Inheritance of Growth Habit and Time of Flowering in Beans, *Phaseolus vulgaris* L.[1]

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Abstract. Four true bush snap bean cultivars were hybridized with OSC410, a determinate, sprawling 'Blue Lake' bush breeding line. Observed segregation data fit a single gene hypothesis with the sprawling habit completely dominant to true bush type. Crosses of OSC410 to 2 indeterminate cultivars provided evidence for 2 additional patterns of inheritance. When 'Polaris' was used as the indeterminate parent, segregation ratios indicated that indeterminance was dominant and controlled by a single gene. Epistasis of 2 genes was suggested from the cross Mexico 80R' (normal) x OSC410, with indeterminance dominant.

The genetic relationships controlling the expression of plant stature, duration of growth and flowering, and time of flowering in bean, *Phaseolus vulgaris* L., are complex and their expression is often altered by the environment. Lamprecht (8) characterized the tall type as having only axial inflorescence whereas short types included individuals with terminal, terminal and axial, or only axial inflorescence. Generally, it is considered that the tall, indeterminate types differ from the short types by a single gene, with tall stature dominant (10). Indeterminate plants have been found to flower later than determinate ones although plant type is not inseparable from flowering time. Coyne (2) has shown that this association is often due to genetic linkage between indeterminance and late flowering. Photoperiod and temp have been shown to influence flowering temp time and growth habit of determinate types depending on the genotype and combination of environmental factors (1,3,9).

Frazier et al. initiated a program, in 1951, to transfer certain desirable traits of 'Blue Lake' pole beans into bush beans suitable for mechanical harvesting (7), but they found it difficult to recover phenotypes combining the desirable pod characters and true bush type. They found that determinate growth habit was controlled primarily by a single recessive gene. However, within the determinate class there were plants described as being either upright or sprawling. They concluded that at least 3 major recessive genes or many minor genes were responsible for the upright bush habit. Davis and Frazier (5) later determined the genetic basis of habit differences between 'Blue Lake' bush plants that are determinate but sprawling and true bush plants. They found that habit *per se* was continuously variable and that additive effects were predominant in the net effect of gene action on growth habit expression, even though superior (upright) habit was recessive. Coyne (1) also concluded that the growth habit was inherited quantitatively because of the continuous nature of distribution in segregating populations.

In 1960, 'Blue Lake' bush breeding lines were received from Frazier, of Oregon State University. These lines were not well-adapted to Wisconsin growing conditions, but they have been useful sources of genetic variability. OSC410-1816-1 (referred to as OSC410) was used as a parent in several crosses since it possessed certain desirable pod quality traits. This paper reports the results of crosses made to transfer traits from OSC410 to true bush plant types, and of crosses made to determine the relationship of the 'Blue Lake' bush growth habit to other plant types.

Materials and Methods

OSC410, a 'Blue Lake' bush breeding line (determinate, but sprawling) was crossed with 'Cascade', 'Tempo', 'Tenderette', 'Sprite' (all true bush cultivars), 'Polaris' (pole bean), and 'Mexico 80R' (indeterminate, but short statured). All had white seed coats and green stems with the exception of 'Mexico 80R' which had red seed coats and stems. Row plots of parents and hybrid populations were planted in a completely random design at the Hancock, Wisconsin, Experiment Station on June 4, 1970. Two replicates of each parent were used and the number of replicates of each segregating population varied, depending on the number of individual families available. The seeds were planted 30 cm apart in rows 90 cm wide. The date of first bloom per plant was recorded and the height of each plant was measured 45 days following planting when differences in plants could be seen clearly but before the indeterminate plants had become entwined.

Results and Discussion

The F_1 plants from crosses of OSC410 with the true bush cultivars closely resembled OSC410. The segregation ratios observed in the F_2, F_3 and both backcross populations show that sprawling growth habit is completely dominant to true bush type and controlled by a single gene (Table 1). The mean flowering time of OSC410 was nearly 2 weeks later than that of true bush cultivars. In general, true bush plants flowered early and sprawling plants were late flowering in the segregating populations.

Other morphological characters did not appear to be strongly associated with growth habit. In the segregating populations, true bush plants having the large, thick leaves similar to OSC410 were recovered. Small, thin leaves comparable to those of the true bush parents were observed on some large, sprawling, late-flowering plants. The pod types of the F_1 plants appeared to be intermediate to the parents, and there were no obvious associations between pod type and growth habit in the segregating populations. Other 'Blue Lake' bush breeding lines, similar to those described by Davis and Frazier (5), have some traits similar to OSC410, however, the presence of true bush segregates in progenies of crosses between OSC410 and true bush commercial cultivars seem to make OSC410 rather unique. It is not suitable for commercial use because of its poor growth habit, late flowering, and extended flowering period. The plants grown under short day, winter conditions in the greenhouse flowered in nearly the same length of time as plants grown under field conditions. Other studies have shown certain 'Blue Lake' bush strains to be responsive to changes in photoperiod and temp (1).

The ratios observed in populations resulting from the cross 'Polaris' x OSC410 support the hypothesis that indeterminance

[1]Received for publication January 25, 1971. Published with the approval of The Director, Research Programs Division, College of Agricultural and Life Sciences, University of Wisconsin.

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Table 1. Segregation based on plant type for the parental F_1, F_2, F_3 and backcross populations of crosses between true bush cultivars and OSC410-1816-1.

