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Determining Optimum Maturity of Bush Romano Beans for Machine Harvest

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SUMMARY. Several pod characteristics were evaluated to select methods for determining optimum maturity for mechanical harvest of flat podded 'Roma II' beans (*Phaseolus vulgaris* L.). The test was conducted over a 3-year period (1993-1995) at Crossville, Tenn. A total length of 3.6 to 4.4 inches (90 to 112 mm) for the center seed from each of 10 of the more mature pods was a rather reliable and rapid field guide for determining optimum maturity for mechanical harvest of 'Roma II' bush beans.

Production of flat podded 'Roma II' bush snap beans for processing and in home gardens has increased in the past 15 years. Due to their desirable flavor, interest has developed in Tennessee for marketing hydrocooled 'Roma II' pods on the fresh market. The flat pods of 'Roma II' do not fit the standard sieve size distribution method used to determine mechanical harvest maturity of round podded bush snap beans. Other methods for rapidly determining harvest maturity in the field must be used for pods of 'Roma II'.

Bloom development and pod set of bush green beans occurs over two to three weeks and pod sizes vary considerably at optimum maturity for machine harvest (Gonzalez et al., 1989). Round pods increase in diameter with maturity, although cultivars vary in the rate of increase and in maximum pod diameter attained (Robinson et al., 1964). Harvest maturity is usually based on the percentage of pods of no. 2 to no. 4 sieve size which are 14.5 / 64 to 23.9 / 64 inches (5.8 to 9.5 mm) in diameter, and distribution usually varies from 50% to ≈100% in this size range (Rutledge, 1991). Pod length of most cultivars increases as pods mature, although some cultivars such as 'Eagle' develop long pods at a rather small diameter (Gonzalez, et al. 1989).

Snap bean pods increase in fiber, seed content, and dry weight as they mature (Guyer and Kramer, 1950; Robinson et al., 1964; Ross, et al., 1956; Silbernagel and Drake, 1978). A seed index, the product of pod seed length by pod seed weight, was suggested as an indicator of snap bean pod maturity for medium and large sieved cultivars (Silbernagel and Drake, 1978). They found that the length of seeds in pods was also a reliable indicator of snap bean pod maturity, although optimum seed length varied among cultivars.

Heat unit calculations using several methods have been inconsistent for determining harvest maturity of various crops including snap beans (Daningsih, 1991; Perry et al., 1986; Dufault et al., 1989). Cumulative days from planting to harvest were as reliable as heat units in predicting harvest date (Daningsih, 1991). Soil moisture conditions appear to affect maturity, a factor that has apparently not been incorporated into heat unit formulas. Length of the growing season for snap beans varies with environmental conditions (Wallace and Enriquez, 1980). More days are required for crops grown in the cooler spring or fall seasons as compared to midseason when temperatures are higher. Producers plan for these maturity differences and schedule snap bean plantings accordingly.

A study was conducted from 1993 through 1995 at The University of Tennessee Plateau Experiment Station at Crossville, Tenn. to measure changes in pod quality characteristics and yields as 'Roma II' bush beans matured. The objective was to select reliable and rapid pod measurements for field use in determining when to harvest mechanically for maximum yields and optimum pod quality.

Materials and methods

'Roma II' beans were produced using standard commercial production techniques for Tennessee. Plots consisted of two rows, each 20 ft (6.1 m) long and spaced 38 inches (97 cm) apart. Experimental plot design in all plantings was a randomized complete block with four replications. Planting dates were 10 May (planting 1) and 9 June 1993 (planting 2), 18 May 1994 (planting 3), and 9 June 1995 (planting 4). A harvest date that was obviously before optimum maturity was selected for the first harvest, and mechanical harvests were made afterward at 2-d intervals until yields peaked and declined. Plots were harvested using a two-row mechanical harvester (Chisholm Ryder, Niagara Falls, N.Y.). Harvest dates were 3, 5, 7, and 9 July 1993 (planting 1); 30 July and 1 and 3 Aug. 1993 (planting 2); 11, 13, 15, 17, 19, 21 July 1994 (planting 3); and 27, 29, and 31 July and 2 and 4 Aug. 1995 (planting 4).

