VOL. 9, NO. 5, MAY 2014 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science
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www.arpnjournals.com

MODE OF INHERITANCE OF GENES CONTROL MATURITY IN SOYBEAN

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ABSTRACT

Inheritance of a character has important significance in determining plant breeding strategies so that improvements in the character can be better. The crossbreeding materials used in this research included Nanti, Dempo, Dieng, Malabar and Grobogan varieties. The research was conducted at the Jambegede Experiment station, Kepanjen, Malang, East Java Province in July 2009. The population was grown in the form of rows of 2.5 m long, spaced by 40 cm x 15 cm, one plant per hole. The population included P_1 (parent), P_2, F_1 F_{1r} (reciprocal F_1) and F_2. Test on the effects of female parent was done by using a mean-difference test (t-test) at 5% level of significance. The degree of dominance of genes (gene action) on the days to maturity was calculated by applying a potency ratio formula showing the gene action's effect on the crossbreeding of both parents on F_1. The chi-square test was used to find out the pattern of F_2 segregation population. The genetic analysis to estimate the number of controlling genes, gene action, and the pattern of segregation was done by employing the SAS program-version 9. The crosses between the used parents had no maternal effect. The days to maturity of soybean led to the parents having earlier maturing days, and the age of the F_1 generation plant was shorter than the parent of longer maturing plants. The major genes had a role in controlling the characters of days to maturity of soybeans in the F_2 population. The cross between Grobogan (early maturity) and Dieng (moderate maturity) varieties followed the ratio of 1 (early maturity): 3 (moderate maturity) which means moderate maturity was controlled by dominant genes.

Keywords: soybean, inheritance, days to maturity

INTRODUCTION

Plant life space is important in agriculture as it relates to cropping pattern. In areas with limited water resources, it is considered as one of the crucial aspects. Early maturity defined as harvest fine than 80 days is one of the characters prefered by farmers' cultivation. In areas which are prospective for the development of soybean plants, but suffering from drought, early maturing soybean varieties have advantage by escaping drought impacts during the plant life (Sweeney *et al*., 2003; Kazuya, 2004; Kyei-Boahen and Zhang, 2006).

Early maturing soybean plants can be produced through crossbreeding techniques. Through breeding methods, improvement in the characters through crossbreeding requires understanding of the related genetic characters, primarily the way those characters can be inherited to filial generations. Based on the analysis of inheritance pattern, the days to maturity of the green bean plants (Cerna and Beaver, 1990), peanut plants (Upadhyay and Nigam, 2004), wheat plants (Iqbal *et al*., 2006) and long beans plants (Kabeta, 2006) are genetically controlled, and their genetic variants play a greater role in the control (Niessl *et al*., 1995; Iqbal *et al*., 2007).

Information about the days to maturity genes of soybeans especially those in tropical areas which is required to examine the inheritance pattern of characters of soybean plants is still limited. Understanding of the inheritance patterns of days to maturity characters of soybean plants will provide an overview of the prediction about a plant's genetic characters in order to increase or assemble high-yielding varieties, as well to get early-maturing plants. This study is aimed at determining the inheritance pattern of days to maturity characters of soybean plants.

MATERIALS AND METHODS

The crossbreeding materials for the parental generations were Nanti, Dempo, Dieng, and Grobogan varieties. The population was grown in the form of rows of 2.5 m, spaced by 40 cm x 15 cm, one plant per hole. The population included P_1, P_2, F_1, F_{1r}, and F_2. The research was conducted at the Jambegede Experiment station, Malang, East Java at an altitude of 335 m above sea level, on alluvial soil type, precipitation type A (Schmidt and Ferguson), and in the early dry season (July 2009).

Fertilization was done seven days after planting by lining the plants. The doses of fertilizers were given in accordance with the recommendation for soybean plants, i.e. 50 kg/ha of Urea, 100 kg/ha of SP-36, and 75 kg/ha of KCl. Plant maintenance was performed intensively including watering, weeding, monitoring, and control of pests and diseases. The maturity of plants was conducted in accordance with the maturity days, i.e. 95 brown pods.

