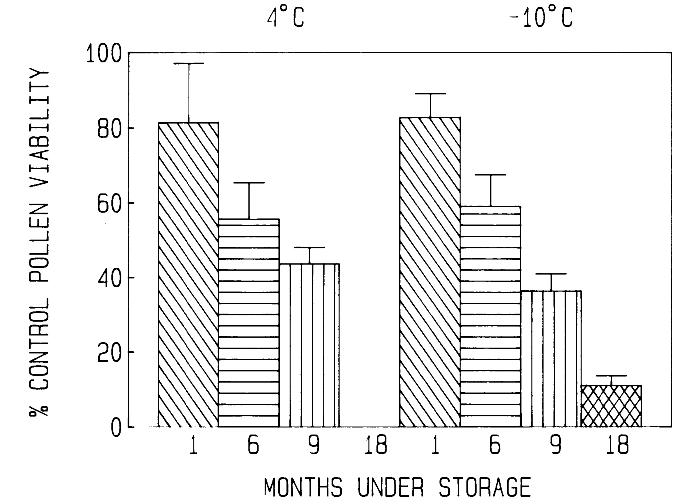

Fig. 4. Viability of celery pollen cv. T.U. 52-70R stored at two temperatures for 18 months expressed as percentage of the control (100% control = 50.9% actual viability). Error bars indicate ± SE.

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Inheritance of Low Temperature Tolerance in Beans at Several Growth Stages

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Additional index words. *Phaseolus vulgaris*, genetics, cold tolerance

Abstract. **Narrow sense heritabilities were 28%, 56%, 45%, and 74%, respectively, imbibition at 5°C and, at 16°, for seedling vigor, plant vigor, and days to bloom in a cross of NY 590 x BBL 92. Cold tolerance at these stages was inherited independently. Pod set at 16° behaved as a recessive, compared to only setting at warmer temperatures. Selections made under 16° generally did very well in an unusually cool season in New York. Double setting was absent in lines that showed set at 16°, and present in many cultivars.**

Beans (*Phaseolus vulgaris* L.) are generally susceptible to low temperature injury at all stages of growth. Temperatures of 10°C or below during imbibition and germination may result in permanent injury and vigor reduction, and prolonged temperatures at or below 15° to 16° can result in stunted plants with no crop.

'Comptesse de Chambord' and 'Widusa' germinate well at 9° to 9.5°C on a germination board, but both lacked vigor at low (10°) growing temperatures (7). Likewise, cultivars such as 'BBL 92' (2) will germinate at low temperatures (8° to 9°) on a germination blotter, but, in soil or greenhouse mix, emerge slowly and have very poor vigor under continued low temperature conditions. Kemp (6) identified bean lines with good leaf growth at 10° (6). NY 5-161 and 'NY 590' (2) germinate at 9.5° to 10° and have good plant vigor at low temperatures.

Although several selection procedures for cold tolerance have been developed (1, 5), they are plant-destructive or not adapted to selection among large numbers of plants. Dickson (2) found that germination of beans at 5°C for 5 days, followed by growth of beans at 16° correlated well with field performance under cool conditions. Farlow et al. (4) observed that low day temperatures reduced seed number per pod due to slow pollen growth. Dickson et al. (3) showed that low night temperatures had less effect on pod set than did low day temperatures.

This paper reports on the use of several screening procedures for evaluating the inheritance of low temperature tolerance in beans at imbibition, seedling and mature vegetative plant growth stages, days to bloom, and at pod set.

Lines NY 590, NY 23, and BBL 92 were used to create two families to study the inheritance of low temperature tolerance during germination, days to bloom, seedling vigor, vegetative vigor, and pod set. Both NY 590 and NY 23 exhibit good low temperature germination (emergence), bloom in 61 days at 16°C and set moderately well under cool nights, although line NY 590 has better seedling vigor than NY 23. Under low temperatures, BBL 92 germinates poorly, exhibits poor seedling vigor, takes 73 days to bloom at 16°, and has poor pod set.

