Effects of reciprocal hybridization on the quality of Solanum photeinocarpum

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Abstract. In order to explore whether reciprocal hybridization can be used to cultivate new varieties of wild vegetable, the experiment used two ecological types (farmland ecotype and mine ecotype) of Solanum photeinocarpum as the experimental material of reciprocal hybridization, and compared the difference of qualities of F1 hybrids and parents. The results showed that the biomass, contents of vitamin C, soluble sugar, total acid, and soluble solids of leaves and stems of the F1 hybrid plants were not significantly different. But the indicators of F1 hybrid were higher than the parents. Among them, mining male × farmland female F1 hybrids has the highest leaf biomass, vitamin C content and soluble sugar content. The highest leaf biomass, vitamin C content and soluble sugar content were increased by 13.70%, 65.90% and 117.26% respectively, compared with the farmland ecotype, and increased by 14.40%, 48.89% and 54.99% respectively, compared with the mine ecotype. It indicated that reciprocal hybridization can effectively increase the biomass and the content of nutrients including vitamin C of F1 hybrids and reciprocal hybridization can be used to get new species of Solanum photeinocarpum.

1. Introduction
Solanum photeinocarpum is an annual erect branched herbaceous plant in the Solanaceae, which grows mostly in orchards, field sides, and roadsides, and is widely distributed in most areas [1]. In addition to its food value, S. photeinocarpum has high medicinal value, and has the effects of clearing heat and dampness, cooling blood and detoxifying, often used to treat diseases such as dysentery, hypertension, lung fever cough, and gum bleeding [2-3].

Hybridization is a common breeding method to obtain new plant varieties, and the F1 hybrid crosses its parents in terms of growth potential, fertility, yield and stress resistance [4-5]. Hybridization technology has shown great application value in the selection and breeding of new varieties of crops and crops [6-7]. At the same time, the hybridization technology has also been applied in the cultivation of new varieties of S. photeinocarpum [8]. Due to different growth environments, the same species forms the different ecotypes to adapt to the local environment. The morphology and physiology of plants may be different between different ecotypes [9]. Different ecotypes can be crossed freely, because their differences between types are not enough to be used as classification indicators of species [10]. In this study, S. photeinocarpum seedlings of farmland and mining ecotypes were collected and subject to reciprocal hybridization. The growth and quality of the F1 hybrids were determined, which could provide the references for other plants.
2. Materials and methods

2.1 Sample collection

A *S. photeinocarpum* plant at the flowering stage was collected from the Tangjiashan lead–zinc mine, Hanyuan Country, Ya’an City, Sichuan Province, China. This was called the mining ecotype (ME). Another *S. photeinocarpum* plant at the flowering stage was collected from the farmland near Ya’an Polytechnic College, Yucheng Country, Ya’an City, Sichuan Province, China. This was called the farmland ecotype (FE). The plants were collected in July 2017.

2.2 Hybridization

The reciprocal hybridization treatment was performed by using the crosses mining male × farmland female and farmland male × mining female. The reciprocal hybridizing method was the same as common hybrid breeding technique [11], and hybridization was performed in August 2017. The day before the *S. photeinocarpum* flowering, the anthers of the female flowers were removed and cleaned, and bags were applied to the female flowers to isolate them. At noon the next day, the bags were removed, and pollen from the male flowers was applied to the female styles. Bags were then applied to the female flowers again. The *S. photeinocarpum* seeds were allowed to mature and then collected, dried in air, and stored at 4 °C [12].

2.3 Experiment design

The experiment was performed at Ya’an Polytechnic College. In April 2018, the soil collected from the farmland near Ya’an Polytechnic College was dried in air, ground, and passed through a 6.72 mm mesh sieve, and 3.0 kg of soil was added to each of a series of 15 cm tall, 18 cm diameter polyethylene pots. Four uniform *S. photeinocarpum* seedlings with four expanded true leaves were transplanted into each pot. Four treatments were Farmland ecotype (FE), Mining ecotype (ME), F1 hybrids of mining male × farmland female (MF), and F1 hybrids of farmland male × mining female (FM). Each treatment was performed in six replicate pots, and there was a 10 cm space between neighboring pots. The soil moisture content was kept at 80% of the field capacity until the plants were harvested.

Once the *S. photeinocarpum* seedlings had matured (defined as the blooming stage, at 60 d of cultivation), the plants were harvested and the stems and leaves was with tap water. The fresh weight of leaves and stems, vitamin C (Vc) content, soluble sugar content, total acid content and soluble solid content were determined. The Vc content was determined by the 2, 6-dichloroindophenol method [13]; the soluble sugar content was determined by the anthrone colorimetry method [13]; the total acid content was determined by the NaOH titration method [14]; the soluble solids were measured by hand-held sugar meter [14].

2.4 Statistical analysis

Statistical analysis was performed using SPSS 20.0 software (IBM, Chicago, IL, USA). The data were analyzed using the one-way analysis of variance method using a least significant difference test (5% confidence level).

3. Results and discussion

3.1 Biomass of *S. photeinocarpum*

For leaf of *S. photeinocarpum*, the hybridization increased the leaf biomass of F1 generations (Figure 1). Compared with the two parents, FM and MF had the higher leaf biomass. Compared with FE, FM and MF increased the leaf biomass of *S. photeinocarpum* by 10.92% (*p* > 0.05) and 13.70% (*p* < 0.05), respectively. Compared with ME, FM and MF increased the leaf biomass of *S. photeinocarpum* by 11.60% (*p* > 0.05) and 14.40% (*p* < 0.05), respectively. For stem of *S. photeinocarpum*, the hybridization increased the stem biomass of F1 generations (Figure 1). Compared with the two parents, FM and MF had the higher stem biomass. Compared with FE, FM and MF increased the stem biomass.
of *S. photeinocarpum* by 5.43% (*p* > 0.05) and 10.35% (*p* > 0.05), respectively. Compared with ME, FM and MF increased the stem biomass of *S. photeinocarpum* by 23.84% (*p* < 0.05) and 29.61% (*p* < 0.05), respectively.

