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E_6, A DOMINANT GENE CONDITIONING EARLY FLOWERING AND MATURITY IN SOYBEANS

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Abstract

Inheritance was studied in natural variants of the soybean cultivar Paraná, developed under photoperiodic conditions ranging from 13 h 31 min day light, at sowing, to 14 h 23 min, 59 days afterwards. Results indicated that early flowering and maturity are controlled by a single dominant gene. Natural mutations that originated cultivars Paranagoiana and SS-1 occurred at the same locus of cultivar Paraná. It was not possible to determine if the recessive alleles of these mutant cultivars are different. The designation E_6 was proposed for the alleles determining earliness in cultivar Paraná, and e_6 for the gene determining late flowering and maturity in cultivars Paranagoiana and SS-1, until the individuality of the alleles of Paranagoiana and SS-1 is confirmed.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) acreage is expanding fast towards lower latitudes in Brazil. The cropping area is growing to the northern part of the country through regions above 20º latitude south, which has contributed towards maintaining Brazil as the second world soybean producer, responsible for more than 20% of world production. The time to flowering and maturity is important for adaptation to specific latitudes.

Five pairs of genes affecting flowering and maturity time in soybeans were described under long-day conditions. Bernard (1971) identified the genes E_1/e_1 and E_2/e_2 in isogenic lines of cultivar Clark. Buzzell (1971) described the gene E_3/e_3, whose dominant allele induces sensitivity to artificial fluorescent light in addition to determining late maturity. Buzzell and Voldeng (1980) identified the gene E_4/e_4, whose recessive allele results in insensitivity to daylength. McBlain and Bernard (1987) described the gene E_5/e_5. The dominant alleles of all five genes determine late flowering and maturity.

Genetic control of flowering and maturity time in soybeans under short-day conditions differs from that for long days, late flowering and maturity, being controlled by recessive alleles (Kiihl, 1976; Hartwig and Kiihl, 1979; Tisselli Jr, 1981; Toledo and Kiihl, 1982ab; Pípolo, 1996). These authors mention the presence of one to five major genes.

Toledo *et al*., (1995) studying the time for flowering of lines derived from crosses among genotypes with normal juvenile period, BR-13, FT-2 and BR85-29009, and with long juvenile period, OCEPAR-8, under different seeding times, concluded that the photoperiodic sensitivity in these two types of genotypes is contolled by a unique genetic system.

MATERIAL AND METHODS

A study was conducted with F_2 and F_3 plants from a diallel cross, without reciprocals, involving the cultivar Paraná and its natural mutants, Paranagoiana, and SS-1. They were planted in Londrina, Paraná State, located at 23° 22' latitude south. From seeding date to the beginning of flowering of the earliest parent, the daylength ranged from 13 h 31 min to 14 h 19 min. The longest day was 14 h 23 min and occurred 59 days after sowing.

Paraná is a maturity group VI cultivar, tested as N59-6800 [Hill x (Roanoke x Ogden)]. This line was introduced from North Carolina Experiment Station, USA, and was released in 1977. It has determined growth habit, white flowers, gray pubescence, yellow seed coat, and buff hilum (Kaster *et al*., 1979). Paraná was cropped for many years in the States of Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Mato Grosso do Sul, Minas Gerais, and Goiás and in Brasília, playing an important role in the development of soybean in these states (OCEPAR/EMBRAPA, 1994).

Cultivars Paranagoiana and SS-1 resulted from natural mutations in time for flowering that occurred in the cultivar Paraná. Both cultivars present the same characteristics as Paraná, differing in the time to flowering and consequently in the characteristics resulting from later flowering, such as time to maturity, plant height, and grain yield (OCEPAR/EMBRAPA, 1988). In 1985, F_2 seeds provided by Romeu A.S. Kiihl, from the National Soybean Research Center, were seeded on October 23, using a randomized block design with split plots, with five replications. The plots received the crosses, while F_2 generations and the parents were seeded in the subplots. Emergence took place on October 29. Notes on the number of days to flowering and to maturity were taken for

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eight plants of each parent and 60 plants of each F_2, in each replication.

