

# Induction of mutations for earliness in the soybean cultivar Paraná

A. Tulmann Neto<sup>1</sup> and M.C. Alves<sup>2</sup>

## ABSTRACT

Mutation induction breeding through gamma ray seed treatment (22 krad) was used to obtain earliness in the soybean cultivar Paraná. Plants flowering earlier than Paraná were selected at the M3 generation. Eight mutant lines were isolated by further selections through several generations and tested in four yield trials carried out in 85/86 (Piracicaba) and 86/87 (Piracicaba, Sertãozinho and Assis) in São Paulo State. The following data were taken in these trials: number of days to flowering, yield, total plant height and height to pod insertion, flower color, pod pubescence and seed and plant growth type. Two of the mutants are of agronomic interest because they were, on average, seven to 10 days earlier in maturity than the control in all trials. Except for shorter plant height, the other agronomic characteristics remained unaltered.

## INTRODUCTION

Many new cultivars have been directly or indirectly derived through mutation induction (Maluszynski *et al.*, 1991), including 41 new soybean mutant cultivars obtained through the use of chemical or physical mutagens. Nineteen of these mutants matured from a few days to three or four weeks earlier than their original genotype. Changes towards earliness are commonly obtained with mutagenics (Donini *et al.*, 1984). Even in Brazil, where work with induced mutation is relatively recent, early mutants have been developed in wheat (Tulmann Neto *et al.*, 1977; Philipovsky *et al.*, 1984), rice (Ando *et al.*, 1986) and the common bean plant (Tulmann Neto and Alberini, 1989). Though no induced mutations in soybean are reported in Brazil, a series of cultivars in this crop has been

derived from spontaneous late-flowering mutations (Gilioli, 1979; Kiihl *et al.*, 1984; Bonato, 1989).

During the 83/84 harvest season the cooperative COPERSUCAR began a soybean breeding program (Peixoto, 1985) to find material for use as a rotation crop in sugar cane plantations. One of the important characteristics for these conditions is early maturity. One of the advantages of mutation induction is that it allows the development of genotypes with few modifications compared with the original material. In this case, if the early mutant is derived from an agronomically interesting cultivar and if there are no undesirable pleiotropic effects in the mutation, it may be delivered rapidly to farmers.

The aim of this study was to generate and select early mutants by treating seeds of the original Paraná cultivar with gamma rays.

## MATERIAL AND METHODS

Selection for earliness was made on 15,000 plants of the M3 generation obtained from dry Paraná

<sup>1</sup> Centro de Energia Nuclear na Agricultura (CENA), Caixa Postal 96, 13400-970 Piracicaba, SP, Brasil. Send correspondence to A.T.N.

<sup>2</sup> Centro de Informática na Agricultura, Caixa Postal 9, 13400-970 Piracicaba, SP, Brasil.

cultivar seeds irradiated with 22 krad of gamma rays,  $^{60}\text{Co}$  source (Tulmann Neto *et al.*, 1984). The M3 generation seeds were planted in Jaboticabal (SP) in 83/84, with the Paraná cultivar as control. Five plants flowering earlier than the control were selected and hand harvested. Selected plants were multiplied at CENA in 1984 and their derived progenies were further subjected to selection (M4 generation) and 25 plants earlier than the control were selected. The progenies (M5 generation) of these new selections were observed under field conditions at COPERSUCAR during 84/85 in the presence of the control. To continue the study, lines with flowering and maturity dates earlier than the control were chosen. In 85/86 the lines (M6 generation) derived from this new selection were planted in a characterization trial in the experimental fields at COPERSUCAR in Piracicaba, using the randomized complete block design, with four replications. The plots were made up of four two-meter rows, with 30 seeds per linear meter. Data for yield, number of days to flowering and maturity, plant height, and height of the first pod were noted. Information on other characteristics such as growth habit, flower color and pod pubescence were also taken. In 86/87 the same lines (M7 generation) were again observed in field trials carried out at the experimental stations of COPERSUCAR in Piracicaba, Sertãozinho and Assis, in the State of São Paulo. The experimental design and the data collected from these trials were similar to those described for the trial carried out in 85/86 in Piracicaba.