Yields were recorded from each plot at each harvest date. Ten of the most mature pods were selected from

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the harvested pods from each plot, and the center seed was removed from these pods. The total length of the 10 seeds was measured. A 3.5 oz (100 g) sample of the most mature pods was oven dried at 153 °F (67 °C) for 48 h, and the percentage dry weight was calculated. Pod firmness was determined with a texture press, model TG4C (Food Technology Corporation, Rockville, Md.). The press was set to shear through a 3 oz (85 g) sample of the most mature pods in 30 s at 300 lb / in^2 (21.1 kg·cm^{-2}).

Days from planting to harvest were counted, and heat degree days were calculated using a 50 °F (10 °C) base for each harvest date. A trimiscus colorimeter (Hunter Associates Laboratory, Reston, Va.) was used to determine pod color values for "L" (darkness), "a" (green) and "b" (yellow). Pod length, width, and thickness were measured for 10 of the more mature pods.

A 2.2 lb (1 kg) sample of the harvested product was selected from each plot. Cluster counts were made; and trash, broken pods, and pods with rhizoctonia tip rot (*Rhizoctonia solani* Kuhn.) were removed from each sample. A cluster was considered as any piece of plant stem over 1 inch long attached to a pod or two or more pods attached by a plant stem. Trash included bean leaves, bean stems, weeds, and soil (anything other than bean pods). Broken pods had any part missing other than stem or snip end. Small pods of no. 1 sieve size or a diameter of 14.5 / 64 inches (5.8 mm) and smaller were removed. Marketable yield consisted of pods remaining after clusters, trash, broken pods, rotten pods, and small pods were removed from the sample.

All data were analyzed by analysis of variance methods, and means of significant dependent variables (P = 0.05) were separated by Duncan's multiple range tests. Correlation analysis was used to calculate r values (Pearson correlation coefficients), as well as the level of probability for each correlation among the factors studied.

Results and discussion

Yields peaked and declined between the first and last harvests in plantings 2 and 3 (Table 1). The same tendency occurred in planting 1, although differences were not significant. Yields reacted differently in planting 4 as yields tended to increase after pod quality had peaked and started to deteriorate. Days from planting to harvest and heat units were not reliable indicators of harvest maturity (Table 1). Results were very similar to previous trials with snap beans and other crops (Daningsih, 1991; Dufault et al., 1989).

Environmental conditions had considerable effect on yields and other characteristics measured in the trial. Rainfall from planting to final harvest date was 4.7 inches (11.9 cm) for planting 1 (1993), 4.1 inches (10.4 cm) for planting 2 (1993), 11.2 inches (28.4 cm) for planting 3 (1994), and 5.6 inches (14.2 cm) for planting 4 (1995). Plantings 1 and 2 in 1993 were grown in relatively dry and hot conditions. Pods tended to develop larger seed more rapidly, and pod tip rot was not observed under the hot dry conditions. Snap beans tend to produce short rough pods with large seeds when stressed. Stress also increases the fiber content of snap bean pods (Kady, 1966).

Total and marketable yields of 'Roma II' beans increased to a point and then decreased, and dry weight increased as pods became mature in these trials. In Arkansas trials (Gonzalez et al., 1989), round podded snap bean cultivars varied from a slight yield decrease with one cultivar to a moderate or large yield increase for nine other cultivars as harvest of adjacent plots was delayed by 3 d. Most cultivars

Table 1. Effect of harvest date on snap bean yieldsand pod characteristics, 1993–95.

