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REPRODUCTIVE DEVELOPMENT OF SOYBEAN GENOTYPES OF MATURITY GROUPS I, II, AND III IN PUERTO RICO

S. Rodríguez de Cianzio

Department of Agronomy, Iowa State University, and
Department of Agronomy and Soils,
University of Puerto Rico, Mayaguez, Puerto Rico 00709

ABSTRACT

Soybean [Glycine max (L.) Merr.] of Maturity Groups (MG) I, II, and III, adapted to temperate environments, are planted at off-season nurseries to reduce the number of years required for cultivar development and genetic research. The objective of this study was to determine the length of time needed for reproductive development of genotypes planted in Puerto Rico throughout the year. The results of the research are needed to schedule planting and harvest activities appropriately. Six cultivars were sown in two photoperiods, natural conditions and under artificial lights to extend day length, during November, February, and June. Days to reproductive (R) stages were determined. Photoperiod had a significant influence on number of days to all R stages, except R8. Average number of days from emergence to full bloom (R2) and maturity (R8) were 39 and 94, and 94 d, respectively, in the lighted environments, and 30 and 88 d, respectively, in the unlighted environments. For each cultivar, number of days to each R stage averaged for all environments was similar. The results indicated that length of the growing season depends primarily on the photoperiod used and that cultivars will grow and develop similarly in plantings throughout the year, regardless of photoperiod and the month in which they are planted.

INTRODUCTION

Reproductive development of soybean (Glycine max (L.) Merr.) genotypes of Maturity Groups (MG) I, II, and III planted in tropical locations is more rapid than in their normal temperate (40-44^{o}) latitude (Fehr, 1976). Soybean, which is classified as a short-day plant (Garner and Allard, 1923), responds to the short-day conditions of the tropics by flowering and maturing earlier than at higher latitudes. These MG I, II, and III genotypes often are planted in the tropics off-season, when the crop cannot be grown in its normal high latitude environment (Cianzio, 1985). The plantings are used for basic and applied research in breeding and genetics to reduce the

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number of years required to complete a project. The soybean breeding program of Iowa State University routinely obtains three generations during the year, two in Puerto Rico and one in Iowa (Cianzio, 1985). In Puerto Rico, two generations may be grown during the 6 months of October to May. During this period, the crop may be planted under natural day-length conditions, or under artificial lights to extend the day length, delay flowering, and extend reproductive duration to obtain more seed.

Coordination of multiple plantings at both tropical and temperate locations requires knowledge of the length of time for reproductive development under different environmental conditions. Approximate duration of stages of vegetative and reproductive development for soybeans of all MG has been described for temperate regions (Fehr et al., 1971; Fehr and Caviness, 1980). No information has been published on stages of development when genotypes are planted outside the area for which they were bred to be full-season lines. The objective of this study was to determine length of reproductive stages of development in soybeans of MG I, II, and III planted in the tropical conditions of Puerto Rico throughout the year. The natural day-length conditions of the island, as well as plantings under photoperiods extended with artificial lights, were used because both types of environments are useful for breeding and genetics research.

MATERIALS AND METHODS

Six cultivars were used in the study: 'Wells' and 'Marion' of MG I, 'Woodworth' and 'Amsoy 71' of MG II, and 'Williams' and 'lumberland' of MG III. Six environments were used at the Iowa State University Soybean Nursery at the Isabela Substation of the University of Puerto Rico during 1982 and 1983. Plantings on 4 November 1982, 24 February 1983, and 23 June 1983 were exposed to the natural day-length conditions of Puerto Rico, referred to as the unlighted (UL) environments. A second planting on the same dates, referred to as lighted (L) environments, was exposed to continuous light for 15 d after emergence, 14.5-h d for an additional 35 d, and natural day length thereafter. The lighting was provided by 240-V, 1,500-W quartz-iodide bulbs installed on poles approximately 7 m high.

The Isabela Substation is located at 18^{o} 28'N and 67^{o}04'W'. Mean annual temperature, averaged over 30 years, ranges from 22.8^{o}C during February to 25.9^{o}C during August (NOAA, 1973)- December has the shortest average day length, 11 h 04 min and June has the longest, 13 h 12 min. The mean annual precipitation is 1604 mm. Monthly precipitation ranges from 75 mm during February to 181 mm 21 during May.

