

Introduction

Dry bean (*Phaseolus vulgaris*) is a common large-scale commodity crop in the U.S. and niche market varieties are gaining in popularity among small-scale growers. Dry beans are well suited to small-scale production because they are relatively easy to produce, harvest and store. In addition, a single dry bean crop can be harvested at several growth stages to produce three distinctly different crops: 1) green beans, 2) fresh shell beans, and 3) dry beans. Harvesting green beans or shell beans from a dry bean crop is a way for a farmer to diversify crop production while maintaining a single crop. While not many bean varieties are suitable for green bean and dry bean production, numerous varieties are suitable for both fresh shell and dry bean production. Fresh shell beans are a high-value niche market crop with wide market acceptability in the U.S., Europe, Africa and Central and South America. Currently, locally produced fresh shell beans are being marketed to restaurants in the Portland area for \$6 per pound. There appears to be insufficient supply to meet the demand for fresh shell beans in the metropolitan regions of the Pacific Northwest and none are offered for sale at local farmers markets or grocery stores.

Growing consumer awareness regarding the health benefit of beans in general will likely increase demand for beans, perhaps especially among those who frequent farmers markets and health food stores. Local farmers require production information in order to meet this market demand. This research study focuses on finding dry bean varieties that are suitable for fresh-shell bean as well as dry bean production in the maritime Pacific Northwest.

Materials and Method

Working with growers who are currently marketing fresh shell beans in the Portland area, we identified characteristics that are currently considered most desirable for fresh shell beans and we identified characteristics that may be desirable for future production. Preferences include large bean size and a correspondingly large pod size, as well as a large number of beans per pod. Currently, white bean color tends to be preferred, due to common European food preferences that use cannellini and flageolet beans for recipes. However, pink colored beans or beans with a color pattern may be desirable as long as the color is pronounced at the fresh shell stage. Based on this information, we identified market classes and varieties that appear to be most suitable for fresh shell bean and dry bean production in our region. We obtained varieties from seed companies and breeding lines from breeders Phil Miklas, ARS Washington, and Jim Kelly, Michigan State University.

We conducted two simultaneous studies at Washington State University Vancouver Research and Extension Unit in 2006. The first study was to evaluate 34 dry bean entries for fresh shell bean production and the second study was to evaluate the same entries for

dry bean production. Both experiments had a randomized complete block design with four replications. Plots were 2 rows wide and 10 feet long, spacing between rows was 2 feet, and spacing in the row was 2 inches.

The field was prepared in May and dry beans were planted on May 15. The field was managed using organic practices. Plots were mechanically cultivated once a week to control weeds between rows until mid July, and hand weeded to control in-row weeds as needed from June through August. Trickle irrigation was applied to the field on a weekly basis or as needed based on precipitation.

In both studies a mix of organic fertilizer 7-7-2 & 12-0-0 was applied at the rate of 17.7 and 4.8 lb N/A, respectively, on June 23. A second organic fertilizer application (13-0-0) was applied at a rate of 32.5 lb N/A on July 11. Total nitrogen applied was 54.8 lb N/A. A cover crop of oats was broadcast at a rate of 70 lbs per acre on July 11 and seed was incorporated with the final field cultivation, which occurred on that date.

In both studies, days after planting (DAP) to 50% emergence, 50% flowering, and harvest were measured. Plant stand was measured in 10 feet of row at harvest. Plant height (cm) was measured at 100% flowering on July 28 for 10 randomly selected plants in each plot, from the base of the plant (soil surface) to the top node.

In the fresh shell bean study, as each entry was mature, 10 plants were harvested from the center of each plot. Pods were ready for fresh shell bean harvest when beans were fully formed and pods were just starting to turn yellow. The total number of pods was counted on each plant. Pods were then removed from the plants, sorted and total marketable yield (g) was measured. 10 pods were chosen at random and length (cm) was measured. Beans were removed from the pods and the total number was recorded. A random sample of 25 beans was selected and length (cm) and width (cm) were measured. 100-bean weight was also measured.