Harvest date	Growing days	Heat units[z]	Total yield (lb/acre)[y]	Mkt. yield (lb/acre)[y]	Unmkt. yield (%)	Pod length (inches)[y]	Pod width (inches)[y]	Seed length (inches)[x]	Dry weight (%)	Pod firmness (lb)[x]
Planting 1 (1993)										
3 July	54	1017	6010 a[w]	5460 a	8.9 a	4.7 c	0.75 a	1.9 d	9.0 c	844 b
5 July	56	1042	7000 a	6350 a	9.4 a	5.0 ab	0.66 b	3.0 c	10.3 c	902 b
7 July	58	1095	6700 a	5950 a	11.8 a	4.8 bc	0.70 b	3.6 b	14.1 b	1060 a
9 July	60	1150	6140 a	5620 a	8.8 a	5.0 a	0.69 b	4.4 a	15.8 a	1062 a
Planting 2 (1993)										
30 July	51	1510	3750 a	3080 a	18.4 a	4.2 a	0.65 a	3.8 c	14.6 b	1246 c
1 Aug.	53	1553	3870 a	3370 a	12.8 b	4.4 a	0.66 a	4.3 b	17.3 a	1345 b
3 Aug.	55	1605	3380 b	3060 a	9.3 b	4.3 a	0.67 a	4.6 a	17.2 a	1465 a
Planting 3 (1994)										
11 July	54	1061	6180 d	4770 d	22.6 b	4.8 d	0.67 a	2.8 d	8.5 c	1092 b
13 July	58	1155	8250 b	6000 b	28.1 ab	5.0 bcd	0.70 a	3.7 c	9.5 c	1057 b
17 July	60	1204	8530 b	6150 ab	28.0 ab	5.1 ab	0.70 a	3.9 bc	9.8 c	1047 b
19 July	62	1251	9950 a	6810 a	31.9 a	5.2 a	0.70 a	4.4 ab	11.3 b	1190 a
21 July	64	1299	6470 cd	4840 cd	25.0 b	5.1 abc	0.71 a	5.0 a	13.7 a	1163 a
Planting 4 (1995)										
27 July	48	1099	6080 a	5330 a	12.5 a	4.4 c	0.63 c	2.4 e	9.4 d	1074 b
29 July	50	1147	7360 a	6390 a	12.8 a	4.8 b	0.68 b	2.9 d	9.6 d	1056 b
31 July	52	1203	6330 a	5630 a	11.0 a	4.8 b	0.69 b	3.5 c	11.6 c	1144 b
2 Aug.	54	1254	7880 a	6260 a	21.0 a	5.3 a	0.70 a	4.4 b	13.5 b	1134 b
4 Aug.	56	1309	7930 a	6170 a	22.7 a	5.3 a	0.70 a	5.3 a	16.8 a	1291 a

[z]Heat units or cumulative growing degree days above 50 °F (10 °C) base: $\sum$[(maximum temp + minimum temp) / 2]–50.
[y]1 lb / acre = 0.89 kg·ha^{-1}, 1 inch = 2.54 cm, and 1 lb = 0.45 kg.
[x]Length of 10 seeds taken from 10 of the most mature pods.
[w]Means within columns within plantings not followed by a common letter are significantly different (P = 0.05) using Duncan's multiple range test.

evaluated in the Arkansas trials were tender podded large sieved processing types.

In the first and last plantings, no significant differences in unmarketable yield were observed among harvest dates (Table 1). Although significant differences were noted in plantings 2 and 3, no discernible trend could be identified. Components comprising unmarketable yield (clusters per pound of pods, percentage trash, and percentage broken pods) varied with planting, but were not different due to harvest date (data not shown). Pod detachment of snap beans during machine harvest was found to vary with cultivar and pod maturity (Bledsoe and Swingle, 1972). The other component comprising unmarketable yield, percentage of rotten pods caused by *Rhizoctonia* (data not shown), increased as harvest date was delayed in plantings 3 and 4. Pod rot can be a severe problem in high rainfall or humidity conditions, and if more than 5% of the pods are damaged, commercial fields may not be harvested in Tennessee. Sometimes, pods are harvested before optimum maturity to avoid excessive pod rot.

Pod length and width (Table 1) increased in the plantings as harvest was delayed. Pod length was a good indicator of pod maturity within each planting. However, the variability among plantings was very high, and pod length was not a consistently reliable indicator of pod maturity. Pod length was much shorter under the hot dry conditions of plantings 1 and 2. Pods of most small-sieve-type snap bean cultivars remain small, but develop larger seeds, as well as and more fiber and dry weight as they mature. In 1988 Arkansas trials with 10 round podded snap bean cultivars, pod length ranged from 4.6 to 5.7 inches (11.7 to 14.5 cm) for no. 4 sieve size pods and 4.8 to 5.8 inches (12.2 to 14.7 cm) for no. 5 sieve pods (Gonzalez et al., 1989). In those trials, some cultivars were the same length at the no. 4 and no. 5 sieve sizes, while others were 0.7 inches (1.8 cm) longer at the larger sieve size.