The genotypes of F_2 plants were checked by the behavior of their progenies. For this purpose, a sample of plants was taken at random from each F_2 population. As the F_2 data indicated the presence of one gene, a limited number of F_3 lines were studied in each cross.

F_3 lines from each cross, along with the three parents used in the diallel, formed individual experiments. F_3 lines were sown to individual rows, without replications, and the parents were replicated from three to five times, depending upon the cross. Sowing was effected on October 24, 1986, and emergence took place seven days later. The dates to flowering (R 1) and to maturity (R 8) were recorded daily for 20 plants of each F_3 line, for 12 plants of each replication of parents in the crosses Paraná x Paragoniana and SS-1 x Paraná, and 40 plants of each F_3 line in the cross SS-1 x Paranagoiana.

RESULTS AND DISCUSSION

A bimodal distribution of F_2 plants was observed in the crosses Paraná x Paranagoiana and SS-1 x Paraná, both for flowering (Figure 1A and B) and maturity dates (Figure 2A and B), with a concentration of individuals towards the early parent (Paraná). It was not possible to separate, through phenotype, the dominant homozygous plants from the heterozygous ones. Nevertheless, for flowering, a frequency of 227 early and intermediate plants to 72 late ones was observed in the cross Paraná x Paranagoiana, and 223:75 in the cross SS-1 x Paraná. Such frequencies are in agreement with the proportion 3:1 (χ^2 probability = 0.71 and 0.94, respectively). Similar frequencies occurred for maturity (χ^2 probability = 0.17 and 0.51). These results show that the mutations originating cultivars Paranagoiana and SS-1 occurred in one gene and were recessive. Although this soybean crop

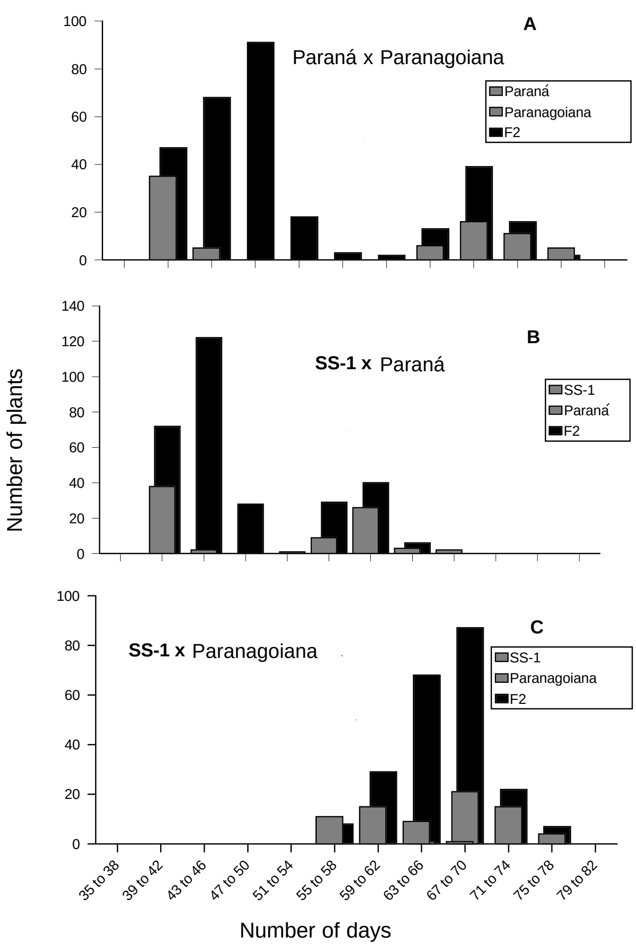

Figure 1 - Frequency of plants of parents and of F_2 generations for the number of days to flowering in three soybean crosses.