In the dry bean study, as each entry was mature, plants were harvested from the center 5 feet of each plot for a total harvest area of 10 feet per plot. Whole plants were harvested, placed in burlap bags, and dried in field ovens for 16 hours at 68° C, until seed moisture was approximately 12%. Ten pods were randomly selected and pod length (cm) and number of beans per pod were measured. Beans were threshed and cleaned with our small-scale mechanical equipment. Total marketable bean yield (g) was measured and 100 beans were randomly selected and weighed. Length and width (cm) of 25 beans were measured.

Results

Fresh shell bean study. DAP to 50% emergence, 50% flowering and to harvest differed significantly among entries (Table 1). 50% emergence occurred from 18 to 26 DAP and the overall mean was 21 DAP. The two Flageolet entries, Flagrano and Flaro, had slow emergence as both these entries do not germinate well in cool soil conditions. Two entries, Cannellini and White Marrow, did not reach 50% emergence. 50% flowering occurred from 47 to 62 DAP and the overall mean was 53. Plant height (cm) and plant

stand (10 row feet) also differed significantly among entries, and the overall means were 35 and 41, respectively (Table 1). Red Hawk (50 cm) had the largest plant height while French Flageolet Flagrano had the smallest (28 cm). Two entries, Thort and UI-686, had the greatest plant stand (50) while the two entries with poor emergence, Cannellini and White Marrow, had the lowest plant stand. Mean days to harvest was 96 and Matterhorn, PS01-207-2-b3, Red Hawk, Black Calypso and Jacob's Cattle were the earliest to mature (93 DAP) while Cannellini, French Flageolet Flagrano and Flaro were the latest (101-102 DAP).

Entries differed significantly in all yield parameters that were measured in this study (Table 2). The overall mean yield was 720 g (per 10 feet row), and Cannellini, Vermont Cranberry, White Marrow and French Flageolet Flaro were the highest yielding while Supremo, Jacob's Cattle and Black Calypso were the lowest yielding. French Flageolet Flaro and Cannellini had the greatest number of pods per plant while all entries in the Cranberry market class, except for Vermont Cranberry, had the lowest. Mean pod length was 11.4 cm and Supremo (14.5) had the greatest pod length while Black Calypso (9.9) had the lowest. The overall mean number of beans per pod was 4.3 cm and Belneb-RR-1 and White Marrow had the largest number of beans per pod (5.3) while entries in the White Kidney market class tended to have the lowest. Overall mean 100-bean weight was 94.6 g and PS01-207-2-B3, Tongue of Fire and PS01-203-2-B3 (all Cranberry types) had the largest 100-bean weight while both Flageolet entries had the smallest. Overall mean bean length and width were 1.7 cm and 1.0 cm respectively. Supremo had the largest bean width and length while both Flageolet entries had the smallest.

Dry bean study. DAP to 50% emergence, 50% flowering and to harvest differed significantly among entries (Table 3). 50% emergence occurred from 19 to 35 DAP and the overall mean was 22 DAP. Just as in the fresh shell bean trial, the two Flageolet entries, Flagrano and Flaro, had slow emergence and Cannellini and White Marrow did not reach 50% emergence. Cannellini did not emerge well in all plots and so was dropped from data analysis. For all other entries, 50% flowering occurred from 47 to 62 DAP and the overall mean was 53 DAP and Capri was the first to reach 50% flowering while Orion, UI-686 and White Marrow were the latest. Mean days to harvest was 113 and PS01-203-3-B3 and Roma II were the earliest (109-110 DAP) while USWK-CBB-16, Vermont Cranberry, Supremo, and White Marrow were the latest (116 DAP). Plant height (cm) also differed significantly among entries, and the overall mean was 30 cm (Table 3). ABL 6 (40 cm) had the largest plant height while PS01-203-3-B3 had the smallest (22 cm). Mean plant stand at harvest differed significantly among entries and was 44 per 10 feet row (Table 3). Thort and PS01-207-B3 had the greatest plant stand (59 and 58 respectively) while the two entries with poor emergence, White Marrow and Flaro, had the lowest (15 and 24, respectively).