In each environment, cultivars were planted in a randomized complete-block design with two replications. For plantings in the L environments, care was taken to assure that all plots were equidistant from the light source. Plots were single rows 1 m long with 0.60 m space between rows, planted with 12 seeds per row and thinned to six plants at stage V4.

Data were collected on six individual plants in each plot. Emergence date was recorded as the day when 75% of the seedlings had their cotyledons above the soil surface, which occurred an average of 4 d after planting. Plots were checked every other day to record the date when individual plants reached beginning (R1) and full bloom (R2), beginning (R3) and full pod (R4), beginning (R5) and full seed (R6), and beginning (R7) and full maturity (R8) (Fehr and Caviness, 1980). Number of days from emergence to each stage was recorded.

Analyses of variance were calculated for the individual and combined environments. F-tests were performed under the assumption that environments and cultivars were random effects.

RESULTS AND DISCUSSION

There were significant differences among environments for the number of days from emergence to each stage of reproductive development (Table 1). For example, the shortest duration from emergence to R1 (25 d) was observed in November UL, and the longest duration (39 d) in February L (Table 2). Similarly, the period from emergence to full maturity (R8) was shortest for the November UL planting (82 d) and longest (99 d) for February L.

The number of days between R stages was similar among environments (Table 2). The flowering (RI and R2) and pod development (R3 and R4) periods had the fewest number of days. The greatest number of days was from the beginning of seed formation (R5) until beginning of maturity (R7). Plants in February UL required 35 d between R6 and R7. The second largest number of days between R stages was from R6 to R7 in February L.

For the November planting, natural photoperiod became increasingly shorter, with the shortest day occurring on 21 December, the winter solstice. Conversely, for the plantings in February the photoperiod increased until the longest day occurred on 21 June, the summer solstice. When the photoperiod decreased, as occurred for the 21 November planting, the longer nights favored early flowering. As the 22 days became longer for the February plantings, the progressively shorter nights delayed the reproductive development of the plants. The magnitude of these effects changed when photoperiods were extended artificially.

When the variation due to environment was partitioned, photoperiods (artificially imposed or natural day length) were significantly different for all stages of reproductive development, except R8 (Table 1). For example, a 9-d difference in the onset of flowering (R1 was observed between the L and UL photoperiods (Table 2). This difference decreased to 8 d by the time cultivars had started to mature (R7). The failure of the photoperiods to have a significant effect on the number of days to reach full maturity (R8) may be expected. Plant senescence seems to be signaled by the developing seeds, which in turn, causes leaf drop and eventual death of the plant (Nooden, 1985). The maturation process in progress by stage R7 is completed by R8. Pod and seed drying that occur between R7 and R8 are characterized by loss of water, a process that may be more dependent on ambient temperatures than on photoperiod.

The effect of the planting month was significant only for the number of days from emergence to R3 (Table 1). There was an average of 40 d to R3 for the February planting, 36 d for the November planting, and 38 d for the June planting (Table 2). These differences, although statistically significant, may not be of practical importance because the days between all other reproductive stages were similar among planting months.

The interaction of planting month and photoperiod was significant for number of days to RI, R6, R7, and R8 (Table 1). Interaction effects were expressed in the magnitude of the differences, rather than changes in the relative ranking of the means (Table 2). More days were always required to reach every stage in the lighted environment of the same planting month. The differences between the L and UL environments within a planting month changed, however, depending on the month. The largest difference was observed in the February plantings; the smallest, in the June plantings.

No significant differences were observed among cultivars for the average number of days from emergence to any of the R stages (Table 1). For each cultivar, number of days to reach every R stage averaged over environments was similar (Table 3). Some interaction terms involving cultivars were significant (Table 1). For stages R1, R3, R4, and R8, the interaction of cultivars x environment was significant. In general, the greatest number of days to these R stages was in February L and, the shortest, in February UL (Table 3). The interaction of cultivar x photoperiod was significant only for R4, and the interaction of cultivar x planting month was significant only for R2. Interactions were due to changes in the magnitude of the differences, rather than changes in the relative ranking of the cultivars (Table 3). The three-way interaction of cultivar x planting month x photoperiod was significant only for number of days to maturity (R8) (Table 1). This is an indication that cultivars reacted differently to the particular conditions of each planting month and photoperiod (Table 3). The magnitude of the cultivar difference, however, was not very large.