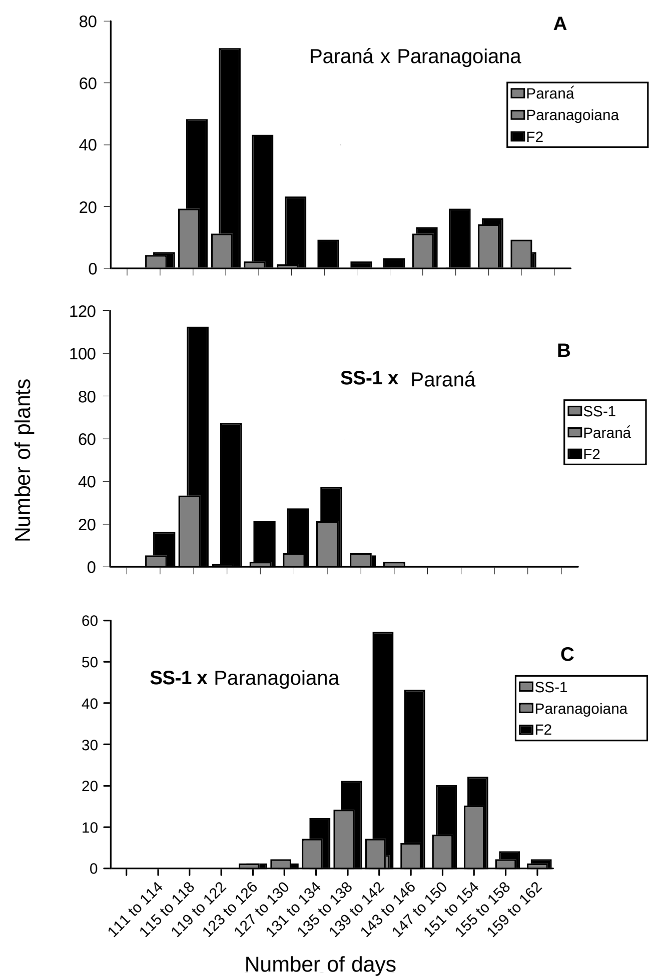

Figure 2 - Frequency of plants of parents and of F_2 generations for the number of days to maturity in three soybean crosses.

developed during days longer than 12 h, with photoperiods between 13 h 31 min and 14 h 23 min, early flowering and maturity were dominant. Results quite similar to the ones of the present study were also obtained by Gilioli (1979), in four crosses, under photoperiods of 13 h 21 min, by Moro et al. (1993) with the cross of Paraná x IAC-8 cultivated at 20º 45' latitude south, by Ray *et al.* (1995) in plantings with days with 13 h 10 min and 14 h 02 min of light, and by Vargas (1996) in crosses involving the cultivars Doko, BR-9 (Savana) and Davis, seeded at 23º 12' latitude south on October 14, November 25, and February 24.

In the cross SS-1 x Paranagoiana, in which the parents showed small differences in the number of days to flowering and to maturity, it was not possible to classify the F_2 plants into well-defined groups (Figures 1C and 2C).

Table I - Classification of F_3 soybean families according to the average of F_2 plants, range, average, and phenotypical variance of number of days to flowering in comparison to the parents of crosses Paraná x Paranagoiana, SS-1 x Paraná, and SS-1 x Paranagoiana.

Parents and crosses	No. of F_3 families	Average of F_2 plants [a]	F_3			Probability χ^2 (1:2:1)
			Range [b]	Average	Phenotypical variance	
Paraná	-	-	34-44	37.9	3.3350	
SS-1	-	-	50-59	53.9	2.4250	
Paranagoiana	-	-	56-69	61.6	5.5978	
Paraná x	6	41.5	37.6-38.7	38.3	2.9867	0.9785
Paranagoiana	11	48.4	43.5-50.5	47.6	68.1008	
	6	69.3	58.9-62.9	61.2	8.7753	
SS-1 x	6	41.0	37.5-42.2	40.1	4.9620	0.8825
Paraná	11	45.1	43.4-48.1	45.2	31.5349	
	7	58.7	52.5-54.7	53.8	2.6280	
SS-1 x	7	61.1	54.9-56.3	55.5	3.4319	0.6800
Paranagoiana	20	66.2	56.8-61.0	58.5	11.0068	
	8	69.5	61.4-64.3	62.6	10.6822	

[a] Progeny tested in the F_3. [b] Range of plants of the parents and of F_3 family means.

