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# Cross - Compatibility of *Petunia exserta* with Other *Petunia* taxa

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# Summary

Cross-compatibility of *Petunia exserta*, a natural species having red flowers, with 46 taxa of *Petunia sensu* Jussieu (20 taxa of *Petunia sensu* Wijsman plus 27 taxa of *Calibrachoa*) was examined to obtain basic information for the breeding of garden petunias. *Petunia exserta* completely failed to set capsules when crossed with any species of *Calibrachoa*. *Petunia exserta* exhibited unilateral interspecific incompatibility with 15 taxa of *Petunia sensu* Wijsman: As a seed parent, it could be crossed with all taxa of *Petunia* except *P. occidentalis*, but the reciprocal crossings were successful with only five taxa. In the  $F_2$  generation of *P. exserta* hybrid crossed with *P. axillaris* subsp. *axillaris* having white flower, individuals having red flowers segregated.  $F_2$  progenies contained delphinidin glycosides as the major floral anthocyanin similar to *P. exserta*. The use of *P. exserta* as an additional gene resource for improving red flowered garden petunias is discussed.

Key Words: anthocyanins, *Calibrachoa*, *Petunia*, red flower color, unilateral interspecific incompatibility.

### Introduction

Garden petunia (Petunia hybrida Vilm.) has been bred since the 1830s, when P. axillaris (Lam.) Britton, Sterns, and Poggenb. (= P. nyctaginiflora Juss.) was crossed with P. integrifolia (Hook.) Schinz and Thell. (= P. violacea Lindl.) in London (Paxton, 1836). Although Petunia parodii Steere and P. inflata R. E. Fr. have been suspected as the historical parents (Sink, 1984), they are now treated as subspecies of P. axillaris and P. integrifolia, respectively (Cabrera, 1977; Wijsman, 1982).

The scarlet red color of the modern garden petunia originated from 'Fire Chief' (Meahl et al., 1950; Whitman, 1981) or 'Tango' (Maatsch and Nolting, 1968; Weddle, 1976) which were registered together in 1950. The red color seems to be attributed to a single genetic mutation. Cultivars with red color (red cultivars) have been inbred more than those of other colors (Griesbach et al., 1999).

A natural species of red flowers was found by Stehmann (1987), *Petunia exserta* Stehmann, which is a very rare species endemic to southern Rio Grande do Sul State in Brazil. Apparently, *Petunia exserta* is not the parent of red cultivars, because those having red pigments have been bred long before *P. exserta* was discovered in Brazil. The flower color was expressed as Red Group 53C (R.H.S. color chart, after Ando et al., 1999b) or 45A (Griesbach et al., 1999). We have shown that the red color of material used in this experiment is produced by delphinidin glycosides (Ando et al., 1999b). The color is dull red, but *P. exserta* should serve as an additional gene resource of red flower color.

The genus *Petunia* (sensu Jussieu) was established by Jussieu (1803) and considered to comprise 35-40 species (Mabberley, 1987; Ando et al., 1992). Wijsman (1990) separated two groups of species in this genus, and treated the species of 2n = 2x = 14 and 2n = 2x = 18 as *Petunia sensu* Wijsman and *Calibrachoa*, respectively.

When we reported interspecific cross compatibility in the genus *Petunia sensu* Jussieu (*Petunia sensu* Wijsman plus *Calibrachoa*) (Watanabe et al., 1996, 1997), a considerable number of *Calibrachoa* species were still designated as *Petunia sensu* Jussieu. Thereafter, Stehmann and Semir (1997) transferred nine species to *Calibrachoa*, so that we can distinguish *Petunia sensu* Wijsman from *Calibrachoa*, based on the taxonomic enumeration (Wijsman, 1990; Stehmann and Semir, 1997). All taxa of *Petunia sensu* Jussieu having 2n = 2x= 14 and 2n = 2x = 18 chromosomes listed in our previous papers (Watanabe et al., 1996, 1997) can be regarded as *Petunia sensu* Wijsman and *Calibrachoa*, respectively.

The objective of this study is to clarify interspecific cross-compatibility of *Petunia exserta* with the total range of natural taxa in *Petunia sensu* Jussieu and obtain basic information for petunia breeding in the future.

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*Petunia sensu* Wijsman will be referred to as solely *Petunia* unless otherwise stated.

