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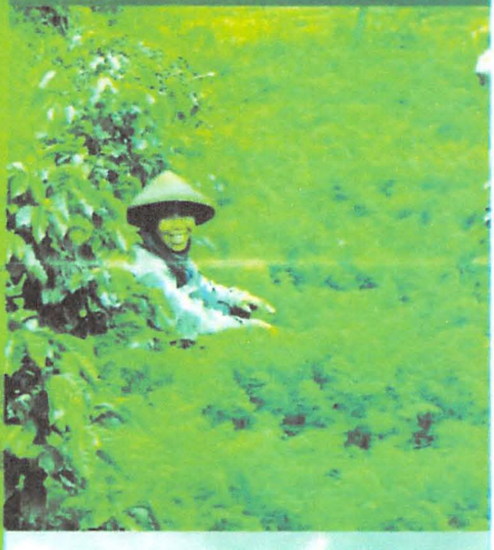

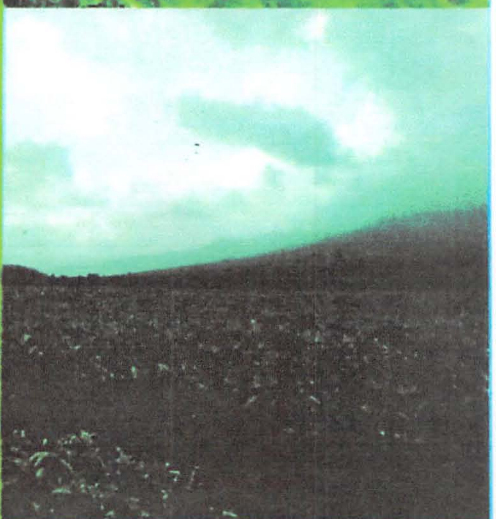

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MAXIMIZING GENETIC IMPROVEMENT IN THE SELECTION OF SOYBEAN FOR ADAPTATION TO LOW LIGHT INTENSITY

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Abstract

Breeding for soybean varieties with improved adaptation to low light intensity under intercropping condition is currently in progress at the Research Group on Crop Improvement, Department of Agronomy and Horticulture, Bogor Agricultural University. A study was conducted to maximize genetic improvement in the selection for tolerance to low light intensity in soybean lines. The study consisted of a genetic study to estimate the response to selection under low light intensity and a selection under field condition of advanced breeding lines. The estimation of response to selection was conducted in a genetic study was carried out in Griffing method II with 12 F_1 genotypes and the parental lines to determined genetic parameters and the estimation of response to selection. The study showed that selection with secondary characters will not result in a higher yield than direct selection based on yield alone. The estimation on response to selection was evaluated in a selection of 150 advanced breeding lines under the canopy of immature rubber trees.

Keywords: correlated response, low light intensity, selection, soybean, tolerance.

INTRODUCTION

Soybean (*Glycine max* (L) Merr.) is an important source of protein for many Indonesian and the consumption of soybean for food is increasing year by year. The soybean consumption in Indonesia in 2005 reached a total of 1.8 million tones for food and 1.1 million tones for feed (Department of Agriculture, 2005). The increasing soybean consumption is not met by national production. In 2000, national soybean production was 1.018 million tones, however, by 2005 the production declined to only 0.808 million tones (National Statistical Agency, 2006). This decline in soybean production is mainly due to decreasing harvest area because the productivity of soybean has remained relatively constant. In 1998 the total harvested area of soybean was 1.09 million hectares. This area was reduced to only 0.825 million hectares in 2000 and further reduced to only 0.621 million hectares in 2005 (Sudaryanto and Swastika, 2007). Competition with corn which is more profitable than soybean is one of the reasons in the declining soybean harvested area.

Expansion of soybean harvested area should be the main priority in the effort to increase soybean production. However, the targeted area should not be in competition with the more profitable corn production. One of the arable land available for soybean production without competition with corn, is the alley of immature estate crops such as rubber and palm oil.