All yield parameters measured in this study differed significantly (Table 4). Mean yield for 10-foot row was 535g and the highest yielding entries were all Great Northern type, USGN-5(842.8), Matterhorn (811.9) and ABL 6 (810.9). The lowest yielding entries were Red Coat Soldier (276.3), Jacob's Cattle (315.7) and Tongue of Fire (352.4). Overall mean pod length was 12 cm and entries with the longest pods were Supremo

(15.9), Vermont Cranberry (13.4) and Montcalm (13.5). Entries with the shortest pod length were Matterhorn, Orion and Marrow Fat (10.9). The overall mean number of beans per pod was 4.7 and Belneb, French Flageolet-Flagrano and Marrow Fat had the largest number of beans per pod (5.9, 5.7 and 5.6, respectively) while Red Coat Soldier and Soldier had the lowest (3.7). Mean weight of 100 beans was 49 g. Entries with the greatest 100-bean-weight were Supremo (70.5), PS01-207-2-B3 (65.3) and Tongue of Fire (62.3) while both Flageolet entries had the smallest (23.5 and 26.6). Mean bean length was 1.4 cm and width was 0.8 cm. Supremo and Montcalm had the greatest bean length (1.7) while Beryl, Great Northern and French Flageolet-Flaro had the shortest (1.1). Mean bean width was 0.8 cm and USCR-14 and Supremo had the greatest bean width (1.0) while the two Flageolet entries had the smallest (0.6).

Discussion and Conclusions

For fresh shell bean production, Cannellini and Flageolet are preferred bean types and in this study both were high yielding due to a high number of pods per plant. However bean size (100 bean weight, bean length, bean width) was significantly smaller than the mean in this study, which is not desirable. In addition, both tend to be sensitive to cold soils and in this study germination and plant stand establishment were significantly reduced due to this issue. The Cranberry market class is also commonly used for fresh shell bean production and PS01-207-2-B3, Tongue of Fire and PS01-203-2-B3 had the largest 100-bean weight. However, except for Vermont Cranberry, yields of all Cranberry entries tended to be below the overall mean. Supremo produced the greatest pod length and the largest beans, both desirable characteristics for fresh shell beans, but yield was very low due to an extremely low number of pods per plant. White Marrow had the largest number of beans per pod, a large bean size, and was very high yielding, all desirable characteristics for fresh shell beans, however emergence was low due to cool soil conditions. These results indicate that many varieties have several of the desired characteristics for fresh shell bean production.

Another finding in this study was that entries with the poorest plant stand, Cannellini, French Flageolet Flaro and White Marrow, were also among the highest yielding, due to the high number of pods per plant. This suggests that optimum plant stand should be further investigated as this impacts not only yield but planting costs as seed of these varieties tends to be more expensive as it is not easy to find in large quantities.

Table 1. Days after planting (DAP) to 50% emergence, 50% flowering, and harvest, plant height mid season (cm), and plant stand at harvest in the fresh shell bean study at WSU Vancouver REU in 2006.

Entry	DAP to 50% Emergence	DAP to 50% Flowering	DAP to Harvest	Plant Height (cm)	Plant Stand
Great Northern					
ABL 6	21	57	94	37	40
Beryl	21	57	97	32	40
Belneb-RR-1	26	59	100	32	30
Great Northern	22	56	100	37	46
Matterhorn	22	60	93	37	44
Orion	22	60	95	38	42
PS01-145-4-2-B2	20	56	97	42	48
USGN-5	20	62	98	40	42
White kidney					
Beluga	20	53	98	38	39
Cannellini	No 50%	52	101	31	22
USWK-CBB-16	20	53	99	39	39
Cranberry					
95-8186C	19	52	95	36	45
Capri (old Coral)	19	49	94	32	48
Cardinal	21	49	94	30	37
PS01-203-3-B3	18	47	94	33	48
PS01-207-2-B3	19	47	93	30	44
Thort	19	56	95	31	50
Tongue of Fire	20	50	95	36	46
UI-686	20	61	96	33	50
USCR-14	19	47	94	30	45
USCR-15	19	50	96	41	44
Vermont Cranberry	26	51	98	31	30
Supremo	19	48	94	33	48
Soldier					
Red Coat Soldier	21	51	98	34	41
Soldier	21	51	95	38	34
Dark Red Kidney					
Montcalm	19	51	94	39	41
Red Hawk	19	50	93	50	47
Flageolet					
French Flageolet- Flagrano	28	52	102	28	33
French Flageolet-Flaro	27	55	102	31	29
Others					
Black Calypso	22	49	93	22	41
Jacob's Cattle	19	47	93	30	37
Marrow Fat	21	56	96	45	43
Roma II	20	50	94	36	39
White Marrow	No 50%	62	99	33	23
Mean	21	53	96	35	41
p-value	0.0000	0.0000	0.0000	0.0169	0.0026

Table 2. Total yield (g), number of pods per plant, pod length (cm), number of beans per pod, weight of 100 beans (g), bean length and width (cm), in the fresh shell bean study at WSU Vancouver REU in 2006.

