Postprint: Study on Differences in Growth and Physiological Indices of Plants from Heteromorphic Seeds of Suaeda corniculata

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Abstract

A pot experiment was conducted to compare and analyze the differences in growth, photosynthetic pigment content, salt ion content, and N, P, K content of plants derived from heteromorphic seeds of different Suaeda corniculata populations under identical cultivation conditions, aiming to explore the physiological and ecological mechanisms underlying S. corniculata' s adaptation to saline-alkali environments in arid regions. The results demonstrated: (1) No significant differences were observed in growth, photosynthetic pigment content, salt ion content, or N, P, K content between plants from brown and black seeds; however, significant differences existed in growth, development, and physiological indices between S. corniculata plants from Xinjiang and Inner Mongolia. (2) Population type significantly influenced aboveground dry weight but not root dry weight; chlorophyll a content, chlorophyll b content, total chlorophyll (chlorophyll a+b) content, and carotenoid content were not significantly affected by either population type or plant type, indicating similar photosynthetic functions among plants from different S. corniculata populations. (3) Significant differences in Na+, K+, Ca2+, Cl-, SO4^2- ion contents and P, K contents were detected between Xinjiang and Inner Mongolia populations, suggesting variations in osmotic maintenance capacity among different S. corniculata populations. (4) The growth differences in aboveground parts of S. corniculata from different populations were associated with variations in ion content and P, K absorption and utilization, but not with nitrogen absorption capacity or photosynthesis. Therefore, a synergistic relationship exists among the salt ion absorption systems of heteromorphic plants from different S. corniculata populations, and this synergistic effect is closely correlated with the contents of major mineral elements P and K, representing one of the important physiological mechanisms for S. corniculata to adapt to environmental changes.

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Differences in Growth and Physiological Indices of Plants Grown from Heteromorphic Seeds of *Suaeda corniculata*

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Abstract

Pot experiments were conducted to compare and analyze differences in growth, photosynthetic pigment content, salt ion content, and mineral nutrient content of heteromorphic seed plants from different populations of *Suaeda corniculata* under identical cultivation conditions, aiming to explore the physiological and ecological mechanisms by which *S. corniculata* adapts to saline-alkali environments in arid regions. The results showed that: (1) Brown and black seed plants exhibited similar responses in growth, photosynthetic pigment content, salt ion content, and N, P, K content to the same environment, but significant differences existed in growth and physiological indices between heteromorphic seeds from different populations. (2) Population type significantly affected aboveground dry weight but not root dry weight. Chlorophyll a content, chlorophyll b content, total chlorophyll content, and carotenoid content were not significantly affected by population type or plant type, indicating similar photosynthetic function among plants from different *S. corniculata* populations. (3) Significant differences in Na^+, K^+, Ca^{2+}, Cl^-, $SO_4{}^{2-}$, P, and K contents were observed between Xinjiang and Inner Mongolia populations, suggesting differences in osmotic maintenance capacity among different populations. (4) Differences in aboveground growth of *S. corniculata* among populations were related to ion content and differential absorption and utilization of P and K, but not to nitrogen absorption capacity or photosynthesis. Therefore, a synergistic relationship exists between salt ion absorption systems in heteromorphic plants from different populations, which is closely related to mineral element P and K content. These represent important physiological mechanisms for *S. corniculata* to adapt to environmental changes.

Keywords: heteromorphism; mineral elements; *Suaeda corniculata*; photosynthetic pigment content

Introduction

Seed heteromorphism in plants generally refers to the phenomenon where a single plant produces different types of seeds. Distinguishing features of heteromorphic seeds often include differences in size, morphology, color, dormancy type, and dispersal pathways. Heteromorphic seeds not only exhibit differences during germination but also show significant variations during plant growth and development. Research indicates that many halophytes possess seed heteromorphism characteristics, such as species in the genera *Atriplex*, *Suaeda*, and *Salicornia*, all of which can produce heteromorphic seeds. Among them, some *Suaeda* species can simultaneously produce both brown and black seeds on the same plant. *Suaeda salsa*, *Suaeda corniculata*, and *Suaeda glauca* are typical examples of seed heteromorphic plants. Previous studies have primarily focused on seed germination and fruiting traits, with less attention paid to whether growth and physiological indices differ among heteromorphic seed plants from different populations of *S. corniculata*.

Currently, more research has focused on the effects of environmental factors (such as salinity and temperature) on heteromorphic seed growth and development. However, few reports have examined whether differences exist in growth, photosynthetic pigment content, and mineral element content among heteromorphic seed plants from different populations. Therefore, this study investigated differences in growth, photosynthetic pigment content, and mineral element content of heteromorphic seed plants from different *S. corniculata* populations to analyze whether responses to the same environment differ among populations and whether significant differences exist in growth and physiological indices between heteromorphic seed plants.

