Grain yield and nutritional characteristics of introduced quinoa (*Chenopodium Quinoa* willd.) Species

Slobodan B. Dražić[1], Maja N. Ječmenica[2], Helena J. Majstorović[3], Đuro P. Zagorac[4], Kiril B. Filiposki[5] and Ilija P. Risteski[5]

[1]Serbian Association of Plant Breeding & Seed Production, Zemun-Belgrade
[2]Directorate for National Reference Laboratories, Belgrade
[3]Tamiš Institute, Pančevo
[4]AD for Agriculture "Napredak", Stara Pazova
Serbia
[5]St. Kliment Ohridski University, Scientific Tobacco Institute
Prilep, Bitola
Macedonia

Abstract

Quinoa (*Chenopodium quinoa* Willd.) is cultivated for its grain, whose nutritional value is similar to that of cereals, though it is a gluten-free grain. We performed experiments with introduced species of quinoa over a period of three years. Experiments were conducted on chernozem soil using two varieties. Sowing was performed in April and harvesting in August. Analysis of variance in the factorial experiment indicated significant differences for treatments in whole as well as years. The type of interaction – varieties x years – was also significant. Over the course of the three-year period, the average grain yield was 1.46 t/ha. The average yield of varieties was similar to the average grain yield. The average content of carbohydrates, proteins, oils and mineral salts was within the expected limit values. The results obtained for yields and nutritional characteristics correspond closely to results obtained in countries that cultivate this plant.

Agroecological conditions, grain yield, introduction, nutritional characteristics, quinoa species, varieties

Introduction

The use of alternative cereals in nutrition requires the introduction of new plant species, such as quinoa of the amaranth family, into agricultural production. Quinoa (*Chenopodium quinoa* Willd.) is an annual plant originating from South America (Bois et al. 2006). This plant was introduced into the U.K. in the 1980s, while studies of the plant were intensified in EU countries in the 1990s. Its significance has been growing due to its nutritional values and its high degree of tolerance to the effects of various abiotic and biotic factors (Garcia et al. 2007). The importance of quinoa is emphasised by the fact that the FAO has pronounced it a plant that could help provide food safety in the 21st century (Jacobsen 2003). According to several authors (Jacobsen et al. 2007; Geerts et al. 2008), quinoa, a plant originating from the Lake Titicaca basin in the Andes, can be successfully grown on poor, alkaline and acid soils in regions with a 100-day freeze-free period. The cultivated species were domesticated from volunteer natural species grown within the spontaneous flora of Andean regions that are today part of Bolivia, Peru and Ecuador (Garcia et al. 2007). It is grown as a grain crop for edible seeds that are, according to its chemical composition and nutritional value, similar to the seeds of wheat and white rice. Quinoa grain's nutritional value is highly valued because it contains a significant percentage of protein (12 – 18%). The high content of the amino acid lysine is of special importance in food (Aluko and Monu 2003). It is particularly important that quinoa grain is gluten-free, in contrast to many cereals, which eliminates numerous allergological reactions (Glamočlija et al. 2012). The presence of several B vitamins and macroelements contributes to the valuable nutritional traits of quinoa grain (Jacobsen 2003). The aim of this study was to monitor the production and nutritional characteristics of quinoa species introduced and cultivated under the agroecological conditions in Serbia (Dražić et al. 2011).

Address for correspondence:
Slobodan B. Dražić
Serbian Association of Plant Breeding & Seed Production
11185 Zemun-Belgrad, Serbia
E-mail: s.drazic47@gmail.com
www.maso-international.cz