Entry	Total Yield (g)	Pods per Plant	Pod Length (cm)	Beans per Pod	100 Bean Weight (g)	Bean Length (cm)	Bean Width (cm)
Great Northern							
ABL 6	727	10	11.4	4.2	85.0	1.7	1.0
Beryl	592	14	10.1	4.7	65.8	1.4	0.9
Belneb-RR-1	1090	21	10.4	5.3	72.0	1.6	1.0
Great Northern	832	15	11.4	5.0	63.5	1.5	0.9
Matterhorn	684	12	10.2	5.0	77.3	1.6	1.0
Orion	536	12	10.4	4.6	70.3	1.6	1.0
PS01-145-4-2-B2	667	10	10.3	4.7	85.3	1.6	1.0
USGN-5	676	11	10.9	4.6	76.5	1.7	1.0
White kidney							
Beluga	560	10	10.8	3.0	100.5	1.8	1.0
Cannellini	1805	28	11.9	3.8	87.5	2.1	1.0
USWK-CBB-16	699	12	10.3	3.0	86.0	1.7	0.9
Cranberry							
95-8186C	629	7	11.2	4.4	113.8	1.8	1.1
Capri (old Coral)	548	6	12.1	4.2	121.5	1.8	1.2
Cardinal	687	8	11.1	4.4	117.8	1.8	1.2
PS01-203-3-B3	695	8	12.4	4.3	129.0	2.0	1.2
PS01-207-2-B3	505	6	11.5	4.4	131.8	1.8	1.2
Thort	507	7	10.9	3.9	102.0	1.7	1.1
Tongue of Fire	777	8	12.1	3.6	129.5	1.8	1.2
UI-686	716	7	11.8	4.6	112.5	1.7	1.2
USCR-14	447	8	11.9	4.7	99.0	1.8	1.1
USCR-15	709	9	11.4	3.6	120.0	1.8	1.1
Vermont Cranberry	1393	17	11.9	4.8	88.5	1.6	1.1
Supremo	337	3	14.5	3.7	128.5	2.2	1.3
Soldier							
Red Coat Soldier	729	10	11.6	3.3	91.3	1.9	1.1
Soldier	672	9	12.7	3.5	115.8	2.1	1.1
Dark Red Kidney							
Montcalm	682	8	11.9	3.8	92.0	2.0	1.1
Red Hawk	478	7	11.8	4.8	91.0	1.9	1.1
Flageolet							
French Flageolet- Flagrano	881	21	10.9	5.2	45.3	1.5	0.7
French Flageolet-Flaro	1138	30	11.3	5.1	50.8	1.6	0.8
Others							
Black Calypso	356	7	9.9	3.3	87.0	1.6	1.1
Jacob's Cattle	354	6	12.6	5.1	117.0	2.1	1.1
Marrow Fat	795	13	10.6	4.2	78.3	1.5	0.8
Roma II	816	10	12.3	4.2	84.0	1.7	1.0
White Marrow	1307	16	12.1	5.3	98.8	1.6	1.1
Mean	720	11	11.4	4.3	94.6	1.7	1.0
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 3. Days after planting (DAP) to 50% emergence, 50% flowering, and harvest, plant height mid season (cm), and plant stand at harvest in the dry bean study at WSU Vancouver REU in 2006.

