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Genetic Parameters of Soybean [*Glycine max* (L.)] Genotypes Tolerant to Salinity

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ABSTRACT

Background: Saline land can be used to increase soybean planting area. Adaptive varieties is one of technology to utilize saline land for soybeans. The objective of this study was to determine the phenotype and genotype performance of the F_3 generation soybean lines in saline soil of Indonesia.

Methods: A total 247 soybean genotypes, including four check varieties, were planted in augmented design in 2018. The field electrical conductivity (EC) value before planting soybean was 10.4 dS/m and soil acidity was 8.1 which was classified as high saline land based on Jones (2002).

Result: The number of selected plants were 172 single plants. GH K13/ Anjasmoro lines has an opportunity to further selection. Average height of GH K13/ Anjasmoro selected lines was 26.4 cm, number of fertile nodes was 11, number of filled pods was 27 and seeds weight per plant was 4.8 g. GH K13/ Anjasmoro lines has a high broad sense heritability for plant height, number of branches and number of filled pods, also high genetic advance for all characters.

Key words: Breeding, Heritability, Salinity, Selection, Soybean.

INTRODUCTION

Salt-affected (saline) soil has many effect on soybean [*Glycine max* (L.)] crop such as inhibit germination, inhibit water and ion uptake so that affect the growth, also decline plant dry weight and seed weight. Sensitive genotypes of soybean yields decrease 78% and 87% in 50 mM and 100 mM NaCl treatments, whereas tolerant genotypes decrease 44% and 68% (Mannan *et al.* 2013; Aini *et al.* 2014; Sahito *et al.* 2017; Juwarno *et al.* 2018).

The potential for saline land in Indonesia is around 9.5 million ha (Cahyaty *et al.* 2017). Saline land has varying electrical conductivity (EC) level up from 4 dS/m. Soil acidity tend to neutral and estimates exchangeable sodium percentage less than 15. Saline tolerant varieties are one of technological components to improve crop cultivation in saline land (Thohiron and Prasetyo 2012). Saline adaptive varieties can be obtained from crosses that are selected directly in saline land with certain selection criteria. Soybean varieties show different responses to salinity (Dianawati *et al.* 2013; Purwaningrahayu and Taufiq 2017; Song *et al.* 2017; Ismail *et al.* 2018).

In Indonesia, breeding of saline adaptive soybean varieties has been carried out since 2015 (Susanto *et al.* 2016; Putri *et al.* 2017; Putri and Susanto 2019). The selection gain of breeding lines obtained need to be predicted using genotypes and phenotypes variability coefficient, heritability and genetic advanced. Wide diversity will increase opportunities in character selection to get the desired genotype (Kuswantoro *et al.* 2018). Selection criteria that can be used for saline adaptive soybean varieties include the ability to germinate, the ability to survive and seed yield (Purwaningrahayu 2016).

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The objective of this study was to determine the phenotype and genotype performance of the F_3 soybean lines in saline soil of Indonesia.

MATERIALS AND METHODS

Experimental site

The research was conducted in the farmer's field in Tuban regency, East Java province, Indonesia on the secondary dry season of 2018. The field electrical conductivity (EC) value before planting soybean was 10.4 dS/m and soil acidity was 8.1. The experimental field classified as high saline land based on Jones (2002).

Plant material

A total of 247 soybean genotypes consist of 243 saline adaptive lines of F_3 generation derived from three crossbreeding combinations (GH K13 / Anjasmoro, MLGG 0160 / Anjasmoro and Argomulyo / Anjasmoro) and four check genotypes which were crossbreeding parents (GH K13, MLGG 0160, Argomulyo and Anjasmoro). Argomulyo and Anjasmoro are the commercial check varieties used in this study.

Experimental design

The study used augmented design and replicated four times. Each genotypes were planted in one row of 2.5 m length and plant distamce of 40 cm × 15 cm, one or two seeds per hole. In 30 days after planting, one plant per hole was maintained to obtain 16 plants per row. The little population applied was due to a limited seed obtained in F_3 generation.

