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1) Inheritance of time of flowering under short-day conditions.

Flowering in soybean is initiated by short daylength. There are several investigations exploring the genetic basis of the photoperiodic response in crop plants. However, such studies in soybean are quite limited. Bernard (1971) found that days to flowering in soybean is controlled by two genes, $\underline{E_1}$ and $\underline{E_2}$, which showed partial dominance for late flowering. A dominant gene, $\underline{E_3}$, with a sensitive response to fluorescent light, was found to delay flowering and maturity compared to a reference cultivar, 'Blackhawk' (Buzzell, 1971). Thseng and Hosokawa (1972) reported two genes, AABB, that control the time of flowering. These genes had inter- and intra-allelic interaction.

The "decapitation technique" (Shanmugasundaram and Wang, 1977) was used on parents, F_1 and F_2 of four different crosses. One branch of each individual plant was subjected to 10-hr photoperiod while the other branch was subjected to 16-hr photoperiod. Days to flowering from planting was recorded for each branch.

The days to flowering of the parents, F_1 and F_2, under 10 hr and 16 hr are shown in Tables 1, 2, 3 and 4. Cultivar 'Shih Shih' and PI 194.647 are early while Acc. 2120, PI 230.970 and PI 230.971 are late under 10-hr photoperiod. Similarly the F_1 was early in all cases. Therefore, early flowering under the 10-hr photoperiod is dominant. In the F_2 of all four crosses studied, even though there is a range in days to flowering, the early individuals can be clearly cut at the 44 days to flowering. Above 45 days to flowering is late flowering. Therefore, under the 10-hr photoperiod the major gene effect on the time of flowering is fully manifested. The mode of segregation fits the expected 3 early : 1 late ratio very well (Tables 1, 2, 3 and 4). However, in the 16 hr the F_1 is partially dominant for late flowering and the time of flowering of the F_2 individuals shows a disturbed continuous distribution. It appears that under the 16-hr photoperiod the major gene action on the days to flowering is modified by either a few minor genes or an interaction of other genes involved.

Investigations on the relationship among $\underline{E_1}$, $\underline{E_2}$, A, B and the gene reported in this paper will be more meaningful for the tropical soybean breeding programs.

Table 1

Number of plants in the different days from planting to flowering class in parents, F_1 and F_2 of the cross Shih Shih x PI 230.970

Cultivar name or generation	Photo-period	Days to flowering class																	
		36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	More than 70
Shih Shih	10-hr				4	6													
Shih Shih	16-hr					10													
PI 230.970	10-hr									10									
PI 230.970	16-hr																		10
F_1	10-hr			2	8	2													
F_1	16-hr														6	4	2		
F_2	10-hr	10	13	41	13	13	1	17	2	4	2								
F_2	16-hr	11	13	24	18	8		13	4	2	6	1	2	3	1				10

Source	Early	Late
F_2 segregation		
Observed	90	26
Expected (3:1 ratio)	87	29
χ^2 =	0.413	
P =	0.75 - 0.50	

Table 2

Number of plants in the different days from planting to flowering class in the parents, F_1 and F_2 of the cross Shih Shih x PI 230.971

Cultivar name or generation	Photo-period	Days to flowering class																		
		34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	More than 70
Shih Shih	10-hr					4	6													
Shih Shih	16-hr						10													
PI 230.971	10-hr										10									
PI 230.971	16-hr																			10
F_1	10-hr				2	8														
F_1	16-hr																10			
F_2	10-hr	1	12	5	26	15	29		21	2	1	3	1	1	1	1	1	2		
F_2	16-hr	2	2	7	22	8	10		11	2	6	5	1	2						44

Source	Early	Late
F_2 segregation		
Observed	88.0	34.0
Expected (3:1 ratio)	91.5	30.5
x^2 =	0.535	
P =	0.50 - 0.25	

Table 3

Number of plants in the different days from planting to flowering class in parents, F_1 and F_2 of the cross PI 194.647 x Acc. 2120 (Aug. 9, 1976 planting)

Cultivar name or generation	Photo-period	Days to flowering class																															
		30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	>94
PI 194.647	10-hr	10																																
PI 194.647	16-hr	10																																
Acc. 2120	10-hr												6	6																				
Acc. 2120	16-hr																																	12
F_1	10-hr						5	2																										
F_1	16-hr																							7										
F_2	10-hr		8	12	38	12	21	13	20		16	5	19	2	2	1																		
F_2	16-hr	1	3	3	14	2	7	1	3		11		4	1	2	3	3	3		3	1	14	7	2	1	5	7	6		3	3		5	51

Source	Early	Late
F_2 segregation		
Observed	124.00	45.00
Expected (3:1 ratio)	126.75	42.25
x^2 =	0.238	
P =	0.75 - 0.50	

Table 4

Number of plants in the different days from planting to flowering class in parents, F_1 and F_2 of the cross PI 194.647 x PI 230.970 (March 15, 1976 planting)

Cultivar name or generation	Photo-period	Days to flowering class																				
		30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	> 70
PI 194.647	10-hr			5	5																	
PI 194.647	16-hr			10																		
PI 230.970	10-hr												10									
PI 230.970	16-hr																					10
F_1	10-hr							8	2													
F_1	16-hr																		2	8		
F_2	10-hr			12	20	4	19	29	18		7	4	5	3	2	2	1	1	1			
F_2	16-hr			11	17	3	20	3	7		7	7	4	7		1					4	37

Source	Early	Late
F_2 segregation		
Observed	102	26
Expected (3:1 ratio)	96	32
X^2 =	1.5	
P =	0.25 - 0.1	

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2) Variation in the photoperiodic response to flowering in soybean.