Population	OSC410-type			True bush type		
	No. families	No. plants	Days to flower[y]	No. plants	Days to flower	Chi square[x]
OSC410 (parent)		158	51 (45-59)			
Tempo x OSC410						
Tempo (P_1)				18	38(35-42)	
F_1		6	53(48-60)			
F_2	6	156	58(41-69)	62	36(33-40)	1.37
$P_1 \times F_1$	1	16	56(50-61	16	35(33-36)	0
$P_2 \times F_1$	1	6	53	0		
F_3	1	18	55	0		
	6	73	55	25	38	.02
	3	0		60	37	
Tenderette x OSC410						
Tenderette (P_1)				17	40(38-42)	
F_1		2	54			
F_2	3	81	56(45-60)	35	38(33-43)	1.65
$P_1 \times F_1$	1	5	57(46-59)	9	38(35-41)	1.15
$P_2 \times F_1$	1	13	54(46-59)	1	38	
F_3	2	30	56	0		
	3	33	57	13	40	.26
	4	0		57	39	
Cascade x OSC410						
Cascade (P_1)				20	40(36-41)	
F_2	3	78	53(45-69)	33	38(35-46)	1.31
$P_1 \times F_1$	1	3	53(48-56)	4	38(35-41)	1.42
$P_2 \times F_1$	1	5	52(46-58)	0		
F_3	2	34	55	0		
	3	32	53	11	39	.02
	4	0		70	38	
Sprite x OSC410						
Sprite (P_1)				19	40(38-42)	
F_2	2	49	55(46-61)	26	37(34-40)	3.73
$P_1 \times F_1$	1	4	57(48-63)	5	38(36-42)	.10
$P_2 \times F_1$	1	10	49(41-55)	0		
F_3	1	22	56	0		
	4	48	55	18	41	.19
	1	0		19	40	
OSC410 x Sprite						
F_1		3	56(54-58)			
F_2	4	113	55(41-61)	36	37(34-39)	.06
$P_2 \times F_1$	1	6	49(41-56)	4	37(35-39)	.40
$P_1 \times F_1$	1	17	52(48-60)	0		
F_3	2	25	54	6	40	.54
	4	0		86	39	

[x]Tested against an expected 3:1(OSC410-type) in F_2 and 1:1 in $F_1 \times P_2$.
[y]Mean number of days to first flower; range of days follows in parentheses.

Table 2. Segregation based on plant type for the parental, F_2, and $F_1 \times P_2$ populations of the cross 'Polaris' x OSC410-1816-1.

Population	Polaris-type			OSC410-type			
	No. plants	Height (cm)	Days to flower[y]	No. plants	Height (cm)	Days to flower	Chi square[x]
Polaris (P_1)	17	85.8	54(52-59)				
OSC410-1816-1 (P_2)				20	28	51(45-59)	
F_2	27	85.0	55(48-62)	6	31	53(50-54)	.81
$F_1 \times P_2$	3	88.3	56(55-58)	3	30	50(48-54)	0

[x]Expected ratio 3:1 (Polaris-type:OSC410-type) in F_2 and 1:1 in $F_1 \times P_2$.
[y]Mean no. of days to first flower; range of days follows in parentheses.

Table 3. Segregation based on plant type for the parental, F_1 and F_2 population of the cross 'Mexico 80R' (normal) x OSC410-1816-1.

Population	Tall, indeterminate			Mexico 80R-type			OSC410-type			True bush type			Chi square[x]
	No.	Height (cm)	Days to flower[y]	No.	Height (cm)	Days to flower	No.	Height (cm)	Days to flower	No.	Height (cm)	Days to flower	
Mexico 80R (P_1)				19	34	47(45-52)							
OSC410-1816-1 (P_2)							20	28	51(45-59)				
F_1	8	91	47(50-54)										
F_2	93	97	55(48-64)	30	46	56(46-58)	29	28	52(46-60)	17	27	51(45-57)	4.36

[x]Tested against an expected ratio of 9:3:3:1.
[y]Mean number of days to first flower; range of days follows in parentheses.

is dominant to determinate habit (Table 2). 'Polaris' and OSC410 differed greatly in plant height and growth habit, but there was little difference in flowering time.

'Mexico 80R' (normal), a cultivar from Central America, is short in height and has indeterminate inflorescence, red seeds, and light red stems. Its flowering time is intermediate between OSC410 and true bush types. The F_1 plants of 'Mexico 80R' (normal) x OSC410 were indeterminate and taller than either parent, with purple stems and black seeds. In addition to the parental phenotypes, tall indeterminate and short determinate plants were present in the F_2 (Table 3). In this population, height and plant type were controlled by 2 epistatic genes, with indeterminance being dominant. Segregation data from 5 F_2 progenies were pooled and the observed ratios did not differ significantly when tested against a 9:3:3:1 ratio which would be expected if expression resulted from epistatic gene action as suggested by the F_1 phenotypes. There was little variability with respect to flowering time, however, the indeterminate phenotypes appeared to be slightly later. Epistasis also occurred in seed color and stem pigmentation. Neither seed nor plant pigmentation appeared to be closely linked to plant type, since non-parental as well as parental combination of traits were recovered in the F_2 generation.

The results of these studies show that the determinate, sprawling phenotype, exemplified by 'Blue Lake' bush breeding line OSC410, is simply inherited in crosses with true bush cultivars. This contrasts with the inheritance patterns shown for other determinate, sprawling phenotypes that have been studied by the author (unpublished data), and that have been reported in other studies (1,5,7). OSC410 has perhaps been used as a parent elsewhere, but the author was unable to find a description of its behavior when used in other crosses or grown at other locations. The distinct nature of this phenotype was also seen in populations resulting from crosses to both tall and short, indeterminate parents. Determinate, sprawling plants similar to OSC410 were recovered in both, but the pattern of inheritance was dependent upon the other parent.

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