The effects of maternal effect were investigated by comparing the mean value of F_1 with the mean value of $F_{1.r}$ (reciprocal F_1) using a mean-difference test (t-test) at 5% level of significance (Steel and Torrie, 1980). The degree of dominance of genes (gene action) on the days to maturity was calculated by applying a potency ratio formula showing the gene action's effect on the crossbreeding of both parents on F_1 (Petr and Frey, 1966). Based on the selection through a discriminant analysis, the

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chi-square test was used to find out the mode of F_2 segregation population. The genetic analysis was done by employing the SAS program-version 9. The segregation ratios were analyzed through the χ^2 value which was obtained from the following formula:

$$x^2 = \sum_{i=1}^{n} \frac{(0_i - E_i)^2}{E_i}$$

where

Oi = the observed number of phenotypes in category i
Ei = the expected number of phenotypes in category i

The ratios would be consistent with the hypothesis if $\chi^2_{calculation} < \chi^2_{table\ (n-1)}$. The Mendel distribution or modification was used as the hypotheses in accordance with the days to maturity characters of soybean plants on the population of F_2 generation plants.

RESULTS AND DISCUSSIONS

The comparison of days to maturity between F_1 and F_{1r} from the cross between two parental generations shows no reciprocal differences (Table-1), which means there was no influence of maternal effect on the inheritance characters. The days to maturity inheritance of the two parents occurs through the cell nucleus, meaning that for the purposes of genetic analysis, the population of F_1 and F_{1r} as well as F_2 and F_{2r} might be combined.

The days to maturity on the F_1 population were between both parent averages and deviated from both parent averages towards the earlier maturing parents. This data shows a dominance of days to maturity characters. The F_1 population from the cross between Dieng and Grobogan was close to the days to maturity of the parental generation of Dieng. The potency ratios of crosses of DempoxGrobogan and NantixGrobogan was classified as negative incomplete dominance ($-1<hp>0$), which means the plant's days to maturity leads to the earlier maturing days. Another research on the F_1 generation indicates that the plants have earlier days to maturity than that on the long-maturing parent generation (Kheradnam *et al*., 1975; Cober *et al*., 2001). The potency ratio of cross between Grobogan x Dieng is classified as positive dominance, which means the days to maturity of F_1 plants is longer than long-maturing parental generations.

Table-1. T-test maturity on F_1 and F_{1r} generations for maturity plant.

Cross	**Days to maturity** (days)		**Difference**
	F_1±SE	**F_{1r}** (reciprocal F_1) **±SE**	
Nanti xGrobogan	82±2.79	82±2.15	0.22 ns
Dempo xGrobogan	82±1.21	82±0.90	0.17 ns
Dieng xGrobogan	81±1.92	82±1.92	0.43 ns
Malabar xGrobogan	79±2.72	78±3.27.	0.86 ns

Remark: F_1: generation F_1 (P_1 xP_2), F_{1r}: generation F_1 (P_2 x P_1), SE: standard error, ns= not significant at P= 0.05.

Results of the Kolmogorov-Smirnov normality test for the distribution of observed data on the days to maturity of four cross combinations of F_2 population did not follow the normal distribution (Table-2), that the major genes played a role in controlling the days to maturity characters of soybean plants in the F_2 population. Those major genes are genes with large individual expression so that they are easily distinguished (Singh, 1986).

Table-2. Normality test, potency ratios Parental means and F_1 values for maturity plant.

Cross (P_1 x P_2)	**Potency ratios**	**K-S value**	**Days to maturity** (days)		**Average pooled**		**Individual number**			
			P_1±SE	**P_2±SE**	**F_1±SE**	**F_2±SE**	**P_1**	**P_2**	**F_1**	**F_2**
Nanti xGrobogan	-0,53	0.21 **	95±1.74	78±1.55	82±2.33	86±3.02	25	25	19	241
Dempo xGrobogan	-0,13	0.25 **	86±0.54	78±1.55	82±0.98	80±3.03	25	34	21	329
Dieng xGrobogan	1,01	0.22 **	81±103	78±1.55	81±1.85	81±3.41	25	36	13	301
Malabar xGrobogan	0,35	0.09 **	79±1.57	78±1.55	78±2.91	80±3.28	25	28	19	348

Remark: K-S: Kolmogorov-Smirnov normality test of F_2 generations, SE: standard error, ** significant at P 0.01, F_1: generation F_1; F_2: Selfed F_1, P_1: parent 1 dan P_2: parent 2.

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The average days to maturity of the two parents and F_1 was different (Pr <0.01), meaning that the three populations had different days to maturity characters, except a cross between MalabarxGrobogan (Pr = 0.27) (Table-3). The parents and F_1 from the cross of DempoxGrobogan and MalabarxGrobogan had different variance (Pr> 0.05), meaning that the diversity of the three populations had different days to maturity characters. Meanwhile, the parents and F_1 from crosses of NantixGrobogan and DiengxGrobogan had the same variance (P> 0.05), meaning that the diversity of the three populations had the same days to maturity characters. All four cross-variant combinations of parents and F_1 differ from F_2 variants (Table-3).

