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Optimum stage of development for harvesting green-shelled beans^{1,2}

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ABSTRACT

Stage of development at harvest affects both the yield and quality of green-shelled beans (*Phaseolus vulgaris* L.). The identification of a morphological marker associated with the occurrence of maximum pod fresh weight would help to increase yield and improve the quality of the crop. Number of days to maximum pod fresh weight was estimated for two white-seeded bean cultivars by using data from field experiments conducted at Isabela, Puerto Rico, in 1985 and 1986. Based on regression estimates, the earlier maturity cultivar Cuarentena produced maximum pod fresh weight 63 days after planting (DAP) in 1985 and 66 DAP in 1986. 'Arroyo Loro' produced maximum pod fresh weight 68 DAP both years. The percentages of green, yellow and dry pods at the estimated maximum pod fresh weight were similar the two years for Cuarentena but varied for Arroyo Loro. Dry pods are considered undesirable for marketing green-shelled beans. The appearance of the first dry pod was considered to be a useful morphological marker to begin the harvest of green-shelled beans because at least 85% of the estimated maximum pod yield had accumulated when the first dry pod appeared in the cultivars Arroyo Loro and Cuarentena. This morphological marker provides a useful compromise between yield potential and quality of green-shelled beans.

Key words: *Phaseolus vulgaris* L., morphological marker, production practices

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RESUMEN

Etapa óptima de desarrollo para cosechar habichuelas verdes

La etapa de desarrollo en que se realiza la cosecha de habichuela verde (*Phaseolus vulgaris* L.) afecta la calidad y rendimiento de la misma. La identificación de un marcador morfológico que coincida con el rendimiento máximo de vainas frescas debería ayudar a aumentar el rendimiento y mejorar la calidad del producto. Se estimó el número de días desde la siembra hasta el rendimiento máximo de las vainas frescas para dos cultivares de habichuela blanca usando datos de experimentos de campo realizados en Isabela, Puerto Rico en 1985 y 1986. A base de los estimados de regresión, la cultivar precoz Cuarentena produjo el rendimiento máximo de vainas frescas 63 días después de la siembra (DDS) en 1985 y 66 DDS en 1986. 'Arroyo Loro' produjo el rendimiento máximo de vainas frescas 68 DDS en ambos años. El porcentaje de vainas verdes, amarillas y secas en la fecha de rendimiento máximo de vainas frescas fue similar entre años para Cuarentena pero varió entre años para Arroyo Loro. La presencia de vainas secas se considera indeseable para el mercadeo de habichuela verde. La fecha en que aparece la primera vaina seca sería un buen marcador morfológico para comenzar la cosecha de habichuela verde porque las cultivares Cuarentena y Arroyo Loro ya han acumulado por lo menos el 85% de su rendimiento máximo. El uso de esta característica morfológica provee niveles aceptables de rendimiento y calidad de habichuela verde.

INTRODUCTION

The stage of development at harvest affects both the yield and quality of green-shelled beans. Yield potential is reduced when green-shelled beans are harvested too early. Both yield potential and the quality of green-shelled beans are reduced when harvested after the optimum stage of development. Therefore, the identification of a morphological marker associated with the optimum stage of development for harvesting green-shelled beans would help to increase yield and improve the quality of the crop. An adequate morphological marker should be a trait that can be easily identified in the field. In addition, the morphological marker should be highly correlated with the optimum stage of development for harvest and should be applicable in diverse environments and for different bean genotypes. Badillo-Feliciano et al. (1985) recommended that green-shelled beans be harvested at the appearance of the first yellow pod. However, this general recommendation was not based on results from field experiments.

The objectives of this study were to determine the optimum stage of development for harvesting two white-seeded bean cultivars and to identify a morphological marker that coincides with the most appropriate harvest time for green-shelled beans.

MATERIALS AND METHODS

Field experiments were planted at the Isabela Substation in October 1985 and June 1986. The soil type is a Coto Clay (clayey, kaolinitic,

isohyperthermic Tropeptic Haplorthox). Two white-seeded bean cultivars, Arroyo Loro and Cuarentena, were planted in blocks of 20 rows that were 5 m in length and 0.6 m apart. Both bean cultivars have an indeterminate, short-vine (Type II) growth habit (CIAT, 1987). Fifty-five seeds were planted in each row. Granular fertilizer (10-10-10) was applied after emergence at a rate of 450 kg/ha. Plots received supplemental irrigation to prevent water stress, and weeds were controlled manually.

After plants initiated pod fill, at approximately 50 days after planting (DAP), ten-plant samples were collected for each bean cultivar. Samples were collected at two-day intervals until harvest maturity. Harvest maturity was determined when all of the pods on the plant were dry. Pod fresh weight and the number of green, of yellow and of dry pods were recorded for every sample.

Pod fresh weights and the number of green, of yellow and of dry pods were estimated for each cultivar-year combination by using linear or quadratic equations. Coefficients of determination of linear and quadratic equations were compared by using F tests ($P < 0.05$) in order to identify the models that provided the best fit (Draper and Smith, 1966). The models for the equations are as follows:

$$Y_1 = b_0 + b_1 X \quad (\text{Linear})$$

where Y_1 = number of green, yellow or dry pods or fresh weight of pods and X is DAP and

$$Y_2 = b_0 + b_1 X + b_2 X^2 \quad (\text{Quadratic})$$

where Y_2 = number of green, yellow or dry pods or fresh weight of pods and X is DAP. Maximum fresh weight of pods was estimated by calculating the first derivative of the quadratic equations for fresh weight of pods. Percentage of green, yellow and dry pods was calculated by dividing the estimated number of green, yellow or dry pods for a sample date by the total number of pods and multiplying by 100.