3.2 Vc content in *S. photeinocarpum*

For Vc content in leaves, the hybridization increased the Vc content in leaves of F1 generations of *S. photeinocarpum* (Figure 2). Compared with the two parents, FM and MF had the higher Vc content in leaves of *S. photeinocarpum*. Compared with FE, FM and MF increased the Vc content in leaves of *S. photeinocarpum* by 48.42% (*p* < 0.05) and 65.90% (*p* < 0.05), respectively. Compared with ME, FM and MF increased the Vc content in leaves of *S. photeinocarpum* by 33.20% (*p* < 0.05) and 48.89% (*p* < 0.05), respectively. For Vc content in stems, the hybridization increased the Vc content in stems of F1 generations of *S. photeinocarpum* (Figure 2). Compared with the two parents, FM and MF had the higher Vc content in stems of *S. photeinocarpum*. Compared with FE, FM and MF increased the Vc content in stems of *S. photeinocarpum* by 65.81% (*p* < 0.05) and 63.43% (*p* < 0.05), respectively. Compared with ME, FM and MF increased the Vc content in stems of *S. photeinocarpum* by 51.25% (*p* < 0.05) and 49.09% (*p* < 0.05), respectively.

3.3 Soluble sugar content in *S. photeinocarpum*

For soluble sugar content in leaves, the hybridization increased the soluble sugar content in leaves of F1 generations of *S. photeinocarpum* (Figure 3). Compared with the two parents, FM and MF had the higher soluble sugar content in leaves of *S. photeinocarpum*. Compared with FE, FM and MF increased the soluble sugar content in leaves of *S. photeinocarpum* by 102.38% (*p* < 0.05) and 117.26% (*p* < 0.05), respectively. Compared with ME, FM and MF increased the soluble sugar content in leaves of *S. photeinocarpum* by 44.37% (*p* < 0.05) and 54.99% (*p* < 0.05), respectively. For soluble sugar content in stems, the hybridization increased the soluble sugar content in stems of F1 generations of *S. photeinocarpum* (Figure 3). Compared with the two parents, FM and MF had the higher soluble sugar content in stems of *S. photeinocarpum*. Compared with FE, FM and MF increased the soluble sugar content in stems of *S. photeinocarpum* by 136.97% (*p* < 0.05) and 161.34% (*p* < 0.05), respectively. Compared with ME, FM and MF increased the soluble sugar content in stems of *S. photeinocarpum* by 56.23% (*p* < 0.05) and 72.30% (*p* < 0.05), respectively.

3.4 Total acid content in *S. photeinocarpum*

For total acid content in leaves, the hybridization increased the total acid content in leaves of F1 generations of *S. photeinocarpum* (Figure 4). Compared with the two parents, FM and MF had the higher total acid content in leaves of *S. photeinocarpum*. Compared with FE, FM and MF increased the total acid content in leaves of *S. photeinocarpum* by 37.78% (*p* < 0.05) and 26.05% (*p* > 0.05), respectively. Compared with ME, FM and MF increased the total acid content in leaves of *S. photeinocarpum* by 35.07% (*p* < 0.05) and 23.57% (*p* > 0.05), respectively. For total acid content in
stems, the total acid contents in stems of F1 generations of *S. photeinocarpum* were between two parents (Figure 4). Compared with FE, FM and MF increased the total acid content in stems of *S. photeinocarpum* by 3.87% (*p* > 0.05) and 3.56% (*p* > 0.05), respectively. Compared with ME, FM and MF decreased the total acid content in stems of *S. photeinocarpum* by 12.28% (*p* > 0.05) and 12.54% (*p* > 0.05), respectively.

### 3.5 Soluble solids content in *S. photeinocarpum*
For soluble solids content in leaves, the hybridization increased the soluble solids content in leaves of F1 generations of *S. photeinocarpum* (Figure 5). Compared with the two parents, FM and MF had the higher soluble solids content in leaves of *S. photeinocarpum*. Compared with FE, FM and MF increased the soluble solids content in leaves of *S. photeinocarpum* by 14.43% (*p* < 0.05) and 6.78% (*p* > 0.05), respectively. Compared with ME, FM and MF increased the soluble solids content in leaves of *S. photeinocarpum* by 13.29% (*p* < 0.05) and 5.71% (*p* > 0.05), respectively. For soluble solids content in stems, the soluble solids content in stems of FM was lower than both two parents, while the soluble solids content in stems of MF was higher than both two parents (Figure 5). Compared with FE, FM decreased the soluble solids content in stems of *S. photeinocarpum* by 1.93% (*p* > 0.05), while MF increased the soluble solids content in stems of *S. photeinocarpum* by 9.52% (*p* > 0.05). Compared with ME, FM decreased the soluble solids content in stems of *S. photeinocarpum* by 3.33% (*p* > 0.05), while MF increased the soluble solids content in stems of *S. photeinocarpum* by 9.52% (*p* > 0.05).
4. Conclusions
The reciprocal hybridization of two ecological types (farmland ecotype and mine ecotype) increased the biomass, Vc content, and soluble sugar content of F1 generations of S. photeinocarpum, while had no significant effects on the total acid content and soluble solids content in F1 generations of S. photeinocarpum. The future work should investigate the mechanism of hybridization on improving the quality of S. photeinocarpum.

Acknowledgment
This work was financially supported by the Application Infrastructure Project of Science and Technology Department of Sichuan Province (2016Y0258).

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