Individual analysis of the four experiments used a randomized complete block design. First, an analysis of the five characteristics was made, using a polynomial regression of the log transformation of the means over that of the variances to check the need for data transformation. Number of days to flowering had variances dependent on the means, and the recommended correction was done by transforming the data to  $1/X$ . For each experiment, a variance analysis to detect genotype effects significant at the 5% level of probability by the F test was performed. A joint analysis for the different locations (Piracicaba, Sertãozinho and Assis) was carried out, as there was uniformity of planning in the individual experiments of agricultural years 85/86 and 86/87. The significance of experiments, genotypes and interaction genotype x experiment was tested using the F test at the 5% level of probability.

Of the various joint analyses which could have been done, the joint analysis of the experiments disregarding agricultural year and location was chosen. The following scheme was used:

Source of variation	Degrees of freedom
Blocks	12
Genotypes (G)	8
Experiments (E)	3
E x G	24
Residue	96
Total	143

The genotypic effect was tested using the genotype x experiment interaction as the error. The experiment and the genotype x experiment interaction effects were tested with the residual. The variable days to maturity was analyzed excluding the data from the experiment at Assis, because it did not have homogeneous variance.

The comparison of the means of the individual or joint experiments was carried out by the Dunnett test at the 5% level. The means of the mutants were only compared to those of the original Paraná control cultivar and not among themselves. The analyses were carried out using the ANOVA module of SAS.

## RESULTS

### Selection results

Seventeen lines had flowering or maturity earlier than the control at COPERSUCAR in 84/85. These lines had growth habit, flower color, pubescence, pods and seeds similar to those of Paraná. Some had low vegetative vigor and were eliminated in spite of their early maturity. Those with similar flowering and maturity cycles were also eliminated. Thus, of the 17 selected only eight mutant lines and the control were included in the yield trials carried out in 85/86 and 86/87.

### Individual analysis results

It can be seen that the genotypes did not have significant yield differences (Table I). In all the experiments there were significant differences among the genotypes for number of days to flowering and maturity (Tables II and III). The mean comparison showed that several mutants had a lower number of days to flowering and maturity than the control, in the four experiments (Tables II and III). There were no

**Table I** - Soybean yield means (kg/ha) with individual and joint analysis of variance.

Genotypes	Location/Year				Mean (genotypes)
	Piracicaba	Piracicaba	Sertãozinho	Assis	
	85/86	86/87	86/87	86/87	
Mutant 8	2616	3403	3539	1911	2867
Mutant 9	1952	3097	3255	2027	2583
Mutant 10	2068	3444	3167	2195	2718
Mutant 13	2119	3294	3585	1968	2741
Mutant 15	2055	3225	3383	2290	2738
Mutant 25	1839	3163	3341	1946	2547
Mutant 27	2306	3271	3384	1773	2683
Mutant 31	2137	3254	3544	2112	2762
Paraná	1862	2966	3574	1859	2565
Mean (Experiments)	2106	3235	3419	1998	2689
F (Genotypes)	0.97	0.42	0.59	1.68	1.55
F (Genotypes x Experiments)	-	-	-	-	0.69
F (Experiments)	-	-	-	-	118.47*
CV (%)	23.07	14.06	11.46	13.33	15.19

\*Significant at the 5% level of probability.

**Table II** - Number of days<sup>1</sup> to flowering in soybean with results of the individual and joint analysis of variance.

Genotypes	Location/Year				Mean (genotypes)
	Piracicaba	Piracicaba	Sertãozinho	Assis	
	85/86 Days	86/87 Days	86/87 Days	86/87 Days	
Mutant 8	43	47	50a	43	46
Mutant 9	43	46	50a	41	45
Mutant 10	44	46	50a	46a	47a
Mutant 13	43	47	50a	46a	47a
Mutant 15	43	47	50a	42	46
Mutant 25	42	46	46	41	44
Mutant 27	43	46	50a	46a	46
Mutant 31	48a	53a	50a	47a	50a
Paraná control	50	53	50	47	50
Mean (Experiments)	44	48	50	44	47
F (Genotypes)	20.11*	49.61*	3.00*	81.23*	6.06*
F (Genotypes x Experiments)	-	-	-	-	7.84*
F (Experiments)	-	-	-	-	175.49*
CV (%)	2.49	1.70	4.17	1.31	2.58

\*Significant at the 5% level of probability.