From a total of 3.3 million ha of rubber estate, 33% are consisted of immature rubber trees which could be intercropped with soybean (Nurhaemi, 2004).

The main constraint in soybean production in intercropping with estate crop is low light intensity. The light intensity under three-year old rubber tree is 547.2 cal/cm^2/day or less than 50% of the light intensity in the open field (Sopandie et al, 2002). Under 50% shading, soybean production reduced by an average of 60% compared to production in the open field. The reduction in yield is lower in the tolerant genotypes (Sopandie et al,2002). However, currently there no soybean varieties which is tolerant to low light intensity and suitable for intercropping with estate crop.

Breeding for soybean varieties with improved adaptation to low light intensity under intercropping condition at the Center for Crop Improvement Studies, Department of Agronomy and Horticulture, Bogor Agricultural University was started in 2000 with selection of tolerant parental lines and hybridization. After 7 generation of bulk segregating population and line development, advanced breeding lines have been developed. More than 200 F_7 lines with good agronomic characters have been developed and ready for selection for adaptation to low light intensity.

In conventional breeding program, selection is mainly based on phenotype of which expression is highly dependent on the environment. Therefore, selection for adaptation to stress environment should be conducted in target environment to avoid genotypes x environment interaction (Ceccarelli 1994). However, selection for characters such as yield under stress environment may result in low genetic gain due to high environmental factors, leading to low heritability (Austin, 1993). Therefore, indirect selection using secondary character linked to yield under stress has been attempted. Various studies have been conducted in the Department of Agriculture and Horticulture, Bogor Agricultural University to develop selection criteria based on morphological, physiological and agronomic characters (Trikoesoemaningtyas *et al*, 2003). Physiological studies on the response of soybean to low light intensity have resulted in several morphological and physiological characters linked to yield (Muhuria *et al* 2006, Kisman *et al*, 2007). These characters have been proposed as selection criteria in the selection of soybean for adaptation to low light intensity.

To maximize genetic improvement in a selection under stress environment, the character for selection should be carefully chosen. Response to selection or selection gain is a good estimation to predict the genetic improvement in the subsequent generation after selection (Fehr, 1987). When a secondary character linked to yield under stress is used, a correlated response to selection is used to estimate genetic improvement made in yield after a selection with the secondary character (Roy, 2000). The merit of a secondary character as a selection criterion depends on the value of the correlated response.

MATERIALS AND METHODS

The study was conducted in two experiments, (1) estimation of response to selection and (2) selection of advanced breeding lines. The genetic study was conducted at BBBIOGEN the experiment station in Bogor from August to January 2006. The selection for advanced breeding lines was conducted in the rubber plantation of PTPN VIII, in Sukabumi, West Java from December 2005 to April 2006.

Estimation of Response to Selection

The estimation of genetic parameters was conducted in a diallel analysis followed by estimation of response to selection. For the estimation of genetic parameters two low-light intensity tolerant genotypes, Pangrango and Ceneng, were crossed in all possible combinations including reciprocals with two low-light intensity sensitive genotypes, Godek A and Slamet in June 2004 to November 2005. The 12 F_1 genotypes and the four parental lines were planted under 50% shading in a Paranet screen house. The seeds were planted in rows of ten plants arranged in a Completely Randomized Block Design with 3 replicates. Observation was conducted on agronomic characters and yield.

The data were analyzed using Hayman diallel analysis (Singh and Chaudhary, 1976) and the estimation of the broad sense and narrow sense heritability (h_{bs}^2 and h_{ns}^2) were conducted according to Mather and Jinks (1982). Response to selection (R) was estimated as R = i hns σ_p according to Roy (2000) where i = selection intensity, h_{ns} = square root of narrow sense heritability, and σ_p = square root of phenotypic variance. The correlated response was calculated as $CR_x/R_x = r_g(i_y h_y / i_x h_x)$ according to Falconer and Mackay (1996), where r_g = coefficient of genetic correlation, i_y and i_x = selection intensity for the secondary character and the primary character; h_y and h_x = square root of narrow sense heritability for the secondary and primary characters.

