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# Floral Biology and Breeding System in the Genus *Salvia* L.

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Studies on floral biology and breeding system in 14 species of *Salvia*, some of them with several varieties revealed that most of them are cross pollinated. Generally large flowered species are outbreeders, and the species with minute flowers are inbreeders. Most of the species possessed both heterostylic i.e. pin, thrum and homostylic flowers. In general, species with large flowers showed the above trend whereas species with minute flowers showed homostylic trend. In the outbreeding species seed setting by open pollination was low. Comparsons of the relative positions of anthers and stigmas in the different species showed that proximity of these organs is directly correlated with good natural seed setting and that the species with pin or thrum flowers do not easily set seed naturally. Along with this factor, the absence of pollinating bees and male sterility are the causes of low seed setting in some species. Interspecific crossability was found to be extremely poor, crosses involving as many species as possible were done, but all of these failed except *S. coccinea* × *S. grahamii* which was highly successful. The combination *S. splendens* × *S. coccinea* was a limited success. All the species were found to be self-compatible.

**Key Words**: *Salvia*, **Floral biology, Pollination mechanism, Seed setting, Crossability**

## Introduction

For initiating a programme on improvement of any plant, knowledge of its breeding system is necessary, as it affects not only the pattern of group variation but also the evolutionary potentialities of the group concerned. The breeding system determines the spread of genetic variability in the population and this in turn is usually reflected to some extent in the morphology of the population. The importance of breeding system in *Salvia* in relation to seed setting has received little attention and the precise nature of its breeding system has never been described. Until this situation is remedied, attempts at improvement cannot proceed smoothly.

*Salvia* is a very large genus with more than

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700 (Bailey 1969, Roy 1971, Willis 1973) to 900 species (Synge 1969), widely distributed in the temperate and warmer regions of both the hemispheres. Several species are economically important for their essential oil content or medicinal and ornamental value. However, works on the breeding system of this genus are very limited. The main contributors in this field are Epling (1947), Anderson and Anderson (1954), Janko and Zolyomi (1962), Grant and Grant (1964), Ilieva (1965), Visco and Carpon (1970), Tursin (1971a, 1971b), Yurtseva and Yurtsev (1971) and Proctor and Yeo (1973). Examination of the floral mechanism to obtain more critical information on the breeding system in *Salvia* was thought to be essential. A detailed study involving floral morphology, pollination mechanism, seed setting in natural and artificial pollination and crossability was done in 14 species and several varieties, so that the relative importance of breeding system in elucidating the interspecific relationships and evolution can be assessed.

## Materials and Methods

Seeds were collected from different sources, both indigenous and abroad (table 1). They were germinated and then seedlings were transplanted individually in pots. When they reached flowering stage, 10 plants were randomly selected in each of the species and varieties and from each plant 25 flowers were examined in relation to style and anther level as well as fertility of anther lobes. To study seed setting in nature, flowers were labelled in each of the plants. For studying self-compatibility, flowers were artificially self-pollinated and then kept under bagged condition. To determine the extent of self-pollination in nature, flowers were bagged and then seeds were collected at maturity. For crossability studies, species and varieties were crossed following standard method.

## Results

### *Floral biology*

Most of the species and varieties showed three types of flowers (table 2). The situation in floral biology can be compared to that of *Primula kewensis*. Here long style and short stamen flowers may be designated as pin, short style and long stamen flowers as thrum and the flowers with stamens and styles at the same level as homostyles. This variation in floral morphology varied from plant to plant and in some cases within the plants also. In *S. coccinea*, three varieties i.e. Red Indian, Pink Pearl and Pseudococcinea showed three types of flowers. However, majority of them were of of pin type. The variety White Dove showed only pin type flowers. Out of four varieties under *S. splendens*, Fireball and Red Hussar showed three types of flowers and Amethyst and Grape Violet showed only pin flowers. In *S. farinacea*, three varieties, Royal Blue, Lavender Blue and White showed only pin flowers. *S. pratensis* also showed the same type. Male sterile plants were also recorded in this species. In *S. grahamii* flowers were heterostylic. Six species of *Salvia* e.g. *S. hispanica*, *S. reflexa*, *S. horminum*, *S. tiliifolia*. *S. aegyptica* and *S. verbenacea* had very minute flowers and all were of homostylic type. *S. taraxacifolia* also showed the same type of flowers. The species, *S. glutinosa* and *S. leucantha* had only pin flowers. In the later species most of the stamens were sterile. Three species i.e. *S. officinalis*, *S. aethiopis* and *S. nemorosa* did not produce any flower here.

