Effects of MnSO₄ on grain output, protein and Mn content of quinoa strains (*Chenopodium quinoa* Willd.)

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**Abstract.** Quinoa is a new crop with great potential in the world. Micronutrients are vital components for balances both growth and development in plants. An experiment was designed for the sake of researching the impacts of MnSO₄ on output and quality parameters of Quinoa strains in Wuhan. Four repetitions stochastic complete block design is used for the partition layout. Major zones were MnSO₄ (contains 28% pure manganese) (2, 4 and 6 g·m⁻²), and sub-zones were Quinoa cultivars (L-1, L-2 and L-3). The meaningful influence of MnSO₄ on the number of fertile ears, the amount of seeds in each ear, the weight of a thousand seeds, grain output, the contents of proteins and manganese in grain. The significant influence of cultivar on number of fertile ears, the weight of a thousand grains, grain output and protein content. The highest values of fertile ear, amount of grain, the weight of a thousand grains, harvest index, grain output, the contents of grain proteins and Mn were achieved in applying 6 g MnSO₄ per m². In addition, the highest amount of fertile ears, amount of grains per ear, grain harvest and grain manganese content were related to L-3”cultivar. The results show that cultivation of “L-3”cultivar and application of 6 g MnSO₄ per m² is recommended for Wuhan.

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a kind of grain crop food as known as South America quinoa, which is an annual herb dicotyledonous plant of *Chenopodium*, originated in the Andes [1]. Also it is a momentary broad-leaved plant, about 2 meters high, with deep rooted, which could be planted up to 3800 meters above sea level. It has high nutritional value with content of high protein, multivitamins and multiple minerals, which make it become proper food [2]. Otherwise, the plant has the characteristics of abiotic stresses resistance such as salt, drought, cold and barren [3, 4].

Salt ions are very important for the quality and growth of crops, which take part in best of the physiological and biochemical activities of crops by disturbing the content of chlorophyll in leaves, and finally affect the photosynthetic activity of plants [5, 6]. Mn is an important trace element in most organisms. Meanwhile, it plays an important role in the composition of proteides, photosynthetic, and enzymes in plants. Mn deficiency is harmful to chloroplasts because it affects the decomposition of water on photosystem II (PSII), and supplies the essential electrons for photosynthesis [7]. However, its surfeit may also lead to damage the photosynthetic apparatus [8]. Less trace elements were needed relatively for plant growth and plant production [9]. El-Shazly reported that foliar spraying of Mn gave the best effect to obtain the appropriate output. Sainju et al [10] found that spraying 6 kg·ha⁻¹ MnSO₄ can reduce the deficiency of tomato in the process of tomato growth. Positive effects of Mn on the
weight of a thousand grains of sunflower [11]. Setia and Sharma [12] conclude that fertilization is a good agronomic measure to achieve the goal of increasing production. There are two functions of Mn in plant metabolism: one is essential trace element, the other is excessive toxic element [13, 14].

In this research, the effects of MnSO₄ on output and quality parameters of quinoa in Wuhan were determined.

2. Materials and methods

2.1. Experiment design

A test was designed in order to research the effects of Mn on output and quality parameters of quinoa strains in Wuhan Academy of Agricultural Science Experimental Field in 2018. A stochastic complete block design with four repetitions was conducted for the partition layout. Major zones were MnSO₄ (contains 28% pure manganese) (2, 4 and 6 g·m⁻²), and sub-zones were quinoa cultivars (L-1, L-2 and L-3). One week before sowing, soil sample was taken at 0 to 30 cm. The soil texture was Calcareous soil (Table 1).

Table 1. Soil analysis of experimental station at 0-30 cm.

|   | S (%) | K (mg/kg) | P (mg/kg) | N (%) | OC (%) | TNV (%) | pH | EC (ds/m) | SP | Soil texture   |
|---|-------|-----------|-----------|-------|--------|---------|----|-----------|----|---------------|
|   | 46    | 389       | 39.1      | 0.08  | 0.82   | 36      | 7.51| 1.3       | 53 | Calcareous soil |

Long term average precipitation was 150 mm. Seed germination and plantation was done from May 20th to 23th in 2018. Based on soil analysis, 8 g per m², K₂SO₄, 6 g per m², (NH₄)₃PO₄, 4 g per m² ZnSO₄, 4 g per m² FeSO₄ and 2 g per m² CuSO₄ was used before seed plantation. Every trial zone owned 10 rows which had 8 m length. The density of plant was 40 seedlings per m². 12 g nitrogen per m² from urea in tillering stage and 12 g nitrogen per m² at stem extension was used.

2.2. Data analysis

It was calculation of protein content after determination of total nitrogen by Kjeldahl method. The content of Mn was determined by Carter and Gregorich [15]. Variance of the data was analyzed with Excel software. Duncan's test were used to compare the average value of each properties (P < 0.05).

