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Short Communication

Phenotypic characteristics of the first generation mealycup sage (*Salvia Farinacea* Benth.) induced by space radiation

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Abstract

To explore the biological effects of the space radiation, dry seeds of mealycup sage (*Salvia farinacea* Benth.) were flown with the Chinese space craft "Shen Zhou VIII". The plants grown from the space exposed seeds displayed considerable changes in phenotypic traits. Eleven space exposed plants (EP) showed one month longer flowering period than the mean of the control plants (CP); 13 EP failed to flower and 23 bore flowers, within which 25 plants mutated in respect of flower production; leaf shape of EP showed two extremes: curling and folding, or totally smooth; 11 EP had mutated height, within which 6 plants were taller and 5 shorter than CP. These results demonstrated that space radiation could induce favorable mutations on plant seeds.

Key words: Mealycup sage, space radiation, phenotypic traits, mutants, variation

Introduction

Mealycup sage (*Salvia farinacea* Benth.) is a herbaceous perennial native to North America, with violet-blue spikes resting on a compact plant of typically narrow salvia-like leaves. It is a popular ornamental flower in China that is widely used in landscape design. The cultivation of flower varieties always gives priority to novelty, but the ornamental value usually depends on mutations. Mutation breeding has the advantages of high mutation frequency and wide mutation range, which can significantly improve certain phenotypic traits of the plants, and can gain mutations rarely presented in conventional breeding [1]. The space environment contains radiation, high vacuum, microgravity and the Earth's magnetic field [2]. In space, there are lots of high energy particles such as protons, electrons and nucleus. Several practical cases have shown that space radiation can cause mutagenic effects in plants [3, 4].

To obtain novel diverse phenotypes of mealycup sage induced from space radiation, mealycup sage seeds were carried by "Shen Zhou VIII" spacecraft. The seeds of the space exposed group were put into one package, boarded on the Chinese "Shen Zhou VIII" spacecraft and flown in space for 16 days from November 1 to 16th, 2011. In the spring of 2012, 36 space exposed seeds and another 36 control seeds were planted for one generation in research field of Hebei University of Technology, China.

A mutated plant was identified when the measured quantities exceeded 3 standard deviations above or below the average values [5, 6]. The mutation rate was defined as the ratio of mutated plant numbers to total EP numbers.

Compared with the CP, 36 EP displayed considerable changes of phenotypic traits in flowering period, flower production, leaf shape and plant height. Table1 shows the phenotypic traits of 36 EP and 36 CP and the maximum, minimum, average, variance and standard deviation of plant height and flower

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production.

In mid-to-late June, 2012, the first set of visible flowers came out in 11 of the 23 flower-borne EP, one week earlier than the CP. Flower buds began to appear in CP, as most EP were already blooming. By the middle of October, flowers of the CP had gradually started to fade, whereas corresponding flowers in EP showed longer duration. All the control flowers had withered at the beginning of November, when flowers in EP just started to fade. All the flowers in EP withered by the end of November. 11 EP bloomed the earliest and withered the latest, with flowering periods nearly one month longer than that of the CP.

Of the 36 CP, the number of flowers per plant varied between 6 and 15. Of the 36 EP, 23 (63.89%) bore flowers and the number of flowers per plant varied from 1 to 45. The other 13 EP did not produce flowers. Furthermore, the flower production of 25 EP exceeded three standard deviations above or below the average values of the CP. These 25 plants were identified as flower production mutations and the mutation rate was 69.44%. Among them, 10 mutated plants which accounted for 27.78% produced higher flower production than the average level of the CP. Of these mutated plants, the highest flower production was 45 flowers, while the lowest flower production was zero.

Usually leaves of CP appeared to be oval, flat and had jagged edges (Fig. 1). However, dramatic changes occurred in leaf shape of the EP. Leaf morphological modifications were significant and the changing tendency showed two extremes. Some leaves were intensively curling and folding while others tended to be totally smooth without jagged edges (Fig. 2). Interestingly, the plants with intensively curling and folding leaves bore many more flowers than the average level of the EP, whereas the plants with smooth leaves completely had no flowers.

The average plant height in control group was 91 cm, measured between 67 and 122 cm. The height of the EP varied between 42 and 158 cm, which exhibited wider range. The characteristics of dwarf were observed in the sterile group and the heights of these 13 sterile plants were much lower than the average level of the CP. However, the height of 11 EP exceeded three standard deviations above or below the average values of the CP. These 11 plants were considered as height mutation and the mutation rate was 30.56%. 6 of 15 plants were taller than the average level of the CP. Notably, one of the mutants was 158 cm, which was a rare height in our research field. According to the criteria for mutations, 11 plants were mutated not only in height but also in flower production.

Our experimental results were consistent with some previous reports. It was worth noting that the phenotype of early-flowering, increased production, significant leaf morphological modifications and plant height mutation were obtained in our study. Pu *et al*. [7] flew rapeseed by “Shen Zhou IV”, and their results showed early-flowering mutated plants were obtained in EP.Similarly, Ma *et al*. [8] studied the strain *Aspergillus awamori 40499* aboard the “Shen Zhou VIII” spacecraft, and they obtained five high pectinase-producing strains with stronger and more stable continuous-producing ability. Cai *et al*. [9] flew dry seeds of tobacco with the Chinese “Shen Zhou III”. A crinkly leaf mutant of tobacco, with a different phenotype from the CP, was obtained in EP, similar to our results. Yu *et al*. [6] flew the rice seeds on “Shen Zhou III” spacecraft, and their results showed 5 tall mutants were found in EP.

The space radiation which is caused by complex factors, is more difficult to control than ground radiation. However, due to the diversification of people’s views towards ornamental value of flowers, mutations

Table1. The maximum, minimum, average, variance and standard deviation of the height, fertility and the flower production of mealycup sage plants

Parameter	Plant height (cm)		Fertility (%)		Flower production (No.)	
	EP	CP	EP	CP	EP	CP
Maximum	158	122	—	—	45	15
Minimum	42	67	—	—	1	6
Average	92.25	91.06	63.89%	100%	17.26	10.67
Variance	1142.99	208.85	—	—	146.93	5.6
Standard deviation	33.81	14.45	—	—	12.12	2.37

EP=Exposed plants; CP = Control plants

Fig. 1. Leaves of plants in control group

Fig. 2. Leaf morphological modifications in EP. A and B are the totally smooth leaves without jagged edges, C and D are the intensively curling and folding leaves

induced by nondirective space radiation may well satisfy this kind of market demand. Thus, to a certain extent, if the desirable characteristics of the flowers can be maintained, variations caused by space radiation will be acceptable. The empirical evidence proved that space radiation has better effects on plants than conventional mutagenesis, which has become another effective approach in molecular breeding techniques.

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