A total seed length of 3.6 to 4.4 inches (90 to 112 mm) for 10 center seeds selected from the more mature pods appeared to be a rather reliable field indicator of harvest maturity of 'Roma II' bush beans. Under the severe drought stress of planting 2 in 1993, seed length was less reliable as an indicator of harvest maturity. Pod firmness readings were higher than desired before maximum yields were attained, and before the pods appeared to be mature. Also, seeds in the pods were relatively large at the first harvest date. A Tennessee Agricultural Extension Service publication from the 1940s (Bonser et al., 1945) recommends hand harvest of bush snap bean pods when the seed is the size of a wheat grain. More recently, a commercial seed company has recommended seed length as a guide for harvest maturity with variable seed lengths for different cultivars.

Dry weight and pod firmness increased as harvest was delayed (Table 1). Dry weight increased as harvest date was delayed, varied considerably with planting, and was not a reliable index of harvest maturity. Firmness is an indicator of toughness of the pods (fiber development) and is one of the most important pod quality factors as tough cooked pods are easily detected and are an undesirable characteristic. The machine used to measure firmness is expensive and is not easily portable for field use. Previous observations at the Plateau Experiment Station have indicated that snap bean pods with firmness readings over 1200 lb (544 kg) force usually have a toughness that is detectable and undesirable in cooked pods. Readings for fresh market type cultivars are usually in the 1000 to 1200 lb (454 to 544 kg) force range. Processing-type cultivars usually have firmness readings of 800 to 1000 lb (363 to 454 kg) force for pods of optimum maturity. Snap bean cultivars vary widely in pod firmness as some cultivars develop fiber rapidly, while others are slow to develop fiber. However, larger pods usually contain the highest fiber content (Gonzalez, et al., 1989).

The Hunter color meter "L" value varied little with harvest date (data not shown). The "a" color value was very inconsistent with harvest date. The "b" color value tended to increase slightly as harvest was delayed, indicating that pods were developing more yellow pigment. In general, 'Roma II' pods have exhibited less green and more yellow pigment than most round podded bush snap beans in previous Tennessee trials.

Pearson Correlation coefficients (r values) and level of probability of the various factors evaluated compared to yield, marketable yield, firmness and dry weight are presented in Table 2. Days from planting to harvest was positively correlated to yield and marketable yield. Pod length was positively correlated with yield and marketable yield. Pod length seemed to be a good indicator of maturity as pods increased in size as maturity increased. However, differences among plantings due to environmental conditions negated the possibility of using pod length to determine harvest maturity.

Pod width was positively correlated to yield and negatively correlated to firmness. Seed length was positively

Table 2. Correlations of yield and quality parameters with easily measurable field indices and laboratory indices of maturity, 1993–95.

	r ($P > r$)							
Parameter	Days	Pod length	Pod width	Seed length	Dry wt	Pod firmness	Pod thickness	Small pods
Yield	0.51	0.44	0.44	–0.11	–0.09	–0.61	–0.28	–0.41
	(0.0001)	*(0.0005)*	*(0.0005)*	*(0.4296)*	*(0.4902)*	*(0.0001)*	*(0.0318)*	*(0.0013)*
Marketable yield	0.34	0.34	0.21	–0.05	–0.25	–0.33	0.16	–1.00
	(0.0094)	*(0.0086)*	*(0.1145)*	*(0.7232)*	*(0.0608)*	*(0.0110)*	*(0.2417)*	*(0.0001)*
Dry weight	0.03	–0.14	–0.08	0.66	---	0.60	–0.30	0.25
	(0.8448)	*(0.3096)*	*(0.5549)*	*(0.0001)*	*(---)*	*(0.0001)*	*(0.0225)*	*(0.0608)*
Pod firmness	–0.08	–0.16	–0.32	0.62	0.60	---	0.21	0.33
	(0.5415)	*(0.2218)*	*(0.0160)*	*(0.0001)*	*(0.0001)*	*(---)*	*(0.1208)*	*(0.0110)*

correlated to firmness and dry weight which are important maturity characteristics. Tough fibrous pods are undesirable and harvest must occur before pods become too tough for desirable culinary characteristics. Seed length was related closely to pod firmness (fiber), and appeared to be a useful indicator of maturity based on relationship to pod quality and was one of the most easily measured and reliable field indicators of harvest maturity. Dry weight was positively correlated to pod firmness. Pod firmness was negatively correlated to yield, marketable yield, and dry weight. Pod firmness and dry weight are excellent indicators of pod quality, but are time consuming and not easily measured under field conditions. Portable penetrometers are available for field usage in measuring firmness of fruits and of soils, but a reliable penetrometer for rapidly measuring firmness of snap bean pods has not been identified. There is a potential for such equipment, as firmness is a major factor in snap bean pod maturity. Pods must be harvested before they become tough and develop poor culinary acceptance, sometimes at the sacrifice of maximum yield. Pod thickness was negatively correlated to yield and dry weight.