Selection of Low-light Intensity Tolerant Soybean Lines

The selection for low-light intensity soybean lines was carried out for 149 F_7 lines derived from crosses of LI-tolerant lines with high yielding varieties. The experiment was conducted in Augmented design with 9 replications only for the parental lines to estimate the experimental errors. Seeds were planted in rows as alley crop between immature rubber trees with 50% shading and in open field. Observation was conducted for agronomic characters and yield.

The data were analyzed for Tolerance index as TI = (Ys/Yp)/ (Yms/Ymp)] according to Pirayvatlou (2006) where Ys is the yield under stress condition, Yp is the yield under optimum condition, Yms = average yield of all lines under stress condition and Ymp = average lines under optimum condition. Selection was conducted with the selection intensity of 10% of all population based on leaf greenness intensity, number of filled pod per plant, yield under low light intensity and tolerance index. Genetic improvement was estimated by selection differential calculated as the difference between the mean of the selected lines from the mean of all the evaluated lines.

RESULTS AND DISCUSSION

Estimation of Response to Selection

Selection is an important activity in plant breeding after a population with good variability have been developed. The purpose of a selection in plant breeding is not to select the best individual from a population, but to predict the performance of the progeny generation of the selected individuals. Prediction of the performance of subsequent generations after a cycle of selection is done by estimating the response to selection or genetic gain after selection (Fehr, 1987).

Estimation of genetic variances following diallel analysis showed that variability of density of trichome, chlorophyll content and agronomic characters under low light intensity were mostly due to genetic variability which was indicated by the high estimate for the broad sense heritability. However, most of the genetic variability are due to the effect of dominant gene action (Muhuria, 2006; Wirnas, 2007). The large effect of dominant genetic variances reduces the estimate for narrow sense heritability, particularly for the number of pod per plant and number of filled pod per plant (Table 1).

The use of secondary characters, such as morphological or yield components, as selection criteria to improve yield under stress condition should be based on the estimation of correlated response. According to Austin (1993), a secondary character will give a high correlated response to selection when the character has higher heritability estimate than yield and is highly correlated with yield under stress condition. The result shows that only the character of trichome density has higher narrow sense heritability estimate than yield under low light intensity.

Table 1. Estimates of broad sense (h_{bs}^2)and narrow sense heritability (h_{ns}^2) and correlated response to selection (CRx/Rx)

Character	Broad sense heritability (h_{bs}^2)	Narrow sense heritability (h_{ns}^2)	CRx/Rx
Trichome density	98.41	52.09	0.97
Chlorophyll a	94.53	48.26	0.89
Chlorophyll b	93.75	29.69	0.55
Total number of pod	73.06	7.00	0.73
No of filled pod	85.92	13.20	0.72
Seed yield /plant	72.99	51.48	

A selection using secondary character will result in high the improvement of yield only if the correlated response to selection is higher than 1.0 (Roy, 2000). The correlated response to selection for the secondary characters ranged from 0.55-0.97 (Table 1). This result indicated that selection using these secondary characters will not be able to improve soybean yield under low light intensity. Therefore, selection for soybean adaptation to low light intensity should be conducted by direct selection on yield or selection of a parameter based on yield.

Genetic Improvement of Soybean Adaptation to Low Light Intensity

The estimation of correlated response to selection corresponds to the improvement of yield when selection is done indirectly using secondary characters. The estimation of correlated response of several characters from the first experiment was evaluated in a selection of 150 advanced breeding lines in intercropping with immature rubber trees. The selection was conducted in an indirect selection using secondary characters of leaf greenness intensity and number of filled pod per plant and in a direct selection using yield under low light intensity and tolerance index based on yield. Trichome density was not used in the selection because this character was difficult to observe under field condition.

