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

W.A. Haglund[1] and W.C. Anderson[2]
Northwestern Washington Research and Extension Center, Washington State University, Mount Vernon, WA 98273-9788

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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·ha^{-1} and 5.86 and 5.80 t·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·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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[1]Plant Pathologist.
[2]Horticulturist.

Table 1. Mean bloom date and nodes to first flower for 'Early Frosty' and 'Darkskin Perfection and selected SPP lines, data from row trials conducted in 1980.

Selection	Bloom day[z] Mean	SD[x]	Bloom node[y] Mean	SD
Early Frosty	4.0 b[w]	1.9	12.6 b	0.65
SPP 1	5.1 c	1.2	12.8 b	0.44
SPP 2	4.9 c	1.1	12.8 b	0.52
SPP 3	7.9 d	1.6	13.9 c	0.71
SPP 4	2.9 a	1.3	12.1 a	0.61
Darkskin Perfection	7.8 b	1.8	15.2 dc	0.80
SPP 5	4.9 a	1.5	15.0 bc	0.46
SPP 6	5.5 a	1.4	15.0 bc	0.49
SPP 7	4.6 a	1.5	14.7 ab	0.48
SPP 8	6.8 b	2.3	14.8 ab	0.72
SPP 9	4.5 a	1.8	14.6 a	0.60
SPP 10	8.0 c	1.6	15.3 d	0.65

[z]Mean bloom, 50% of plants with open flowers on first node.
[y]Mean node to first bloom, cotylendonary node = 0.
[x]SD = standard deviation of sample mean.
[w]Means separated by Student–Newman–Keuls test, $P = 5\%$.

Table 2. Mean plant population, yield, harvest tenderometer, and sieve size of single plant progeny lines and nonselected cultivars, 1980 block plantings.

Cultivar	Selection	Plant population ($\times 10^6$ ha)	Adjusted yield[z] ($t \cdot ha^{-1}$)	Tenderometer	Sieve[y] size[2]
Early Frosty	Parent	1.09	2.85	101	4.4
	SPP 1	1.13	3.30	94	3.9
	SPP 2	1.08	3.38	95	4.0
	SPP 3	1.10	2.85	89	3.4
	SPP 4	1.12	5.06	96	4.3
Darkskin Perfection	Parent	1.32	3.11	93	4.3
	SPP 5	1.32	4.58	97	4.5
	SPP 6	1.21	4.98	97	4.6
	SPP 7	1.16	5.30	95	4.7
	SPP 8	1.18	3.66	88	4.0
	SPP 9	1.18	5.22	96	3.8
LSD 0.05		0.18	0.79	2.7	
CV		10.20	13.60	1.96	

[z]Yield adjusted to 100 tenderometer.
[y]Average sieve size.

Table 3. Yield comparisons between two single plant progeny lines (SPP 4 and SPP 7) and their nonselected parent cultivars.

Year	Early Frosty Parent cultivar	SPP 4	Yield of parent (%)	Darkskin Perfection Parent cultivar	SPP 7	Yield of parent (%)
1980	2.85	5.06	177	3.11	5.22	168
1981	3.39	5.17	153	2.84	5.41	190
1982	6.87	9.04	132	4.84	7.88	163
1983	1.52	3.44	226	1.59	2.83	178
1985	5.70	6.61	116	6.24	7.66	123
Mean	4.07	5.86	144	3.72	5.80	156
LSD 0.05	1.12	1.12		1.12	1.12	

[z]Adjusted to 100 tenderometer.

Block plantings, conducted in 1980 through 1985, were seeded with an 11-run John Deere grain drill with a row spacing of 18 cm and a plot length of 14 m. The seeding rate was adjusted to obtain a stand of about 1×10^6 plants/ha. Concentrated superphosphate, at a rate equivalent to 1 g/m of row, was applied in the seed furrow at time of planting and border rows of barley were planted to minimize alley effect (2).