# **Materials and Methods**

#### Plant materials

Seeds of 46 natural taxa in *Petunia sensu* Jussieu were obtained from voucher specimens collected in northern Argentina, southern Brazil, and Uruguay from 1988 to 1996. The collection localities were listed in previous papers (Watanabe et al., 1996, 1997). A purebred cultivar, *Petunia x hybrida* Vilm. 'Pearl Sky Blue' (multiflora strain), was also used.

Seeds were sown in mid of January, and plants were grown in a greenhouse by the standard horticultural procedure for garden petunias.

#### New names

Unnamed taxa #2 and #3 in a previous paper (Watanabe et al., 1996) were thereafter designated as *Petunia riograndensis* T. Ando and Hashim. and *P. bajeensis* T. Ando and Hashim., respectively (Ando and Hashimoto, 1998). Recently unnamed taxon #8 (Watanabe et al., 1997) was designated as *Calibrachoa eglandulata* Stehmann and Semir (1997). *Petunia integrifolia*  subsp. *occidentalis* (R. E. Fr.) Wijsman was restored as an independent species, *P. occidentalis* R. E. Fr., by Tsukamoto et al. (1998b).

## Crossing

Petunia exserta (strain B931, 2n = 2x = 14) was used as both pistillate (seed parent) and staminate parent (pollen parent) to check the reciprocal cross-compatibility. Flowers of the seed parent were emasculated one day before anthesis and fresh pollen grains were applied to the stigma the next day.

### Confirmation of hybridization

To confirm the success of hybridization, floral morphology, color, and pollen viability of the offspring were compared with those of the parents. The L-values and hues (a- and b-values) of the fresh corolla-lobe were measured by a colorimeter (Minolta CR- 300) and expressed according to Hunter (1958). Pollen viability of *P. exserta* hybrids was assessed by staining the grains with 2.0 % acetic-carmine (Sharma and Sharma, 1980).

# Analysis of floral anthocyanins

Fresh corolla-lobes (0.5 g) were immersed in MAW [methanol: acetic acid: water = 9: 1: 10 (v/v), 2 ml]

Table 1. Cross compatibility of Petunia exserta with taxa of Petunia sensu Wijsman and pollen viability of the offspring.P. exserta was the seed parent.

Pollen parent	Number of pollinated flowers (A)	Number of obtained capsules (B)	B/A × 100 (%)	Number of seeds per capsule	Pollen viability (%)
0 <sup>2</sup> Petunia exserta (infraspecific crossing)	40	40	100.0	$976 \pm 18^{\mathrm{y}}$	96.5
1 P. axillaris subsp. axillaris	41	39	95.1	853 ± 38*	99.3
2 P. axillaris subsp. parodii	40	40	100.0	$547 \pm 27*$	98.7
3 P. axillaris subsp. subandina	40	39	97.5	$629 \pm 47*$	85.0
4 P. integrifolia subsp. integrifolia var. integrifolia	40	15	37.5	$100 \pm 17*$	61.6*
5 P. integrifolia subsp. integrifolia var. depauperata	40	22	55.0	71 ± 9*	61.1*
6 P. integrifolia subsp. inflata	40	2	5.0	$60 \pm 11*$	66.4*
7 P. altiplana	41	5	12.2	$140\pm62*$	54.6*
8 P. bajeensis	40	26	65.0	$108 \pm 13*$	48.6*
9 P. bonjardinensis	40	17	42.5	$167\pm47*$	52.0*
10 P. guarapuavensis	40	15	37.5	$62 \pm 8*$	57.1*
11 P. interior	40	9	22.5	$56 \pm 12*$	51.4*
12 P. littoralis	40	20	50.0	$151 \pm 19*$	68.3*
13 P. mantiqueirensis	41	40	97.6	$293\pm\mathbf{29*}$	51.4*
14 P. occidentalis	40	0	0.0		—
15 P. reitzii	60	16	26.7	$138 \pm 23*$	53.7*
16 P. riograndensis	40	21	52.5	$243\pm30*$	62.5*
17 P. saxicola	40	38	95.0	648 ± 33*	56.0*
18 P. scheideana	40	4	10.0	$68 \pm 15*$	48.8*
19 unnamed taxon # 6	40	9	22.5	$40 \pm 11*$	49.8*
20 P. 'Pearl Sky Blue'	40	36	90.0	$241 \pm 14*$	92.5

<sup>z</sup> Species' code.