Material and Methods

The genus *Chenopodium* includes several plants important in nutrition. They are known as alternative cereals (pseudocereals). Quinoa is an annual, self-pollinated (10 – 15% out-pollinated) herbaceous plant with a growing period from 90 to 125 days. The grain is small (1 – 1.5 mm), globular and reminiscent of millet. Trials with introduced quinoa genotypes (KVL 37 and KVL 52, originating from the University of Life Science, Copenhagen, Denmark) were carried out in the 2009 – 2011 period (Jacobsen and Mujica 2002). The four-replication trials were set up in an experimental field of AD Napredak in Stara Pazova, 35 km north-west of Belgrade at approximately 87 m a.s.l. The soil is calcareous chernozem. According to agrochemical analyses, this soil is humus (3.21%), well supplied with available nitrogen (3.86%), optimally supplied with phosphorus (22 mg·100 g^{-1} soil) and potassium (21 mg·100 g^{-1} soil), and its reaction is neutral (pH in KCl = 7.05). The elementary plot size amounted· to 15 m^2. Permanent sowing was performed in April with an inter-row distance of 50 cm. Quinoa panicle harvesting was performed in two stages in August in all three years of investigation. The production traits analysed were the yield of processed quinoa grain (t·ha^{-1}) and its chemical composition. The results were processed by the factorial analysis of variance.

Meteorological conditions

Mean monthly temperatures (March – August) during the first year of investigation were above the long-term average. Heat conditions during the second and third year were approximately equal to the long-term average. However, these values were higher in July and August (Table 1). The precipitation sum during the growing season was the highest (488 mm), i.e. lowest (268 mm) in the third, i.e. the second year, respectively (Table 1). It is thought that this crop may be cultivated in regions with annual precipitation not lower than 320 mm and with a rather wet spell during sowing and the initial phenophases. The most recent studies indicate that the occurrence of a great precipitation deficit and extremely high temperatures, particularly in the summer period, lead to a significant reduction in yields (Dražić et al. 2013a). The characteristics of the meteorological conditions in Serbia are similar to those in some other countries in the Balkans (FYR Macedonia, Bulgaria, Bosnia and Hercegovina, Croatia).

Table 1. Average monthly temperature and total rainfall

Month	Temperature [°C]				Rainfall [mm]			
	2009	2010	2011	Perinetell mean	2009	2010	2011	Perinetell mean
3	8.3	6.5	6.2	6.3	60	56	16	45
4	16	13	13	11.6	10	46	20	46
5	20	17	17	17	30	158	63	56
6	21	20.2	20.6	20	145	78	70	85
7	24	23	22	21.6	85	77	93	46
8	24	22	22.5	21	40	73	6	62
Mean	19	17	17	16.3	Total: 370	488	268	340

Results and Discussion

The factorial analysis of variance points to extremely significant differences between treatments, years and genotypes. The year × genotype interaction was very reliable (Table 2).

Table 2. Factorial analysis of variance

Source of variation	d.f.	MS	F	$F_{tab.}$	
				0.05	0.01
Treatments	5	0.088	6.286**	2.8	4.3
A	2	0.118	8.428**	3.6	6.0
B	1	0.031	2.215	4.4	8.3
AB	2	0.087	6.214**	3.6	6.0
Error	18	0.014	-	-	-
Total	23				

**significant at the 0.01 probability level

Similar results were obtained by Dražić et al. (2013). These authors indicate significant differences obtained between treatments, years and genotypes. Moreover, grain yield varied between locations and genotypes (Dražić et al. 2011, 2013a).

The average grain yield amounted to 1.46 t·ha^{-1}during the three-year period. The average yield was highest (1.60 t·ha^{-1}) in the first year, being higher by 0.23 t (i.e. 17%) and 0.18 t (12%) than the yield in the second and third year, respectively. The differences recorded were statistically significant. The average yield of the individual varieties was fairly uniform, amounting to 1.43 and 1.50 t/ha in KVL 37 and KVL 52, respectively. Both the highest (1.68 t·ha^{-1}) and the lowest (1.23 t·ha^{-1}) grain yields were recorded in KVL 37 in the first two years of the study (Plate xy, Fig. 1). It can be seen from the data in the literature that yields obtained under conditions of dry land farming were the same or even higher than the yields achieved in countries in which this crop is grown (Ritchie and Smith 1991; Jacobsen 2009). If irrigation is applied in periods with a precipitation deficit, the yields may be increased by as much as 30% (Geerts et al. 2008).