Harvest of the block plantings used a side delivery swather and a Food Machinery Corporation (Scott) pea and bean combine. An area 1.6 m wide and 7.5 m long (12.2 m^2) was harvested from the center of each plot. Harvested peas were cleaned with a key sample grader and maturity measured with a FMC tenderometer.

Data from the 1980 row trials included mean bloom date and nodes to first bloom. Four SPP lines of 'Early Frosty' and six SPP lines of 'Darkskin Perfection'were planted together with the original cultivars. Mean bloom date was determined by observing the blooms on 20 plants in each of four replications of each SPP line and commercial cultivar. The 20 plants were selected at the four- to six-node stage of development. Mean bloom occurred when 50% of the test plants were observed to have open flowers. Day 1 was set as the day when the first flower was observed within the cultivar or SPP line selected from the cultivar. Nodes to first flower were determined by starting with the cotyledonary node as node zero.

Table 1 lists the mean bloom date and nodes to first flower for four SPP lines of 'Early Frosty', seven SPP lines of 'Darkskin Perfection', and the two commercial cultivars. Day one was 28 June for 'Early Frosty' and the four SPP lines from 'Early Frosty' and 1 July for 'Darkskin Perfection' and the seven SPP lines selected from 'Darkskin Perfection'. The mean bloom date for 'Early Frosty' was 4.0 days after first bloom of that cultivar or its selections. The mean bloom dates for the SPP lines ranged from 3.0 to 7.9 days after first bloom. First bloom of SPP line 4 occurred significantly earlier and on a lower node than 'Early Frosty'. The deviations of SPP line 3 with respect to bloom date and nodes to first bloom were of a magnitude that would indicate that this selection was a result of contamination of the cultivar or a wide outcross, therefore, it was not considered within the phenotype of 'Early Frosty'.

Mean bloom date for 'Darkskin Perfection' and some of the SPP lines selected from it differed significantly (Table 1). Data on nodes to first flower established that the SPP lines were significantly different from each other as well as from the parent. In most instances, the standard deviation of the mean for both date of bloom and node to first flower was smaller in the SPP lines than the commercial cultivars (Table 1). The obvious exception is SPP line 8, in which the standard deviation for bloom date exceeded that of the commercial cultivar.

The block planting in 1980 included 'Early Frosty', 'Darkskin Perfection', and nine SPP lines. Planting in 1981 through 1985 included the two commercial cultivars and a single SPP line from each cultivar. Data in 1980 included stand, yield, tenderometer, and sieve size; in 1981–85 data included stand, yield, and tenderometer. Yields were adjusted to 100 tenderometer using a yield–tenderometer relation developed from 'Darkskin Perfection' peas grown under northwestern Washington environmental conditions (10). Average sieve size indexes were calculated by obtaining the product of each size number and its percent by weight, then summing the products and dividing by 100. Sieve size represents the maximum size of peas that will pass through round holes having the following diameter (in mm): 1 = 7.15; 2 = 7.94; 3 = 8.73; 4 = 9.53; 5 = 10.32; and 6 = 10.32.

Table 2 lists data from the 1980 block plantings. Variations in plant populations were not significantly different within cultivar groups (Table 2); however, the analysis of variance indicated that the plant population between 'Early Frosty' and 'Darkskin Per-

Table 4.—Analysis of variance for yield of SPP lines and parent cultivars of peas.

Analysis of variance for yield		
Source of variation	df	F
Years	4	101.4 **
Replication × years	15	1.15
Genotypes	3	41.5 **
Early Frosty parent vs. Darkskin Perfection parent	1	1.91
Early Frosty parent vs. SPP 4	1	52.7 **
Darkskin Perfection parent vs. SPP 7	1	70.4 **
Replication × genotype	12	2.62**
Experimental error	45	
Total error	63	

** Significant at the 0.01 probability level.

fection' differed significantly. Yields of shelled peas adjusted to 100 tenderometer for SPP lines and parent cultivars varied significantly. One SPP line of 'Early Frosty' and four SPP lines of 'Darkskin Perfection' were significantly superior in yield to their parents. Sieve size of the SPP lines were equal, and no statistical difference was noted in color or defects in the SPP lines compared to the parents.