Leaf greenness was used in indirect selection for yield under low light intensity to replace chlorophyll content because the character is more easily observable under field condition. Intensity of leaf greenness was found to be highly correlated with chlorophyll content (Muhuria *et al*, 2006). The selection was conducted for 15 lines with the highest intensity of leaf greenness. These lines have variable seed yield per plant from 2.44 g to 10.86 g with the mean of 6.43 g/plant (Table 2). Only 3 lines selected by intensity of leaf greenness are among the highest yielding lines under low light intensity namely GC-19-6 , SC-55-4 and SC-39-1.

Table 2. Yield of soybean lines selected by leaf greenness

Selected Lines	Leaf greenness	Yield/plant (g)
GC-75-1	1.18	3.56
GC-22-9	1.16	5.22
GC-19-6	**1.15**	**9.93**
GC-19-5	1.13	6.94
GC-19-7	1.12	7.30
SC-55-4	**1.11**	**10.86**
SC-68-2	1.11	6.76
GC-70-6	1.10	8.70
PS-9-6	1.10	6.59
GC-74-7	1.10	5.73
SC-68-1	1.10	4.62
GC-1-3	1.10	4.45
GC-75-10	1.10	3.82
SC-39-1	**1.09**	**9.55**
GC-17-3	1.08	2.44

Under optimum condition, the F7 lines produced an average of 178 pods per plant. Under low light intensity when intercropped with rubber trees, these lines produced 18.8 to 95.2 filled pods per plant. This was mainly due to high incidence of unfilled pod under low light intensity and the percentage of unfilled pod could reach as high as 45 %. The range of number of filled pod/plant from all the lines is shown in Figure 1.

Selection based on the number of filled pod per plant was conducted for 10% of lines with the highest number of filled pod per plant. The selected 15 lines have filled pod ranging from 56 to 95 filled pods. The yield of the lines selected by number of filled pod per plant ranged from 4.45 g to 11.41 g/plant with a mean yield of 7.24 g/plant. From the lines selected for highest number of filled pod per plant, only two lines were among the lines with highest yield under low light intensity, namely SP-42-1 and GC-13-7 (Table 3).

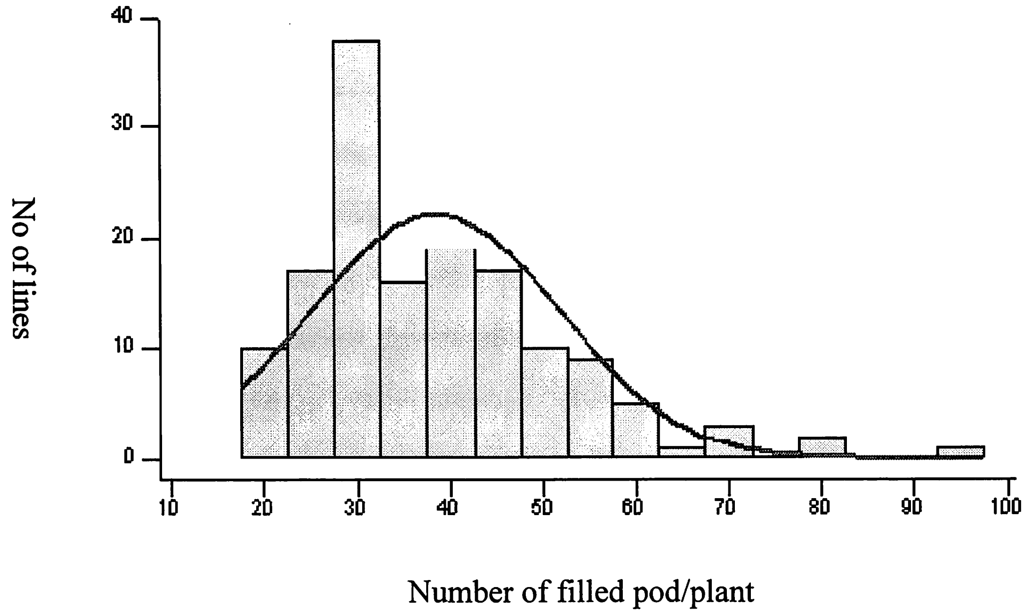

Figure 1. Distribution of soybean lines for number of filled pod per plant under low light intensity.