Significant variation among individual plants within cultivars was observed at all reproductive stages (Table 1). These variations however, were of similar magnitude within cultivars and did not affect the average number of days to each stage and number of days between stages.

Table 1. Significance of mean squares in the analysis of variance for number of days from emergence to reproductive stages of six soybean cultivars combined for all environments.

Source	df	Bloom		Pod		Seed		Maturity	
		Beginning	Full	Beginning	Full	Beginning	Full	Beginning	Full
		R1†	R2†	R3†	R4†	R5†	R6†	R7†	R8†
Environments (E)	5	**	**	**	**	**	**	**	**
Month (M)	2	NS‡	NS	*	NS	NS	NS	NS	NS
Photoperiod (P)	1	*	**	**	**	*	*	*	NS
M x P	2	**	NS	NS	NS	NS	**	*	**
Replications (R)/E	6	23.67	20.11	34.92	49.45	14.30	29.73	17.56	25.73
Cultivars (C)	5	NS	NS	NS	NS	NS	NS	NS	NS
C x E	25	*	**	*	*	NS	NS	NS	**
C x M	10	NS	*	NS	NS	NS	NS	NS	NS
C x P	5	NS	NS	NS	**	NS	NS	NS	NS
C x M x P	10	NS	NS	NS	NS	NS	NS	NS	*
Error	30	13.37**	12.76**	10.29**	10.37**	20.16**	23.38**	15.83**	16.01**
Plants/CRE	360	4.07	3.93	3.59	3.48	3.14	3.57	4.34	3.38

*,** Significant at the 5 and 1% probability levels, respectively.

† Reproductive stage (Fehr and Caviness, 1980).

‡ NS = Not significant.

Table 2. Average number of days from emergence to reproductive stages in six environments (three planting months and two photoperiods) across six cultivars and two replications.

Environment		Bloom		Pod		Seed		Maturity	
Planting month	Photoperiod conditions	Beginning R1[†]	Full R2[†]	Beginning R3[†]	Full R4[†]	Beginning R5[†]	Full R6[†]	Beginning R7[†]	Full R8[†]
		no. of days							
November	lighted	35	37	40	44	48	68	84	90
February	lighted	39	41	44	47	50	58	90	99
June	lighted	34	38	42	45	50	64	88	93
$\bar{x}$		36	39	42	45	49	63	88	94
November	unlighted	25	28	32	38	41	52	77	82
February	unlighted	28	32	35	38	41	46	81	90
June	unlighted	28	31	34	38	43	56	82	91
$\bar{x}$		27	30	34	38	42	51	80	88
$LSD_{(0.05)}$[‡]		3	2	3	4	2	3	2	NS[#]
$LSD_{(0.05)}$[§]		NS	NS	4	NS	NS	NS	NS	NS
$LSD_{(0.05)}$[¶]		5	4	6	7	4	5	4	5

† Reproductive stage (Fehr and Caviness, 1980).

‡ Least significant difference for comparison between photoperiod.

§ Least significant difference for comparison among planting months.

¶ Least significant difference for comparison among environments.

NS = Not significant.

Table 3. Average number of days from emergence to reproductive stages of six cultivars in six environments across two replications.

	Bloom		Pod		Seed		Maturity	
Environment†	Beginning R1‡	Full R2‡	Beginning R3‡	Full R4‡	Beginning R5‡	Full F6‡	Beginning R7‡	Full R8‡
				Wells				
Nov L	34	36	40	43	46	70	84	88
Nov UL	24	27	31	38	40	50	74	79
Feb L	38	40	44	46	48	58	88	95
Feb UL	32	34	38	40	43	48	82	90
Jun L	36	39	42	45	51	64	86	91
Jun UL	30	34	36	40	44	56	80	92
$\bar{x}$	32	35	38	42	45	58	82	89
				Marion				
Nov L	37	39	42	46	50	68	87	91
Nov UL	24	28	33	39	43	55	80	85
Feb L	39	41	44	47	50	58	92	102
Feb UL	27	30	34	36	39	44	82	91
Jun L	34	38	42	46	50	65	90	95
Jun UL	27	30	32	36	42	55	84	90
$\bar{x}$	31	34	38	42	46	58	86	92