<sup>y</sup> Mean  $\pm$  standard error.

\* Significantly different from infraspecific crossing of P. exserta by t- test at a 1% level.

Table 2.	Cross compatibility of taxa of Petunia sensu	Wijsman with P.	exserta and pollen viability of the offspring.
P	exserta was the pollen parent.		

Seed parent	Number of pollinated flowers (A)	Number of obtained capsules (B)	B/A × 100 (%)	Pollen viability (%)
0 <sup>2</sup> Petunia exserta (infraspecific crossing)	40	40	100.0	96.5
1 P. axillaris subsp. axillaris	43	29	67.4	97.8
2 P. axillaris subsp. parodii	40	40	100.0	99.3
3 P. axillaris subsp. subandina	40	39	97.5	82.9
4 P. integrifolia subsp. integrifolia var. integrifolia	40	0	0.0	_
5 P. integrifolia subsp. integrifolia var. depauperata	41	5	12.2	76.0
6 P. integrifolia subsp. inflata	40	0	0.0	—
7 P. altiplana	40	0	0.0	—
8 P. bajeensis	40	0	0.0	_
9 P. bonjardinensis	40	0	0.0	
10 P. guarapuavensis	40	0	0.0	
11 P. interior	40	0	0.0	
12 P. littoralis	40	0	0.0	
13 P. mantiqueirensis	40	0	0.0	_
14 P. occidentalis	40	40	100.0	76.4
15 P. reitzii	40	0	0.0	_
16 P. riograndensis	40	0	0.0	
17 P. saxicola	40	0	0.0	
18 P. scheideana	40	0	0.0	
19 unnamed taxon # 6	40	0	0.0	
20 P. 'Pearl Sky Blue'	59	27	45.8	96.6

<sup>z</sup> Species' code.

overnight and crushed to extract the pigments. The extract was analyzed by high pressure liquid chromatography (HPLC) on a Waters C 18 ( $4.6\phi \times 250$ mm) column at 40 °C with a flow rate of 1 ml/min.; the absorbance was recorded at 530 nm. The solvent system was the same as that described previously by Tatsuzawa et al. (1997).

#### Results

#### Reciprocal crossings

Reciprocal crossings between *P. exserta* and 26 species of *Calibrachoa* were tried repeatedly (2,125 crossings in total), but no capsule was obtained.

When Petunia exserta was used as the seed parent, crossings with all Petunia taxa except P. occidentalis were successful, even though the rate of capsule set varied from 5.0 [P. integrifolia subsp. inflata (R. E. Fr.) Wijsman] to 100 % [P. axillaris subsp. parodii (Steere) Cabrera] (Table 1).

In contrast, Petunia exserta as a pollen parent would hybridize only with 'Pearl Sky Blue', three subspecies of P. axillaris, P. occidentalis, and P. integrifolia subsp. integrifolia var. depauperata (R. E. Fr.) Smith and Downs (Table 2). The last taxon will be referred hereafter as var. depauperata. Thus, 'Pearl Sky Blue', three subspecies of P. axillaris, and var. depauperata are the taxa which can be reciprocally crossed with P. exserta.

Infraspecific crossings of P. exserta yielded large capsules containing ca. 1,000 seeds (Table 1). However, the number of seeds in the capsule yielded by the interspecific crossings of P. exserta were significantly less, ranging from 40 to 850 seeds per capsule.

# Floral morphology and pigment of $F_1$ hybrid

The  $F_1$  seeds germinated well and produced an abundance of hybrid plants. These progenies were easily distinguishable from the parents by the floral morphology. Corolla-lobes of *P. exserta* as well as its  $F_1$  hybrids reflected as the flowers aged (see Fig. 1 in Stehmann, 1987).

Flower colors of the hybrids obtained from P. exserta as seed and pollen parents were similar, so that only progenies of P. exserta are shown in Fig. 1. Flower colors of the hybrid plants (open circles in Fig. 1) resembled those of pollen parent (solid circles) rather than the seed parent, P. exserta.

