YIELD PERFORMANCES OF QUINOA FOR LEAVES UNDER IRRIGATION AND FERTILIZATION REGIMES

PERFORMANTE DE PRODUCTIE LA QUINOA PENTRU FRUNZE SUB INFLUENTA IRIGARII SI FERTILIZARII

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Abstract. *Quinoa (Chenopodium quinoa sp.) is a pseudo-cereal native to South America, known mainly for seeds. In recent years, studies and research have begun to be done on leaves, as it is known that in the area of origin, some local populations used as vegetables. The aim of the research is to evaluate the effect of fertilization and irrigation on the growth and development of two quinoa varieties (Vikinga and Puno), in order to introduce them on the Romanian economic market. The experience was organized in vegetation pots, in 42 variants, in the greenhouse. The obtained results show that the species is suitable for cultivation in protected areas, under the influence of factors: variety, fertilization and irrigation. The highest amount of leafy mass was obtained by Vikinga variety under biological fertilization irrigated with 75% of water from soil capacity (SC) positively correlated with the leaf area and the number of leaves. The irrigation with a rate of 75 % of the field capacity obtained the best results, compared to the regimes of 50 % and 100 % of the soil capacity.*

Key words: quinoa, fertilization, irrigation, variety.

Rezumat . *Quinoa (Chenopodium quinoa sp.) este o pseudocereală originară din America de Sud, care a devenit populară în întreaga lume, reușind, în ultimii ani, să cucerească noi teritorii și să fie cultivată în mai toate zonele globului, cunoscută fiind în principal pentru semințe. În ultimii ani, studii și cercetări au început să se facă și pe frunze, cunoscut fiind faptul că în zona de origine, anumite populații locale sunt utilizate ca legume pentru frunze. Scopul cercetărilor este de a evalua efectul ferilizării și irigării asupra creșterii și dezvoltării a două cultivare de quinoa (Vikinga și Puno), în vederea introducerii acesteia pe piața economică din România, ca plantă legumicolă cultivată pentru frunze. Experiența a fost organizată în vase de vegetație, în 42 de variante, în sera USV Iași. Rezultatele obținute arată că specia se pretează la cultura în spații protejate, sub influenta factorilor: cultivar, fertilizare și irigare. Cele mai bune rezultate fiind obținute la Vikinga, varianta fertilizată ecologic cu irigare 75% din capacitatea de câmp, pozitiv corelată cu suprafața foliară și numărul de frunze pe plantă. Varianta irigată cu 75 % din capacitatea de câmp a obținut cele mai bune rezultate comparativ cu variantele 50 % și respectiv 100 % din capacitatea de câmp.*

Cuvinte cheie: quinoa, fertilizare, irigare, cultivar

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INTRODUCTION

Quinoa (*Chenopodium quinoa* sp.) is a pseudo-cereal native to South America, which has become popular all over the world, and in recent years has managed to conquer new territories and be cultivated in most parts of the globe, being known mainly for its seeds. In recent years, studies and research have begun to be done on leaves, as it is known that in the area of origin, some local populations use them as leaf vegetables.

Quinoa is a plant grown mainly for its edible seeds, with a high degree of digestibility (Asao *et al.*, 2010). Also, the leaves can be eaten as a substitute for spinach, in various dishes, well known in the area of origin (Stoleru *et al.,* 2021; Vitanescu, 2020). The nutritional value of quinoa leaves is special, quinoa is a very interesting food, being a precious source of protein, vitamins and minerals (FAO, 1992).

According to the Food and Agriculture Organisation of the United Nations (FAO), quinoa can assure the global food security due to its high nutritional qualities as well as tolerance to various abiotic stresses including salinity (FAO, 2013).

Due to the fact that it can be grown in the fields, as well as in tunnels and greenhouses, quinoa can ensures also a sustainable production throughout the year (Stoleru *et al.,* 2022; Pedereson *et al.,* 2020). In this respect, the efforts of researchers are mainly focused on the following research directions, namely: drought resistance, salinity and the defence mechanisms of the quinoa species against abiotic stressors - drought and salinity.

The aim of our research was to establish the upper and lower limits, which the quinoa species could tolerate without significantly affecting the growth and development, being subject to the influence of the irrigation and fertilisation factors.