3. Results and discussion

3.1. Effects of manganese sulfate application rates on agronomic Traits of quinoa

The significantly effect of MnSO₄ on amount of functional ears, the amount of seeds per ear, the weight of a thousand seeds, grain output, the content of protein and Mn in grain. The significantly affect of cultivar on amount of viable ears, the weight of a thousand grains, grain output and protein content. The amount of viable ears and amount of seeds per ear were notably raised from application of 2 to 6 g nitrogen/m². Three treatments of MnSO₄ application were no notable difference. The maximum grain output and proteide could be acquired by applying 6 g MnSO₄ per square meter. The immediate influence of grain output with the amount of viable ears were vigorous, implying the adding amount of viable ears is immediately related to the raise in amount of ears. The application of MnSO₄ fertilizer notable raised the content of Mn in grain as well (Table 2).

3.2. Effects of manganese sulfate application rates on quinoa strains

Temiz et al. [16] reported gain output could be increased by ameliorating the nourishment condition of the plant. “L-3” had contained the highest amount of fertile ears. “L-3” cultivars contained the most amount of seeds every ear, and all trial strains were notable differences.
Table 2. Mean comparison for experimental characteristics.

| Treatment | Amount of fertile ears per m² | Amount of grains per ear | The weight of a thousand grains (g) | Harvest index (%) | Grain output (g/m²) | Grain protein (%) | The content of Mn in grain (ppm) |
|-----------|-------------------------------|--------------------------|-----------------------------------|------------------|-------------------|------------------|----------------------------------|
| MnSO₄  (g/m³) |                               |                          |                                   |                  |                   |                  |                                  |
| 2         | 554.2e                        | 37.56c                   | 37.6c                             | 44.54a           | 804c              | 9.67c            | 55.22a                           |
| 4         | 568.2b                        | 38.81b                   | 38.7b                             | 44.75a           | 868b              | 11.43b           | 62.81a                           |
| 6         | 598.7a                        | 40.47a                   | 39.9a                             | 45.05a           | 950a              | 12.8a            | 75.81a                           |

| Cultivar |                               |                          |                                   |                  |                   |                  |                                  |
|----------|-------------------------------|--------------------------|-----------------------------------|------------------|-------------------|------------------|                                  |
| L-1      | 587.72b                       | 35.2c                    | 41.4a                             | 46.23a           | 893b              | 11.34b           | 60.81a                           |
| L-2      | 552.31a                       | 38.4b                    | 39.97b                            | 45.43a           | 820c              | 11.84a           | 64.31a                           |
| L-3      | 598.44c                       | 43.3a                    | 36.91c                            | 46.87a           | 968a              | 11.01c           | 65.61a                           |

No significant difference in the common letters in each column.

Therefore, it might conclude the amount of seeds each ear is a dependable step of higher harvest and could be used as a standard for screening the right variety [17]. The maximum and minimum of the weight of a thousand grains were related to “L-1” and “L-3” strains, separately. No meaningful difference was in harvest index among different strains. The most output and protein in grain concerned “L-3” and “L-2”, separately, and there were no notable differences in Mn content in grain among the lines.

4. Conclusion
The nutritional value of quinoa is very important, because it plays an important role in crop species and is widely planted as a stable food source. The results of this trial clearly shown that application of MnSO₄ fertilizer resulted high values of the weight of a thousand grains, harvest index, grain output, the contents of grain protein and Mn in grain. Besides, obviously, selecting the right variety of quinoa is the best way to get the right grain output and protein. It is recommended to plant “L-3” strain and apply 6 g MnSO₄ per m² for Wuhan.

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References
[1] Bhargava A, Shukla S and Ohri D 2006 Ind Crop Prod. 23 73.
[2] Nowak V, Du J and Charriottiere U R 2016 Food Chem. 193 47.
[3] Jacobsen S E, Liu F and Jensen C R 2009 Sci Hortic. 122 281.
[4] Maughan P J, Turner T B, Coleman C E, Elzinga D B, Morales J A, Udall J A, Fairbanks D J and Bonifaclo A 2009 Genome. 52 647.
[5] Kanwar J S and Randhawa N S 1967 A Review (New Delhi:Indian Council of Agricultural Research).
[6] Graham R D, Welch R M and Bouis N E 2001 Adv Agron. 70 77.
[7] Buchanan B B, Gruissem W and Jones R L 2000 In:American Society of Plant Physiologists
(Maryland) pp 1367.

[8] Mukhopadhyay M and Sharma A 1991 Bot Rev. 57 117.
[9] El-Shazly S M and Dris R 2004 J Food Agric Environ. 2 126.
[10] Saniju U M, Dris R and Singh B 2003 J Food Agric Environ. 1 176.
[11] Farzanan M, Yarnia M, Javanshir A and Tarinejad A R 2010 J Food Agric Environ. 8 305.
[12] Setia R K and Sharma K N 2004 J Food Agric Environ. 2 260.
[13] Ducic T and Polle A 2005 Braz. J. Plant Physiol. 17 103.
[14] Kochian K, Hoekenga O and Pineros M 2004 Annu Rev Plant Biol. 55 459.
[15] Carter M R and Gregorich E G 1993 Canadian Society of Soil Science (London/Tokyo: Lewis Publishers).
[16] Temiz M, Kenan K Y, Aydin F and Karahan E 2009 J Food Agri Environ. 7 118.
[17] Mohsin T, Khan M and Nasir N F 2009 J Food Agri and Environ. 7 278.