The crosses of NantixGrobogan, Diengx Grobogan, and MalabarxGrobogan created a larger F_1 variance than those of the two parents, while a cross of DempoxGrobogan produced a larger F_1 variance than P_2. The F_1 variance, based on another research, was smaller from two homozygous parents. This phenomenon took place due to an individual buffering (Allard and Bradshaw, 1964). The variance of F_2 population of the four cross combinations had a larger variance. This shows the phenomenon of F_2 segregating population. The F_2 segregating population is indicated by a larger variance compared to its two parents and F_1 (Table-2).

Table-3. t test an variance of both parents, F_1 and F_2.

	Nanti x Grobogan	Dempo x Grobogan	Dieng x Grobogan	Malabar x Grobogan
$\mu_{P1} = \mu_{P2} = \mu_{F1}$	<0.01 **	<0.01 **	0.02 *	0.27 ns
$\mu_{P1} = \mu_{P2}$	<0.01 **	<0.01 **	<0.01 **	0.11 ns
$\mu_{F1} = \mu_{P1}$	<0.01 **	<0.01 **	0.95 ns	0.72 ns
$\mu_{F1} = \mu_{P2}$	<0.01 **	<0.01 **	<0.01 **	0.27 ns
$\mu_{F1} = \mu_{mMP}$	<0.01 **	0.06 ns	<0.01 **	0.68 ns
$\sigma^2_{P1}= \sigma^2_{P2}= \sigma^2_{F1}= \sigma^2$	0.16 ns	<0.01 **	<0.01 **	<0.01**
$\sigma^2_{F2}= \sigma^2$	<0.01 **	<0.01 **	<0.01 **	<0.01**

Remarks: F_1: generation F_1; F_2: Selfed F_1, P_1: parent 1 dan P_2: parent 2; μ: average and σ: variance.ns= not significant at P 0.05; *, ** significant at P 0.05 and 0.01 respectively

The crosses of Grobogan x Nanti are derived from parents that have different days to maturity and its F_1 days to maturity are not of the days to maturity of both parents. By using a single-locus model, the F_2 population will segregate ¼ (one-quarter) similar to parental generation Nanti, ½ (one-half) similar to F_1, and ¼ (one-quarter) similar to parental generation Grobogan where the partial dominance of gene action employs the single-locus model. The cross between Nanti xGrobogan produces 241 F_2 plants, and based on the selection through a discriminant analysis, and it did not follow the ratio of 1: 2: 1.

Grobogan x Dempo is derived from parents that have different days to maturity and its F_1 days to maturity are located in the middle of the days to maturity of both parents. By using a single-locus model, the F_2 population will segregate ¼ (one-quarter) similar to the parental generation of Dempo, ½ (one-half) similar to F_1, and ¼ (one-quarter) similar to parental generation of Grobogan where the partial dominance gene action employs the single-locus model. A cross between DempoxGrobogan produced 329 F_2 plants and based on the selection through a discriminant analysis, it deviated from the ratio of 1: 2: 1 (Table-4) and did not follow the ratio of 1: 2: 1. By using a two-locus model, the F_2 population would then segregate 9/16 like the parental generation of Nanti or Dempo, 6/16 like its $F_{1,}$ and 1 like the parental generation of Grobogan. In this case, the longer maturing days of a plant was controlled by a large number of dominant loci. A cross between NantixGrobogan produced 241 F_2 plants. Based on the selection through a discriminant analysis, it deviated from the ratio of 9: 6: 1. A cross between DempoxGrobogan produces 329 F_2 plants and based on the selection through a discriminant analysis, it deviated from the ratio of 9: 6: 1 (Table-4), and did not follow the ratio of 9: 6: 1.