Table 3. Yield of soybean lines selected by no of filled pod

Selected Lines	No.filled pod /plant	Yield/plant under shading (g)
SP-42-1	**95.20**	**11.41**
GC-89-2	78.50	7.75
CG-75-1	77.70	7.77
GC-87-3	70.70	7.67
PG-65-6	69.70	6.24
GC-70-6	69.40	8.70
CG-22-10	63.70	8.20
GC-1-3	61.30	4.45
GC-78-1	60.40	6.01
PG-44-4	59.00	5.43
GC-74-7	58.50	5.73
GC-13-7	**58.20**	**8.70**
GC-31-2	57.40	7.06
SP-32-1	57.10	7.46
CS-50-2	56.50	6.08

Under open field condition, the F_7 soybean lines produced up to 61.33 g/plant with an average of 27.56 g/plant. However, under low light intensity when grown as alley crop with rubber trees, the highest line, SC11-1 only produced up to 14.13 g. The distribution of lines based on seed yield under low light intensity is shown in Figure 2.

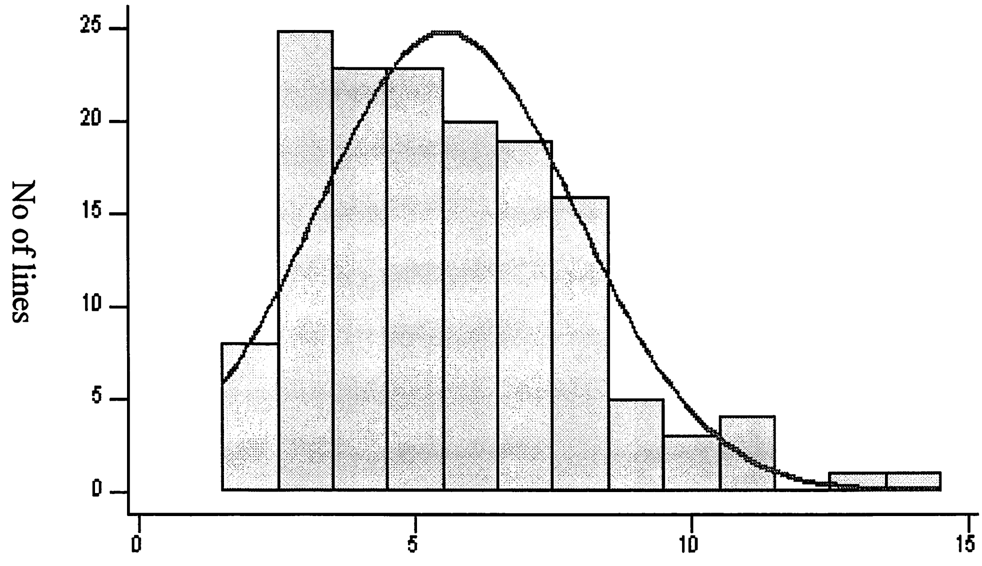

Figure 2. Distribution soybean lines based on seed yield per plant under low light intensity