Backcross and F_2 seed were developed from crosses of NY 590 x BBL 92 and NY 23 x BBL 92. The F_2 seed and BC seed were planted in the field and seed harvested on an individual plant basis. The F_3 and BC F_2 lines from individual BC and F_2 plants were planted in late November in 15-cm pots in Cornell mix prewetted and cooled to 5°C in a growth chamber. After 5 days, the pots were moved to a greenhouse at 16° where, from December to March in Geneva, N.Y., it was possible to keep the temperature of the greenhouse at 16° with about ± 1° fluctuation. Good air turbulance resulted in uniform temperatures throughout the greenhouse.

Three pots, each with five seeds from each individual F_2 and BC plant, were planted. The mean performance of the beans in the three pots was used as the value for each F_2 or BC_1 plant. Line means were analyzed rather than the performance of the individual F_2 seed, since the performance of a single seed is unsatisfactory for evaluating factors related to germination. Seedling emergence and vigor were recorded 3 to 4 weeks after planting, and each pot then was thinned to the two most vigorous seedlings. Seedling vigor was rated on a 1 to 5 scale to represent the minimum to maximum expression of the character. Plant vigor was recorded at 60 days after planting when the earliest plants were starting to bloom. The plant height at 60 days was measured; plants <15 cm were rated 1,

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Table 1. Mean cold tolerance performance and standard errors at four plant development stages for the crosses NY 590 x BBL 92 and NY 23 x BBL 92.

Pedigree	Germination	Seedling vigor[z]	Plant vigor[z]	Days to bloom	n[y]
NY 590 x BBL 92 F_2	12.09 ± 0.28	2.22 ± 0.12	2.67 ± 0.10	65.6 ± 0.59	58
(NY 590 x BBL 92) BBL 92 BC_1	13.79 ± 0.15	2.28 ± 0.09	3.01 ± 0.06	64.1 ± 0.14	71
(NY 590 x BBL 92) NY 590 BC_1	12.70 ± 0.51	2.87 ± 0.17	3.51 ± 0.11	61.1 ± 0.77	24
BBL 92	9.85 ± 0.28	1.50 ± 0.08	1.43 ± 0.08	72.7 ± 0.52	18
NY 590	14.40 ± 0.27	3.53 ± 0.13	3.60 ± 0.16	59.9 ± 0.36	15
Heritability (%)					
Narrow	28	56	45	74	
Broad	69	74	57	83	
NY 23 x BBL 92 F_2	4.39 ± 0.13	2.42 ± 0.12	2.92 ± 0.09	67.6 ± 0.70	48
(NY 23 x BBL 92) BBL92	4.41 ± 0.11	2.27 ± 0.18	2.91 ± 0.13	67.5 ± 0.49	55
(NY 23 x BBL 92) NY 23	4.40 ± 0.12	3.06 ± 0.13	3.76 ± 0.10	63.5 ± 0.43	61
BBL 92	0.50 ± 0.21	1.00 ± 0.02	1.43 ± 0.08	72.7 ± 0.30	18
NY 23	3.14 ± 0.23	3.50 ± 0.31	3.48 ± 0.18	61.0 ± 1.12	14
Heritability (%)					
Narrow	22	1>	1>	10	
Broad	11	19	22	60	

[z]Rating scale: 1–5 with 1 = poor and 5 = excellent.
[y]Number of lines tested.

Table 2. Number of lines in pod set classes at 16°C of cross NY 590 x BBL 92 and NY 23 x BBL 92.

Pedigree	Germination		
	Set	Poor set	No set
NY 590 x BBL 92 F_2	10	7	38
(NY 590 x BBL 92) BBL 92 BC_1	16	15	37
(NY 590 x BBL 92) NY 590 BC_1	8	1	11
NY 590	17	1	0
BBL 92	0	0	15
NY 23 x BBL 92 F_2	10	4	31
(NY 23 x BBL 92) BBL 92	11	3	41
(NY 23 x BBL 92) NY 23	27	8	26
NY 23	9	2	3
BBL 92	0	0	15

16 to 20 cm rated 2, 21 to 25 cm rated 3, 26 to 30 cm rated 4, and plants ≥31 cm rated 5. The day of first bloom for each plant also was recorded. About 20 days after initiation of bloom, pod set was recorded. One or more full pods were recorded as "set." A single pod with only one or two seeds was recorded as "poor", and no pods as "no set".

