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Quinoa Vikinga Response to Salt and Drought Stress under Field Conditions in Italy †

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Abstract: Agriculture in south Europe is facing the negative effect of abiotic stresses such as salinity that mostly affect the seed production and seed quality of traditional crops. Under these conditions, quinoa represent a good alternative to ensure the production of high-protein-quality seeds thanks to its tolerance to abiotic stresses. In 2015–2017, a sweet variety of quinoa, "Vikinga", was tested in Italy within the PROTEIN2FOOD project (EU Horizon2020) as high-quality-protein crop to enhance food protein production in Europe. A field trial was carried out at the experimental farm of CNR-ISAFOM in South Italy, to evaluate the combined effect of drought and salinity on quinoa Vikinga; both freshwater and saline water were used for irrigation. The plots were arranged in a randomized complete block design. The main yield parameters (seed yield, aboveground dry biomass 1000 seed weight), the protein content and other quality traits were analyzed at harvest, to evaluate the effect of applied treatments. The results showed that, in general, different treatments did not affect the main production and quality traits of quinoa "Vikinga".

Keywords: salinity; seed quality; protein crops; quinoa

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1. Introduction

Salinity is an adverse environmental factor that affects the growth of plants in the Mediterranean region [1,2]. Salinization is rapidly increasing on a global scale, with average yields for most major crop plants declining by more than 50 percent [3]. Salinization may result in the loss of 30% of current agricultural land in the coming 25 years, a figure set to rise by up to 50% by 2050, also due to the rapid rate of population growth. It is estimated that salinization affects around 3.8 million ha in Europe [4]; we can distinguish primary salinization due to natural processes and secondary salinization introduced by human interventions such as irrigation with saline water.

A possible approach is the introduction of species capable of tolerating high-soil salinities and guaranteeing acceptable yields.

Quinoa (*Chenopodium quinoa* Willd.) produce high-quality-protein seeds and is well-known for its tolerance to salinity compared to traditional crops.

A multi-annual field trial was planned to evaluate the effect of saline water irrigation on the protein quantity and quality of these crops, which could represent a source of vegetable proteins in salt-affected environments.

2. Materials and Methods

The field experiments were carried out in Vitulazio (Caserta, Italy) at the experimental research station of CNR-ISAFoM (41°12′ N and 14°20′ E, 23 m above sea level) during three growing seasons: 2015, 2016 and 2017. The soil of the experimental site was characterized by a clay loam texture; the volumetric soil water contents at field capacity was 0.38 m^3m^{-3}, while the permanent wilting point was 0.13 m^3m^{-3}.

The Danish quinoa variety "Vikinga" received from University of Copenhagen was sown. A randomized complete block (RCB) design with two treatments (irrigation regime and water quality) per crops and three replicates per treatment was adopted. Each experimental plot consisted of 10 rows, 4 m length.

Quinoa was grown under two irrigation regimes: (I100, restitution of 100% of the water necessary to replenish to field capacity (F.C.) at 40 cm soil layer and I33, corresponding respectively to restitution of 33% of full irrigation). For each irrigation level, a non-saline treatment irrigated with fresh water (100N and 33N) and a treatment irrigated with saline water was performed at a known salt concentration (100S and 33S).

Irrigation was carried out at fixed weekly intervals using a drip irrigation system. The conductivity achieved in the solution 1/1 (seawater/groundwater) was about 22 dS/m.

At harvest the total yield, the 1000 seed weight and the above-ground biomass were determined on each plot.

The seed samples for each harvest and for each treatment being studied were then chemically analyzed to evaluate the principal qualitative components. The data collected during three years of experimental work were analyzed according to an RCB design.

3. Results

Seasonal precipitation (November–June) was 437, 550 and 220 mm in the first, second and third growing season, compared to the historical average (1976–2017). of 377 mm.

After computing the deciles index (DI) designed by Gibbs and Maher (1967), the first (2015) and second (2016) seasons were classified as normal (DI = 9 and 7, respectively) whereas the third (2017) season was weak dry (DI = 4).

The crop cycle length ranged from 110 to 117 days in the three experimental years. Irrigation was applied 7 times during 2015 and 2016, and 5 times in 2017.

In 2015, 2016 and 2017, 256, 240 and 201 mm of freshwater was applied, respectively, for treatment 100N, and 217, 201 and 192 mm of saline water for treatment 100S. Obviously, the amounts of salt supplied by irrigation water to the soil were higher in the first year than in 2016 and 2017.

The initial ECe (0–0.6 m) value showed an increasing trend over three years for both 100S and 33S treatment, ranging from 1.4 to 2.62 dS m^{-1}; The final ECe value was significantly higher compared to the ECe initial value for each considered treatment; it reached values of 9.3 dS m^{-1} in 2017 for 100S treatment.

From the statistical analysis of the main yield components (yield, dry biomass, harvest index) measured during the three experiments, no significant differences were found for both single effects (Irrigation level and water quality) and interaction irrigation treatment × saline treatment. Vikinga registered low seed yields, ranging from 0.30 g $plant^{-1}$ in 2016 to 0.9 g $plant^{-1}$ in 2015.

No significant differences were recorded for each quality parameter (Table 1). The average protein content of quinoa seeds was about 15% of seed weight.

Table 1. Seed-quality parameters as affected by water quality and water supply on Quinoa.

Source of Variation	Starch (%)	Ashes (%)	Total Protein (%)	Fat (%)
Water quality (WQ)	ns	ns	ns	ns
Fresh water	49.00 ± 2.36	4.37 ± 0.62	14.97 ± 0.92	3.70 ± 0.43
Salinity	49.00 ± 2.21	4.53 ± 0.95	15.30 ± 0.70	3.52 ± 1.40
Water supply (WS)	ns	ns	ns	ns
I100	47.63 ± 1.56	4.47 ± 0.73	15.13 ± 0.50	3.55 ± 0.78
I33	50.37 ± 1.87	4.43 ± 0.87	15.13 ± 1.08	3.66 ± 1.25
WQ × WS	ns	ns	ns	ns

4. Discussion

The results confirm, as reported in the literature, a high tolerance of quinoa to drought and salinity. Titicaca, a quinoa bitter Danish variety was previously shown to have high resistance to drought and saline stresses, in terms of seed yield and qualitative parameters, under the same experimental conditions [5]. Vikinga recorded lower seed yield levels than Titicaca, Regalona [6] and Puno, which are well-adapted to Italian pedo-climatic conditions.

5. Conclusions

The field trials carried out from 2015 to 2017 in Italy confirmed that quinoa is tolerant to high levels of salinity; in fact, seed yield did not significantly vary passing from saline to not-saline treatments for a $p \leq 0.05$.

In addition, total protein content in the seeds did not vary between different treatments; since no differences were found in harvested seed weight and in protein content, was assumed that no changes occurred in the amino acidic composition of quinoa. These results suggest that quinoa has good adaptability and a high degree of flexibility regarding tolerance or resistance to salt stress; this crop represents a valid source of high-quality protein for cultivation in marginal European areas affected by primary and secondary salinization problems.

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