Chemical composition of seeds

Quinoa is a pseudocereal with excellent nutritional properties and is an extremely important source of carbohydrates that are the principal component of the quinoa grain. It is important to stress the fact that the carbohydrates in quinoa have a low glycaemic index. The average content of carbohydrates obtained in this study was 54.0%. In comparison with other common cereals (wheat, maize, rice), the protein content in quinoa is high (16.4%), while the relationship between essential amino acids is balanced and very close to the ideal content and composition of proteins according to FAO recommendations (Glamočlija et al. 2012). Due to its oil content, quinoa is considered a complete food in terms of energy. The average oil content obtained in these studies amounted to 4.6%. The average content of minerals was 3.4% which is higher than the content in cereals (wheat, maize, rice: 0.5 – 1.8). The fibre content was uniform, though higher than the content found in common cereals (Plate III, Fig. 2).

Conclusions

The obtained grain yields of quinoa are satisfactory under the agroecological conditions in our country. The year × genotype interaction was highly significant. This is emphasised by the yields obtained over the years of the study. The average content of carbohydrates, proteins, oils and mineral salts was within the expected limits. The obtained yields and qualitative traits did not differ from these characteristics in countries where this plant is cultivated.

References

Aluko RE and Monu E 2003: Functional and bioactive properties of quinoa seed protein hydrilysates. J Food Sci **68**(4): 1254-1258

Bois F, Winkel T, Lhomme JP, Raffaillac JP, Rocheteau A 2006: Response of some Andean cultivars of quinoa (Chenopodium quinoa Willd.) to temperature: Effects on germination, phenology, growth and freezing. Europ J Agron **25**: 299-308

Dražić S, Glamočlija Đ and Blagojević S 2011: Proizvodne osobine introdukovane vrste kvinoja (Chenopodium quinoa Willd.) u našim uslovima gajenja. J Sci Agric Res **72** (259): 17-24 (In Serbian)

Dražić S, Živanović T, Maletić R, Glamočlija Đ, Žarković B, Dražić M. 2013: Varijabilnost svojstava introdukovanih genotipa kvinoje (Chenopodium quinoa Willd.), Selekcija i semenarstvo, vol.XIX, 1,19-26, Zemun-Beograd, Serbia

Dražić S, Žarković B, Glamočlija Đ, Dražić M, Zagorac Đ,Kolarić Lj, Živanović LJ 2013a: Uticaj suše na prinos zrna kvinoje (Chenopodium quinoa Willd.). Agroznanje/Agro-knowledge J **14** (2): 277-283

Garcia M, Raesb D, Jacobsen SE and Michel T 2007: Agroclimatic constraints for rainfed agriculture in the Bolivian Altiplano. J Arid Environ **71**: 109–121

Geerts S, Raes D, Garcia M, Vacher J, Mamani R, Mendoza J, Huanca R, Morales B, Miranda R, Cusicanqui J and Taboada C 2008: Introducing deficit irrigation to stabilize yields of quinoa (Chenopodium quinoa Willd.). Europ J Agronomy **28**: 427-436

Glamočlija Đ, Dražić S, Popović V, Filipović V 2012: Agronomske, nutritivne i lekovite osobine kvinoje, novog alternativnog žita. Lekovite sirovine **32**: 27-35. (In Serbian)

Jacobsen SE and Mujica A 2002: Genetic resources and breeding of the Andean grain crop quinoa (Chenopodium quinoa Willd.). Plant Gen Res Newsletter **130**: 54-61

Jacobsen SE 2003: The worldwide potential for Quinoa. Food Rev Inter 19: 167-177

Jacobsen SE, Monteros CLJ, Corcuera LJ, Bravo LA, Christiansen JL and Mujica A 2007: Frost resistance mechanisms in quinoa (Chenopodium quinoa Willd.) Europ J Agr **26**: 471-475

Jacobsen SE, Andreasen C and Rasmusen J 2009: Weed control in organic grown quinoa (Chenopodium quinoa Willd.). Book of Abstracts of the IV Symposium-Innovation in Crop and Vegetable Production, October 23rd-24th 2009. Belgrade, Serbia, pp. 21