Small pods (no. 1 sieve and smaller) were negatively correlated to yield, marketable yield, and firmness (Table 2). A distribution of small pods in the 2% to 3% range appeared to be a rather reliable indicator of harvest maturity. Pods are set over a rather long period, and bush beans are better adapted to multiple than to once over harvest. Due to labor requirements, however, once over mechanical harvest is utilized for essentially all bush beans grown commercially in Tennessee. Completion or near completion of blooming has been used as one of our criteria for determining harvest maturity, and we have often considered that the percentage of small pods could be as useful as the percentage of large pods in determining mechanical harvest maturity.

Conclusion

This study indicated that a seed length of 3.6 to 4.4 inches (90 to 112 mm) for total length of the center seed selected from 10 of the most mature pods is a rapid and reliable indicator of pod quality and can be used as a field guide for determining mechanical harvest maturity of flat podded 'Roma II' bush beans. Harvest should occur when a total seed length of 3.6 to 4.4 inches (90 to 112 mm) of the center seed selected from 10 of the most mature pods is attained.

Literature cited

Bledsoe, B.L. and H.D. Swingle. 1972. Detachment properties of snap beans. Trans. Amer. Soc. Agr. Eng. 15:1174–1178.

Bonser, W.J., E.B. Fickel, and C.E. Allred. 1945. Costs, returns, and practices in growing snap beans, Johnson County, Tennessee, 1942. Univ. Tenn. Rural Res. Ser. Monogr. 182.

Daningsih, E. 1991. A phenological study of snap bean (*Phaseolus vulgaris* L.) for predicting harvest. MS thesis. Univ. Tenn., Knoxville.

Dufault, R.J., D.R. Decoteau, J.T. Garrett, R.T. Nagata, K.D. Batal, W.J. McLaurin, D.M. Granberry, K.B. Perry, and D.C. Sanders. 1989. Determination of heat unit requirements in the southeastern United States. J. Amer. Soc. Hort. Sci. 114:898–903.

Gonzalez, A.R., J. Mays, and G. Prokakis. 1989. Snap bean trials. Ark. Agr. Expt. Sta. Res. Ser. 387.

Guyer, R.B. and A. Kramer. 1950. Factors affecting yield and quality measurements of raw and canned green and wax beans—A preliminary report. Proc. Amer. Soc. Hort. Sci. 56:303–314.

Kady, M.S. 1966. Fiber content of green snap beans as influenced by variety and environment. Proc. Amer. Soc. Hort. Sci. 89:361–367.

Perry, K.B., C.W. Todd, and. L.J. Gregory. 1986. Comparison of 14 methods to determine heat unit requirement for cucumber harvest. HortScience 21:419–423.

Robinson, W.B., D.E. Wilson, J.C. Moyer, and J.D. Atkins. 1964. Quality versus yield of snap beans for processing. Proc. Amer. Soc. Hort. Sci. 84:339–347.

Ross, E., J.E. Brakke, and J.F. Moore. 1956. The objective evaluation of some green bean varieties used for processing in the northwest. Proc. Amer. Soc. Hort. Sci. 68:398–411.

Rutledge, A.D. 1991. Commercial bush snap bean production. Univ. Tenn. Agr. Ext. Serv. PB 897.

Silbernagel, M.J. and S.R. Drake. 1978. Seed index, an estimate of snap bean quality. J. Amer. Soc. Hort. Sci. 103:257–260.

Wallace, D.H. and G.A. Enriquez. 1980. Day length and temperature effects on days to flowering of early and late maturing beans (*Phaseolus vulgaris* L.). J. Amer. Soc. Hort. Sci. 105:583–591.