RESULTS AND DISCUSSION

The estimated number of days to maximum pod fresh weight was similar the two years for both cultivars (Table 1). The earlier maturity cultivar Cuarentena produced maximum pod fresh weight 63 DAP in 1985 and 66 DAP in 1986. Arroyo Loro produced maximum fresh pod weight 68 DAP both years. Similar rates of development should be expected because in the tropics accumulation of heat units measured as degree-days is more similar between years than at temperate locations (Dennet, 1984). When environmental factors are not limiting, most farmers should be able to predict within a few days when the harvest should occur, once the number of days from planting to maximum pod

TABLE 1.—*Characteristics of two white-seeded bean cultivars at estimated maximum pod fresh weight.*

Genotype	Year	Days from planting to maximum pod fresh weight	Green pods	Yellow pods	Dry pods		
						----- % -----	
Cuarentena	1985	63	44	20	36		
	1986	66	42	24	35		
Arroyo Loro	1985	68	47	47	6		
	1986	68	32	30	38		

fresh weight has been established for a bean cultivar at a particular site in Puerto Rico.

Regression equations explained a large portion of the variability of the traits that were measured (Tables 2 and 3). Coefficients of determination ranged from 76 to 93% for pod fresh weight, 73 to 97% for number of green pods, 74 to 91% for number of yellow pods, and 91 to 96% for number of dry pods. Linear equations provided the best fit for number of green and dry pods, whereas pod fresh weight and number of yellow pods were best explained by quadratic equations.

The estimated percentages of green, yellow and dry pods of Arroyo Loro varied more between years than those of Cuarentena (Table 1). The estimated percentage of green pods at maximum pod fresh weight was similar between bean cultivars, ranging from 32 to 47 percent. However, Arroyo Loro had a greater percentage of yellow pods than Cuarentena at maximum pod fresh weight. Because of the indeterminate growth habit of these bean cultivars, some pods on the plant began

TABLE 2.—*Regression equations used to estimate pod fresh weight, number of green, yellow and dry pods of Cuarentena.*

Trait	Year	Intercept (b_0)	DAP ¹ (b_1)	DAP × DAP (b_2)	Coefficient of determination		
						----- % -----	
Pod fresh weight	1985	-2791.1	96.0	-0.77	76		
	1986	-4438.8	143.4	-1.09	84		
Green pods	1985	430.2	-6.07		95		
	1986	558.5	-7.79		94		
Yellow pods	1985	-408.1	13.30	-0.10	83		
	1986	-1459.9	44.18	-0.33	74		
Dry pods	1985	-390.7	6.86		96		
	1986	-420.9	6.92		96		

¹DAP=days after planting

TABLE 3.—*Regression equations used to estimate pod fresh weight, number of green, yellow and dry pods of Arroyo Loro.*

Trait	Year	Intercept (b ₀)	DAP ¹ (b ₁)	DAP × DAP (b ₂)	Coefficient of determination ----- % -----
Pod fresh weight	1985	-4431.8	135.6	-0.98	93
	1986	-8265.6	254.9	-1.89	84
Green pods	1985	616.6	-8.0		73
	1986	534.6	-7.3		97
Yellow pods	1985	-6872.6	200.8	-1.45	91
	1986	-2877.9	85.4	-0.62	80
Dry pods	1985	-1061.6	15.8		91
	1986	-534.3	8.3		95

¹DAP=days after planting

to dry before the whole plant reached maximum fresh pod weight. Cerna and Beaver (1989) observed that maximum seed dry weight occurred when a high percentage of the pods on the plant were dry. The percentage of dry pods at maximum pod fresh weight was similar between years for Cuarentena, whereas there was more than 30% difference in the estimated percentage of dry pods at maximum fresh pod weight for Arroyo Loro.

Because the presence of many dry pods is considered undesirable for marketing green shelled beans, farmers are faced with the decision whether to harvest before maximum pod fresh weight and receive higher market prices, or produce maximum yield and suffer lower prices due to inferior quality of the crop. At least 85% of the estimated maximum pod fresh weight was produced at the date of the last reading before the appearance of dry pods (Table 4). The date of the last sampling before the appearance of dry pods occurred five to seven days before the estimated date of maximum fresh pod weight of Cuarentena,

TABLE 4.—*Characteristics based on regression estimates of two white-seeded bean cultivars at the last reading before the appearance of dry pods.*

Genotype	Year	Green pods ----- % -----	Yellow pods ----- % -----	Days after planting	Maximum pod fresh weight ----- % -----
Cuarentena	1985	85	15	56	85
	1986	86	19	61	91
Arroyo Loro	1985	59	41	66	96
	1986	80	20	63	89

and two to five days earlier than the date of maximum fresh pod weight of Arroyo Loro. The appearance of the first dry pod on the bean plants meets most of the requirements of a useful morphological marker. This marker, which is easy to use in the field, would coincide with a period when green-shelled beans would have accumulated most of their fresh pod yield and when the quality of the crop would be highest.

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