Measurements and data nalyses

Observation was conducted on plant height, number of branches, number of fertile nodes, number of filled and unfilled pods and seeds weight per plant. Broad sense heritability (H^2) was calculated as described by Mahmud and Kramer (1951):

$$H^2 = [\sigma^2_{F3} - \sqrt{(\sigma^2_{P1} \times \sigma^2_{P2})}\ ]/\ \sigma^2_{F3}$$

Where

σ^2_{F3} = Phenotypes variety among F_2.

σ^2_{P1} = Phenotypes variety among P_1 (parent 1).

σ^2_{P2} = Phenotypes variety among P_2 (parent 2).

Genetic advance was calculated to determine selection effectiveness. Genetic advances (%) at 20% selection intensity calculated by the formula:

$$GA = [(i \times H \times \sigma_P)/\mu] \times 100\%$$

Where

GA = Genetic advance.

i = Selection index at 20% selection intensity.

H^2 = Broad sense heritability.

σp = Phenotype variety.

μ = Population mean.

Soil electrical conductivity (EC) measurements were carried out four times, *i.e.* before planting, 34, 45 and 56 DAS (He *et al.* 2014; Feng *et al.* 2018).

RESULTS AND DISCUSSION

Land electrical conductivity

The condition of soybean plants in the experimental field became the basis for land division into three areas for electrical conductivity (EC) measurement, namely north, central and south. EC in the northern area is relatively lower than central and southern areas. EC value increases at 45 days after sowing (DAS) and decreases at 56 DAS. EC values in experimental field ranged 8.7-18.4 dS/m from before planting to harvest (Fig 1).

Crossbreed combination lines

Soybean lines resulting from Argomulyo/Anjasmoro crossbreed combination had significantly lower plant height, number of fertile nodes and number of filled pods compared to the other two crossbreed combination lines, but not significantly different in the number of branches and seeds weight per plant. Number of filled pods had the highest diversity compared to the other characters in the three crossbreed combinations (Table 1).

T-test also employed to compare parental and filial pheotype. Parental observation result value and the mean of each yield component, are presented in Table 2. GH K13/ Anjasmoro lines have significantly higher plant than its female parent, but not significant than its male parent. MLGG 0160 as a female parent has more filled pods than MLGG 0160/Anjamoro lines as its filial. Argomulyo/ Anjasmoro lines has no significant difference with its female parent, Argomulyo, in number of fertile nodes and filled pods, but has significantly less than Anjasmoro as the male parent (Table 2).

Phenotype variance

Phenotype variance value of saline adaptive soybean lines in F_3 generation was higher than genotypic variance value. This value suggested that the involvement of environmental factor occured in the phenotypic performance that will determine the heritability of certain trait. Heritability

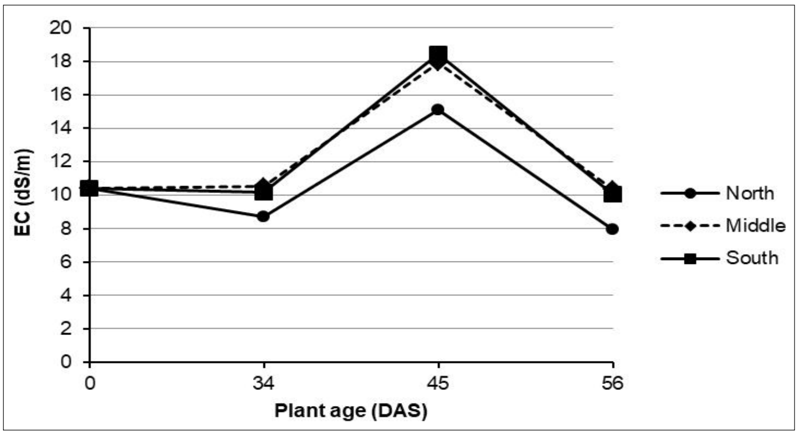

Fig 1: Experimental land electrical conductivity at three region which are north, middle and south, on secondary dry season of 2018. The observation of electrical conductivity was held at before planting, 34, 45 and 56 days after sowing (DAS).

determines the selection progress and selection method that could be used in breeding program (Kuswantoro, 2017b). Plant height character had high heritability value on the results of crossing GH K13/Anjasmoro and low to medium on the results of the other two crosses. The number of branches had a high heritability value on the results of crossing GH K13/ Anjasmoro and low to medium on the results of the other two crosses. The number of fertile node had a low heritability value on the results of the crossing of MLGG0160 / Anjasmoro and Argomulyo / Anjasmoro, as well as the medium on the GH K13/Anjasmoro crossing results.

