.

The mean yield of green matter obtained in America was very low. In Europe there was found a slightly higher yield of green matter, but it slightly deviated from the results recorded in America. Bydgoszcz (Poland), as compared with the means for Europe and America, showed a higher yield of green matter (a high value of the character).

The diameter of *Chenopodium quinoa* in Europe and in America was average. In Bydgoszcz (Poland) the seeds of *Chenopodium quinoa* are also average in size.

The reproduction effect of *Chenopodium quinoa* obtained as an average for Europe and for Bydgoszcz (Poland) is very low, while in America slightly better results were noted (the index value is low).

Yielding effects of *Chenopodium quinoa* cultivation in Europe

By comparing the *Chenopodium quinoa* potential in European countries based on the profile analysis, one can state that they differ a lot. The most similar profiles based on the average value for the cultivars analyzed were recorded for Uppsala (Sweden) and Copenhagen (Denmark), (Fig. 2). They demonstrated a high vegetation period, very low seed and green matter yield, mean value of the seed diameter and very low reproduction

Table 2
Mean values of *Chenopodium quinoa* traits for the European sites analyzed.

Location	Mean length of the vegetation period (days)	Mean seed yield ($kg \times ha^{-1}$)	Mean biomass ($kg \times ha^{-1}$)	Mean seed diameter (mm)	Mean reproduction effort (%)
Valdichiani (Italy)	115.9	1375.7	8311.6	1.6	16.9
Larisa (Greece)	106.0	2261.0	9779.0	1.6	23.3
Uppsala (Sweden)	139.6	255.3	1823.8	1.8	14.3
Kopenhaga (Denmark)	133.7	342.9	1468.8	1.8	23.2
Bydgoszcz (Poland)	128.1	1652.9	17927.1	1.8	9.2

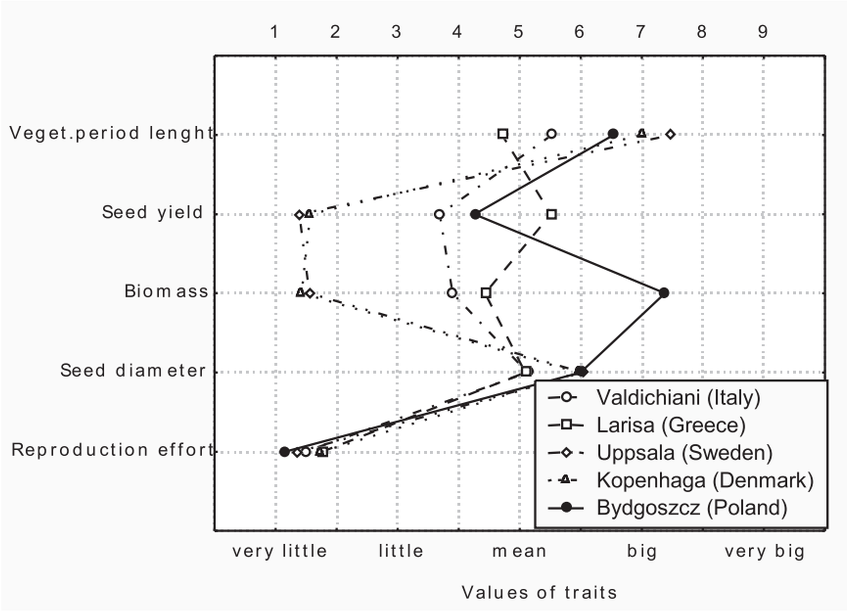

Fig. 2. *Chenopodium quinoa* multi-trait profile for the European locations analyzed.

effect. Considering the length of the vegetation period in the other locations analyzed in Europe: Valdichiani (Italy) and Larisa (Greece), they showed an average value of this character, while Bydgoszcz (Poland) with a much longer vegetation period, was more similar to northern Europe, while the seed yield and green matter yield for Valdichiani (Italy) assumed a low character value, for Larisa (Greece) a mean value. In Bydgoszcz (Poland) there was recorded a high yield of green matter and a mean value of the seed yield (Tab. 2).

