MAPPING OF THE Sn LOCUS TO CHROMOSOME 2

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Six genes have been described that specifically influence flowering in the garden pea (1,4). The gene Lf is located on chromosome 1 near A, E on chromosome 6 near Na, Hr on chromosome 3 near M and Lap-2, and Dne on chromosome 3 near St (1,2). Despite considerable effort (3), the two remaining loci, Sn and Veg, have not been mapped. The Sn gene is of major practical importance since in addition to flowering node it influences other traits of horticultural significance, including branching pattern, number of reproductive nodes, and seed yield (4). Homozygous sn plants are nonphotoperiodic and generally earlier flowering than Sn plants. Many early flowering cultivars are homozygous recessive at the Sn locus. We report here that this locus maps very near Amy-1 on chromosome 2.

During analysis of an F2 population from the cross between 'Sparkle' and a line from Afghanistan (originally obtained from Dr. T. A. LaRue, Boyce Thompson Institute, Ithaca, NY as a source of the sym-2 mutant), we observed an association between node of flowering and amylase phenotype. The locus responsible for the variation in amylase phenotype, Amy-1, has been mapped to one arm of chromosome 2 distal to Oh (5). Because none of the four previously mapped flowering genes are located on chromosome 2, we suspected that we might be following segregation at Sn. However, daylength had not been monitored rigorously in the initial experiments. A second F2 from the same cross was, therefore, grown under short day conditions (9.5 hr light) to maximize the difference between Sn and sn segregates. Tne plants were grown under a combination of fluorescent and incandescent light in a growth chamber with a constant temperature of 19°. All plants fLowering at or before node 14 (nodes were counted from the first scale leaf as node 1) possessed the Sparkle Amy-1 genotype, aa. (Table 1). None of the plants flowering after node 14 had the aa genotype. The Sparkle control bloomed one node earlier than the earliest blooming- F2 plant, whereas the Afghanistan control bloomed about node 40, concurrently with the latest blooming F2 plants. Additional data (not presented) were obtained on cosegregation of flowering node and the Loci A, M, and Lap-2, both in the above and other crosses. The data indicated that the Afghanistan line was Lf Hr, and photoperiodic (genotype Sn Dne) and that Sparkle was lf hr, and nonphotoperiodic (presumably sn Dne). Since there were no early photoperiodic segregates (genotype lf E Sn Dne) in the Afghanistan x Sparkly cross both parents appear to have genotype e.

To confirm that the early-flowering gene linked to Amy-1 was sn, Sparkle was crossed with HPL73, a line known to be Lf sn hr. lf Sparkle was lf sn hr, the progeny of this cross should be sn sn (nonphotoperiodic). Alternatively, if the F1 was photoperiodic Sparkle must contain a recessive mutation different from sn. The F1 plant flowered early (node 11) under short day conditions (Table 2), confirming that the genotype of Sparkle was, indeed, lf sn hr.

To further characterize the interaction of the flowering genes in the second Sparkle x Afghanistan F2 population, F3 progeny from selected F2 plants were grown under short day conditions along with control lines of known flowering genotype. The F2 plants were selected on the basis of phenotypes at the marker genes A, Amy-1, Lap-2, and M. Both white- and wild type-flowered plants were chosen to test the effect of the lf - Lf difference. Although approximately 10% recombination was expected between A. and Lf, most of the white-flowered F3 can be assumed to be homozygous recessive lf. All three Amy-1 phenotypes were involved. Finally, all plants selected were homozygous hr in order to avoid the very late flowering Sn Hr phenotype.

The results of these experiments are given in Tables 2 and 3. Days to flower and nodes to flower showed very little within-line variation as can be seen by the low standard errors. The Influence of lf on flowering time, as indicated by the white-flowered phenotype, can be seen in several progenies. However, even plants with colored petals bloomed early (node 11-14) as long as they were homozygous Amy-1^{a} . In contrast, those plants in progenies 3741-4 and 3741-6 possessing either an Amy-1^{ab} or Amy-1^{bb} genotype did not produce fully developed flowers until nodes 17-22, inclusive, although flower primordia occasionally formed at lower nodes in the former progeny. Abortion of flower buds at lower nodes in short day conditions is typical of Sn plants (4). The flowering differences found among the different amylase genotypes therefore mimicked those observed between the control lines homozygous for sn (HPL59 and HPL73) and those containing the dominant allele Sn (HPL60 and HPL2).