Heritabilities were estimated using backcross and F_2 variance for the narrow sense (NSH) estimates (9) and F_2 and parental variances for broad sense (BSH) estimates (8).

Means and SEs for the cold tolerances at germination, seedling vigor, vegetative plant vigor, and days to bloom are presented in Table 1. For the cross, NY 590 x BBL 92, narrow sense heritability (NSH) estimates were moderately low to high. The environmental variances were large, and considerable genetic variation was detected. The magnitudes of h^2 estimates for the NY 23 x BBL 92 cross were not promising. The BSH estimates were low and the NSH estimates generally negative. However, in both crosses, the mean of the F_3 lines approximated the midparental mean, and the lines from the backcross to the cold-tolerance parent approached the mean of the F_2 and cold-tolerance parent. All results indicate additive effects. Although NY 23 has exhibited cold tolerance compared to most cultivars in this relatively extreme test, its performance was inferior to NY 590, perhaps contributing to the lower or negative NHS values from the NY 23 × BBL 92 cross. Likewise, in subsequent field selections, progenies of crosses with NY 23 as a parent have not exhibited superior cold tolerance, while those with NY 590 have exhibited superior cold tolerance. In both the F_2 and BC populations, the full parental range of cold tolerance was expressed, giving opportunity for selection for cold tolerance.

In general, days to bloom had little or no correlation with plant vigor, seedling vigor, and/or germination. Little or no correlation was found between germination and seedling or immature plant vigor. This lack of association agreed with previous results in New York involving a group of 20 cultivars. Among F_3 lines of the NY590 x BBL 92 cross, the correlation of days to bloom and vigor was high (r = 0.72), and might be expected as the early flowering cold-tolerant lines were generally vigorous. Germination itself is probably less important than seedling vigor at low temperatures, as even BL 92 germinates (Table 1) quite well at low temperatures, but subsequent growth is very poor.

The tendency of a line to set pods at 16°C (Table 2) indicated setting at low temperatures was recessive and quantitative. During the 1985 season, which was the second coolest June of this century in New York State, many commercial cultivars and breeding lines exhibited double set in trials unrelated to these cold-tolerance studies. Progenies of plants that set at 16° in the greenhouse set well in the field in 1985. The capacity to set at low temperatures reduces the chance of double setting due to low temperatures during the bloom period. It is also apparent from previous studies that a low night temperature of 8° does not prevent pod set (2, 4). Most cultivars need a period each day above 16° for pollen tubes to grow sufficiently for fertilization and for subsequent pod development to occur. The need to test for vigorous plant growth and pod set at low temperatures was illustrated clearly by line 336, which exhibited excellent germination and seedling vigor; however, under continuous 16°, this line lacked vegetable plant vigor and set no pods after flowering.

Weather conditions fluctuate widely from year to year in New York field trials. Greenhouse screening and selection for cold tolerance are much more efficient and reliable than field trials, since the greenhouse temperature fluctuations are in the order of ± 1°C during December, January, and February. Remnant seeds of lines that performed well in the greenhouse tests were planted in the field. Most were considerably more vigorous and produced larger plants—flowering earlier and with better germination than the snap bean check cultivars. Some cold-tolerant lines had tender, long, round pods and will be released.

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Effect of Single Plant Selection in Commercial Pea Cultivars on Bloom Dates and on Green Pea Yield for Processing

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Additional index words. Risum sativum, reselection, pureline