With Petunia axillaris having white flower as a parent, floral color of the progenies ranged from white (*P. exserta* x subsp. axillaris, #1 in Fig. 1) to pink (*P. exserta* x subsp. parodii, #2), whereas when *P. exserta* was crossed with *P. reitzii* L. B. Sm. and Downs (#15 in Fig. 1) and *P. saxicola* L. B. Sm. and Downs (#17), b-values of the hybrids were lower than those of the pollen

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Fig. 1. Distribution of floral color of 20 taxa of *Petunia* ( $\bullet$ ) and the F<sub>1</sub> *Petunia exserta* hybrids ( $\bigcirc$ ) plotted on Hunter's chromaticity graph. *P. exserta* was used as the seed parent. The numbers are corresponding to those in Table 1.

parents. The b-values of remaining natural taxa increased and tended to concentrate into a small area on the Hunter's chart (Fig. 1).

## *Fertility of* $F_1$ *hybrid*

Pollen viability, as assessed by stainability with acetic - carmine, of *P. exserta* hybrid varied considerably, from 48.6 to 99.3 %, depending on the parental stock (Table 1). Pollen viability of hybrids with 'Pearl Sky Blue' and *P. axillaris* were 92.5 and 85.0 to 99.3 %, respectively. Thus, they did not significantly different from that of *P. exserta*. But pollen viability of its hybrids with the remaining taxa decreased significantly.

# Segregation in $F_2$ hybrid of P. exserta x P. axillaris

The HPLC profile of floral anthocyanins of *P. exserta* (Fig. 2) reveals peak numbers identical to those in a previous paper (Ando et al., 1999b); respective components have been unambiguously identified to be delphinidin-3-glucoside (pigment #3), delphinidin-3-rutinoside (#4), cyanidin-3-rutinoside (#6), and petunidin-3-rutinoside (#7).

The HPLC profile of floral anthocyanin in  $F_2$  progenies of *P. exserta* (Fig. 2) shows that their floral color approached that of *P. exserta* (the individual indicated by asterisk in Fig. 3). In addition to four peaks of shorter retention time identical to those found in *P. exserta* (pigments #3, 4, 6, and 7), unknown peaks of longer retention time were also detected in this individual.

Floral colors of  $F_2$  individuals of *P. exserta* hybrid crossed with *P. axillaris* subsp. *axillaris* (Fig. 3, top) have a wide spectrum which corresponds to the relative content of anthocyanins and reflected by the L-value of corolla-lobe (bottom). Among eight  $F_2$  individuals having a-values larger than 30, four have positive bvalues similar to *P. exserta* which are characterized by the dominant delphinidin-3-rutinoside (pigment #4) followed by delphinidin-3-glucoside (#3). However, the other four individuals have negative b-values unlike *P. exserta* (Fig. 3, bottom).

Among 43 individuals of  $F_2$  generation, 16 individuals contained detectable amounts of cyanidin-3-rutinoside (Fig. 3, top). However, none accumulated this pigment to any degree.

#### Discussion

We previously concluded (Watanabe et al., 1996, 1997) that selected taxa of *Petunia* could not reciprocally be crossed with *Calibrachoa*. In this study, reciprocal crossings between *Petunia exserta* and 26 taxa of *Calibrachoa* were repeated 2,125 times, but no flowers set a capsule. Herein, *Petunia* and *Calibrachoa* seem cross-incompatible by the conventional pollination method.

From our data, we conclude that *P. exserta* is crosscompatible with all *Petunia* taxa, including garden petunia (Tables 1 and 2), even though the direction of the crossing varied. The floral morphology and color



Fig. 2. HPLC profiles of floral anthocyanin in *Petunia exserta* (top) and an individual of F<sub>2</sub> hybrid crossed with *P. axillaris* subsp. *axillaris* (bottom). This F<sub>2</sub> individual is indicated by asterisk in Fig. 3. Pigment #3 = delphinidin-3- glucoside, #4 = delphinidin- 3- rutinoside, #6 = cyanidin- 3- rutinoside, and #7 = petunidin- 3- rutinoside after Ando et al. (1999b).

(Fig. 1) of the offsprings are strong evidence that interspecific crossing with *P. exserta* are possible. A significant decrease in the pollen viability of hybrid plants may be evidence that hybridization occurred (Table 1).