Despite the high within-line reproducibility of days to flower and node to flower, these parameters did vary among lines with the same genotype at the three flowering loci being monitored. The differences were particularly obvious in the Lf sn hr genotypic class in which the control (HPL 73) and progeny from the F2 plant 3940-24 were clearly later flowering than progeny from 3741-3, 3741-6, and 3740-9 (Tables 2 and 3). Such differences among plants of the Lf sn hr genotypic class have been examined previously and attributed to quantitative systems (4).

Five of the six known major flowering genes are now located and at least four (Lf, Sn, Dne , and Hr) are close to good markers. Segregation for some flowering genes can be obscured in certain environmental conditions or as a result of epistatic relationships among the genes themselves. The availability of a good marker for Sn is particularly welcome since this gene is of major applied significance and great intrinsic interest in regard to the physiological mechanism by which it controls flowering and the ability to respond to photoperiod.

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(2) Murfet, I. C. 1978. PNL 10:48-52.
(3) Murfet, I. C. 1978. PNL 10:56.
(4) Murfet, I. C. 1985. Handbook of Flowering, Vol. IV. A. H. Halevy, Ed. CRC Press, Florida, pp 97-126.
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Table 1. Joint segregation analysis of flowering node and amylase (Amy-1) phenotype in the F2 of cross Sparkle x Afganistan grown in a 9.5 hr photoperiod.

Amylase phenotype	First flowering node		
	10-14	16-22	23-40
aa (sparkle;	4	0	0
bb (Afghanistan)	0	0	2
aa	13	0	0
ab	0	13	19
bb	0	4	14

Table 2. Days to flower, node of flower initiation, and flowering genotype of control lines and Sparkle x HPL 73 F, grown under short day conditions.

Line	No. of plants	Days to flower	Node of flower initiation	Flowering genotype
HTL2	5	67.4+/-1.0	28.8+/-1.1	Lf Sn hr Dne E
HPL59	5	37.2+/-0.6	10.0+/-0.0	If sn hr Dne E
12.6+/-0.2[1] HPL60	5	55.6+/-1.9		If Sn hr Dne E
HPL67	5	--[2]	--[2]	Lf Sn Hr Dne E
HPL73	3	47.3+/-3.1	16.7+/-0.6	Lf_ sn hr Dne E
K218	5	38.8+/-1.1	15.0+/-0.7	Lf_ Sn hr dne E
Sparkle	8	38.5+/-0.5	10.8+/-0.1	lf sn hr Dne e
Afghan.	2	--[2]	--[2]	Lf Sn Hr Dne e
Sparkle x HPL 73 (Fl)	1	40	11	Lf/lf sn hr Dne E/e

1 - Initial flower buds did not develop into flowers. First flowers to develop were usually on secondary branches.
2 - Did not flower during the short-day period of the experiment.

Table 3. Days to flower, node of flower initiation, and postulated flowering genotype of Sparkle x Afghanistan F3 plants grouped according to F2 parent, flower color, and amylase phenotype.

Parental line	Flower color	Amylase phenotype	No. of plants	Days to flower	Node of flower initiation	Presumed genotype[2]
3774-3	white	aa	1	34	11	lf sn
	violet	aa	5	36.2+/-0.8	13.0+/-0.4	Lf sn
3741-4	white	aa	1	33	11	lf sn
	white	ab	6	56.4+/-3.2	20.8+/-1.3[1]	lf Sn
	white	bb	3	57.3+/-5.7	20.0+/-1.6[1]	lf Sn
3741-6	violet	aa	7	40.5+/-1.4	12.0+/-0.5	Lf sn
	violet	ab	10	58.0+/-0.7	19.1+/-0.5[1]	Lf Sn
	violet	bb	3	57.3+/-5.7	20.0+/-1.6[1]	Lf Sn
3741-13	white	aa	1	32	12	lf sn
	violet	aa	7	36.9+/-0.6	13.3+/-0.4	Lf sn
3940-9	white	aa	1	31	11	lf sn
	violet	aa	2	36.0+/-2.0	12.0+/-0.0	Lf sn
3940-23	white	aa	2	36.5+/-4.9	11.5+/-1.0	lf sn
	violet	aa	3	40.0+/-1.4	14.3+/-1.1	Lf sn
3940-24	violet	aa	9	44.6+/-0.8	15.9+/-0.3	Lf sn

1 - Development of flowers often on secondary branches.
2 - All plants hr Dne e.

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