Effect of Exogenous Amino Acids on Yield and Quality of Tartary Buckwheat in Non-saline and Saline-alkali Soil

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SUMMARY Heading: Amino acids on yield and quality of Tartary buckwheat

Salt-tolerant variety of Chuanqiao No.1 and salt-sensitive variety of Chuanqiao No.2 in Tartary buckwheat were used as experimental materials, through treatment of foliar spraying amino acids to study the effect of exogenous amino acids on yield and quality of Tartary buckwheat in non-saline and saline-alkali soil. The results showed that the treatment of amino acids could significantly increase the Tartary buckwheat yield in saline-alkali soil, under appropriate treatment of amino acids, the content of seed protein, mineral element and rutin in two Tartary buckwheat varieties was significantly increased in non-saline and saline-alkali soil, and that in salt-tolerant Tartary buckwheat variety was increased obviously higher than that in salt-sensitive one. It indicated that the effect of exogenous amino acids on yield and quality varies obviously between the two Tartary buckwheat varieties. In addition, through measuring the soil composition of non-saline and saline-alkali soil, we found that the content of calcium in saline-alkali soil was higher, and that of iron and selenium in saline-alkali soil was significantly lower than that in non-saline one, while that of calcium, iron and selenium of Tartary buckwheat seeds in saline-alkali soil was significantly higher than that in non-saline one, indicating that the Tartary buckwheat in saline-alkali soil shows enrichment in calcium, iron and selenium, and should be more nutritious than that in non-saline one. From the actual usage of amino acids, the amount of amino acid used per hectare is less and the price is low, so it is very suitable for popularization and application in saline-alkali soil.

Keywords: Tartary buckwheat, amino acids, non-saline and saline-alkali soil, yield, quality

Core Ideas

- Amino acids treatment could significantly increase the yield of Tartary buckwheat in saline-alkaline soil.
- Appropriate amino acid treatment could make the Tartary buckwheat in saline-alkali soil more nutritious.
- This way with low cost is very suitable for popularization and application in saline-alkali soil.

Introduction

Saline-alkali soil is a kind of soil with high pH, poor permeability, easy surface hardening and low nutrient content. It accumulates too much salt on the surface. Therefore, most plants are difficult to survive, which has become an important factor restricting the development of agriculture and animal husbandry, leading to the deterioration of the ecological environment and other issues. It is reported that the area of saline alkali soil in China is nearly 100 million hectare (Zhu et al., 2018), and the loss of agricultural production caused by soil salinization is difficult to estimate (Li et al., 2008). Recently, research on plant physiological characteristics in saline-alkali soil is mostly focused on wheat (Yang et al., 2001), cotton (Wang et al., 2007), soybean (Pan et al., 2007) and other crops, while the studies on physiological and biochemical characteristics of buckwheat in saline-alkali soil are few, even, researches on yield, nutrition and health components of buckwheat under the saline-alkali condition are less than that on physiological and biochemical characteristics, as a result, it has become an urgent and important task to improve the yield and quality of crops in the saline-alkali soil. With the deepening understanding of stress resistance mechanism in plants, mining crop stress resistance has become a hot research topic and a promising way to improve crop yield and quality. Buckwheat (*Fagopyrum esculentum*) is a dicotyledonous plant of *Fagopyrum*, because its seeds are triangular ovoid, also known as triangular rice (Meng, 2011). Buckwheat is rich in protein, vitamin B, mineral nutrition, plant fiber, rutin, etc. It also contains special trace element and medicinal ingredients, which can prevent and treat modern civilization diseases and cardiovascular and cerebrovascular diseases in the middle and old age, while other food crops lack these elements and medicinal ingredients. Buckwheat is rich in cultivation and wild resources, among which Tartary buckwheat has the best edible quality and health care effect, it has become raw materials in high-grade food, health food and medicine (He and Hui, 2008). With the gradual improvement of people's living standards, people's dietary structure began to develop in a healthy and natural direction. This kind of food is more and more popular because of its reputation of "dual-use of medicine and food". Therefore, vigorous development and research on nutrition and health care products have a broad market prospect and high social and economic value

(Yang and Yang, 2002).

Protein content reflects the nutritional value of plants to a certain extent, so it is of great practical significance to study the effect of exogenous substances on protein content of crops. The main bioactive components of buckwheat are glutenin, water-soluble globulin and salt-soluble albumin, this glutenin is different from grain protein but similar to legume protein, and the protein quality of buckwheat is better than that of rice, wheat and maize (Du et al., 2004). From the amino acid composition of protein, it can be seen that buckwheat protein contains 18 kinds of amino acids, including 8 kinds essential amino acids for human beings. Moreover, its composition and proportion are similar to that of egg protein and meet or exceed the standard of essential amino acid content of food protein drafted by FAO and WHO.

The World Health Organization points out that the essential trace elements for human body include iron, nickel, selenium, manganese, copper, silicon, chromium, zinc, tin, cobalt, fluorine, iodine, etc., which are closely related to human life activities due to their important roles in metabolic process. Mineral elements contain calcium, iron, zinc, selenium, copper, magnesium, potassium, etc., which are rich in Tartary buckwheat, and they are important sources of essential nutrients for human body (Zhu et al., 2009). Vitamin B_2, a riboflavin, plays an important role in maintaining human visual function and promoting cell growth and regeneration.