The behavior of two varieties of quinoa (Vikinga and Puno) is considered, under the direct action of irrigation and nutrition (controlled by humidity and temperature) a study that has not been carried out in Romania until now.

MATERIALS AND METHODS

The research was carried out in a greenhouse of Iasi University of Life Sciences (IULS), Romania, during March 29 to April 07/2021. The goal of study was to evaluate quinoa response to different regimes of fertiliser and irrigation doses under controlled conditions of temperature (16-18ºC/20-22ºC), humidity (70-75%/60-65%) and natural light (13/11hours).

The biological material used was represented by quinoa (*Chenopodium quinoa*, Willd.) seeds of two cultivars Puno and Vikinga. The seeds were kindly provided by Quinoa Quality ApS (Denmark).

All plants were harvested at 35 days after sprouting (DAS) and all leaves were collected for further measurements and determinations. For this purpose, were made biometric determinations regarding the number of leaves, leaf surface and production. Physiological determinations were also made regarding chlorophyll pigments.

To achieve the proposed goal, the following objectives were pursued:

1. Evaluation of cultivar influence on morphological and physiological characteristics of quinoa species.

2. Evaluation of the influence of the fertilization factor, represented by the biological fertilizer Micoseed MB® and chemical fertilizer KSC I® - on the morphological and physiological characteristics of the quinoa species.

3. Evaluation of the influence of the irrigation factor on the morphological and physiological characteristics of the quinoa species.

The biotechnical working materials that were used in the experiment were represented by the organic fertilizer Micoseed MB® (substrate 500 g/m3, substrate 1000 g/m3, substrate 1500 g/m3) and the chemical fertilizer KSC I® (1000 g/m3, substrate, substrate 2000 g/m3, substrate 3000 g/m3).

Soil substrate was peat Kekkila® (300 l x 2) mixed with Orgevit® (3.00 kg/m^3) and Perlite® (3.00 kg/m^3). Kekkila® is a substrate for seeding production, with pH adjusted to 5.5-5.9, with fertilised formula “starter” NPK 14-16-18 + ME. Orgevit® is a fertiliser that can be used in organic crops and contains micro and macro-elements. Perlit® results from volcanic rock with a granular structure and high porosity, produce rapid rooting of seedlings and seed germination, ensuring a harmonious development of plants.

The general research methods used to achieve the proposed goal were observation and experimentation (Jităreanu, 2007).

The experience was organised in vegetation pots (2700 cm^3 capacity). Corresponding to the proposed factors resulted 42 variants, of 5 replicates, 8 plants for each repetition.

For statistical analyses the data are expressed as the means ± standard deviation (SD). The analysis of variance (ANOVA) was used to see the influence of cultivar, fertilization and irrigation on the number of leaves, chlorophyll pigments, leaf surface and green leaf biomass of quinoa. To determine the significant differences between treatments were established by using Tukey’s post hoc test with a degree of confidence of 95% ($p \leq 0.05$), using a SPSS ver. 21.

The research was carried out under conditions of water stress (with three gradations 50%, 70%, 100%).

RESULTS AND DISCUSSIONS

1. The results on the influence of the cultivar on the number of leaves, photosynthetic pigments, leaf surface and production are presented in table 1.

Table 1

The influence of the cultivar on the morphological and photosynthetic indicators

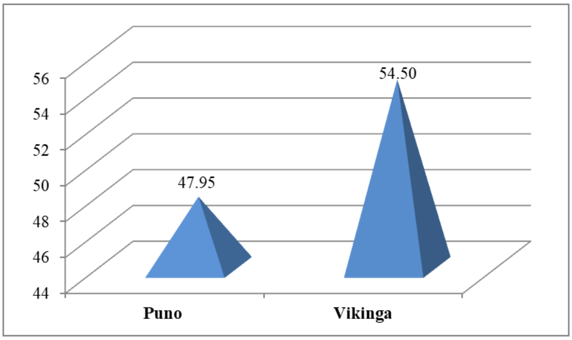
Cultivar	No. of leaves	Pigments (CCI)	LAI (cm²)
Puno	110.3 ± 2.6 b	11.9 ± 0.3 b	1454.5 ± 69.2 ns
Vikinga	120.5 ± 2.34 a	13.4 ± 0.2 a	1447.0 ± 43.8 ns

*The values represent the mean ± standard error. The lowercase letters represent the results of the Tukey test for $p \leq 0.05$ (a - represents the highest value; ns – nonsignificant);

The number of leaves is the character which recorder significant differences between the two variants, these being 110.4 leaves for the Puno and 120.5 leaves for Vikinga, the difference between the two cultivars is 10.2 leaves.

