Inheritance of Photoperiodic Flowering Response and Stem Striping in *Salvia splendens* Sello[1]

C. H. Lai, Jules Janick, and T. C. Weiler[2]
Purdue University, West Lafayette, Indiana

Abstract. **The flowering response of 'St. John's Fire' salvia is day neutral and occurs between the 8-13th node under both 8 (SD) and 24 hour (LD) photoperiods. In contrast 'Bonfire' flowers between the 8-13th node under SD, and under LD flowering is delayed to the 16-19th node. Genetic experiments indicate that this difference in photoperiodic response is controlled by a single gene: *RR* flowers from node 16-20, *Rr* from node 13-17, and *rr* from node 8-13. A single dominant gene *S* conditions stem stripedness; *ss* is solid colored. *S-s* and *R-r* are independently inherited.**

Salvia splendens, which is indigenous to Mexico, $2n = 32$, $x = 8$ (1), is increasing in popularity as a bedding plant. Photoperiods beyond 14 hr delay flowering in some salvia cultivars, but not in others (2, 3). The maximum delay is obtained in continuous illumination (4). This study describes the inheritance of photoperiodic response and stem stripedness from crosses involving 'St. John's Fire' (SJF) which flowers at an early node in LD and SD and 'Bonfire' (BF) in which flowering is delayed in LD.

The work was conducted in late winter and spring greenhouse conditions with a 21°C minimum temp. Black cloth covered all plants from 4:30 PM to 8:30 AM. Incandescent illumination of approximately 0.0015 Langley/min was provided under the cover for plants receiving continuous lighting.

Hybridizing salvia. The salvia flower is hermaphroditic and naturally self-pollinating. We determined the optimum stage for crossing by emasculating flowers with a sharp forceps when the corolla tube was 1.5 cm and subsequently pollinating at various stages of maturity based on corolla length and openess of the forked stigma which ranges from 0-75°. Pollen was applied using the mature flower as a brush. A plastic bag was applied before emasculation and subsequently kept until nutlets enlarged after 2-5 days and depending on temp, darkened 3-4 weeks later.

The greatest amount of seed set was obtained with corolla length from 4.0-4.8 cm and stigma opening from 70-75° (Table 1). For hybridizing, emasculation can be performed when corolla length is $\leq$ 3.0 cm and stigma opening is $\leq 35°$; pollinations should be made the following day.

Table 1. Determination of the optimum stage of pistil receptivity.

Time of pollination		
Corolla length (cm)	Stigma openness (degree)	Seed set (%)
1.5	0	0
1.8	10	0
2.5	20	0
3.0	35	10
3.5	45	50
4.0	70	50-80
4.5	75	50-80
4.8	75	50-80
4.8 + 1 day	75+	10
4.8 + 2 days	75+	0

Flowering response to daylength. 'BF' and 'SJF' both flowered from node 8-13 under SD but under LD flowering in 'BF' was delayed until node 16-19 (Table 2). Seedlings of reciprocal crosses between 'SJF' and 'BF' were compared under SD and LD. No difference in the flowering response occurred between reciprocal crosses in the F_1 so the data are combined. Of the 107 F_1 plants, 1 flowered at node 13, 6 flowered at node 17, and the remainder were distributed in nodes 14, 15 and 16. The F_1's, therefore, were delayed in flowering as in 'BF' under LD, but the actual number of vegetative nodes of flowering was intermediate between 'SJF' and 'BF'

F_2 and backcross generations were only grown under LD and flowering ranged from node 10-20. The backcross of the F_1 to 'SJF' flowered from node 10-17, while the backcross of the F_1 to 'BF' flowered from node 14-20.

We used the ability to flower at the 13th node in LD to separate 2 classes of photoperiodic response. Plants that flowered $\leq$ node 13 under LD were considered nonphotoperiodically responsive (NR); plants that flowered beyond the 13th node were photoperiodically responsive (PR). The 2 class segregation ratio in LD can be explained with a single gene (*R* vs. *r*) with *RR* and *Rr* genotypes being PR and *rr* genotypes being NR. Under this assumption, 'BF' is *RR* and 'SJF' is *rr*. The reciprocal F_1's are both heterozygous *Rr* and PR indicating dominance for delayed flowering in long days.

The F_2 ratio of 288 PR:99 NR fits the expected 3:1 ratio assuming a single gene difference (Table 3). The backcrosses segregated 1 PR:O NR (F_1 × 'BF') and 1 PR:1 NR (F_1 × 'SJF'), as expected.