Abstract. **Single plant progeny (SPP) lines of peas (*Pisum sativum* L.) selected from the cultivars Early Frosty and Darkskin Perfection were compared for days to bloom, nodes to first flower, and yield. In 1980, SPP lines from within a cultivar deviated significantly in bloom date, nodes to first flower, and yield. One SPP line from each cultivar was compared to the commercial cultivar for yield from 1980 through 1985. The average yield during 5 years for 'Early Frosty' and 'Darkskin Perfection' was 4.07 and 3.72 $t \cdot ha^{-1}$ and 5.86 and 5.80 $t \cdot ha^{-1}$ for their respective SPP lines, equivalent to 44% and 56% yield improvement for the SPP lines. The data obtained from the SPP lines establish that genetic diversity existed within the two cultivars studied. This diversity could be stabilized in SPP lines. With one exception, variation between the SPP lines and/or the cultivar were within the phenotypic descriptions of the original cultivars. The superior yield of the SPP lines selected from 'Early Frosty' and 'Darkskin Perfection' could not be attributed to the selection of an unknown cultivar contaminating 'Early Frosty' and 'Darkskin Perfection'.**

Green peas are a major crop in northwestern Washington, with an average yield of 4.8 $t \cdot ha^{-1}$. Economic return to the grower is determined by the weight of shelled peas/ha and average maturity based on a tenderometer reading. Ideally, all plants within a cultivar should mature simultaneously as the crop is combined in a single destruct harvest. However, variation in plant genotype does occur in commercial cultivars, as demonstrated by the recovery of plants with resistance to *Fusarium oxysporum* f. sp *pisi* Race 6 in a frequency of <2 plants/1000 (4). Also, variation in bloom date, nodes to first bloom, pods per node, and plant height have been observed within commercial cultivars grown in pea cultivar trials near Mount Vernon, Wash. In commercial plantings of 'Early Frosty' and 'Darkskin Perfection', we have observed that variation in plant maturity between individual plants may range from bud to flat pod on the first reproductive node. This variation in maturity may be due to environmental and/or genotypic variation.

In peas, components of yield have been defined as pods per plant, seeds per pod, and average seed weight (1, 3, 6, 9, 12). These yield components are controlled by complex genetic systems (5, 8, 9, 11). The effect of environment on yield and/or yield components has been studied; however, minimal information is available on the effect of genotypic variation within a pea cultivar on yield of shelled green peas.

Commercial cultivars of peas usually are considered to be pure lines, derived from a single plant selection within this self-pollinated species, and the within-cultivar genetic variation will be dependent on the filial generation of the originating single plant. Variations in plant phenotype have been observed by us, and outcrossing has been reported by Loennig (7).

The magnitude of genetic diversity among single plant progeny (SPP) lines within pea cultivars with respect to yield has not been documented. This study was initiated to determine if the variation in plant phenotype observed among SPP lines derived from 'Early Frosty' and 'Darkskin Perfection' was due mainly to environment or genetic differences. We also wanted to determine whether SPP lines could be isolated from commercial cultivars for improved yields of green peas.

Commercial seed lots of 'Early Frosty' and 'Darkskin Perfection' were obtained from the Maffei Seed Co., Newman, Calif., and used as the seed sources. One hundred single plant selections were made from block plantings of each cultivar in 1978. These single plants were selected for uniformity and conformity to the accepted phenotype of each cultivar. Selection was based on a) number of nodes to first pod, b) pods per node, c) plant height, and d) peas per pod. Data on plant habit and productivity on the first three fruiting nodes were used to reduce the number of single plants to 35 for each cultivar. Seeds of the 35 single plants were planted in progeny rows in 1979. Data were recorded from 15 plants in each row for plant height, bloom date, nodes to first pod, pods per node, and peas per pod. Based on progeny row data, four SPP lines of 'Early Frosty' and seven SPP lines of 'Darkskin Perfection' were selected for further testing. Seeds of the SPP lines and commercial cultivars were increased during the winter in Yuma, Arizona, before evaluation in replicated trials.

In both the row trials and block planting, soil pH was maintained at 5.8–6.2 by the addition of agricultural lime. Preplant fertilizer contained K, Mg, and Mn at recommended rates based on soil tests. Weed and insect control programs were based on commercially acceptable practices for western Washington. The experimental design for all of the trials was a randomized block with four replications per treatment.

Row trials conducted in 1979 and 1980 were planted with a cone planter with a row spacing of 1 m. One hundred seeds were planted per row at a seeding rate of 25 seeds/m. Phosphate was applied as liquid monoammonium phosphate and injected 1 to 2 cm below the seed at a rate equivalent to 1 g P/m of row.

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