Also, the data from table 1 show that the maximum value of the chlorophyll index recorded is 13.4 CCI in the case of the Vikinga cultivar and the minimum value is 11.9 CCI in the case of the Vikinga cultivar.

Regarding the study of influence of the cultivar on the leaf area, the data show that there are no significant differences, obtaining close value (1454.5 cm²-1447.0 cm²). Also, between the two cultivars there were no significant differences in production (47.95 leaves – 54.50 leaves), as in figure 1.



*The values represent the mean ± standard error.

Fig. 1. The influence of the cultivar on the production

2. The results of the influence of the fertilisation regime on the number of leaves, photosynthetic pigments, leaf surface and production are presented in table 2.

Table 2

The influence of the fertilisation on morphological and photosynthetic indicators

Fertilisation	No. of leaves	Pigments (CCI)	LAI (cm²)
NF	133.5 ± 6.5 a	10.1 ± 0.2 b	1597.3 ± 91.5 ab
F1	127.6 ± 3.2 a	9.9 ± 0.2 b	1723.3 ± 53.0 ab
F2	124.4 ± 1.4 a	9.9 ± 0.2 b	1908.3 ± 86.8 a
F3	116.7 ± 3.5 a	10.5 ± 0.2 b	1533.1 ± 64.1 b
F4	131.5 ± 3.7 a	15.2 ± 0.5 a	1613.2 ± 76.1 ab
F5	93.2 ± 3.9 b	17.1 ± 0.7 a	1062.3 ± 75.2 c
F6	81.2 ± 2.8 b	15.8 ± 0.9 a	718.0 ± 71.7 d

*The values represent the mean ± standard error. The lowercase letters represent the results of the Tukey test for p ≤ 0.05 (a - represents the highest value; ns – nonsignificant, V-Vikinga, NF – control, F1- 500 g/m³ MB, F2 –1000 g/m³ MB, F3- 1500 g/m³ MB, F4 – 1000 g/m³ KSC I, F5 –2000 g/m³ KSC I, F6- 3000 g/m³ KSC I)

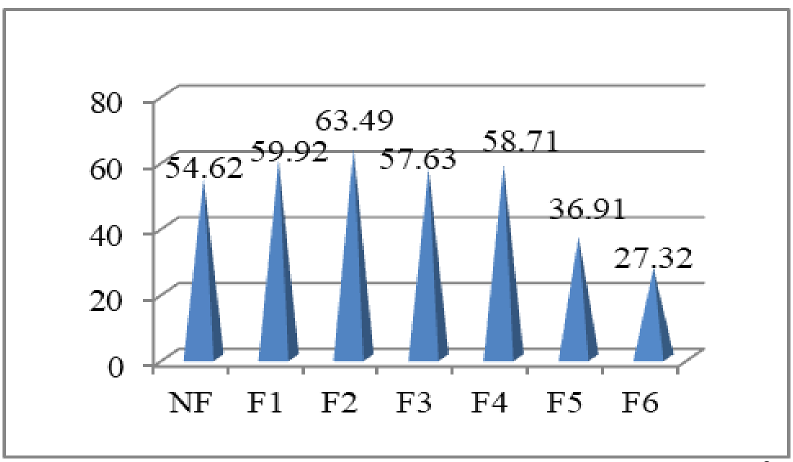
The effects of fertilisation on the growth of quinoa plants are shown in table 2, where significant differences are observed between control and chemical variants, where the value varied from 133.5 leaves to 81.2 leaves, for the character number of leaves.

Also, higher values (127.6 leaves and 124.4 leaves) are observed for the biologically fertilised variants F1 - F2, compared to the chemically fertilised variants F5 and F6. There was a significant difference of 50.3 leaves between chemically fertilised F4 and F6 variants. It can be concluded that the plants suffer from a higher concentration of chemical fertiliser > 2000 g/m^3 KSC I.

The data of table 2, showed that in the case of chemical fertilisation F5, the photosynthetic pigments have the highest chlorophyll index of 17.1 CCI. We can also notice significant differences between biologically and chemically fertilised variants. Between biological variants F1**-** F3 there is a significant difference, also between the chemically fertilised variants F4 – F6.