The *R* allele appeared incompletely dominant to *r* with respect to the node of flowering under LD. The *RR* genotype ('BF') flowered from node 16-19, *Rr* (F_1) flowered from node 13-17, and *rr* ('SJF') flowered from node 8-11. There was some overlapping of the *RR* and *Rr* genotypes at nodes 16 and 17 but most *RR* genotypes flowered above node 17. Therefore in crosses segregating for *RR* and *Rr* (F_2 and F_1 × 'BF') all plants which flowered

Table 2. Distribution of node of first flowering in crosses involving 'SJF' and 'BF' by photoperiod.

		No. of plants					
	Node of 1st flower	Parents		F_1 (reciprocals)	F_2	Backcrosses	
Photoperiod		SJF	BF			F_1 x SJF	F_1 X BF
SD	8	2	6	7	–	–	–
(8 hr)	9	6	1	29	–	–	–
	10	1	1	28	–	–	–
	11	1	1	16	–	–	–
	12	0	1	7	–	–	–
	13	0	0	3	–	–	–
	14-20	0	0	0	–	–	–
Avg node no.		9.1	8.5	10.0			
LD	8	1	0	0	0	0	0
(24 hr)	9	7	0	0	0	0	0
	10	1	0	0	3	4	0
	11	1	0	0	11	16	0
	12	0	0	0	56	12	0
	13	0	0	1	29	5	0
	14	0	0	31	14	6	1
	15	0	0	42	47	12	16
	16	0	2	27	107	12	34
	17	0	6	6	72	3	27
	18	0	1	0	34	0	19
	19	0	1	0	8	0	7
	20	0	0	0	6	0	4
Avg node no.		9.2	17.0	15.1	15.3	13.3	16.8

[1]Parents grown in 1972; F_1, F_2 and backcrosses grown in 1973.

[1]Received for publication June 21, 1974. Journal Paper No. 5548 of the Purdue University Agricultural Experiment Station.
[2]Graduate Research Assistant, Professor, and Assistant Professor, Department of Horticulture.

Table 3. Segregation for node of flowering under LD of crosses involving 'SJF' and 'BF'.

Cross	2 class segregation: Node of flowering in LD 14-20	8-13	Expected ratio	P	3 class segregation: Node of flowering in LD 17-20	14-16	8-13	Expected ratio	P
SJF	0	10			0	0	10		
BF	10	0			8	2	0		
F_1 (SJF x BF)	47	1			2	45	1		
F_1 (BF x SJF)	59	0			4	55	0		
F_2	288	99	3:1	.50-.70	120	168	99	1:2:1	.01-.02
F_1 x SJF	33	37	1:1	.50-.70	3	30	37	0:1:1	.50-.70
F_1 x BF	108	0			57	51	0	1:1:1	.50-.70
Assumed genotype	*R-*	*rr*			*RR*	*Rr*	*rr*		

Table 4. Inheritance of stem striping in crosses involving 'SJF' and 'BF'.

Crosses	No. of plants: Striped	Non-striped	Expected ratio	P
SJF	10	0		
BF	0	10		
F_1 (SJF x BF)	48	0		
F_1 (BF x SJF)	59	0		
F_2	294	93	3:1	.50-.70
F_1 x SJF	70	0		
F_1 x BF	56	52	1:1	.50-.70

from $\geq$ node 17 were assumed to be *RR* while plants between 14-16 were assumed to be *Rr*.

The segregation for node of flowering under LD of 3 classes (8-13, 14-16, 17-20) is shown in Table 3. While the F_2 distribution is significantly different for the expected 1:2:1 ratio at the 5% level (P = <2%), the backcross of the F_1 x 'BF' fits the expected 1:1 ratio. The results support the hypothesis that while the *R* allele is dominant for delay of flowering, the action is incompletely dominant if the actual node of flowering is considered.

Plant height. Under LD 'SJF' was of short stature and 'BF' was tall. This difference in height is due to the node of flowering. In Fig. 1, the average height of parents, F_1, F_2 and backcrosses reflects the node of flowering although heterosis of the F_1 was observed. Thus, plant height under LD is effectively controlled by the *R-r* alleles.

Days from transplanting to visible bud. Under LD 'SJF' flowered early and 'BF' flowered late. The difference in days to flower between these cultivars and crosses between them is also primarily due to the node of flowering (Fig. 2).

Stem striping. The lower stems of both cultivars are purple but 'SJF' is striped, with the purple color confined to the vascular strands, while 'BF' is solid purple. The plants are easily scored for this character at the 4th internode. The reciprocal F_1's were all striped; the F_2 segregated 3 striped:1 non-striped. The F_1 x 'SJF' were all striped, while the F_1 x 'BF' segregated 1 striped:1 non-striped (Table 4). We conclude that striped vs. non-striped, (solid colored) stem is controlled by a single gene; *SS* and *Ss* are striped, *ss* is non-striped.