Rutin or vitamin P, is a kind of flavonoid with strong anti-inflammatory effect, it can maintain and restore the normal function of capillary, maintain vascular resistance, reduce vascular permeability and fragility. It also has the function of inhibiting aldose reductase, which is beneficial to the treatment of diabetic cataract. Some representative modern civilization diseases, such as cardiovascular and cerebrovascular diseases, diabetes, obesity and gout etc., rutin has been achieved certain results in remission and treatment research on these diseases, it can promote insulin secretion by affecting the function of pancreatic β cells to reduce blood sugar, at the same time, it can regulate blood pressure, increase blood vessel toughness and elasticity, so it can prevent and treat cerebral hemorrhage and subarachnoid hemorrhage (Ma and Pang, 2013). Therefore, rutin can be used not only to treat or alleviate modern civilization diseases, but also to further study its biological activity and make full use of health care functions as a green and pure natural drug (Zang et al., 2007).

Study has shown that exogenous Pro could significantly improve the physiological characteristics of buckwheat seedlings under salt stress, and the best mitigation effect on salt stress in buckwheat seedlings is Pro treatment with concentration of 30 μM (Chen and Yang, 2012). Glu treatment could also significantly improve the salt tolerance of buckwheat seedlings, and the optimum concentration of Glu treatment is 60 μM (Ji et al., 2014). In addition, appropriate concentration of Asp treatment could significantly promote the seed germination and seedling growth of buckwheat under salt stress, and significantly increase the root vigor and chlorophyll content of buckwheat seedlings under salt stress, and the optimum concentration of Asp treatment is 40 μM (Yang, 2014). Therefore, chemical regulation is also an effective way to improve stress resistance of crops. At present, there is no relevant report on application of amino acids to improve yield and quality of buckwheat. In this paper, salt-tolerant variety of Chuanqiao No.1 and salt-sensitive variety of Chuanqiao No.2 in Tartary buckwheat were used as experimental materials, through sowing in non-saline and saline-alkali soil, and foliar spraying with the treatment of 3 kinds of amino acids, the indexes of Tartary buckwheat yield, seed protein content, mineral element content, content of vitamin B_2 and rutin were determined to study the effect of exogenous amino acids on yield and quality of different Tartary buckwheat varieties, and it aims to provide some basis for improving the yield and quality of crops.

Materials and Methods

Materials Culture and Treatment

Salt-tolerant variety of Chuanqiao No.1 and salt-sensitive variety of Chuanqiao No.2 in Tartary buckwheat were used as experimental materials, and were respectively sown in saline-alkali soil with salt concentration of 0.6% and non-saline soil in drill, and the sowing space and rowing spacing were 20 cm and 30 cm, and the area of each split plot was 0.1 hm^2, then applying foliar spraying with 3 kinds of amino acids twice during the seedling growth and flowering stage. The treatment concentration of Pro is 30 μM (Chen and Yang, 2012), and that of Glu and Asp is 60 μM and 40 μM (Ji et al., 2014) respectively. From 2016 to 2018, Tartary buckwheat was sown on June 26 and harvested on September 26 every year, comparing the quality differences among the three batches of Tartary buckwheat seeds. Three repetitions were set in per treatment each year.

Crop Management

The method of Wan (2003) was referred for field management. The seedling stage of Tartary buckwheat is more drought-tolerant and water should not be too much. When meeting rainy conditions, it is necessary to exclude accumulated water in time, while the water demand of flowering season is more, and it can be watered properly. It is advisable to choose sunny day when applying amino acids treatment and to spray the leaves without dropping water. The yield of Tartary buckwheat was measured by random sampling in 5 points.

Determination of Mineral Element Content

The content of nitrogen (N) in soil was determined by the Kjeldahl method (Wu et al., 2009), and that of other mineral elements was determined by ICP-OES inductively coupled plasma emission spectrometer. 1 g sample was taken to the digestive tube, mixed acid (10 mL HNO_3 and 2 mL $HClO_4$) was put in, and sample was static sealed overnight. On the following day, heating on the temperature control and digestion instrument, and maintaining the micro boiling state (160℃~170℃), when a large amount of brown NO_2 gas came out for about 1 h, continuing to heat until brown gas disappeared. Sample liquid gradually became light yellow, when it turned to transparent, it would completely digest, didn't stop heating evaporation to remove a large amount of HNO_3 and $HClO_4$ until the solution was left in the tube with about 1 mL. After a slight cooling, directly poured the water into digestion tube for about 10 mL, kept heating and removing acid in the digestion apparatus in micro boiling for 5 min, then transferred the sample solution to 25 mL volumetric flask and set the constant volume with deionized water after cooling. ICP-OES was used to determinate the mineral element content.

Determination of Protein, Vitamin B_2 and Rutin Content

Refering the method of Hui et al. (2004) to determine the protein content in buckwheat seeds; refering the high performance liquid chromatography method of Liang et al. (2005) to determine vitamin B_2 content; refering the ethanol extraction method of Jia et al. (1998) to extract rutin in buckwheat seeds; refering the high performance liquid chromatography method of Zhang et al. (2003) to determine the rutin content.

Determination of Soil Composition

In the study of soil properties, 3 samples were collected from soil under 10 cm. The determination of soil composition including determination of a large number of elements and trace elements, a large number of elements include P, N, K, Ca, and Mg, and trace elements include Fe, Mn, B, Zn, and Se. Refering the Kjeldahl method of Wu et al. (2009) to determine nitrogen content in soil; ICP-OES was adopted to determinate other mineral element content in soil.

Data Processing

The method of variance calculation was used to process the seed quality data obtained during the two years. Using ANOVA and t-test to analysis the significant difference of data between different amino acid treatments and two Tartary buckwheat varieties (Wang et al., 2010), and each test sample was provided with 3 duplicates.