Entry	DAP to 50% Emergence	DAP to 50% Flowering	DAP to Harvest	Plant Height (cm)	Plant Stand
Great Northern					
ABL 6	21	56	114	40	44
Beryl	21	56	114	27	53
Belneb-RR-1	25	61	115	27	31
Great Northern	23	58	112	30	41
Matterhorn	22	60	115	39	52
Orion	21	62	113	34	51
PS01-145-4-2-B2	22	56	112	36	46
USGN-5	22	61	114	36	55
White kidney					
Beluga	20	53	114	30	47
Cannellini				19	
USWK-CBB-16	21	54	116	34	55
Cranberry					
95-8186C	19	52	111	30	50
Capri (old Coral)	19	47	113	24	48
Cardinal	22	48	113	26	33
PS01-203-3-B3	20	48	109	22	57
PS01-207-2-B3	19	48	112	26	58
Thort	19	56	111	29	59
Tongue of Fire	20	60	112	26	42
UI-686	21	62	112	34	52
USCR-14	19	48	111	25	46
USCR-15	19	51	111	39	42
Vermont Cranberry	28	52	116	25	29
Supremo	20	48	116	31	56
Soldier					
Red Coat Soldier	24	53	112	28	34
Soldier	22	50	112	33	44
Dark Red Kidney					
Montcalm	20	51	112	34	47
Red Hawk	19	51	111	32	55
Flageolet					
French Flageolet- Flagrano	26	52	114	29	28
French Flageolet-Flaro	35	55	115	28	24
Others					
Black Calypso	21	48	115	25	48
Jacob's Cattle	22	48	111	24	42
Marrow Fat	24	58	112	37	35
Roma II	24	51	110	25	33
White Marrow	No 50%	62	116	33	15
Mean	22	53	113	30	44
p-value	0.0000	0.0000	0.0185	0.0000	0.0000

Table 4. Total yield (g), pod length (cm), number of beans per pod, weight of 100 beans (g), bean length and width (cm), in the dry bean study at WSU Vancouver REU in 2006.

Entry	Total Yield (g)	Pod Length (cm)	Beans per Pod	100 Bean Weight. (g)	Bean Length. (cm)	Bean Width. (cm)
Great Northern						
ABL 6	811	12.5	5.0	44.8	1.3	0.8
Beryl	653	11.0	5.2	31.2	1.1	0.7
Belneb-RR-1	660	11.3	5.9	37.1	1.2	0.7
Great Northern	562	12.2	5.5	33.0	1.1	0.7
Matterhorn	812	10.9	5.5	36.6	1.2	0.8
Orion	720	10.9	5.2	38.0	1.2	0.8
PS01-145-4-2-B2	636	11.3	5.1	44.3	1.2	0.8
USGN-5	843	11.5	4.7	41.1	1.3	0.8
White kidney						
Beluga	554	11.5	3.8	52.2	1.5	0.8
Cannellini						
USWK-CBB-16	680	11.2	3.9	46.3	1.4	0.7
Cranberry						
95-8186C	605	11.3	4.3	56.5	1.4	0.9
Capri (old Coral)	477	12.0	4.3	57.9	1.4	0.9
Cardinal	502	11.2	4.7	59.0	1.4	0.9
PS01-203-3-B3	404	12.2	4.5	59.0	1.5	0.9
PS01-207-2-B3	419	11.3	4.2	65.3	1.5	0.9
Thort	469	11.2	4.5	52.5	1.2	0.9
Tongue of Fire	352	12.1	4.8	62.3	1.4	0.9
UI-686	648	11.9	4.4	61.2	1.3	0.9
USCR-14	363	12.4	4.4	53.8	1.4	1.0
USCR-15	631	12.7	4.6	63.8	1.5	0.9
Vermont Cranberry	475	13.4	5.2	43.2	1.3	0.8
Supremo	473	15.9	4.7	70.5	1.7	1.0
Soldier						
Red Coat Soldier	276	11.7	3.7	47.5	1.6	0.7
Soldier	499	12.2	3.7	61.1	1.6	0.8
Dark Red Kidney						
Montcalm	408	13.5	4.0	52.5	1.7	0.8
Red Hawk	461	12.1	4.2	47.6	1.5	0.8
Flageolet						
French Flageolet- Flagrano	507	12.1	5.7	23.5	1.2	0.6
French Flageolet-Flaro	585	11.9	5.4	26.6	1.1	0.6
Others						
Black Calypso	433	11.0	4.0	54.1	1.2	0.9
Jacob's Cattle	316	13.2	4.3	59.3	1.6	0.8
Marrow Fat	586	10.9	5.6	37.8	1.2	0.8
Roma II	371	12.4	5.5	45.2	1.2	0.7
White Marrow	532	11.9	5.5	55.1	1.2	0.9
Mean	535	12.0	4.7	49.1	1.4	0.8
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000