In all the locations analyzed in Europe, the seed diameter of *Chenopodium quinoa* was similar (mean value of the character), while the reproduction effect was defined at the level of low value (Fig. 2).

DISCUSSION

Analysis of the yielding potential of *Chenopodium quinoa* showed that Europe is very similar to the areas the species comes from, namely South America. Evaluating the seed yield, one can note that on both continents there are both places in which the growing conditions are more favorable and places where the growing potential of the species is lower (Mujica et al. 2001). A defensive effect on the growing effect (yield) of *Chenopodium quinoa* is attributed to weather conditions, while the latitude and the climate have an effect on the vegetation period length of this species and the number and diameter of this seed. As reported by Bertero et. al (1999), under short-day conditions the seed diameter is greater and the conditions of long-day and the occurrence of high air temperature (28°C) stimulate the small seed diameter, while on average in Europe and in Southern America *Chenopodium quinoa* needs long day for the growth and development, similarly as in Bydgoszcz (Poland) (Gęsiński, 2006).

The mean green matter yield of *Chenopodium quinoa* in Europe was higher than in America (Grochowski, 2001; Gęsiński, 2006). These relationships also coincide with the results reported for Bydgoszcz (Poland), which show better conditions of vegetative growth of the plant, and at the same time greater possibilities of the green matter potential in Europe (Gęsiński 2001). Risi and Galwey (1989), based on Bolivian studies researchers found that in European conditions *Chenopodium quinoa* has a more abundant vegetative growth and a longer vegetative period, while low reproduction effort in Europe and also in Bydgoszcz (Poland) does not come from low unitary seed yield but from the high weight of the plant which in these conditions grows longer and is greater in size.

Evaluating the possibilities of *Chenopodium quinoa* cultivation in the locations analyzed in Europe based on the average of the seven cultivars, one can state that the most favorable location for the cultivation for seed was Larisa (Greece). A lower seed yield, but also outstanding in Europe, was reported in Bydgoszcz (Poland), but from the point of view of the green matter yield Bydgoszcz (Poland) was the most favorable, and slightly worse results were reported in southern Europe – Larisa (Greece), and then Valdichiani (Italy). These results show high Chenopodium quinoa potential in Poland, not only as compared with Europe but also Southern America, while even better effects will probably be reached based on the breeding of the Polish cultivar of Chenopodium quinoa and so best adapted to our conditions (Gęsiński and Kwiatkowska 1999a).

CONCLUSIONS

1. The conditions in Europe facilitate the cultivation of *Chenopodium quinoa*.
2. *Chenopodium quinoa* shows an average vegetation period length in Poland as compared with Europe.
3. The highest seed yield in Europe was found in Greece.
4. Conditions in Bydgoszcz (Poland) are very favorable for the cultivation for green matter and favorable for seed yield.

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Ocena możliwości rozwoju i plonowania komosy ryżowej (*Chenopodium quinoa* Willd.) w warunkach klimatycznych Europy

Część druga: Możliwości plonotwórcze *Chenopodium quinoa* w różnych warunkach

Streszczenie

Ocenę efektów uprawy *Chenopodium quinoa* w Polsce przedstawiono na tle wyników badań europejskich. Na ich podstawie stwierdzono, że warunki panujące w Europie sprzyjają uprawie komosy ryżowej podobnie jak w Ameryce. *Chenopodium quinoa* w Polsce charakteryzuje się średnią długością okresu wegetacji. Maksymalną wartość tej cechy stwierdzono w Szwecji. Warunki panujące w Bydgoszczy (Polska) są bardzo korzystne do uprawy na zieloną masę oraz korzystne, jeżeli chodzi o plon nasion. Najkorzystniejszy plon nasion stwierdzono w Grecji.