Results

Effect of Exogenous Amino Acids on Tartary Buckwheat Yield in Non-saline and Saline-alkali Soil

Figure 1 shows the yield of Tartary buckwheat in non-saline and saline-alkali soil, under the treatment of Asp, the yield of Chuanqiao No.1 in non-saline soil was increased significantly, which was increased by 7.78%

than the control, while under the treatment of Pro, Glu and Asp, that of Chuanqiao No.1 in saline-alkali soil was all increased significantly, which was increased by 28.58%, 22.72% and 39.92% respectively than the control, and the largest increase of the treatment among them was Asp. The effect of exogenous amino acids on yield of Chuanqiao No.2 in non-saline soil was small, although there was a slight increase, there was no significant difference between the treatment and the control, however, under the treatments of Pro, Glu and Asp, that of Chuanqiao No.2 in saline-alkali soil was increased significantly, which was increased by 12.61%, 30.92% and 20.94% respectively than the control, and the largest increase of the treatment among them was Glu. Under the treatment of 3 kinds of amino acids, the yield of Chuanqiao No.1 in non-saline or saline-alkali soil was significant higher than that of Chuanqiao No.2.

Effect of Exogenous Amino Acids on Protein Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 2 shows the protein content of Tartary buckwheat in non-saline and saline-alkali soil, the seed protein content of Tartary buckwheat in non-saline and saline-alkali soil was increased in different degrees under the treatments of 3 kinds of exogenous amino acids, under the treatment of Pro, that of Chuanqiao No.1 in saline-alkali soil was increased significantly, which was increased by 14.56% than the control, and under the treatment of Asp, that of Chuanqiao No.1 in non-saline and saline-alkali soil was increased significantly, which was increased by 22.32% and 29.93% respectively than the control. Under the treatment of Glu, that of Chuanqiao No.2 in non-saline and saline-alkali soil was increased significantly, which was increased by 14.46% and 20.68% respectively than the control. Under the treatment of proline and aspartic acid, the seed protein content of Chuanqiao No.1 was significantly higher than that of Chuanqiao No.2.

Effect of Exogenous Amino Acids on Calcium (Ca) Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 3 shows the Ca content of Tartary buckwheat in non-saline and saline-alkali soil, there are obviously different effect of exogenous amino acids on seed calcium content of different Tartary buckwheat varieties, under the treatments of Pro, Glu and Asp, the seed Ca content of Chuanqiao No.1 in non-saline soil was increased significantly, which was increased by 83.90%, 71.16% and 90.69% respectively than the control, and the largest increase of the treatments among them was Asp, and under the treatments of Pro and Glu, that of Chuanqiao No.1 in saline-alkali soil was increased significantly, which was increased by 46.91% and 27.13% respectively than the control, the larger increase between them was Pro. Under the treatments of Pro and Asp, that of Chuanqiao No.2 in non-saline soil was increased significantly, which was increased by 34.31% and 75.36% respectively than the control, and the larger increase between them was Asp, and under the treatment of Pro, that of Chuanqiao No.2 in saline-alkali soil was increased significantly, which was increased by 45.26% than the control. Under the treatment of proline and glutamic acid, the seed Ca content of Chuanqiao No.1 in non-saline soil was significantly higher than that of Chuanqiao No.2; while that of Chuanqiao No.2 in saline-alkali soil was significantly higher than that of Chuanqiao No.1 under the treatment of proline and aspartic acid.

Effect of Exogenous Amino Acids on Iron Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 4 shows the Fe content of Tartary buckwheat in non-saline and saline-alkali soil, there is no significant change of seed iron (Fe) content of the two Tartary buckwheat varieties in non-saline soil under the treatment of 3 kinds of amino acids. It indicated that the effect of exogenous amino acids treatment on seed Fe content in non-saline soil was small. Under the treatments of Pro, Glu and Asp, the seed Fe content of Chuanqiao No.1 in saline-alkali soil was increased significantly, which was increased by 194.85%, 85.46% and 82.83% respectively than the control, and the largest increase of the treatment among them was Pro, and under the treatments of Pro and Glu, that of Chuanqiao No.2 in saline-alkali soil was increased significantly, which was increased by 76.69% and 59.52% respectively than the control, and the larger increase of the treatment between them was Pro. Under the treatment of 3 kinds of amino acids, the seed iron content of Chuanqiao No.1 in saline-alkali soil was significantly higher than that of Chuanqiao No.2.

Effect of Exogenous Amino Acids on Zinc Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 5 shows the Zn content of Tartary buckwheat in non-saline and saline-alkali soil, the seed Zn content of two Tartary buckwheat varieties in saline-alkaline soil was generally larger than that in non-saline one under the treatment of 3 kinds of amino acids. With the treatments of Glu and Asp, the seed Zn content of Chuanqiao No.1 in non-saline soil was increased significantly, which was increased by 37.88% and 46.64% respectively than the control, the larger increase between them was Asp. With the treatments of Pro, Glu and Asp, that of Chuanqiao No.1 in saline-alkali soil was increased significantly, which was increased by 32.16%, 30.14% and 58.85% respectively than the control, the largest increase of the treatment among them was Asp, and that of Chuanqiao No.2 in non-saline soil was increased significantly, which was increased by 22.90%, 26.22% and

44.57% respectively than the control, the largest increase of the treatment among them was Asp. With the treatments of Glu and Asp, that of Chuanqiao No.2 in saline-alkali soil was increased significantly, which was increased by 24.33% and 32.40% respectively than the control, and the larger increase of the treatment between them was Asp. Under the treatment of proline, the seed Zn content of Chuanqiao No.1 was significantly higher than that of Chuanqiao No.2.