The character of the number of filled pods had a high heritability value on the results of crossing GH K13/ Anjasmoro, medium on Argomulyo/Anjasmoro and low on MLGG0160/Anjasmoro. Character weight of seeds per plant had a high heritability value on the results of the Argomulyo/ Anjasmoro crossing, medium on GH K13/Anjasmoro and low on MLGG0160/Anjasmoro (Table 3). Selection/genetic advance of the five characters in all crossbreed combination lines was varied low to high. GH K13/Anjasmoro crossbreed combination lines had higher selection/genetic advance compared to the others for all yield component characters (Table 3).

Performance of selected lines

Selection based on number of filled pods produced 172 lines from three cross combinations. The performance of selected lines is listed in Table 4. The most average height of selected lines was only 26.4 cm, with 11 fertile nodes, 27 filled pods and 4.8 g seed weight per plant which owned by GH K13/ Anjasmoro lines. The highest seed weight per plant was 5.3 g, belongs to Argomulyo/Anjasmoro lines.

Individual plants that grow normally have ability to survive due to salinity stress at the initial growth. Aini *et al.* (2014) reported that soybean growth at early vegetative phase could be a selection indicator for salinity tolerance in soybean genotype. Genotypes that are sensitive to salinity will show salt toxicity symptoms, *i.e.* chlorosis, burnt leaf edges and stunted growth. The lines phenotypic diversity value was greater than the genotypic diversity. This showed environmental influence on the lines performance in this study.

Table 1: T-test results among F_3 generation saline adaptive soybean lines in Tuban, on secondary dry season of 2018.

Variable	Crossbreed combination lines					
	GH K13 /Anjasmoro	Variance	MLGG 0160 /Anjasmoro	Variance	Argomulyo /Anjasmoro	Variance
Plant height (cm)	24.2^a±6.9	47.9	24.7^a±4.4	19.7	21.4^b± 5.0	25.2
Number of branches	2±1.5	2.3	2±1.8	3.3	2±1.2	1.4
Number of fertile nodes	9^a±4.6	20.9	10^a±3.2	9.0	8^b±3.4	11.4
Number of filled pods	21^a±12	142.7	19^a±8.5	72.8	15^b±7.8	60.5
Seed weight per plant (g)	4.1±1.9	3.5	3.9±1.6	2.5	3.9±1.9	3.8

Remarks: The same letter behind the numbers on the same line shows no significant difference at the 5% significance level.

Table 2: T-test results of mean yields component between F_3 generation lines and the parental.

Variable	Population		
	GH K13/Anjasmoro	**GH K13**	**Anjasmoro**
Plant height (cm)	24.2^a±6.9	18.8^b±5.6	23.6^a±4.2
Number of branches	2±1.5	2±0.9	2±1.2
Number of fertile nodes	9±4.6	7±2.4	10±4.7
Number of filled pods	21±12	17±9.1	20±7.8
Seed weight per plant (g)	4.1±1.9	3.7±1.6	4.4±1.8
	MLGG 0160/Anjasmoro	**MLGG 0160**	**Anjasmoro**
Plant height (cm)	24.7±4.4	26.1±6.8	23.6±4.2
Number of branches	2±1.8	3±1.4	2±1.2
Number of fertile nodes	10±3.2	11±4.4	10±4.7
Number of filled pods	19^b±8.5	27 ^{a}±11.7	20^b±7.8
Seed weight per plant (g)	3.9±1.6	4.5±1.7	4.4±1.8
	Argomulyo/Anjasmoro	**Argomulyo**	**Anjasmoro**
Plant height (cm)	21.4±5.0	22±3.9	23.6±4.2
Number of branches	2±1.2	3±1.4	2±1.2
Number of fertile nodes	8^b±3.4	8^b±3.8	10^a±4.7
Number of filled pods	15^b±7.8	15^b±5.4	20^a±7.8
Seed weight per plant (g)	3.9±1.9	2.8±1.0	4.4±1.8

Remark: The same letter behind the numbers on the same line shows no significant difference at 5% significance level.