Continued

Table 3. Continued

Environ-ment†	Bloom		Pod		Seed		Maturity	
	Beginning R1‡	Full R2‡	Beginning R3‡	Full R4‡	Beginning R5‡	Full F6‡	Beginning R7‡	Full R8‡
					Woodworth			
Nov L	34	36	39	44	47	67	84	87
Nov UL	24	28	32	38	41	52	71	78
Feb L	40	42	45	48	50	58	88	94
Feb UL	32	36	38	41	44	50	80	90
Jun L	35	38	41	44	48	62	84	90
Jun UL	30	33	36	40	45	58	78	89
$\bar{x}$	32	36	38	42	46	58	81	88
					Amsoy 71			
Nov L	36	37	40	44	46	68	87	90
Nov UL	26	28	33	39	42	54	79	83
Feb L	40	42	44	46	50	59	92	104
Feb UL	26	29	34	37	40	44	81	92
Jun L	33	36	40	44	50	64	88	94
Jun UL	28	30	34	38	44	58	81	89
$\bar{x}$	32	34	38	41	45	58	85	92

Continued

Table 3. Continued

	Bloom		Pod		Seed		Maturity	
Environ-	Beginning	Full	Beginning	Full	Beginning	Full	Beginning	Full
ment[†]	R1[‡]	R2[‡]	R3[‡]	R4[‡]	R5[‡]	F6[‡]	R7[‡]	R8[‡]
				Williams				
Nov L	36	38	40	46	50	70	88	92
Nov UL	25	28	33	38	42	53	78	82
Feb L	39	41	44	47	50	58	90	99
Feb UL	26	29	34	38	40	44	79	88
Jun L	34	38	44	47	51	66	90	95
Jun UL	27	30	33	36	41	55	83	90
$\bar{x}$	31	34	38	42	46	58	85	91
				Cumberland				
Nov L	35	38	39	44	46	67	88	90
Nov UL	26	28	32	38	40	51	79	84
Feb L	40	42	44	47	50	60	92	102
Feb UL	28	32	34	37	40	44	80	90
Jun L	34	37	42	44	49	64	90	94
Jun UL	26	28	32	36	42	56	85	94
$\bar{x}$	32	34	37	41	44	57	86	92

Continued

Table 3. Continued

Environment†	Bloom		Pod		Seed		Maturity	
	Beginning R1‡	Full R2‡	Beginning R3‡	Full R4‡	Beginning R5‡	Full F6‡	Beginning R7‡	Full R8‡
$LSD_{(0.05)}$§	7	7	6	6	NS	NS	NS	8
$LSD_{(0.05)}$¶	NS††	6	NS	NS	NS	NS	NS	NS
$LSD_{(0.05)}$#	NS	NS	NS	4	NS	NS	NS	NS

† Nov L = November lighted, Nov UL = November unlighted, Feb L = February lighted, Feb UL = February unlighted, June L = June lighted, June UL = June unlighted.

‡ Reproductive stage (Fehr and Caviness, 1980).

§ Least significant difference for comparison among cultivar x environment.

¶ Least significant difference for comparison among cultivar x planting month.

Least significant difference for comparison among cultivar x photoperiod.

†† Not significant.

When multiple plantings of an experiment are conducted throughout the year, information on generation length for each planting is essential for proper scheduling of the field activities at the same location or between the tropical and temperate environments. Results indicated that, for plantings in Puerto Rico throughout the year, the major changes to be expected in generation lengths and days to flowering are with the use of artificially lighted environments. Within a certain photoperiod, differences observed among planting months were small.

Results also indicated that, in Puerto Rico, cultivars of MG I to III will grow and develop similarly in plantings throughout the year, regardless of photoperiod and the month in which they are planted. These findings facilitate the management of genotypes from MG I to III for coordination of flowering to obtain artificial hybridizations.

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