Effect of Exogenous Amino Acids on Selenium (Se) Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 6 shows the Se content of Tartary buckwheat in non-saline and saline-alkali soil, there is no significant change of seed Se content in non-saline and saline-alkali soil of the two Tartary buckwheat varieties under the treatment of 3 kinds of amino acids. It indicated that the effect of 3 kinds of exogenous amino acids treatment on seed Se content in non-saline soil was small. With the treatments of Pro and Glu, seeds Se content of Chuanqiao No.1 in saline-alkali soil was increased significantly, which was increased by 29.37% and 21.27% respectively than the control, and the larger increase of the treatment between them was Pro, with the treatment of Asp, seed Se content of Chuanqiao No.2 in saline-alkali soil was increased significantly, which was increased by 20.35% than the control. Under the treatment of 3 amino acids, the seed Se content of Chuanqiao No.2 in non-saline or saline-alkali soil was significantly higher than that of Chuanqiao No.1.

Effect of Exogenous Amino Acids on Vitamin B_2 Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 7 shows the vitamin B_2 content of Tartary buckwheat in non-saline and saline-alkali soil, under the treatments of Pro, Glu and Asp, the seed vitamin B_2 content of Chuanqiao No.1 in non-saline and saline-alkali soil had a small change, and that in saline-alkali soil was slightly higher than that in non-saline one. Under the treatments of Glu, that of Chuanqiao No.2 in saline-alkali soil was lower than that in non-saline one, while under the treatments of Pro and Asp, that of Chuanqiao No.2 in saline-alkali soil was higher than that in non-saline one, however, both did not reach the level of significant difference. It indicated that the effect of 3 kinds of amino acids on seed vitamin B_2 content of the two Tartary buckwheat varieties in non-saline and saline-alkali soil was small.

Effect of Exogenous Amino Acids on Rutin Content of Tartary Buckwheat in Non-saline and Saline-alkali Soil

Figure 8 shows the rutin content of Tartary buckwheat in non-saline and saline-alkali soil, under the treatment of Asp, the seed rutin content of Chuanqiao No.1 in non-saline and saline-alkali soil was increased significantly, which was increased by 30.38% and 18.56% respectively than the control, and with the treatment of Pro, that of Chuanqiao No.2 was increased significantly, which was increased by17.80% than the control, while that of Chuanqiao No.2 in saline-alkali soil had no significant difference change under the treatment of 3 kinds of amino acids. It indicated that the effect of 3 kinds of amino acids on seed rutin content of Chuanqiao No.2 in saline-alkali soil was small. Under the treatment of proline, the seed rutin content of Chuanqiao No.2 in non-saline soil was significant higher than that of Chuanqiao No.1.

Element Content in Non-saline and Saline-alkali Soil

Table 1 shows the large amount of element content in non-saline and saline-alkali soil, there is no significant difference of N content between non-saline and saline-alkali soil, while the content of P, K, Ca and Mg in non-saline soil was significantly different from that in saline-alkali one, and the content of P in saline-alkali soil was 39.53% lower than that in non-saline one, while the content of K, Ca and Mg in saline-alkali soil was 23.84%, 217.97% and 339.13% higher than that in non-saline one respectively.

Table 1. Large amount of element content in non-saline and saline-alkali soil.

Element content	N(mg/g)	P(mg/g)	K(mg/g)	Ca(mg/g)	Mg(mg/g)
Non-saline soil	0.91±0.10^{e}	0.86±0.09^{f}	13.63±1.27^{b}	4.23±0.34^{c}	0.46±0.05^{g}
Saline-alkali soil	0.95±0.11^{e}	0.52±0.07^{g}	16.88±1.53^{a}	13.45±1.06^{b}	2.02±0.41^{d}

Table 2 shows the trace element content in non-saline and saline-alkali soil, there is no significant difference of trace element content of Mn and Zn between non-saline and saline-alkali soil, while the content of Fe, B and Se in saline-alkali soil was significantly lower than that in non-saline one, which was 44.27%, 98.76% and 44.31% lower than that in non-saline one respectively.

Table 2. Trace element content in non-saline and saline-alkali soil.

Element content	Fe(mg/g)	Mn(mg/g)	B(μg/g)	Zn(μg/g)	Se(ng/g)
Non-saline soil	33.93±2.65^{d}	0.44±0.05^{g}	10.49±0.86^{f}	61.10±5.06^{c}	131.77±12.23^{a}
Saline-alkali soil	18.91±1.56^{e}	0.46±0.06^{g}	0.13±0.03^{h}	67.66±6.10^{bc}	73.38±6.35^{b}

Discussion

Study showed that the azophoska could significantly improve the biological yield of sweet sorghum in saline-alkali soil (Wang et al., 2013). This article illustrated that the effect of exogenous amino acids on yield in non-saline soil was small while that on the yield in saline-alkali one was high, and the yield of two Tartary buckwheat varieties in saline-alkali soil increased significantly under the treatment of 3 kinds of amino acids. The effect of Asp treatment on yield increasement was the best in salt-tolerant Tartary buckwheat variety, while that of Glu treatment on yield increasement was the best in salt-sensitive Tartary buckwheat variety, and the yield of salt-tolerant Tartary buckwheat variety increased more than that of salt-sensitive one. In addition, the yield of Tartary buckwheat in saline-alkali soil changed little in the past 2 years, indicating that the effect of saline-alkali soil environment on yield of Tartary buckwheat was small, while the external application of amino acids was an important factor affecting the yield of Tartary buckwheat in saline-alkali soil, and the experimental data were reliable and persuasive.

The soluble protein content of leaves in Pingshan pomelo and citrus seedling could increase obviously under salt stress, and that would increase to a higher level with the increasing concentration of salt stress (Ma et al., 2005); Song et al. (2008) had founded that the appropriate concentration of 5-amino acid (ALA) treatment could significantly promote the growth of spinach and significantly increase the soluble protein content so as to improve the quality of spinach. As shown in this article, the seed protein content of salt-tolerant variety increased obviously in saline-alkali soil, and that of salt-tolerant variety increased significantly under the treatment of Asp, and that of salt-sensitive variety increased significantly under the treatment of Glu, and the increase in saline-alkali soil was more than that in non-saline one, also, the increase of salt-tolerant variety was more than that of salt-sensitive one.