Table 3: Genetic parameters of F_3 generation saline adaptive soybean lines.

Characters	σ^2p			σ^2g			H^{2} 2)			Genetic/selection advance3) (%)		
	1[1)]	2	3	1	2	3	1	2	3	1	2	3
Plant height	47.9	19.7	25.2	43.5	14.1	21.4	0.6^H	-0.4^L	0.4^M	22.8^H	-8.9^L	14.1^H
Number of branches	2.3	3.3	1.4	1.3	1.9	0.2	0.6^H	0.5^M	-0.07^L	62.2^H	49.6^H	-7.4^L
Number of fertile nodes	20.9	8.9	11.4	17.2	4.6	7.2	0.5^M	-1.2^L	-0.4^L	36.6^H	-48.7^L	-24.7^L
Number of filled pods	142.7	72.8	60.5	134.8	62.9	53.8	0.6^H	-0.2^L	0.4^M	44.8^H	-11.4^L	27.8^H
Seed weight per plant	3.9	2.5	3.8	2.2	0.8	2.4	0.3^M	-0.1^L	0.6^H	22.7^H	-7.9^L	40.3^H

Remarks:

1) Crossbreed combination (1) GH K13/Anjasmoro; (2) MLGG 0160/Anjasmoro; (3) Argomulyo/Anjasmoro.

2) Broad sense heritability: L = low (<0.2); M = moderate (0.2 ≤ H^2 ≤ 0.5); H = high (>0.5) (Stanfield 1991 in Widyawati *et al.* 2014).

3) Genetic/selection advance with 20% selection intensity: L = low (<3.3%); RL = rather low (3.3% ≤ KS ≤ 6.6%).

HE = high enough (6.6% ≤ KS ≤ 10%); H = high (>10%) (Karmana *et al* 1990 in Widyawati *et al.* 2014).

Table 4: Selected lines (number of filled pods ≥ 15 pods) and comparative genotypes average of yield components.

	Number of selected single plant	Plant height (cm)	Number of filled pods	Number of fertile nodes	Seed weight per plant (g)
Crossbreed line					
GH K13/Anjasmoro	55	26.4	27	11	4.8
MLGG 0160/Anjasmoro	49	24.7	19	10	3.9
Argomulyo/Anjasmoro	68	22.8	22	10	5.3
Comparative genotypes					
GH K13	7	18.9	17	7	3.7
MLGG 0160	20	26.1	27	11	4.5
Anjasmoro	14	23.6	20	10	4.4
Argomulyo	7	22	15	8	2.8

Heritability estimation was employed to determine the chance of a character inheritance in each generation. Plant height, number of branches and number of filled pods in GH K13/Anjasmoro crosses and seed weight per plant in Argomulyo/Anjasmoro crosses have high heritability. High heritability estimation value indicate that the inheritance is more influenced by genetic factors. Combination of genetic variability, high heritability and genetic advance or selection progress of a character indicates that it is appropiate to be used as selection indicator (Baraskar *et al.* 2014; Osekita and Olorunfemi 2014; Astari *et al.* 2016; Kuswantoro 2017a; Kuswantoro *et al.* 2018). Number of filled pods was suitable to be used as a selection indicator in this study, based on the value of genetic variability and heritability. Plant height was also considered an effective trait as a direct selection criteria to obtain high seed yield in soybean breeding (Ghodrati 2013; Malek *et al.* 2014; Krisnawati and Adie's 2016).

Genetic advance or selection progress is used to determine the success of the selection using an indicator character in each generation. GH K13/Anjasmoro lines have high selection progress for all characters and could be carried out in the further stage with several improvements.

CONCLUSION

GH K13/Anjasmoro lines has an opportunity for further selection based on phenotypic and genotypic characters. Plant height average of GH K13/Anjasmoro selected lines was 26.4 cm, number of fertile nodes was 11, number of filled pods was 27 and seeds weight per plant was 4.8 g. GH K13/Anjasmoro lines has a high broad sense heritability except for number of fertile nodes and seed weight per plant, also high genetic advance for all phenotype characters. Number of filled pods was suitable to be used as a selection indicator in this study, based on the value of genetic variability and heritability.

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Conflict of interest: None.

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