The days to maturity characters of soybean plants on the cross of NantixGrobogan and DempoxGrobogan were possibly determined by more than two genes (polygenic). Other studies suggest that early maturity of soybean plants are recessively controlled by monogenic genes (Mc Blain and Bernard, 1987; Bernard, 1987; Cober and Voldeng, 2001a; Cober *et al*., 2001). This gives an understanding that any cross involving two parents does not necessarily produce the same results (Table-4). The parental generations of Dieng and Grobogan had different days to maturity and their F_1's days to maturity is the same as one of the parents, i.e. Dieng. The flow of thought by using a single-locus model result in ¾ part of F_2 was similar to F_1 so that the characters shown by the F_1 were dominant characters, if the character of the late maturity was dominant so the F_2 ratio would be 3 (late maturity): 1 (early maturity), and if the character of the early maturity was dominant so the F_2 ratio would be 3 (early maturity): 1 (late maturity). The use of a two-locus model would be: a) $^9/_{16}$ part of its F_2 was like its parent, so the days to

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maturity was controlled by two complementary genes, b) $^{13}/_{16}$ part of its F_2 was like F_1, so the days to maturity was controlled by two epistatic dominant genes, c) $^{15}/_{16}$ part of its F_2 is like F_1, so the days to maturity was controlled by two duplicate genes. The inheritance pattern of days to maturity on the cross of Dieng (217 plant) x Grobogan (84 plant), which means that the days to maturity was controlled by dominant genes. The dominant effect of the gene refers to the most important genetic parameter to control most of the plant properties (Khaghani, 2012; Refaey and Razek, 2013). This result is consistent with a study on the maturity on groundnut plant's leaves (Adisyahputra, 2011).

A cross between Malabar and Grobogan had the same days to maturity and F_1 from the cross was the same as the parent. Thus, it can be described as follows: a). If the $^{13}/_{16}$ part of its F_2 is like F_1, then the early maturity of the plant was controlled by two Epistatic dominant genes, b). If the $^{15}/_{16}$ part of its F_2 is like F_1, then the days to maturity was controlled by two duplicate genes. Based on chi-square analysis, the digenic inheritance was selected based on the filial generation F_1 and the discriminant did not follow the ratio of 13: 3 and 15: 1 (Table-4). Other studies on plants like a cross between a large chili with curly chili, the days to maturity character is controlled by positive incomplete dominant gene action (Arif *et al*., 2012).

In the green bean plants, the days characters are additive and controlled by multiple genes (Imrie *et al*., 1988). The additive effect is defined as the average effects of genes, dominance as an allelic gene interaction and epistasis as a non-allelic gene interaction, which affects certain properties (Rahman and Malik, 2008). Parents as a source of genes necessary for the genetic improvement of a variety with superior characters are essential in breeding programs. Thus, breeding programs to assemble varieties with the character of early maturity (<80 days) using the cross of the two parents have a large quantity of F_2 population used to get the early maturing plants.

Table-4. Chi-square analysis to test goodness of fit for monogenic and digenic inheritances.

Gene and Dominance	Segregation ratio	Observed ratio	Expected Ratio	Chi-square Test
NantixGrobogan				
Monogenic	1 : 2 : 1	21 : 213 : 7	60.25 : 120.5 : 60.25	143.64 **
DempoxGrobogan				
Monogenic	1 : 2 : 1	28 : 236 : 65	82.25 : 164.5 : 82.25	70.48 **
Digenic	9 : 6 : 1		185.06 : 123.38 : 20.56	332.14 **
DiengxGrobogan				
Monogenic	3 : 1	217 : 84	225.75 : 75.25	1,36 tn
Digenic	13 : 3		244.56 : 56.44	16,57 **
	15 : 1		282.19 : 18.81	240,94 **
	9 : 7		169.31 : 131.69	30,70 **
MalabarxGrobogan				
Digenic	13 : 3	220 : 128	326.26 : 21.75	451.71 **
	15 : 1		282.75 : 65.25	1927.51 **

Remark : ns= not significant at P 0.05, * ,** significant at P 0.05 and 0.01, respectively

CONCLUSIONS

a) There is no influence of maternal effect on the inheritance of days to maturity characters of both parents.
b) The plant's days to maturity leads to the earlier-maturing days, and the F_1 generation plants have earlier maturing days compared to the late-maturing parents.
c) The major genes play a role in controlling the days to maturity characters of soybean plants in the F_2 population.
d) The F_2 population from the crosses of Grobogan (early maturity) and Dieng (moderate maturity) on the days to maturity character follows the ratio 1(early maturity) : 3 (moderate maturity)

ACKNOWLEDGEMENTS

I would like to thank the Indonesian Agency for Agricultural Research and Development, which has funded this research, as well as Mr. Sumardi (technical coordinator at the Jambegede Experiment station) and Antoni (technician at the Indonesian Legumes and Tuber Crops Research Institute) who have assisted me in the research activities.

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