Calcium is one of the essential elements of the human body, the calcium supplementation has a slowing effect on bone losses, it helps to lower cholesterol levels in the blood so as to prevent heart diseases (Ye et al., 1998). As shown in this article, the seed calcium content of two buckwheat varieties in non-saline soil was increased significantly under the treatment of Pro and Asp, and that under the treatment of Asp increased more than that of Pro, and that of salt-tolerant variety increased more than that of salt-sensitive one, and that of two Tartary buckwheat varieties in saline-alkali soil was increased significantly under the treatment of Pro. The trace element iron is an important component of hemoglobin, and the iron element has a catalysis function to promote β-carotene into vitamin A, and to promote the synthesis of purine, collagen and antibody. In addition, the iron can also enhance the body immunity and the swallow capability of neutrophils and macrophages. As shown in this article, the effect of exogenous amino acids on seed iron content in non-saline soil was small, while the seed iron content of the two kinds of Tartary buckwheat varieties in saline-alkali soil was increased significantly under the treatment of Pro and Glu, and the increase under the treatment of Pro was more than that under the treatment of Glu, and that in salt-tolerant variety was increased more than that in salt-sensitive one. Zinc can promote the growth and development in human body, and the serious lack of zinc in children would induce "dwarf" and mental retardation (Zhang et al., 2000). Zinc is a nutritional element in the development of thymus, only the sufficient amount of zinc could effectively guarantee the development of the thymus, and the normal T lymphocyte could be differentiated (CETTIC, 2007). As shown in this article, the seed zinc content of the two kinds of Tartary buckwheat varieties in non-saline and saline-alkali soil was increase significantly under the treatment of Glu and Asp, and the increase under the treatment of Asp was more than that under the treatment of Glu, and that of salt-tolerant variety was increased more than that of salt-sensitive one. Selenium (Se) is a very scarce trace element, and few foods rich in selenium. Se is the component of antioxidant enzymes in the body, so it could protect the cell membranes from oxidative damage, also, it could protect the β cells of pancreatic islet and maintain their normal functions, which could effectively improve the symptoms of diabetic patients (Chen, 2012). This article showed that the effect of exogenous amino acids on seed Se content in non-saline soil was small, while the seed Se content of salt-tolerant Tartary buckwheat variety in saline-alkali soil was increased significantly under the treatment of Pro and Glu, and the increase under the treatment of Pro was more than that under the treatment of Glu, and that of salt-sensitive Tartary buckwheat variety in saline-alkali soil was increased significantly under the treatment of Asp.

UV-B could increase the activity of enzyme in the route of dilantin synthesis pathway, and promoting the accumulation of rutin in buckwheat (Kreft et al., 2002), therefore, long time sunshine could promote the synthesis of rutin in buckwheat. The average rutin content of *Fagopyrum esculentum* in long time sunshine was obviously higher than that in short sunshine time (Kim et al., 2002), and the rutin content of buckwheat in summer sowing was almost two times as that in autumn sowing, it indicated that the rutin content increasing of buckwheat was closely related to the sunlight (Fabjan et al., 2003). As shown in this article, the seed rutin content of salt-tolerant variety was increased significantly under the treatment of Asp, and the increase in non-saline soil was more than that in saline-alkali one, and that of salt-sensitive variety in non-saline soil was increased significantly under the treatment of Pro, while that of salt-sensitive variety in saline-alkali soil had no significant change under the treatment of 3 kinds of amino acids. The amino acids treatment increasing the seed rutin content might be related to the prolonging of growth period in Tartary buckwheat.

High K, Ca and Mg is a common soil condition in saline-alkali soil (Li et al., 2017), which is beneficial to the enrichment of Ca in saline-alkali plants, and that is in accordance with the results of Tartary buckwheat in saline-alkali soil. Under the condition of content of Fe and Se in saline-alkali soil significantly lower than that in non-saline one, while the content of Fe and Se of Tartary buckwheat seeds in saline-alkali soil was significantly higher than that in non-saline one, indicating that saline-alkali soil environment was beneficial to the enrichment of Fe and Se in Tartary buckwheat. Meanwhile, appropriate amino acid treatment played a good role in promoting the enrichment of Ca, Fe and Se in Tartary buckwheat seeds, and made the Tartary buckwheat in saline-alkali soil more nutritious. According to the analysis of soil composition for 3 years, the content changes in non-saline and saline-alkali soil are small, and the significant changes in the quality of Tartary buckwheat should be the result of the effect of exogenous amino acids. Generally speaking, although the yield of Tartary buckwheat in saline-alkali soil is lower than that in non-saline soil, but the quality of Tartary buckwheat in saline-alkali soil is better than that in non-saline soil, so it is suitable for popularizing sowing in saline-alkali soil.

It's essential to take the relative costs of applying amino acids into account for large-scale agronomic crops, on the basis of our experiments, the results showed that nearly 150 L proline acid solution with a concentration of 30 μM, 150 L glutamic acid solution with a concentration of 60 μM and 150 L aspartic acid solution with a concentration of 40 μM were needed in per hectare soil once. Because the total of 4 times with foliar spraying during the whole process, following this calculation, 2.07 g proline acid, 5.6 g glutamic acid or 32 g aspartic acid were needed in per hectare soil. According to the market price of proline acid, glutamic acid and aspartic acid, approximately $ 0.33 proline acid, $ 1 glutamic acid or $ 5 aspartic acid was needed in per hectare. To sum up, this way is very environmentally friendly with low cost and can effectively increase the yield and quality of Tartary buckwheat, so it is very suitable for popularization and application in saline-alkali soil.