Linkage between R and S. The genotypes of the two cultivars with respect to photoperiodic flowering response and stem striping are:

'BF' = *RRss*
'SJF' = *rrSS*.

The 4 class F_2 ratio of 222 (PR, striped):66 (PR, non-striped):72 (NR, striped):27 (NR, non-striped) does not differ significantly from the expected 9:3:3:1 ratio indicating independent segregation *R* and *S* In this type of cross, linkage cannot be determined from backcrosses. Combining the 1:2:1 ratio for node of flowering and the 3:1 ratio for stem striping ratio gives a 6 class F_2 ratio of 3:1:6:2:3:1. The observed segregation fits the expected (X^2 = 10.54, P = 5-10%) although it approaches significance. The Chi square analysis indicates that most of the deviation is due to the poor 1:2:1 fit; there is no evidence for linkage.

Conclusion. The discovery of a single gene that determines the node of flowering under LD makes it possible to clearly separate at least 2 true-breeding classes of *Salvia splendens.* One consists of plants of short stature that flower early under any daylength *(rr).* Further selection may result in plants of this genotype varying as to the precise node of flowering, height, and flowering date. The other class, homozygous for the *R* gene, is tall and late flowering under long days. Selection within these types might yield a range of genotypes with respect to plant height and days from transplanting to visible bud. Further studies should be based on F_3 analysis and additional crosses involving other genotypes to determine if there are other major or modifying genes.

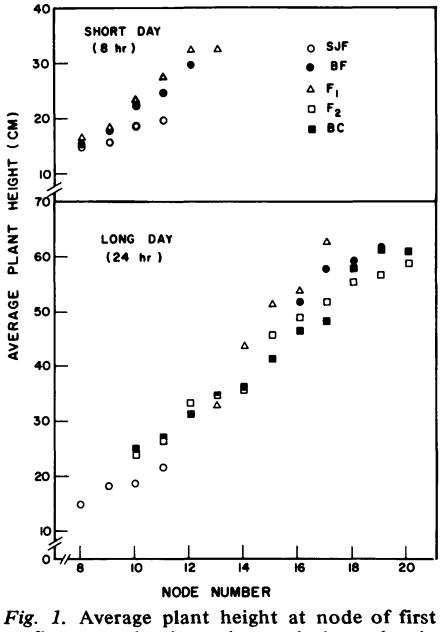

Fig. 1. Average plant height at node of first flower under long day and short day in crosses involving 'SJF' and 'BF'.

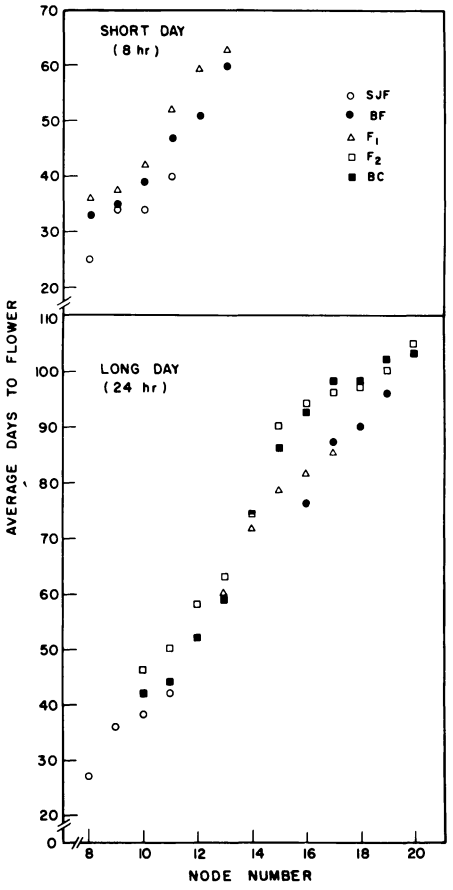

Fig. 2. Days from transplanting to visible flower bud in long day and short day in crosses involving 'SJF' and 'BF'.

Literature Cited

1. Darlington, C. D., and A. P. Wylie. 1956. Chromosome atlas of flowering plants. George Allen and Unwin, London.
2. Lai, C. H. 1974. Photoperiodic and genetic studies of flowering in *Salvia splendens* Sello. M.S. Thesis, Purdue University, West Lafayette, Indiana.
3. Weiler, T. C. 1972. The variable flowering response of *Salvia splendens* Sello to daylength. *J. Amer. Soc. Hort. Sci.* 97:355-357.
4. ———, and C. H. Lai. 1973. Critical daylength for inflorescence formation of several cultivars of *Salvia splendens* Sello. *HortScience* 8:184.