<sup>1</sup>Means followed by the letter "a" are not significantly different from the control cultivar Paraná according to the Dunnett test at the 5% level of significance.

significant differences in plant height (Table IV). There were significant differences in height for the first pod only in experiment in Piracicaba 86/87 where the

Dunnett test indicated that five mutants (mutants 8, 9, 10, 15 and 25) had a lower height for pod insertion than the cultivar Paraná (Table V).

## Results of the joint analysis

The criterium that only the variables with homogeneous variances in the different experiments would be aggregated in a joint analysis was set. According to this criterium the variable number of days for maturity in the experiment at Sertãozinho was excluded.

The F values for experiments of all traits were significant indicating that the agricultural year or the location effect affected all five characteristics (Tables I to V). This can be observed from the means of the different experiments.

No significant differences were observed for yield (Table I). Mutants 8, 9, 15, 25 and 27 flowered significantly earlier (Table II) and mutants 8 and 25 matured significantly earlier than the control (Table III). The Dunnett test (Table IV) indicated that mutants 8, 9, 10, 13 and 25 were shorter than the control Paraná. No significant genotypic differences were observed for height of pod insertion (Table V).

There were significant interactions (genotypes x experiments) only with regard to the number of days to flowering and maturity, indicating that the agricultural year or the location influenced the behavior of the genotypes for these characteristics. These aspects had already been observed in the individual analyses.

## DISCUSSION

Several authors (Freire Filho, 1968; Verneti, 1982) report a positive correlation between days to flowering and maturity in soybean. Selection of the trait days to maturity should be more effective if made indirectly, by selection of the trait days to flowering (Moro, 1990). This is due to the positive genotypic correlation among these characteristics and to the fact that heritability of days to flowering is greater than that of days to maturity.

Studies performed by Oliveira (1985) for soybean show significant positive correlations between grain yield and maturity, and yield and plant height. In the present study, in spite of mutants 8 and 25 being earlier and shorter than Paraná, yields were similar. As for pod insertion, the lower values observed for these mutants were not significant. However, the general tendency for reduction in plant height and pod insertion may be a limitation for the release of the mutants as cultivars. The other characteristics of the original cultivar remained unaltered, such as determinate growth habit, white flower color, grey pubescence, brown pods and yellow seeds. In some studies with mutation induction for earliness in soybean (Baradjanegara and Umar, 1988) yield and other characteristics were maintained or were even greater than the control, while in other studies (Kotyvics, 1981), the yield of the mutant was smaller than that of the original cultivar.

There are five genes related to flowering in soybean and, in all of them, the dominant allele determines late flowering and maturity and the recessive alleles play an important role in the development of early cultivars (Bonato, 1989). As the majority of genetic studies with induced mutants for various traits in other crops report recessive mutations, it is possible that this may have also occurred in the early mutants obtained in the present research.

## CONCLUSION

Selection of plants with fewer days to flowering in the M3 generation derived from seeds of cultivar Paraná treated with 22 krad of gamma rays resulted in eight early flowering or maturing mutants.

Two of the selected mutants, numbered eight and 25, were on average seven and 10 days earlier in maturity than the control. The early mutants 8 and 25, except for a shorter plant height, had the other agronomic characteristics (yield, height of pod insertion, growth habit, flower color, pubescence and seeds) unaltered in relation to the original cultivar Paraná.

Table III - Number of days<sup>1</sup> to maturity in soybean with results of the individual and joint analysis of variance.

Genotypes	Location/Year				
	Piracicaba 85/86	Piracicaba 86/87	Sertãozinho 86/87	Assis 86/87	Mean (genotypes)
Mutant 8	114.75	116.50	109.00	97.75	109.66
Mutant 9	114.75	116.50	108.00	105.50a	112.25a
Mutant 10	114.75	117.25	109.00	104.25a	112.08a
Mutant 13	111.75	118.00	109.25	106.00a	111.91a
Mutant 15	116.50a	117.25	108.00	107.50a	113.75a
Mutant 25	108.00	116.25	108.00	97.50	107.25
Mutant 27	113.00	118.00	109.25	107.50a	112.83a
Mutant 31	120.00a	121.00a	109.75	107.25a	116.08a
Paraná control	120.00	123.50	116.00	108.00	117.16
Mean (Experiments)	114.83	118.25	109.58	104.58	112.55
F (Genotypes)	10.73*	13.38*	345.77*	4.39*	5.34*
F (Genotypes x Experiments)	-	-	-	-	14.41*
F (Experiments)	-	-	-	-	2.70*
d.m.s. (Dunnett 5%)	5.58	3.19	0.64	9.44	6.55
CV (%)	2.02	1.12	0.24	3.75	2.43

<sup>1</sup>See Table II.