In 1981 through 1985, single plant progeny lines 4 and 7 were selected for additional yield tests in block plantings. Mean yields for 1980 through 1985 for SPP 4 and its parent 'Early Frosty' were 5.86 and 4.07 $t{\cdot}ha^{-1}$, respectively. Yields of SPP 4 were significantly greater than for 'Early Frosty' in 4 of the 5 years, and the difference was significant when the data were combined over the 5 years. A similar yield increase was obtained for SPP 7 and its parent 'Darkskin Perfection', with average yields of 5.80 and 3.72 $t{\cdot}ha^{-1}$, respectively (Table 3).

The tenderometer readings differed statistically between cultivar and SPP line, indicating that maturity differences occur between SPP lines from a common parent and between the commercial cultivar and its SPP line. The difference in average sieve size of the harvested peas was not significant within cultivar or SPP lines or between 'Early Frosty' and 'Darkskin Perfection'.

The yield varied among years for both the SPP lines and commercial cultivars; however, the increases in yield of the SPP lines, as compared to their parent cultivars, were consistent within years. The ANOVA for the 1985 comparison of cultivar and SPP line yield is presented in Table 4. The yield differences between 'Early Frosty' and 'Darkskin Perfection' were not significant. However, the increase in yields obtained with the SPP lines as compared to their respective parents were highly significant. These results establish that the yield increase obtained through reselection of two commercial cultivars was stable through five winter seed increases (Fall 1978 through Fall 1982). Also, deviation in plant habit of the SPP lines compared to the commercial cultivars was not sufficient to place the SPP lines outside the phenotype of the cultivar from which the lines were selected.

The yield increase obtained with SPP lines 4 and 7 as compared to their parents over a 6-year period established the yield superiority of the SPP lines (Table 4). Genetic diversity in self-pollinated crops is well known —the diversity is determined by the parents in the original cross and the filial generation in which the single plant selection was made to establish the cultivar. Stability of a cultivar depends on the frequency of mutation and the frequency of outcrossing. In peas, relatively large variations in phenotypes are considered detrimental and periodically a new seed stock is established. This new stock is commonly developed by a) selecting 25 to 100 individual plants for uniformity to cultivar type, b) planting seed in single plant progeny rows, c) observing progeny for uniformity, and d) bulking similar types to form new planting stock. In some instances, cultivars may be planted in such a manner as to allow for efficient roguing of off-type plants. In many instances, small variations in plant phenotype are considered by some plant breeders to be advantageous in maintaining high yields over a wide range of environmental conditions. Pea breeders have stated to us that SPP lines established from their commercial cultivars were visually more uniform in phenotype than the parent cultivar. However, the yields of green peas have not equaled that of the original cultivar. They also indicate that when a SPP line is established, this line may carry a genetic weakness that existed in low frequency in the original cultivar. However, if a SPP line can be selected that carries a genetic weakness that will result in lower yields and quality, then, conversely, a selection should be possible that eliminates a weakness of the parent and enhances yield.

The cool marine climate in northwestern Washington during the summer is helpful in selecting variations in maturity between plants because maturity changes occur at a slower rate than in warm areas. The individual single plants were tested and selected for uniformity of plant habit and maturity. Data from single plant progeny rows confirmed the greater uniformity of plant phenotype within rows compared to variation of plant phenotype among rows.

The yield increase obtained by single plant selection of 'Early Frosty' and 'Darkskin Perfection' cannot be explained by uniformity alone. Two of the SPP lines from 'Early Frosty' with a high degree of uniformity of data bloom and bloom node (SPP 1 and SPP 2) did not outyield the original cultivar. Studies conducted in the past 5 years have yet to establish the factors involved in the yield increase. Further studies are necessary to determine the influence of both maturity among and within individual plants and seedborne diseases on green yield of peas. Yield components and uniformity of maturity must be responsible for the difference in green harvest yields between the SPP lines and the parent cultivars.

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