### Unilateral interspecific incompatibility

As for interspecific cross-compatibility with *P. exser*ta (Tables 1 and 2), *Petunia* taxa can be classified into three groups as follows:  $1^{st}$  group comprising three subspecies of *P. axillaris*, var. *depauperata* and 'Pearl Sky Blue' which were successfully crossed reciprocally with *P. exserta* to produce hybrids,  $2^{nd}$  group solely comprising *P. occidentalis* which could be crossed with *P. exserta* only when *P. exserta* was used as the pollen parent, and  $3^{rd}$  group comprising remaining 14 taxa of *Petunia* which could be crossed with *P. exserta* only when *P. exserta* was used as the seed parent.

Phenomena observed in the  $2^{nd}$  and  $3^{rd}$  groups resemble "unilateral interspecific incompatibility" (UII), a term which was originally defined by Lewis and Crowe (1958). UII is a common phenomenon found in genera composed of both self-compatible and self-incompatible species such as *Lycopersicon* (Lewis and Crowe, 1958; Hogenboom, 1972), Solanum (Lewis and Crowe, 1958) and Lilium (Ascher and Peloquin, 1968). UII is observable when reciprocal crosses between a selfcompatible (SC) and a closely related self-incompatible (SI) species were made: The stigma of the SC plant accepts the pollen from the SI plant, but the stigma of the SI plant rejects the pollen from the SC plant.

UII is typically observed in the  $3^{rd}$  group because *P*. exserta is SC, and all taxa belonging to the  $3^{rd}$  group are SI (Tsukamoto et al., 1998a). Hence, UII observed in the  $2^{nd}$  group is not typical since *P*. occidentalis is SC (Tsukamoto et al., 1998a). Petunia exserta can be crossed reciprocally with members of the  $1^{st}$  group; UII was not observed in this group. Note that *P*. axillaris subsp. parodii and subsp. subandina T. Ando are SC, but subsp. axillaris, var. depauperata and 'Pearl Sky Blue' are SI (Ando et al., 1998; Tsukamoto et al., 1998a). Therefore, successful reciprocal crossings between *P*. exserta (SC) and each of SI taxa in  $1^{st}$  group are contrary to UII rule.

The complicated features of UII in the genus *Petunia* should be analyzed to better understand the basis for the unilateral reaction of the style for promoting or inhibiting the growth of pollen tube. To do so, pollen growth in the style of the seed parent should be observed initially to seek a morphological and/or histological explanation in this genus.

#### Systematic relationship

Pollen viability of hybrids crossed with three subspecies of *P. axillaris* and 'Pearl Sky Blue' was not significantly different from that of *P. exserta* itself. It decreased significantly in the *P. exserta* hybrid crossed with the other taxa (Tables 1 and 2). When a subspecies of *P. axillaris* was used as a pollen parent, *P. exserta* yielded capsules containing more than 500 seeds per capsule which suggest that *P. exserta* may be genetically close to *P. axillaris*. Actually, Stehmann (1987) stated that the overall morphology of *P. exserta* is close to that of *P. axillaris*, even though their floral color is different.

Pollen viability of *P. exserta* hybrids crossed with 'Pearl Sky Blue' exceeded 90 % (Tables 1 and 2). The high percentage of viability may be the influence of the historical seed parent, *P. axillaris* (Paxton, 1836). Pollen viability of the hybrid crossed with the historical pollen parent, *P. integrifolia*, was as low as 60 % (Tables 1 and 2). Therefore, *Petunia exserta* may be utilized as a parent for the breeding of garden petunias without reducing pollen viability.

# Floral anthocyanins of $F_1$ hybrid

Ando et al. (1999a) reported that most *Petunia* taxa have reddish-purple flowers with acylated petunidin or malvidin as the component. However, non-acylated delphinidin and petunidin exceeded in *P. exserta*, *P. reitzii* and *P. saxicola*, which have more reddish floral color than the rest. It may be noted that the b-value of 38



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Fig. 3. Distribution of floral color of Petunia exserta and P. axillaris subsp. axillaris (●), and their F<sub>1</sub> (○) and F<sub>2</sub> generations (△ and ▲), respectively, plotted on Hunter's chromaticity graph (top). The relative anthocyanin contents of respective F<sub>2</sub> individuals are shown below. Solid and open triangles represent individuals having detectable amounts of cyanidin - 3 - rutinoside and those lacking it, respectively. An HPLC profile of floral anthocyanin for the individual marked by asterisk is shown in Fig. 2 (bottom). Del-3R (4) = delphinidin - 3 - rutinoside (pigment #4), Del - 3G (3) = delphinidin - 3 - glucoside (#3), Cy - 3R (6) = cyanidin - 3 - rutinoside (#6), and Pet - 3R (7) = petunidin - 3 - rutinoside (#7).

the flowers of *P. exserta* decreased when crossed with species having non-acylated anthocyanin as the floral pigment (*P. reitzii*, #15 and *P. saxicola*, #17), whereas b -values of the species having acylated anthocyanin increased (Fig. 1).