Conclusion

(1) Yield of Tartary buckwheat in saline-alkaline soil could be increased significantly under the amino acids treatment. The effect of Asp treatment on yield increase in salt-tolerant variety was the best, and that of Glu treatment on yield increase in salt-sensitive variety was the best, and that in salt-tolerant variety increased more.

(2) The seed protein content of salt-tolerant variety increased significantly under the treatment of Asp, and that of salt-sensitive variety increased significantly under the treatment of Glu, and the increase in saline-alkali soil was more than that in non-saline one, and that of salt-tolerant variety increased more.

(3) With an appropriate treatment of amino acid, the seed mineral element (Ca, Fe, Zn and Se) content of

the two Tartary buckwheat varieties in non-saline and saline-alkali soil was increased significantly, and that of the salt-tolerant variety was increased more.

(4) The seed rutin content of salt-tolerant variety was increased significantly under the treatment of Asp, and the increase in non-saline soil was more than that in saline-alkali one, and that of salt-sensitive variety in non-saline soil was increased significantly under the treatment of Pro.

(5) The effect of exogenous amino acids on yield and quality of the two Tartary buckwheat varieties were obviously different.

(6) Appropriate amino acid treatment could play a good role in promoting the enrichment of Ca, Fe and Se of Tartary buckwheat seeds in saline-alkali soil, and made the Tartary buckwheat in saline-alkali soil more nutritious and suitable for large area popularization and application in saline-alkali soil.

(7) This way is very environmentally friendly with low cost and can effectively increase the yield and quality of Tartary buckwheat, so it is very suitable for popularization and application in saline-alkali soil.

Author Contributions

J-NS analyzed the experimental data, and wrote the manuscript. Y-QW determined the element content in non-saline and saline-alkali soil. SL determined the nutrient content of Tartary buckwheat seed. F-LL guided sowing and harvesting of Tartary buckwheat. Y-JH determined the yield of Tartary buckwheat. H-BY designed the experiment and revised the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Legends

Table 1. Large amount of element content in non-saline and saline-alkali soil.

Table 2. Trace element content in non-saline and saline-alkali soil.

Fig.1. Effect of exogenous amino acids on Tartary buckwheat yield in non-saline and saline-alkali soil.

Values followed by different letters are significantly different at the 0.05 probability level (*n*=3). The same as below.

Fig.2. Effect of exogenous amino acids on protein content of Tartary buckwheat in non-saline and saline-alkali soil.

Fig.3. Effect of exogenous amino acids on Ca content of Tartary buckwheat in non-saline and saline-alkali soil.

Fig.4. Effect of exogenous amino acids on Fe content of Tartary buckwheat in non-saline and saline-alkali soil.

Fig.5. Effect of exogenous amino acids on Zn content of Tartary buckwheat in non-saline and saline-alkali soil.

Fig.6. Effect of exogenous amino acids on Se content of Tartary buckwheat in non-saline and saline-alkali soil.

Fig.7. Effect of exogenous amino acids on vitamin B_2 content of Tartary buckwheat in non-saline and saline-alkali soil.

Fig.8. Effect of exogenous amino acids on rutin content of Tartary buckwheat in non-saline and saline-alkali soil.

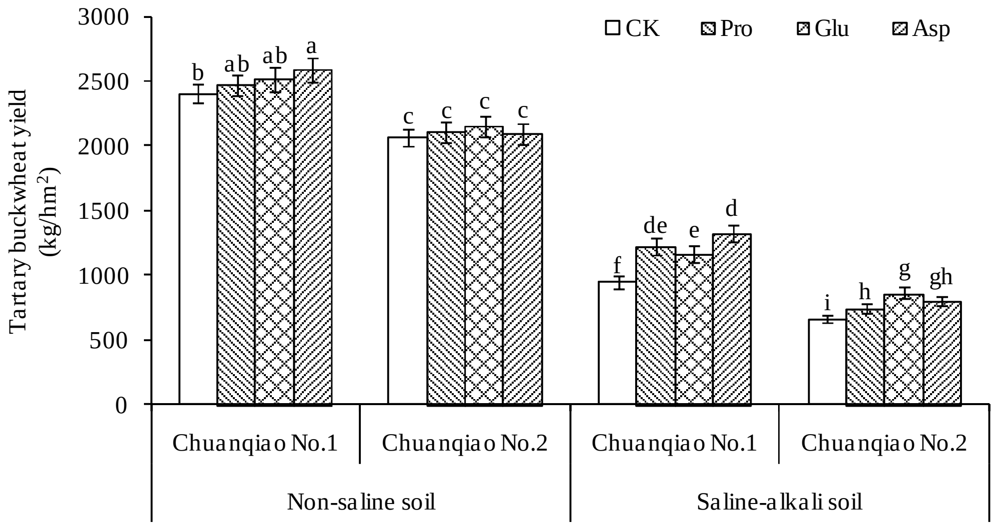

Fig.1. Effect of exogenous amino acids on Tartary buckwheat yield in non-saline and saline-alkali soil.

Values followed by different letters are significantly different at the 0.05 probability level (n=3). The same as below.