### *Pollination and Seed Setting*

Pollination studies have shown that several kinds of ants and blackbees visit the flowers of *Salvia* and effect pollination. In *S. coccinea* flowers are mainly entomophilous and ants were regularly observed to visit the flowers. In the variety Red Indian seed setting in open

**Table 1** *Sources of collection of materials studied*

| Sl. No. | Species/Varieties | Source |
|---|---|---|
| 1. | *Salvia coccinea* Juss. (vars. Red Indian, White Dove, Pink Pearl.) | Sutton & Sons (India) P. Ltd. Calcutta |
| 2. | *S. splendens* Sell. (vars. Fireball, Red Hussar) | |
| 3. | *S. farinacea* (vars. Royal Blue, Lavender Blue, White) | |
| 4. | *S. splendens* Sell. (vars. Amethyst, Grape Violet) | N. Cooper & Co. Poona |
| 5. | *S. hispanica* Linn. | |
| 6. | *S. coccinea* (var. Pseudococcinea Gray) | Zoo and Botanic Garden Rotterdam Holland |
| 7. | *S. grahamii* Benth. | |
| 8. | *S pratensis* Linn. | |
| 9. | *S. taraxacifolia* Coss. | |
| 10. | *S. aegyptica* Linn. | Kew Garden, UK |
| 11. | *S. tiliifolia* Vahl. | Jardin Botanique de'l Universite Louis France |
| 12. | *S. nemorosa* Linn. | Department of Agriculture, Ottawa, Canada |
| 13. | *S. reflexa* Hornem | |
| 14. | *S. glutinosa* Linn. | Botanischer Garten der Universitat, Zurich |
| 15. | *S. verbenacea* Linn. | Institute of Plant Breeding, Plant Introduction Section, Sofia, Bulgaria |
| 16. | *S. horminum* Linn. | |
| 17. | *S. officinalis* Linn. | |
| 18. | *S. aethiopis* Linn. | |
| 19. | *S. leucantha* Cav. | G. Ghosh & Co., Townend Darjeeling |

pollination was more than 50 per cent However, by bagging of flowers no seed setting was observed, which indicates that natural self-pollination does not occur. By artificial self-pollination seed setting increased. The variety Pseudococcinea also showed the same trend. But the varieties Pink Pearl and White Dove slightly differed regarding this. In Pink Pearl seed setting in open pollination was slightly higher than in Red Indian. By hand pollination almost cent per cent of the flowers produced seeds and also by bagging a few seeds were obtained. It shows that occasional self-pollination occurs in nature. Seed setting in the variety White Dove by open pollination was perceptibly lower than in the case of other

varieties. By hand pollination it was very high, although by bagging it was nil. All the varieties were found to be self-compatible.

In *S. splendens*, all the varieties were cross-pollinated and black ants played the major role in pollination. *S. splendens* has got large, bright, scarlet corolla and at the base of the ovary there is secretion of juicy substances that attract the ants. Yet seed setting by open pollination was very low. In the varieties Fireball and Red Hussar approximately 30% of labelled flowers produced seeds. Bagging of flowers did not set seed. In the remaining two varieties, Amethyst and Grape Violet, seed setting by open pollination was very low. Only by hand pollination seeds were obtained. All the varieties were self-compatible.

In *S. farinacea*, three varities were studied. The varieties Royal Blue and Lavender Blue were entomophilous and blackbees are responsible for pollination besides the ants. However, the variety White was only ant pollinated. No blackbee visited the white flowers. Self-pollination in nature does not take place. By open pollination about 40% of the flowers produced seeds. However, in the variety White seed setting was slightly lower than in the other varieties. All the varieties were self-compatible.

*S. pratensis* was cross-pollinated and mainly insects play the major role. Seed setting by open-pollination was low. Actually it was nil in case of male sterile plants. But by hand pollination seed setting increased. When the flowers of male sterile plants were crossed with the pollen grains of the male fertile plants, they produced seeds indicating that the gynoecium is functional. In *S. grahamii* both self and cross-pollinations take place, although the latter occurs more and ants play the major role. In open-pollination seed setting was high, by hand-pollination it also increased. By bagging a considerable number of flowers produced seeds, which indicates that natural self-pollination also occurs in this species.

Five species, *S. reflexa*, *S. tiliifolia*, *S. hispanica*, *S. verbenacca* and *S. aegyptica* had very minute flowers and all are supposedly self-pollinated and seed setting by open pollination was extremely high, almost all the flowers produced seeds. As the flowers were minute, bagging and artificial selfing was not possible. However, in each of the species one plant was kept isolated from the others and then percentage of seed setting was recorded. In this condition also, almost cent per cent of the flowers produced seeds. It indicates that probably self-pollination is the rule in these species. In *S. hispanica* male sterile plants were also recorded. Two other species e.g. *S. taraxacifolia* and *S. horminum* had also small flowers and these are also supposed to be self-pollinated. However, seed setting was very poor.