# Floral anthocyanins of $F_2$ hybrid

Petunia exserta is unique in the genus, because it is the only natural species to have cyanidin as a floral pigment (cyanidin-3-rutinoside, pigment #6 in Fig. 2) (Ando et al., 1999b). However, cyanidins in the flower make up merely 3 % of the total pigment so that the red color is hardly attributable to cyanidins. Cyanidin-3rutinoside is also found in the flower of  $F_2$  *P. exserta* hybrid (Fig. 3), but its relative contents are still limited.

Four individuals of *P. exserta*  $F_2$  hybrid with *P. axillaris* subsp. *axillaris*, which have red flowers similar to that of *P. exserta*, contain predominantly delphinidin-3-rutinoside (#4, Fig. 3, bottom) followed by delphinidin-3-glucoside (#3). This finding is additional evidence that delphinidin glycosides are responsible for the red color, even in the  $F_2$  hybrid of *P. exserta*.

# Floral anthocyanins of Petunia exserta and red petunias

Two contradictory papers were recently published, almost simultaneously, with regard to the anthocyanin composition of P. exserta (Ando et al., 1999b; Griesbach et al., 1999). The HPLC profiles of the floral anthocyanins of P. exserta provided by Ando et al. (1999a) and Griesbach et al. (1999) superficially resembled each other. Our group has determined pigment #3 (Fig. 2) as delphinidin-3-glucoside, #4 as delphinidin-3-rutinoside, #6 as cyanidin-3-rutinoside, and #7 as petunidin-3-rutinoside based on FAB mass and <sup>1</sup>H NMR analyses of pigments isolated from dried corolla of ca. 100g (Ando et al., 1999b). Griesbach et al. (1999) determined the pigment #3 as cyanidin-3-rutinoside, #4 as cyanidin-3-glucoside, #6 as pelargonidin-3-rutinoside, and #7 as pelargonidin-3-glucoside based on HPLC and spectral analyses.

Griesbach et al. (1999) reported that *P. exserta* flowers were the same color and had the same anthocyanin

composition as *P. x hybrida* 'Red Magic' flowers. However, our analyses revealed that a sample of mixed flowers of *P. exserta* and various commercial red petunias exhibited twin peaks for #4, #6, and #7 pigments (Ando et al., 2000). Apparently, the floral anthocyanin content of our *P. exserta* is different from that of commercial red petunias.

Petunia exserta can be crossed with a garden petunia (Tables 1 and 2) so that analyses of floral anthocyanins in the hybrids between *P. exserta* and red petunias should resolve the contradiction.

The red flower color in garden petunias is considered to be a combination of cyanidin glycosides and low pH of the corolla tissue (de Vlaming et al., 1983; Griesbach, 1996). The system that causes the red floral color in *P. exserta*, at least of our material, may be different from that operating in red petunias. Therefore, *P. exserta* may provide another germplasm source to give red flower color in garden petunia.

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# Petunia exserta の交雑親和性

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要

### 摘

ペチュニア品種の育種に資するため、赤花の希少種である Petunia exserta (2n=14) と Petunia sensu Jussieu (Petunia sensu Wijsman と Calibrachoa の総体) 46分類群との交雑親 和性を調査した. P. exserta と Calibrachoa の正逆交配から はさく果が得られなかった. P. exserta を母親とした場合は P. occidentalis を除くすべての Petunia sensu Wijsman 分類 群と交雑可能であったが、父親とした場合、交雑可能なのは

6分類群に限られ、本種が一方向不親和性 (unilateral interspecific incompatibility)を示す場合の多いことが判明した. *P. exserta* × *P. axillaris* subsp. *axillaris* の  $F_2$ 世代は赤花個体 を分離したが、*P. exserta* に最も近い発色をする個体には*P. exserta* の主要色素である delphinidin 配糖体が優位に存在し、 従来の赤花とは異なる機作によって赤色を発現させる可能性 が示唆された.