Table IV - Plant height<sup>1</sup> (cm) in soybean with results of the individual and joint analysis of variance.

Genotypes	Location/Year				
	Piracicaba 85/86	Piracicaba 86/87	Sertãozinho 86/87	Assis 86/87	Mean (genotypes)
Mutant 8	46.50	58.75	47.00	33.00	46.31
Mutant 9	45.00	58.75	44.75	33.75	45.56
Mutant 10	45.75	57.75	44.75	37.00	46.31
Mutant 13	45.25	59.50	45.50	34.25	46.12
Mutant 15	50.75	60.50	44.75	34.75	47.68a
Mutant 25	44.75	61.00	48.00	33.25	46.75
Mutant 27	50.00	58.75	48.75	33.25	47.68a
Mutant 31	49.75	63.25	48.00	37.50	49.62a
Paraná control	50.75	65.25	51.00	38.75	51.43
Mean (Experiments)	47.61	60.38	46.94	35.05	47.50
F (Genotypes)	2.03	1.31	1.20	1.15	5.65*
F (Genotypes x Experiments)	-	-	-	-	0.64
F (Experiments)	-	-	-	-	241.06*
d.m.s. (Dunnett 5%)	-	-	-	-	3.24
CV (%)	7.74	7.10	8.54	11.38	8.41

<sup>1</sup>See Table II.

The genetic system involved in maturity and flowering in soybean and the ease with which selection in large populations is performed make mutation induction an attractive alternative technique for soybean breeding for earliness.

**Table V** - Height<sup>1</sup> (cm) of the first pod in soybean with results of the individual and joint analysis of variance.

Genotypes	Location/Year				Mean (genotypes)
	Piracicaba 85/86	Piracicaba 86/87	Sertãozinho 86/87	Assis 86/87	
Mutant 8	11.00	10.00	10.25	7.25	9.62
Mutant 9	11.00	10.25	10.25	5.75	9.31
Mutant 10	10.50	10.25	9.25	8.50	9.62
Mutant 13	11.75	11.00a	8.50	7.00	9.56
Mutant 15	12.50	10.00	11.00	8.25	10.43
Mutant 25	13.50	10.00	10.75	7.50	10.43
Mutant 27	13.50	12.75a	9.75	6.75	10.68
Mutant 31	11.00	11.75a	9.25	7.75	9.93
Paraná control	12.50	13.50	10.25	9.00	11.31
Mean (Experiments)	11.91	11.05	9.91	7.52	10.10
F (Genotypes)	0.99	4.20*	1.69	1.69	1.76
F (Genotypes x Experiments)	-	-	-	-	1.45
F (Experiments)	-	-	-	-	48.25*
d.m.s. (Dunnett 5%)	-	2.60	-	-	-
CV (%)	19.13	11.60	12.90	20.19	16.26

<sup>1</sup>See Table II.

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## RESUMO

Através da indução de mutações pelo tratamento de sementes com 22 krad de raios gama, objetivou-se a obtenção de mutantes precoces no cultivar de soja Paraná, que mantivessem inalteradas as outras características agrônomicas. Foram selecionadas na geração M3 plantas com menor número de dias de florescimento que Paraná controle. Através de seleções posteriores e avanço de gerações, foram selecionados oito mutantes mais precoces que foram ensaiados no campo em quatro experimentos em 85/86 (Piracicaba) e 86/87 (Piracicaba, Sertãozinho e Assis). Nestes ensaios, foram anotados o número de dias para florescimento e maturação, produção, altura de plantas e inserção de vagem e observadas a cor da flor, vagem e pubescência e sementes e hábito de crescimento. Os resultados indicaram que, dentre os mutantes, dois deles apresentaram interesse por serem em média sete e 10 dias mais precoces na maturação do que o original em todos os experimentos, mantendo inalteradas, com exceção da altura de plantas que foi menor, as demais características agrônomicas originais.

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