Materials and Methods

1.1 Collection of Heteromorphic Seeds of *Suaeda corniculata* *Suaeda corniculata* is an annual euhalophyte that can produce two types of seeds (brown and black) on a single plant, which differ significantly in color, morphology, dormancy type, and germination characteristics. Brown seeds have stronger water absorption capacity and higher germination rates and salt tolerance than black seeds. In mid-October, fully mature seeds were collected from *S. corniculata* populations in Urumqi, Xinjiang (43°44 15 N, 87°41 23 E, soil soluble salt content 3.8 $g \cdot kg^{-1}$) and Ordos, Inner Mongolia (38°14 15 N, 107°30 24 E, soil soluble salt content 10.7 $g \cdot kg^{-1}$). After air-drying at room temperature, the dried pericarps were rubbed off. Seeds were classified as brown or black based on seed coat color and stored separately in seed bags.

1.2 Experimental Design On May 10, 2019, quartz sand and vermiculite were mixed in a 2:1 ratio, and base fertilizer was applied. The nutrient ratio was 15:11:13:2 (N:P:K:organic matter), which was thoroughly mixed and placed in pots (20 cm × 20 cm). Brown and black seeds from Xinjiang and Inner Mongolia populations were sown separately in pots. The experiment was conducted in a greenhouse at the Fukang Desert Ecology Station (44°13 22 N, 87°40 54 E) of the Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, with natural light and day/night temperatures of 28°C/18°C. The experiment consisted of 4 treatments: different populations (Xinjiang and Inner Mongolia) and heteromorphic seeds (brown and black), with 10 replicates per treatment. Top dressing was applied once per week (Mondays), with 100 mL of 0.3 $g \cdot L^{-1}$ Huaduoduo quick-acting fertilizer solution (N:P:K = 20:20:20). As a euhalophyte requiring salt for growth, salt treatment was applied twice per week (Wednesdays and Sundays) with 100 mL of 3 $g \cdot L^{-1}$ salt solution ($NaCl:Na_2SO_4:NaHCO_3$ = 20:20:1). Salt treatment began one week after germination. When no top dressing or salt solution was applied, 100 mL of deionized water was sprayed. Plants were sampled for measurement 90 days after sowing.

1.3 Measurement Indicators

1.3.1 Biomass Determination Plants were washed with deionized water and dried. Shoots and roots were separated, placed in envelopes, oven-dried at 80°C to constant weight, and weighed.

1.3.2 Photosynthetic Pigment Content Determination Approximately 0.2 g of fresh leaves from the middle portion of plants was collected, washed with deionized water, dried, and placed in test tubes with 10 mL of extraction solution (ethanol:acetone = 1:1). Samples were kept in darkness until they turned white. Absorbance was measured at wavelengths of 663 nm, 646 nm, and 470 nm using a spectrophotometer.

1.3.3 Salt Ion Content Determination Dried plant samples were ground to determine salt ion content in shoots. Na^+ and K^+ contents were measured using a PerkinElmer Sciex DRC II, Ca^{2+} content was determined by atomic absorption spectrophotometry, and Cl^- and $SO_4{}^{2-}$ contents were measured by ion chromatography.

1.3.4 Total Nitrogen, Phosphorus, and Potassium Content Determination Dried plant samples were digested using H_2SO_4-$HClO_4$ digestion. Total nitrogen was determined by semi-micro Kjeldahl method, total phosphorus by colorimetry, and total potassium by atomic absorption spectrophotometry.

1.3.5 Data Analysis One-way and two-way ANOVA were performed using SPSS 16.0 software. Differences were tested by ANOVA, and if significant, Tukey' s test was used to determine differences among treatments.

Results

2.1 Aboveground Biomass and Root Dry Weight Two-way ANOVA showed that population type significantly affected aboveground dry weight but not root dry weight, while plant type and their interaction did not significantly affect either aboveground or root dry weight (Table 1). No significant difference was observed in aboveground dry weight between brown seed plants from Inner Mongolia and Xinjiang populations, but a significant difference existed between black seed plants from the two populations (Figure 1), indicating physiological and ecological adaptation differences among heteromorphic plants from different populations.

2.2 Photosynthetic Pigment Content Chlorophyll content is an important indicator of leaf photosynthetic capacity. Two-way ANOVA showed that plant type, population type, and their interaction did not significantly affect photosynthetic pigment content (Table 1). No significant differences were found in chlorophyll a, chlorophyll b, total chlorophyll, or carotenoid contents between brown and black seed plants. Similarly, no significant differences were observed in these parameters between Xinjiang and Inner Mongolia heteromorphic plants (Figure 2), indicating that not only the photosynthetic capacity of the two heteromorphic seed plants (brown and black seeds) was similar, but also that photosynthetic characteristics were comparable between Xinjiang and Inner Mongolia populations.

