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The Role of Heritability and Genetic Variability in Estimated Selection Response of Soybean Lines on Tidal Swamp Land

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ABSTRACT

Selection response is affected by genetic variability and heritability. High selection response is achieved by broad genetic variability and or high heritability. The objective of this study is to estimate the selection response of soybean lines. Forty soybean lines derived from "Sinabung" × MLGG 1087 cross were grown in tidal swamp land in Barito Kuala, South Kalimantan. Broad genetic variability was shown by seven agronomical characters, such as days to flowering and maturing, number of branches per plant, number of reproductive nodes per plant, number of filled pods per plant, weight of 100 grains, and grain yield. Narrow genetic variability was shown by plant height. High heritability was shown by days to flowering (0.923), days to maturity (0.896) and weight of 100 grains (0.762); where their selection responses were 4.34 days, 3.53 days and 1.21 g, respectively. Moderate heritability was shown by plant height (0.435) and number of filled pods per plant (0.226) with the selection response of 6.41 cm and 1.82 pods. Low heritability was shown by number of branches per plant (0.121), number of reproductive nodes per plant (0.160) and grain yield (0.056) that lead selection response of 0.10 branch, 0.58 nodes and 0.03 t/ha grain. In this study, the characters with high genetic variability but low heritability produced low selection response. It indicates that the role of heritability was greater than genetic variability.

Keywords: Acid soil, genetic variability, heritability, selection response, soybean, tidal swamp land

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INTRODUCTION

Soybean ranks as the third most important food crop in Indonesia, after rice and maize. Soybean is used to make tempeh and tofu. The average demand of soybean is estimated to be 2.2 million tons every year

(Kementerian Pertanian, 2015). In 2015 total area where soybean was harvested was 614,095 ha, a decrease of 1,590 ha or 0.26% from 2014 (BPS, 2016). Soybean demand in 2019 is expected to be 3.25 million tons (Bapennas, 2013) and due to constraints in available land suboptimal land such as swamp area covering 33.4 million ha, which includes of 20.19 million ha of tidal and 13.28 million ha of water logged areas are seen as the alternative (Alihamsyah et al., 2003).

Tidal swamp land is suboptimal land (acidic Organosols) where issues such as macronutrients deficiency and micronutrients toxicity (von Uexkull & Mutert, 1995) need to be addressed. Soil amelioration and developing tolerant plant are two techniques to overcome some of the challenges, of which developing and cultivating tolerant plant is the more affordable. The objective of the research in the present work was to compare the role of genetic variability and heritability in estimated selection response of soybean lines on tidal swamp land.

MATERIALS AND METHODS

The study was carried out from February to May 2012 on tidal swamp land type C in Wanaraya, Barito Kuala, South Kalimantan. Tidal swamp land type C is a type of swamp land, where there is no water logging even in high tidal phase and water table level that is less than 50 cm below the soil surface (Alihamsyah et al., 2003). The soil properties for the site was acidic as indicated by very low pH and high Al saturation. Exchangeable aluminum (Al_{ex}) and hydrogen (H_{ex}) were 9.65 me/100 g and 0.46 me/100 g, respectively resulting very high Al saturation of 79.09% (Table 1). Organic C is very high in this peat soil. These soil properties, especially Al saturation, are appropriate for determining tidal swamp land-tolerance for soybean planting. The design was randomized completely block with three replications. Forty populations of F7 derived from crossing between "Sinabung" and genotype of MLGG 1087 - "Sinabung" is a high yielding variety in optimal condition, while MLGG 1087 is a land race that adaptive in tidal swamp land.