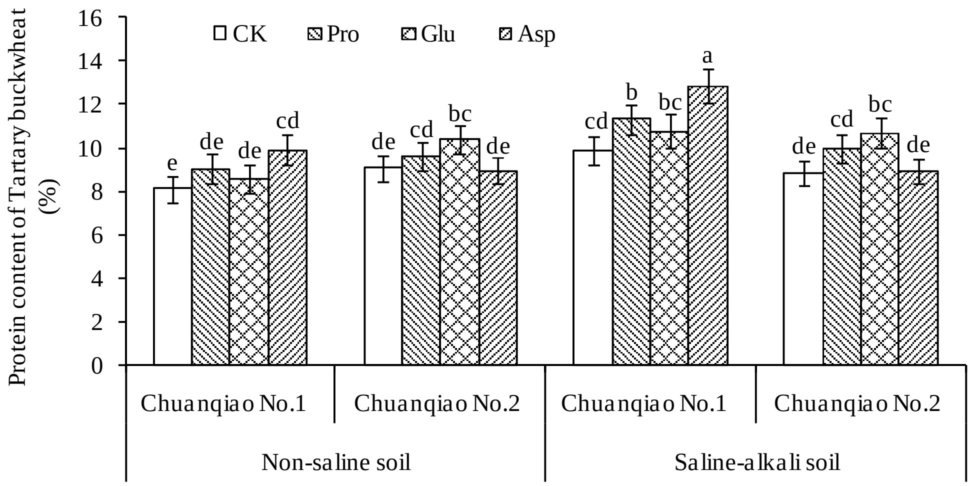

Fig.2. Effect of exogenous amino acids on protein content of Tartary buckwheat in non-saline and saline-alkali soil.

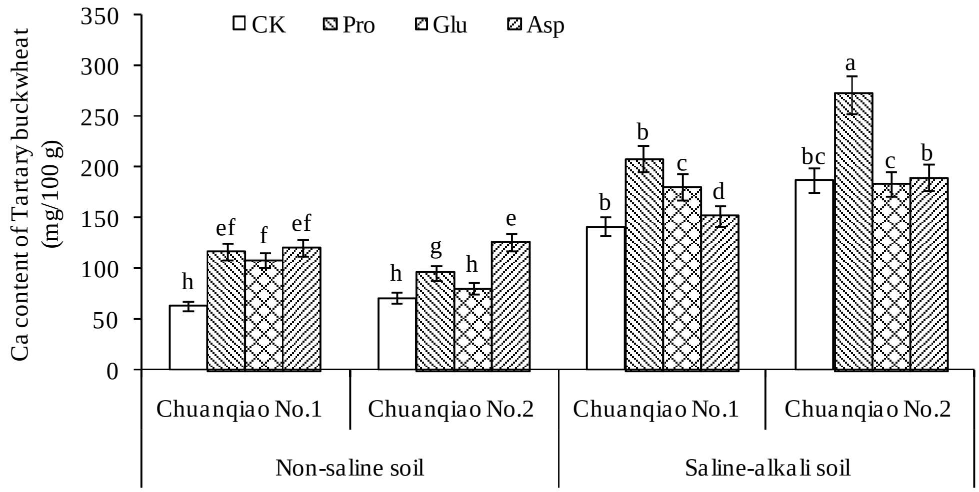

Fig.3. Effect of exogenous amino acids on Ca content of Tartary buckwheat in non-saline and saline-alkali soil.

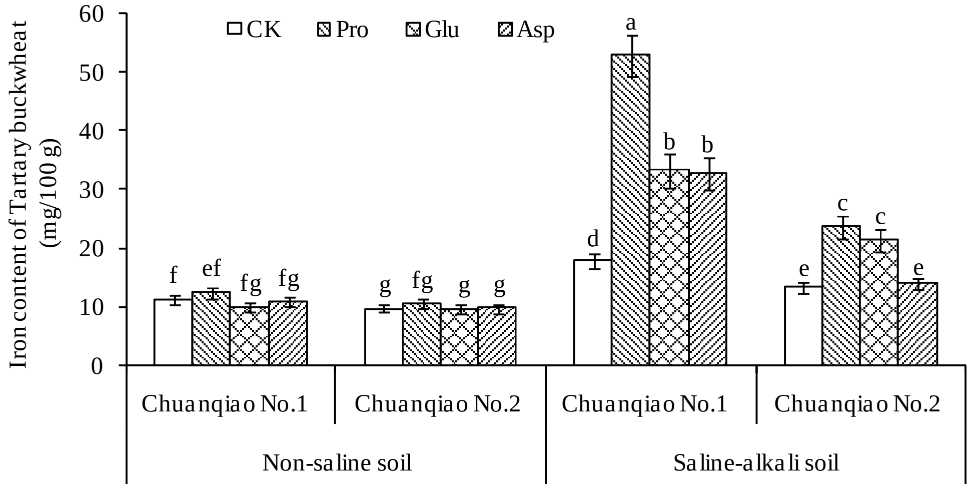

Fig.4. Effect of exogenous amino acids on Fe content of Tartary buckwheat in non-saline and saline-alkali soil.

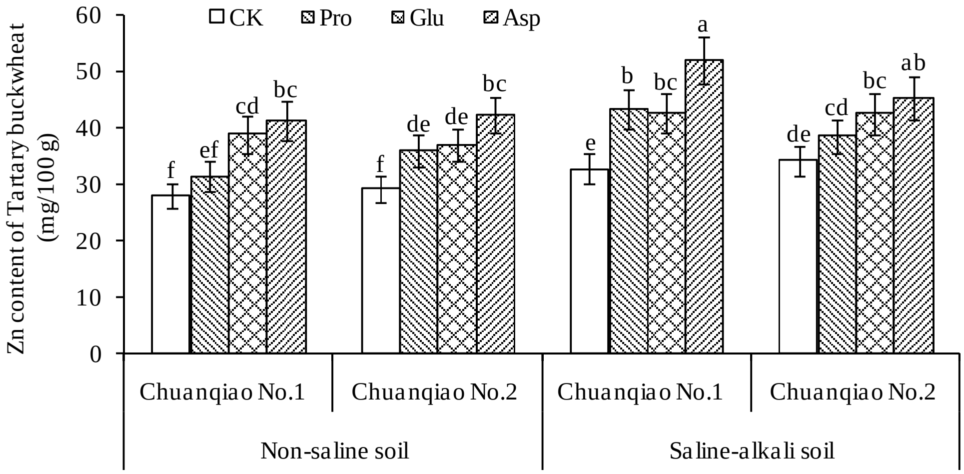

Fig.5. Effect of exogenous amino acids on Zn content of Tartary buckwheat in non-saline and saline-alkali soil.