The species *S. glutinosa* and *S. leucantha* did not set seed here. In the former, flowers were fertile with enormous pollen grains but seed setting was nil. Even by hand-pollination, there was no seed setting. In the latter species most of the anthers were sterile. Hand pollination with foreign pollens did not set seed.

### *Crossability*

Crosses were made involving as many species as possible. Crossing experiments were continued for three consecutive years, but in most of the cases the attempts failed. In the first year i.e. 1975 only three species e.g. *S. splendens*, *S. coccinea* and *S. farinacea* with their varieties were crossed reciprocally, but none of the crosses was successful. So it was thought that the stigma may contain some inhibitory substances that may stop growth of foreign pollen grains or the pollen tube may not reach the nucellus. To overcome these probable barriers, crosses were

also made using several devices as has been used by Charles et al. (1974). The species and varieties were the same that were used in the previous crossing.

A. Prior to pollination, stigmas were dipped in a solution of 1% sucrose with a small amount of 0.1% Ca $No_3$+0.1% boron.
B. Stigma lobes were removed by sterilized scissors during pollination.
C. The middle portion of the style was removed and then pollination was done.
D. Style was removed and then pollination was done.

Even by using these devices none of the crosses was successful. In the second year crosses were also made using the same species and varieties alongwith a new species *S. tiliifolia.* In this year also the crosses failed.

However, in the year 1977, several new species were obtained and crosses were made involving new combinations. Some encouraging results were obtained specially in crosses involving *S. coccinea* and *S. grahamii.* All the three varieties of *S. coccinea* were used in crosses and all of them were successful. Another interesting result was also obtained in crosses between the species *S. coccinea* and *S. splendens.* In this year several immature, poorly developed seeds were obtained although all the previous attempts failed. Intervarietal hybridisation of *S. splendens* was also tried. The crosses were successful and produced a good number of seeds (table 3).

## Discussion

From the observations on breeding system, it can be concluded that *Salvia* is a predominantly outbreeding genus. In the present studies 14 species some of them with several varieties were considered. Of these, 7 species with 11 varieties were cross-pollinated and it has been found that specially large flowered varieties were outbreeders, whereas 7 species with minute flowers were found to be inbreeders (table 2). As regards floral structure extreme variations in the position of style and anther level have been recorded. This variation has been found between the species, between the varieties of the same species and in some cases between the plants of the same variety. Our previous observation on 3 species of *Salvia* also showed such variation (Haque & Ghoshal 1977).

Pollination studies have shown that several kinds of ants and Blackbees visit the flowers of *Salvia* and effect pollination. It has been found that in all cases where flowers are large and heterostylic mostly cross-pollination takes place. Species which had very minute homostylic flowers have been found to be self-pollinated. This observation on minute flowers fits very well to the observations of Proctor and Yeo (1973) who mentioned that the small flowered species are habitually self-pollinated.

Studies on seed setting in *Salvia* haveshown that in the out-breeding species seed setting by open pollination is very low, especially in those cases where flowers are heterostylic i.e. pin or thrum flowers. The relative positions of anthers and stigmas in the different species is directly correlated with good natural seed setting and that species with stamens at a lower level than the stigma or vice versa do not easily set seed naturally. Along with this factor, the absence of pollinating bees, ants and in some species male sterility are the causes of low seed setting in *Salvia.* In all the cases seed setting is increased by hand pollination. Khoshoo (1981) also mentioned lower seed setting in some ornamentals with heterostylic flowers and it increased by hand pollination. All the species studied, have been found to be self-compatible which is similar to the observation of Valentine (1972) who reported that