Table II - Classification of F_3 soybean families according to the average of F_2 plants, range, average, and phenotypical variance of number of days to maturity in comparison to the parents of crosses Paraná x Paranagoiana, SS-1 x Paraná, and SS-1 x Paranagoiana.

Parents and crosses	No. of F_3 families	Average of F_2 plants [a]	F_3			Probability χ^2 (1:2:1)
			Range [b]	Average	Phenotypic variance	
Paraná	-	-	93-104	98.7	2.4209	
SS-1	-	-	117-130	122.4	4.9692	
Paranagoiana	-		129-145	138.3	7.1535	
Paraná x	6	116.7	98.2-101.0	99.0	2.5914	0.9785
Paranagoiana	11	121.9	106.7-117.1	113.2	166.5825	
	6	146.7	136.0-140.9	137.9	10.5983	
SS-1 x	6	117.3	97.4-100.5	99.6	5.1596	0.8825
Paraná	11	119.7	102.8-111.1	107.3	71.9024	
	7	131.4	120.2-121.5	121.2	4.4979	
SS-1 x	7	137.4	123.8-127.3	125.1	12.8065	0.6800
Paranagoiana	20	142.4	127.8-135.7	131.8	36.6358	
	8	151.4	135.9-140.2	137.5	15.4769	

[a] Progeny tested in the F_3. [b] Range of plants of the parents and of F_3 family means.

Unimodal distributions were observed, without transgressive segregation.

In the crosses Paraná x Paranagoiana and SS-1 x Paraná, the genotypes of F_2 plants that originated F_3 lines segregated in agreement with the theoretical proportion 1:2:1, showing that only one gene differs in each parent compared to the other (Tables I and II). When the plants of the 11 F_3 heterozygous families of the two crosses were pooled into early and late classes, they gave a good fit to the expected 3:1 ratio, confirming the F_2 results (χ^2 probability = 0.44 and 0.78 for flowering, and 0.14 and 0.83 for maturity, respectively). Correlations between number of days for flowering and number of days for maturity of F_2 plants and means of their progenies were r = 0.95 ($P < 0.01$) and r = 0.92 ($P < 0.01$), for the cross Paraná x Paranagoiana, and r = 0.93 ($P < 0.01$) and r = 0.89 ($P < 0.01$), for the cross SS-1 x Paraná, respectively. It was not possible to separate the F_3 families into well-defined groups in the cross SS-1 x Paranagoiana. The small difference in the number of days for flowering and number of days for maturity existing between parents made it impossible to separate the 35 F_3 families studied. The unimodal distribution observed in the F_2 generation indicates that cultivars SS-1 and Paranagoiana are genetically similar (Figures 1C and 2C). However, it was not possible to determine if the alleles of cultivars SS-1 and Paranagoiana are different alleles at the same locus, through the behavior of F_3 lines. Correlation coefficients of number of days for flowering and number of days for maturity between F_2 plants and means of their F_3 lines, in this cross, were r = 0.67 ($P < 0.01$) and r = 0.75 ($P < 0.01$), respectively.

The Soybean Genetics Committee has reviewed the information presented and assigned E_6 to the gene determining early flowering and maturity, present in the cultivar Paraná, and e_6 for the gene determining late flowering and maturity in Paranagoiana and SS-1, until the individuality of the alleles of Paranagoiana and SS-1 is confirmed.

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RESUMO

A herança foi estudada em variantes naturais de soja do cultivar Paraná, cultivados sob condições fotoperiódicas que variaram de 13 h 31 min, na data de semeadura, até 14 h 23 min, 59 dias após. Os resultados indicaram que o florescimento e a maturidade precoces são controlados por um gene dominante. As mutações naturais que originaram os cultivares Paranagoiana e SS-1 ocorreram no mesmo loco do cultivar Paraná. Não foi possível determinar se os alelos recessivos desses cultivares mutantes são separados. Foi proposta a designação E_6 para os alelos que determinam o florescimento e a maturação precoces no cultivar Paraná, e e_6 para os alelos que determinam florescimento e maturação tardios nos cultivares Paranagoiana e SS-1, até que a individualidade dos alelos de Paranagoiana e SS-1 seja confirmada.