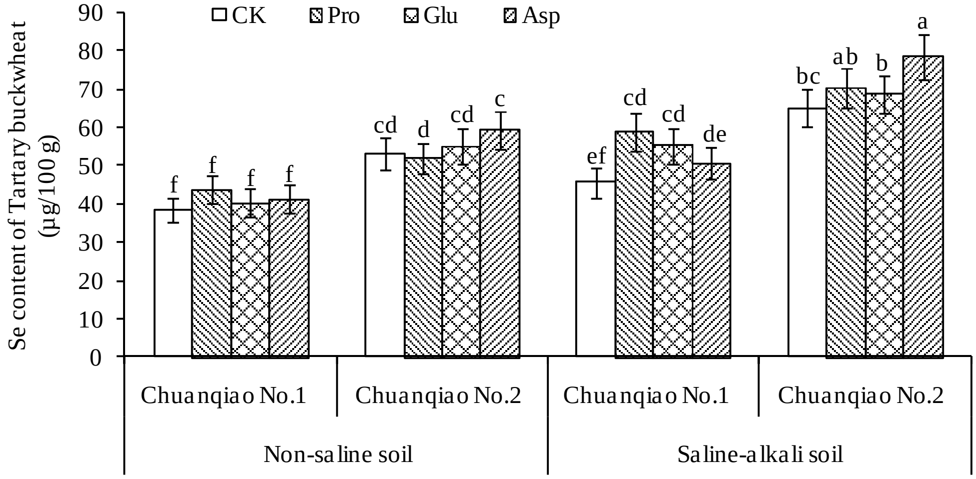

Fig.6. Effect of exogenous amino acids on Se content of Tartary buckwheat in non-saline and saline-alkali soil.

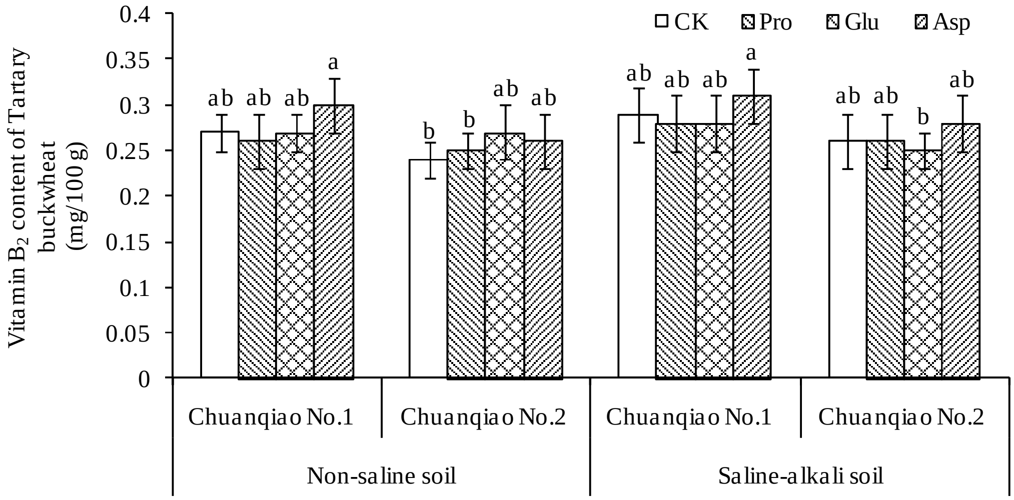

Fig.7. Effect of exogenous amino acids on vitamin B_2 content of Tartary buckwheat in non-saline and saline-alkali soil.

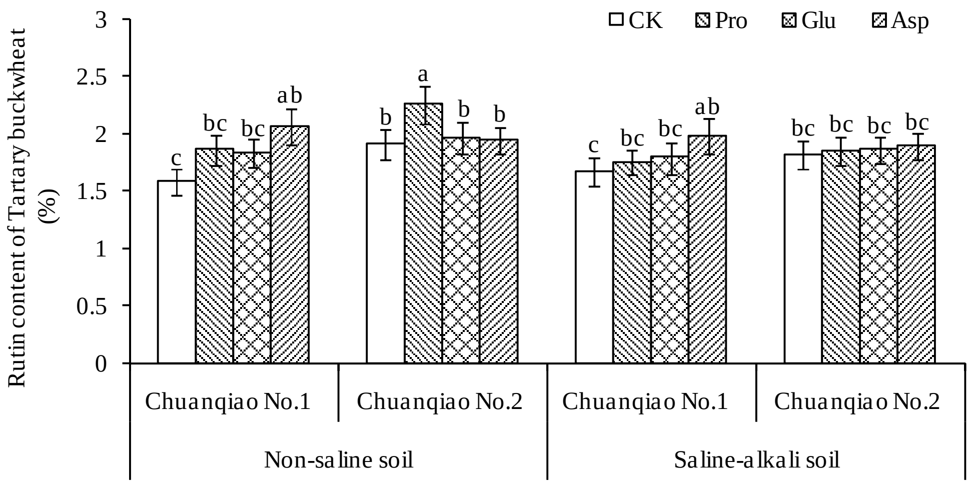

Fig.8. Effect of exogenous amino acids on rutin content of Tartary buckwheat in non-saline and saline-alkali soil.