Soybean cultivars representing each of the 10 U.S. Maturity Groups (MGS) (00 to VIII) were screened for the photoperiodic response to flowering from March, 1974 to June, 1974; another set was screened from October, 1974 to January, 1975 using natural daylength in the field as the short-day treatment. In another distant field artificial light was used to extend the natural daylength to 16 hr which represented the long-day treatment. In the March screening, 1,898 cultivars were screened while in October, 1,547 cultivars were screened.

The difference in days to flowering between the natural daylength treatment and the 16-hr treatment in general ranged from 0 to more than 90 days. In previous studies the photoperiodic response of soybean was classified as either sensitive or insensitive (Criswell and Hume, 1972; Polson, 1972; Asian Vegetable Research and Development Center, 1975; Nissly, 1976). Since different degrees of delay in the 16-hr photoperiod was observed, it was felt that to classify the cultivars according to the degree of delay in flowering might be practically useful. Therefore, a scoring method has been developed to classify the cultivars into different degrees of photoperiod sensitivity. The 10 different score classes are given on the following page.

Depending upon the need, sensitivity score 0 and 1 may be considered insensitive while scores 8 and 9 are the most sensitive. The frequency distribution of cultivars with each photoperiod sensitivity score for the two screenings are given in Tables 1 and 2. More low sensitive score (0 and 1) cultivars were observed in the early MGS. This agrees with the general statement that most of the cultivars insensitive to photoperiod belong

Table 1

Frequency of cultivars (%) in the different photoperiod sensitivity score (March 22, 1974 screening)

Maturity group	Photoperiod sensitivity score 0	1	2	3	4	5	6	7 and above	Total no. of cultivars
00	72.7	5.5	10.9	1.8	3.6	5.5	0.0	0.0	55
0	40.5	14.9	20.7	5.0	3.3	15.7	0.0	0.0	121
I	14.1	29.1	28.1	11.6	5.0	10.1	0.0	2.0	199
II	4.3	23.3	39.0	11.0	7.0	14.0	0.3	1.0	300
III	2.1	7.3	37.5	15.6	14.6	18.2	1.0	3.7	192
IV	1.0	2.0	21.0	19.7	14.2	26.8	3.1	12.2	295
V	0.0	0.0	9.2	11.8	14.5	32.9	3.9	27.6	76
VI	0.0	0.0	9.0	19.2	7.7	19.2	2.6	42.3	78
VII	0.0	0.0	0.0	0.0	3.6	0.9	0.9	94.6	112
VIII	0.0	0.0	2.9	0.0	0.0	0.0	0.0	97.1	35
Unknown	6.0	3.4	7.1	4.8	7.8	6.2	0.2	64.4	435
Pooled	8.6	9.7	20.2	10.3	8.5	14.0	1.0	27.6	1898

Table 2

Frequency of cultivars (%) in the different photoperiod sensitivity score (October 8, 1974 screening)

Maturity group	Photoperiod sensitivity score									Total no. of cultivars
	0	1	2	3	4	5	6	7	8 & 9	
00	84.9	12.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	73
0	50.4	29.1	12.1	4.3	2.6	1.7	0.0	0.0	0.0	117
I	36.3	30.2	21.4	7.7	2.2	1.6	0.5	0.0	0.0	182
II	31.8	31.8	20.6	7.7	5.2	1.0	0.7	0.3	0.7	286
III	22.7	25.4	24.9	11.6	12.7	0.0	1.7	1.1	0.0	181
IV	11.4	19.7	29.2	18.6	9.5	3.8	3.8	0.4	3.8	264
V	1.5	6.2	16.9	23.1	21.5	4.6	10.8	1.5	13.8	65
VI	8.6	11.4	32.9	11.4	14.3	10.0	1.4	2.9	7.1	70
VII	0.0	8.0	12.5	17.0	9.1	5.7	0.0	0.0	47.7	88
VIII	0.0	0.0	13.0	26.1	34.8	0.0	4.3	0.0	21.7	23
Unknown	13.6	10.6	12.6	13.6	11.1	4.5	1.5	0.0	32.3	198
Pooled	24.8	21.1	20.0	11.8	8.5	2.7	1.8	0.5	8.9	1547

Number of days delay under the 16-hr photoperiod	Sensitivity score
0 to 4	0
5 to 8	1
9 to 16	2
17 to 24	3
25 to 32	4
33 to 40	5
41 to 48	6
49 to 56	7
57 to 64	8
65 and above	9

to the early MGS (Criswell and Hume, 1972; Polson, 1972; Asian Vegetable Research and Development Center, 1975). However, no definite pattern between the MGS and the sensitivity score is observed. For the first time the photoperiod screening of cultivars from MGS IV to VIII are presented. Even though the number of cultivars with low sensitivity scores in the late MGS are very few when compared to the early MGS, cultivars with 1 and 2 sensitivity score were observed. Such photoperiod insensitive, late maturing cultivars may be better for breeding tropic-adapted soybeans than those in the earlier MGS. The early MG cultivars, when planted in the tropics, tend to flower too soon and therefore have low yields.

References

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