**Table 2** *Floral biology, pollination and seed setting in different species of* Salvia

| Species/Varieties | Flower types | Flower size | Pollination | Nature | Percentage of seed set Bagging | Hand Pollination |
|---|---|---|---|---|---|---|
| 1. *S. coccinea* | | | | | | |
| Red Indian | Pin, thrum, homostyle | Large | Cross | 51.5 | 0 | 91.0 |
| Pink Pearl | Pin, thrum, homostyle | Large | Cross | 52.8 | 10.0 | 93.0 |
| Pseudococcinea | Pin, thrum, homostyle | Large | Cross | 50.0 | 0 | 92.0 |
| White Dove | Pin | | Cross | 41.0 | 0 | 90.0 |
| 2. *S. splendens* | | | | | | |
| Fireball | Pin, thrum, homostyle | Large | Cross | 29.8 | 0 | 90.0 |
| Red Hussar | Pin, thrum, homostyle | Large | Cross | 30.1 | 0 | 93.0 |
| Amethyst | Pin | Large | Cross | 1.1 | 0 | 92.0 |
| Grape Violet | Pin | Large | Cross | 1.5 | 0 | 90.0 |
| 3. *S. farinacea* | | | | | | |
| Royal Blue | Pin | Large | Cross | 40.0 | 0 | 61.0 |
| Lavender Blue | Pin | Large | Cross | 39.5 | 0 | 57.0 |
| White | Pin | Large | Cross | 28.7 | 0 | 60.0 |
| 4. *S. pratensis* | Pin | Large | Cross | 39.0 | 0 | 80.0 |
| 5. *S. grahamii* | Pin, thrum, homostyle | Large | Cross | 69.0 | 31.7 | 90.0 |
| 6. *S. glutinosa* | Pin | Large | Cross | 0 | 0 | 95.0 |
| 7. *S. leucantha* | Pin | Large | Cross | 0 | 0 | 0 |
| 8. *S. reflexa* | Homostyle | Small | Self | 89.3 | — | 0 |
| 9. *S. tiliifolia* | Homostyle | Small | Self | 93.0 | — | — |
| 10. *S. horminum* | Homostyle | Small | Self | 37.0 | — | — |
| 11. *S. aegypitica* | Homostyle | Small | Self | 91.0 | — | — |
| 12. *S. verbenacea* | Homostyle | Small | Self | 93.1 | — | — |
| 13. *S. taraxacifolia* | Homostyle | Small | Self | 41.7 | — | — |
| 14. *S. hispanica* | Homostyle | Small | Self | 91.5 | — | — |

**Table 3** *Record of hybridisation in the year* 1977

| Combination | No. of flowers crossed | No. of flowers setting seeds | Percentage of flowers setting seeds | No. of seeds obtained |
|---|---|---|---|---|
| *S. splendens* var. Fireball × *S. coccinea* var. Red Indian | 20 | 4 | 20 | 8 |
| *S. coccinea* var. Red Indian × *S. splendens* var. Fireball | 50 | 2 | 4 | 2 |
| *S. coccina* var. Red Indian × *S. grahamii* | 41 | 33 | 80.48 | 102 |
| *S. grahamii* × *S. coccinea* var. Red Indian | 33 | 23 | 69.69 | 37 |
| *S. coccinea* var. White Dove × *S. grahamii* | 25 | 20 | 80.00 | 51 |
| *S. grahamii* × *S. coccinea* var. White Dove | 22 | 17 | 77.27 | 33 |
| *S. coccinea* var. Pink Pearl × *S. grahamii* | 26 | 19 | 73.08 | 48 |
| *S. grahamii* × *S. coccinea* var. Pink Pearl | 21 | 12 | 57.14 | 25 |
| *S. splendens* var. Rose × *S. splendens* var. Fireball | 21 | 19 | 90.43 | 51 |
| *S. splendens* var. Fireball × *S. splendens* var. Amethyst | 38 | 14 | 36.84 | 34 |

genus *Salvia* is self-compatible and in many cases self-pollinating. However, the species with homostylic flowers showed a high degree of seed setting in nature. Two species, *S. glutinosa* and *S. leucantha* did not set any seed here. *S. glutinosa* is stricktly entomophilous and Bumble bee, *Bombus agrorum* pollinates the flowers (Proctor & Yeo 1973). The absence of this bee may be the cause of no seed setting here. In *S. leucantha* most of the flowers were male sterile and it is assumed that due to the absence of fertile pollen grains seed setting did not take place.

For studying crossability in *Salvia*, almost

all the crosses involving as many species as possible were done, but all of these failed except the combinations *S. coccinea* × *S. grahamii* and *S. splendens* × *S. coccinea*. The combination of the former two species was more successful than the later species (table 3). If crossability data are indications of any interspecific relationship then undoubtedly these two species show affinity with each other. However, in other cases, interspecific relationships were remote. Davis and Heywood (1963) state that crossability criteria must be assessed for purposes of general classification, like any other taxonomic characters.

The variation in the floral structure in differnt species and varieties of *Salvia* can be explained on the basis of their outbreeding nature. When considering the evolutionary aspects on the basis of breeding system, the species with minute and homostylic flowers may be assumed to be primitive. Furthermore it is well known that the blue flowered plants are mostly primitive (Harborn 1967) and in the present studies it has been found that all the minute and homostylic flowered species have blue flowers, whereas most heterostylic, large flowered species have scarlet or red flowers. In course of evolution, these scarlet or red flowered species may have been evolved from the blue flowered species. On this notion, it can be presumed that *S. splendens* and *S. coccinea* are most advanced. Our studies on chromosome relationships and anthocyanin pigments in some of these *Salvia* species also showed these two species as the most advanced (Haque et al. 1980, 1981).

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