REFERENCES

Bernard, R.L. (1971). Two major genes for time of flowering and maturity in soybeans. *Crop Sci. 11*: 242-244.

Buzzell, R.I. (1971). Inheritance of soybean flowering response to fluorescent-daylength conditions. *Can. J. Genet. Cytol. 13*: 703-707.

Buzzell, R.I. and **Voldeng, H.D.** (1980). Inheritance of insensitivity to long daylength. *Soybean Genet. Newsl. 7*: 26-29.

Gilioli, J.L. (1979). Herança do número de dias para a floração e maturação em quatro mutantes naturais em soja (*Glycine max* (L.). Merrill). Master's thesis, Universidade Federal de Viçosa, Viçosa.

Hartwig, E.E. and **Kiihl, R.A.S.** (1979). Identification and utilization of a delayed flowering character in soybeans for short-day conditions. *Field Crops Res. 2*: 34-51.

Kaster, M., Queiroz, E.F., Vernetti, F.S. and **Terasawa, F.** (1979). Soja: cultivar Paraná - descrição e comportamento. *In: Seminário Nacional de Pesquisa de Soja, 1*. Anais. EMBRAPA/CNPSo. Vol. 1. Londrina, PR, pp. 389-392.

Kiihl, R.A.S. (1976). Inheritance studies for two characters in soybean (*Glycine max* (L.) Merrill): I. Resistance to soybean mosaic virus. II. Late flowering under short-day conditions. Ph.D. thesis, Mississippi State University, Starkville.

McBlain, B.A. and **Bernard, R.L.** (1987). A new gene affecting the time of flowering and maturity in soybeans. *J. Hered. 78*: 160-162.

Moro, G.L., Reis, M.S. and **Sediyama, F.** (1993). Avaliação do grau médio de dominância e de divergência genética dos progenitores, dos caracteres dias para florescimento e dias para maturação em soja *(Glycine max* (L.) Merrill). *Rev. Ceres 40*: 8-15s.

OCEPAR/EMBRAPA (1988). Recomendações para a cultura da soja no Paraná, 1988/1989. *Boletim Técnico* No. 23, Cascavel, Paraná.

OCEPAR/EMBRAPA (1994). Recomendações técnicas para a cultura da soja no Paraná, 1994/1995. *Boletim Técnico* No. 36, Cascavel, Paraná.

Pípolo, V.C. (1996). Herança do período juvenil longo em soja *(Glycine max* (L.) Merrill) sob condições de dias curtos. Master's thesis, Universidade Estadual de São Paulo, Botucatú.

Ray, J.D., Hinson, K., Mankoono, J.E.B and **Malo, M.F.** 1995). Genetic control of long-juvenile trait in soybean. *Crop Sci. 35*: 1001-1006.

Tisselli Jr, O. (1981). Inheritance study of the long-juvenile characteristic in soybeans under long- and short-day conditions. Ph.D. thesis, Mississippi State University, Starkville.

Toledo, J.F.F. and **Kiihl, R.A.S.** (1982a). Análise do modelo genético envolvido no controle de dias para o florescimento em soja. *Pesqui. Agropecu. Bras. 17*: 623-631.

Toledo, J.F.F. and **Kiihl, R.A.S.** (1982b). Método de análise dialélica do modelo genético em controle das características dias para a floração e número de folhas trifoliadas em soja. *Pesqui. Agropecu. Bras. 17*: 745-755.

Toledo, J.F.F., Oliveira, M.F. de, Arias, C.A.A., Triller, C., Miranda, Z.F.S. and **Souza, R.F. de** (1995). Variabilidade no florescimento em linhas avançadas de soja sob diversos fotoperíodos. *Rev. Bras. Genet. 18* (Suppl. 100): Resumo A.31.

Vargas, A.T. (1996). Estudo genético em variantes naturais de cultivares de soja *(Glycine max* (L.) Merrill) para florescimento tardio. Master's thesis, Universidade Estadual de Londrina, Londrina.

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