Before planting, weed control measures were adopted to eradicate the weeds, and the minimum tillage was applied by plowing and leveling the soil. Every soybean line

Table 1
Soil properties

Soil properties	Value
pH (H2O)	4.40
pH (KCl)	4.37
N (Kjedahl) (%)	0.70
C organic (Kurnis) (%)	8.05
P2O5 (Bray I) (ppm)	81.50
SO4 (ppm)	144.00
Fe (ppm)	471.83
Zn (ppm)	2.44
Cu (ppm)	1.89
K (me/100 g)	0.25
Na (me/100 g)	0.40
Ca (me/100 g)	0.97
Mg (me/100 g)	0.47
CEC (me/100 g)	103.00
Al exchangeable (me/100 g)	9.65
H exchangeable (me/100 g)	0.46

was grown in a plot of 1.6 m × 3 m size with planting space of 0.4 m × 0.15 m. Fertilizers of 125 kg/ha Urea, 250 kg/ha SP36 and 150 kg/ha KCI were applied two times, at sowing time with dosages of 50 kg/ha Urea, 250 kg/ha SP36 and 150 kg/ha KCI, while the rests were applied when the plants began to bloom. Two and four weeks after planting, manual weeding was done in order to control weed growth. The presence of pests and diseases were intensively monitored and harvesting was carried out when plants reached physiological maturity.

The temperature at the experiment site ranged between 26.8-27.5°C with an average minimum temperature 24.1 °C and maximum temperature 32.2°C. The relative humidity and rainfall ranged between 80.6-85.3% and 126.3-402.8 mm with the highest relative humidity and rainfall recorded in February and April respectively (Table 2).

The data was analysed by PKBT-STAT 1.0; expected mean squares, genoytpic coefficient of variance (GCV) was calculated (Singh & Chaudhary, 1979). Genetic variability criteria were classified based on genotypic standard deviation ($\sigma_{\sigma_g^2}$) according to Anderson and Bancroff in Wahdah et al. (1996). The broad genetic variability was achieved when GCV ≥ 2 $\sigma_{\sigma_g^2}$, whilst narrow genetic variability was achieved when GCV < 2$\sigma_{\sigma_g^2}$. Selection response was estimated according to Falconer (1989) as SR = i·h^2·SD; where SR = selection response, i = selection intensity, h^2 = heritability, SD = standard deviation.

Table 2
Weather data from February to May 2012

	Minimum temperature (°C)	Maximum temperature (°C)	Average temperature (°C)	Relative humidity	Rainfall (mm) (%)
February	24.2	31.3	26.8	85.3	155.7
March	24.1	31.9	26.9	84.3	263.6
April	24.2	33.0	27.2	84.4	402.8
May	24.1	33.1	27.5	80.6	126.3
Average	24.1	32.3	27.1	83.6	237.1

RESULTS AND DISCUSSION

Analysis of variance for phenotypic performance of the observed agronomical characters showed that six characters were significantly different (Table 3). Six characters that differed significantly were days to flowering, days to maturity, plant height, number of reproductive nodes per plant, number of filled pods per plant and weight of 100 grains. To measure genotypic performance, the data was studied by eliminating environmental factor. Hence, the non significant calculation based on analysis of variance on number of branches per plant and grain yield does not indicate no genetic variability.

Table 3
Analysis of variance of agronomical characters of 40 soybean lines

Character	MS_g	MS_e
Days to flowering (day)	21.49**	0.58
Days to maturity (day)	15.11**	0.56
Plant height (cm)	210.20*	63.43
Number of branches per plant	0.89^{ns}	0.63
Number of reproductive nodes per plant	12.83*	8.17
Number of filled pods per plant	63.38**	33.81
Weight of 100 grains (g)	2.44**	0.23
Grain yield (t/ha)	0.20^{ns}	0.17

**significant at level of 1%, *significant at level of 5%, nsnot significant at level ≤5%

The average of days to flowering reached 41 (Table 4). The earliest days to flowering was 35 days and the longest 46 days. Similar pattern was shown with regards to days taken to reach maturity, and which averged 84 days. There were two soybean lines where maturity was lower than 80 days, i.e. Snb/1087-210-4-8 (79 days) and Snb/1087-119-2-6 (78 days). These two lines are prospective choices for developing early maturity soybean variety.