Ritchie JT and Smith DS 1991: Temperature and crop development. Modeling Plant and Soil Systems. Agronomy Monograph 31st Ed. Madison, WI: ASA, CSSA and SSSA, pp. 5-29

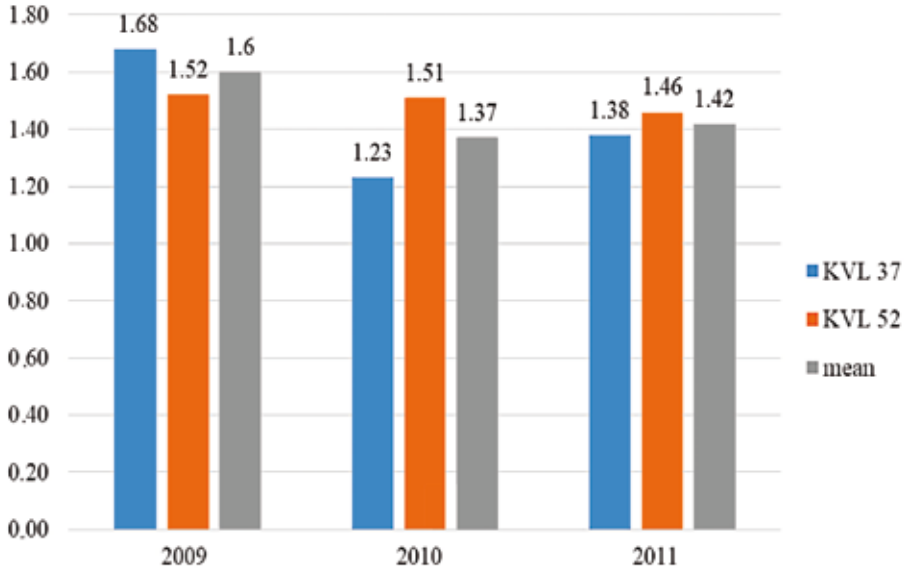

Fig. 1. Quinoa grain yield ($t \cdot ha^{-1}$)

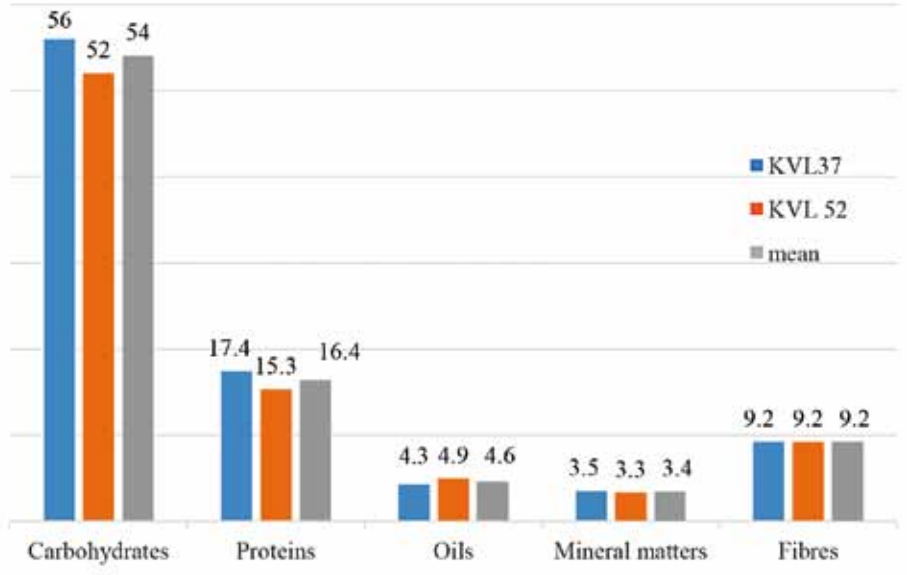

Fig. 2. Chemical composition of quinoa seeds [%]