Table 4. Lines with highest yield under low light intensity

Selected lines	Yield under shading (g/plant)	Yield in open field (g/plant)
SC-11-1	14.13	23.99
SC-52-6	13.06	32.40
SP-42-1	11.41	38.44
SP-10-4	11.15	35.73
SC-55-4	10.86	16.91
SC-54-1	10.69	37.80
GC-19-6	9.93	35.68
SC-39-1	9.55	20.32
SP-16-2	9.55	37.35
SC-1-8	9.44	20.32
PS-60-2	8.82	29.63
GC-13-7	8.70	27.91
GC-70-6	8.70	41.38
SC-7-1	8.58	34.46
CG-63-4	8.47	32.24

Tolerance index is a parameter which is commonly used to identify genotypes with ability to maintain performance under stress condition relative to optimum condition. The tolerance index was calculated as a ratio of the performance of an individual genotype to the mean performance all the genotype evaluated (Fisher and Maurere, 1978). In this trial, the tolerance index was based on the yield. Selection for the tolerance index was conducted with 10% selection intensity and selected 15 lines with the highest tolerance indexes. Some of the lines with high tolerance index have very low yield both under low light intensity and under open field, namely GP-5-7, PS-33-1, PG-29-5 (Table 5).

Table 5. Tolerance index and yield of soybean lines selected by tolerance index

Selected lines	Tolerance index	Yield in open field (g/plant)	Yield under shading (g/plant)
CG-75-1	4.064	9.46	7.77
SC-55-4	**3.178**	**16.91**	**10.86**
SC-11-1	**2.914**	**23.99**	**14.13**
GC-20-2	2.731	13.59	7.50
GP-5-7	2.517	5.15	2.62
CS-29-1	2.501	12.05	6.09
PS-33-1	2.489	9.72	4.89
SC-54-1	**2.347**	**16.51**	**7.83**
SC-39-1	**2.325**	**20.32**	**9.55**
PS-57-6	2.185	18.32	8.09
SC-52-6	**1.994**	**32.40**	**13.06**
SC-68-2	1.912	17.49	6.76
CG-22-10	1.822	22.27	8.20
SP-24-1	1.721	18.00	6.26
PG-29-5	1.720	9.52	3.31

The main objective in breeding for soybean adaptation to low light intensity is to develop not only genotype with the ability to tolerate low light intensity as measured by the ability of a genotype to avoid yield reduction (high tolerance index), but also genotype with high yielding ability. Therefore, the yield of the tolerant lines under low light intensity should also be taken into consideration when making selection based on tolerance index. Five of the highly tolerant lines have high yield under low light intensity, namely SC-55-4, SC-11-1, SC-54-1, SC-39-1, and SC-52-6 which yield from 7.83 – 14.13 g /plant.

Evaluation of selection criteria in the selection of 149 F_7 lines under field condition showed that selection with leaf greenness with 10% selection intensity resulted in 15 lines with mean yield of only 6.43 g/plant (Table 6). Similarly, selection using number of filled pod resulted in lines with mean yield of 7.24 g/plant. The results showed that direct selection of yield under low light intensity gives the highest mean yield of the selected lines of 10.2 g/plant.

Table 6. Selection Differential of Different Selection Criteria

Selection criteria	Mean yield of selected lines (g)	Mean yield of all lines under shade (g)	Selection Differential (g)
Leaf greenness	6.43	5.57	0.86
No of filled pod	7.24	5.57	1.67
Tolerance index	7.79	5.57	2.22
Yield under shade	10.2	5.57	4.63

Genetic improvement following a selection is measured by the selection differential, the difference between the mean of the selected lines with the mean of all the lines being evaluated. To maximize genetic improvement in the selection for soybean adaptation to low light intensity should be conducted using yield under low light intensity as selection criteria, because it gives the highest selection differential (Table 6). To further improve the genetic gain in the selection, more stringent selection intensity of 5% should be applied with larger number of lines used in the evaluation.

CONCLUSION

Estimation of correlated response showed that indirect selection with morphological character and yield component will not give needed genetic improvement in soybean yield under low light intensity. Direct selection on yield under low light intensity gave the highest selection differential in the selected F_7 lines.

Acknowledment

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