Table 4
Range, average and standard deviation of agronomical characters of 40 soybean lines

Character	Range	Average
Days to flowering (day)	35.0 – 45.7	41.4
Days to maturity (day)	78.3 – 87.0	84.1
Plant height (cm)	28.2 – 70.1	49.5
Number of branches per plant	0.6 – 3.2	2.3
Number of reproductive nodes per plant	5.7 – 15.3	11.0
Number of filled pods per plant	7.1 – 29.3	17.1
Weight of 100 grains (g)	5.26 – 9.12	7.45
Grain yield (t/ha)	0.26 – 1.43	0.70

Plant height ranged between 30 – 70 cm with the average being 49.5 cm (Table 4). The highest number of plants was about 45 cm which might be due to the high acidity suppressing plant vegetative growth. Verde et al. (2013) reported plant height is suppressed due to high acidity. In this study number of branches ranged between 1 – 3 branches per plants. Number of reproductive nodes per plant is also often affected by branches, where more branch nodes and branch reproductive nodes are produced from greater branch dry matter per plant (Carpenter & Board, 1997).

Grain yield is the most important character in soybean, and average of grain yield was 0.70 t/ha ranging from 0.26 – 1.43 t/ha (Table 4). There were four soybean lines having grain yield higher than 1 t/ha, i.e. Snb/1087-210-4-13 and Snb/1087-238-1-1 (1.1 t/ha), Snb/1087-210-4-9 (1.20 t/ha), and Snb/1087-159-4-4 (1.43 t/ha). Grain yield is a complex trait that has relationship with other yield components, especially number of filled pod and grain size. In this study, number of filled pods per plant ranged 7.1 – 29.3 pods with average of 17.1 pods per plant. The highest number of filled pods per plant was reached by Snb/1087-148-2-10 (29 pods) and Snb/1087-210-4-7 (27 pods). One of the four soybean lines (line of Snb/1087-210-4-13) with highest grain yield, also had relatively high number of filled pod per plant (23 pods per plants). In this study one of the four soybean lines with the highest grain yield, Snb/1087-159-4-4, also had the highest grain size (9.12 g/100 grains). Therefore, these two lines are very prospective for developing high yielding soybean variety for tidal swamp land tolerance.

In analysis of variance, environmental factor is included in calculating the variance. Separation environmental factor is needed to ascertain genotypic performance such as genotypic coeficient variance (GCP) and heritability. Based on the genetic standard deviation ($\sigma_{\sigma^2_g}$), all of the observed characters had broad genetic variability, except plant height that had narrow genetic variability (Table 5). The broad GCV allows high selection response, as reported in Barma et al. (2012) that the crosses with high genetic variability tended to produce high selection response because genetic variability is calculated from genetic variance. The GCV values were lower than phenotypic coefficient of variation (PCV) values for all observed charcaters (Table 5). The difference between PCV and GCV values varied among the observed characters. The characters of days to flowering, days to maturity, and weight of 100 grains achieved closer values between these two parameters. The presence of wider adaptability of the closer values between PCV and GCV indicate the low environmental factor influencing the characters (Dilnesaw et al., 2013; Reni and Rao, 2013; Nidhi et al., 2015; Eka & Lal, 2016). Therefore, this closer values is important because phenotypic expression indicates its genotypic value.