2.3 Salt Ion Content Research shows that halophytes require certain salt ions for osmotic regulation during growth, which promotes *S. corniculata* development. Two-way ANOVA indicated that population type significantly affected Na^+, K^+, Ca^{2+}, Cl^-, and $SO_4{}^{2-}$ contents, while plant type only significantly affected Ca^{2+} content (Table 1). Na^+ and K^+ contents in brown and black seed plants from Inner Mongolia were significantly higher than those from Xinjiang. Cl^- and $SO_4{}^{2-}$ contents in Inner Mongolia brown and black seed plants were significantly higher than in Xinjiang plants. Ca^{2+} content in Xinjiang brown seed plants was significantly higher than in black seed plants, while no significant differences in Ca^{2+} content existed between Inner Mongolia brown and black seed plants. These results indicate that different populations of *S. corniculata* differ in their capacity for osmotic maintenance, which may be related to their growth differences.

2.4 Total Nitrogen, Phosphorus, and Potassium Content Plant type, population type, and their interaction did not significantly affect total nitrogen content (Table 1), indicating no significant difference in nitrogen absorption capacity between Xinjiang and Inner Mongolia populations. No significant difference in total nitrogen content was observed between black and brown seed plants, nor between Xinjiang and Inner Mongolia heteromorphic plants, suggesting that nitrogen absorption was similar not only between heteromorphic plants but also between populations (Figure 4). Population and plant type significantly affected total phosphorus and potassium content (Table 1). Total phosphorus content in Inner Mongolia brown seed plants was significantly higher than in Xinjiang brown and black seed plants, and Inner Mongolia black seed plants also had higher phosphorus content than Xinjiang black seed plants (Figure 4).

Discussion

Current research on *S. corniculata* has mainly focused on germination characteristics, molecular biology, and saline-alkali land cultivation. This study is the first to investigate growth, photosynthetic pigment content, and mineral nutrition of heteromorphic plants from different *S. corniculata* populations. The results show that heteromorphic seed plants exhibited similar responses in growth, photosynthetic pigment content, and mineral nutrition to the same environment. However, significant differences existed between Xinjiang and Inner Mongolia populations in plant growth and mineral nutrition, though photosynthetic pigment content was similar.

The similar photosynthetic pigment content between heteromorphic seed plants indicates comparable photosynthetic capacity between brown and black seed plants of *S. corniculata*. The high salt ion concentration in *S. corniculata* plants demonstrates their requirement for salt ions to maintain osmotic regulation, which promotes growth and development. Similar salt ion contents in brown and black seed plants suggest no significant difference in osmotic regulation capacity between heteromorphic plants, which is not significantly related to their growth differences. The similar total nitrogen, phosphorus, and potassium contents in brown and black seed plants indicate no difference in nutrient absorption capacity between heteromorphic plants, which may be one of the main reasons for their similar growth.

Heteromorphic seed plants from Xinjiang and Inner Mongolia showed similar responses to the same environment, indicating no differential performance during growth and development. While aboveground biomass was similar between heteromorphic seed plants, significant differences in photosynthetic pigment content existed between Xinjiang and Inner Mongolia populations, though photosynthetic differences between populations were not significant. Significant differences in salt ion content between Xinjiang and Inner Mongolia populations indicate substantial differences in osmotic regulation capacity between populations, which may be a primary reason for growth differences. Plant type, population type, and their interaction did not significantly affect total nitrogen content, indicating similar nitrogen absorption capacity between Xinjiang and Inner Mongolia populations. However, they significantly affected total potassium and phosphorus content, indicating significant differences in potassium and phosphorus absorption capacity between populations, which may explain their growth differences.

Conclusion

Based on analysis of growth and physiological indices of heteromorphic seed plants from different *S. corniculata* populations, the main conclusions are: (1) Under the same environmental conditions, black seed plants showed no significant differences from brown seed plants in growth, photosynthetic pigment content, and mineral nutrition. (2) Significant differences existed between Xinjiang and Inner Mongolia populations in growth, ion content, and mineral nutrition, though photosynthetic capacity was similar. (3) Growth differences between different *S. corniculata* populations were related to differential absorption of ions and phosphorus/potassium, but not to nitrogen absorption or photosynthesis.

These represent important physiological mechanisms for different populations of *S. corniculata* to adapt to environmental changes in arid saline-alkali regions.

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