For the character of the leaf surface the values varied from 718.0 cm^2, in case of the variant F6, to 1908.3 cm^2, in case of the variant F2.

Regarding the production, the results presented in Figure 5, in the case of biological fertilisation with Micoseed MB®, variants F1- F3, recorded higher values compared with control. The maxim value obtained was 63.4g, of variant F2, due to the effect of microorganisms introduced into the crop substrate, this being also the maximum value registered within the experimental variants. Also, the variant F4 registered a higher value than the control.



* The values represent the mean ± standard error; NF – control, F1- 500 g/m^3 MB, F2 – 1000 g/m^3 MB, F3- 1500 g/m^3 MB, F4 –1000 g/m^3 KSC I, F5 –2000 g/m^3 KSC I, F6- 3000 g/m^3 KSC I

Fig. 2. The influence of the fertilisation regime on the production

The variant F5 and F6 with the minim values of the measured biometric indicators- number of leaves, leaf surface and production, shows significant differences compared with all the other variants. This is explained by the fact that the concentration > 2000 g/m3 affects the growth and producion of quinoa plants.

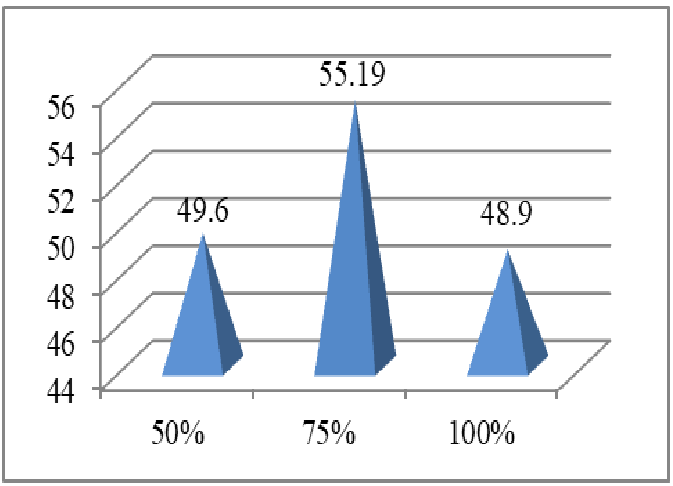
3. The results on the influence of the irrigation factor on the number of leaves, photosynthetic pigments, leaf surface and production are presented in table 3.

Table 3

The influence of the irrigation on morphological and photosynthetic indicators

Irrigation	No. of leaves	Pigmenţs (CCI)	LAI (cm^2)
50%	112.9 ± 2.7 ns	12.6 ± 0.2 ns	1666.0 ± 40.2 a
75%	118.9 ± 2.7 ns	12.3 ± 0.5 ns	1419.9 ± 68.1 b
100%	114.5 ± 2.7 ns	13.0 ± 0.3 ns	1266.4 ± 43.1 b

*The values represent the mean ± standard error. The lowercase letters represent the results of the Tukey test for $p \le 0.05$ (a - represents the highest value; ns – nonsignificant); The values represent the mean ± standard error.



*The values represent the mean ± standard error; 50%, 75%, 100% irrigation regime

Fig. 3. The influence of the irrigation regime on the production

The variants benefited from gradual irrigation starting from 50%, 75% and 100% of the substrate capacity.
For the character of the leaf surface, there are significant differences, the higher value of 1666.0 cm^2 recorded by irrigation variant of 50%, determines significant differences compared to the other two types of irrigation (75% and 100%).

CONCLUSIONS

1. Vikinga is the cultivar that obtained the best results, but the differences are not significant compared to Puno, in terms of production, which means that the species is suitable for leaves cultivation.

2. The highest yield of quinoa leaves was obtained from chemical fertilisation, under the influence of the fertilisation regime, followed by the biological, which is recommended for the sustainable crops.

3. The irrigation at a rate of 75 % of the substrate capacity obtained the best results. In the case of overirrigation the results obtained were much lower than in case of 50 % and 75 % irrigation regime. It can be concluded that the species has mechanisms of resistance and adaptation to water stress.

The result regarding all the factors shows that the specie is suitable for cultivation in protected areas.

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