The characters: days to flowering, days to maturity and weight of 100 grains

Table 5
Phenotypic and genotypic coefficient of variance and variability criteria of agronomical characters of 40 soybean lines

Character	PCV	GCV	$\sigma_{\sigma^2_g}$	Criteria
Days to flowering (day)	6.641	6.381	1.583	Broad
Days to maturity (day)	2.767	2.620	1.114	Broad
Plant height (cm)	21.407	14.126	17.004	Narrow
Number of branches per plant	36.056	12.538	0.096	Broad
Number of reproductive nodes per plant	28.439	11.367	1.310	Broad
Number of filled pods per plant	38.662	18.368	5.990	Broad
Weight of 100 grains (g)	13.202	11.525	0.181	Broad
Grain yield (t/ha)	60.219	14.194	0.024	Broad
Grain yield (t/ha)	60.219	14.194	0.024	Broad

showed the highest heritability, i.e. 0.923, 0.896 and 0.762 respectively (Table 6). Some authors also reported high heritability on days to flowering (Aditya et al., 2011), days to maturing (Kuswantoro, 2012; Ojo & Ayuba, 2016), and weight of 100 grains (Aditya et al., 2011). On the other hand, some studies reported lack of consistency in heritability values on the matter of weight of 100 grains (Aditya et al., 2011; Alt et al., 2002; Johnson et al., 2001; Kuswantoro et al., 2006, 2013; Reni & Rao, 2013). This inconsistency may be due to the different genotypes, environment, and interaction between genotypes and environments.

Plant height and number of filled pods per plant showed moderate heritability (Table 6). In optimal soil condition, some studies reported high heritability for plant height (Malek et al., 2014; Reni & Rao, 2013; Yadav et al., 2015) and number of pods (Adsul & Monpara, 2014). The difference heritability between soil acid condition and optimal may be due to the suppressing plant height by acid soil condition. Moderate heritability on plant height and number of filled pods suggests that genetic factor and environmental factors have an effect on these two characters.

Low heritability was indicated by the number of branches per plant, number of reproductive nodes per plant, and grain yield (Table 6). Low heritability on these three characters suggests environmental factors have high role in expressing these characters. However, some studies reported that number of branches per plant had high heritability (Aditya et al., 2011; Reni & Rao, 2013). However, low and moderate heritability for two different populations was obtained by Wiggins (2012), and high heritability on grain yield in Aditya et al. (2011) and Adsul and Monpara (2014). Low heritability indicates that environmental factor has a higher role than genetic factors. The inconsistent heritability value on grain yield may be due to the different populations.

High heritability values were shown by number of days taken for plants to flower, period to reach maturity and the weight of 100 grains. These three characters will affect

Table 6
Standard deviation, heritability and selection response of agronomical characters of 40 soybean lines

Character	Standard deviation	H_{bs}	$SR_{1.755}$
Days to flowering (day)	2.68	0.923	4.34
Days to maturity (day)	2.24	0.896	3.53
Plant height (cm)	8.39	0.435	6.41
Number of branches per plant	0.49	0.121	0.10
Number of reproductive nodes per plant	2.07	0.160	0.58
Number of filled pods per plant	4.59	0.226	1.82
Weight of 100 grains (g)	0.90	0.762	1.21
Grain yield (t/ha)	0.26	0.056	0.03

selection response (Table 6). Selection responses for these three characters were 4.34 days, 3.53 days and 1.21 g/100 grains. It means that one cycle of selection will decrease 4.34 days and 3.53 days for days to flowering and days to maturing respectively, and increase 1.21 g/100 grains for weight of 100 grains. These values are the highest values that can be achieved in this population because the heritability factor is of the broad heritability kind that is still included epistatic effect. This selection response is selected individually based on the single character. In grain yield, the selection response is 0.03 t/ha in one cycle. This selection response was supported by selection response of number of filled pods and weight of 100 grains, due to the relationship between grain yield with number of filled pods and weight of 100 grains.

CONCLUSION

The offspring of "Sinabung" × MLGG 1087 achieved broad genetic variability with regards to days taken to flower and reaching maturity, number of branches per plant, number of reproductive nodes per plant, number of filled pods per plant, weight of 100 grains, and grain yield (t/ha). The broad genetic variability of a character is expected to produce high selection response. In this study, not all of characters with high genetic variability produced high selection response due to the low heritability. The role of heritability in selection response was higher than genetic variability. The characters with high heritability reached higher selection response and per se.

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