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Potential yield of soybean promising lines in acid soil of central Lampung, Indonesia

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Abstract

Most of Indonesia dryland is covered by acid soil which lead to the decreasing potential yield of the crops. In different areas soybean potential yield also different depends on the different soil pH and the availability of the soil. The objective of the research was to study the potential yield of soybean promising lines in acid soil of Central Lampung, Indonesia. Ten promising lines and two check varieties (Tanggamus and Wilis) were grown in acid soil with pH 4.7. The results showed that the highest seed yield was showed by SC5P2P3.5.4.1-5 with 2.51 t/ha. Other soybean promising lines with seed yield over than 2 t/ha^{-1} was SJ-5/Msr.99.5.4.5-1-6-1 and the check variety Tanggamus. The highest yield of SC5P2P3.5.4.1-5 was caused by the high number of filled pods and the large of seed size. Other nine promising lines also can be developed to obtained grain yield as many as Tanggamus yield in the area with similar soil and climate conditions.

Introduction

Approximately 30-40% of the world total land area is covered by acid soil.[1] Indonesia also has acid soil problem, where most of the dryland (69%) is covered by acid soil.[2] Central Lampung is one of the Indonesian regencies in Province of Lampung that experiences acid soil on the most area. There are many problems found in this soils, that can be divided into macronutrient deficiencies and micronutrient toxicities. Mineral nutrients deficiencies occur on calcium, magnesium, molybdenum, and phosphorus; while micronutrient toxicities occur on aluminum and manganese.[3,4] Therefore, acid soil can limit crop growth potential.[5] For improving crops production, minerals toxicity can be ameliorated by surface application of lime. But this lime application usually only for short term period and the soil properties will be back to the previous acidic soil condition. An alternative strategy can be provided for increasing crops production on acid soils by improving genetic Al^{3+} resistance. The use of stable genotypes for high grain yield is very important.[6] However, under diverse agro-ecological conditions, phenotypic performance of a genotype is not similar.[7] It is because genotypic expression of a phenotype is environmentally dependent, where the gene expression is subject to modification by the environment.[8] High yield capacity and favorable weather conditions may contribute to the high yield.[9] It suggests that ecophysiological parameters are very important in selecting good varieties,[10] as well as the genetic ones. In a specific area, a crop has similar performances when the environmental factors, such as rain fall, humidity, solar intensity and temperature, is similar. This is because soil condition is relatively similar for a long period, since in the agricultural land the soil condition is usually maintained similar by adding fertilizers. In this scheme, generally specific adapted variety has higher performance than national superior variety. Therefore, specific adapted variety is suggested to be grown in this specific area. This study was aimed to find out potential yield of soybean promising lines in acid soil of Central Lampung Province.

Materials and Methods

The materials consisted of 10 promising lines (SC2P2.99.5.4.5-1-6-1, SC2P2.151.3.5.1-10, SC5P2P3.5.4.1-5, SC5P2P3.23.4.1-3-28-3, SC5P2P3.23.4.1-5, SC5P2P3.48.31.1-10, SJ-5/Msr.99.5.4.5-1-6-1, Msr/SJ-5.21.3.7-3-27-1, Msr/SJ-5.23.4.1-3-28-3 and Msr/SJ-5.23.4.1-5) and two check varieties (Tanggamus and Wilis). The study was conducted in Central Lampung from November 2009 to February 2010. The soil pH was 4.7, which is classified as very strong acid according to the USDA;[11] soil properties are shown in Table 1.

The rainfall was about 250-350 mm, with temperature of 25-32°C. The experimental design was a randomized completely blocks design with 4 replications. Plot size was 2.8×4.5 m, a spacing of 40×15 cm, 2 plants per hill. Fertilization was applied with 33.75 Kg N, 45 Kg P_2O_5, 37.5 Kg K_2O per ha, which spread before planting. Soil tillage was applied to obtain optimal soil structure condition for ideal growth of the soybean. Drainage canals were done before planting and herbicides applied. Control of weeds, pests and diseases were performed optimally. Observations were carried out on 10 randomly selected plants from each genotype in all of the 4 replications for number of branches per plant, number of reproductive nodes per plant, number of filled pods and unfilled pods per plant, 50% flowering age, 95% maturity age, 100 grains weight and grain yield. Flowering age was determined when the 50% plants in a plot were flowering.

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Analysis of variance was applied for data analyzing and continued with least significant difference (LSD) for mean comparison.

Results and Discussion

Soybean pods appear from the main stem or from the branches of the main stem. The number of branches per plant is related to the number of pod per plant, where the number of branches per plant gives the highest positive direct effect than other soybean characters.[12,13] The number of branches is one of the agronomic traits that had highly positive correlation on grain yield per plant and positive direct effect on grain yield per plant in soybean.[13,14] Therefore, the number of branches can affect the number of pods and grain yield. The results of this study showed that the highest number of branches per plant was achieved by Tanggamus, followed by Wilis (Table 2). Both of these varieties were check varieties which were used as a measure of adaptation in acid soil; this suggests that based on the number of branches, the check varieties are effective to measure the adaptation of soybean lines. However, the measurement of the soybean adaptation in acid soil is not only based on number of branches but also on other characters, especially grain yield.

The reproductive nodes are the nodes on soybeans plant that have pods. Egli *et al.*[15] stated that the nodes on the main stem and on the branches reached a maximum at R5. The highest number of reproductive nodes was shown by Tanggamus followed by SC2P2.99.5.4.5-1-6-1 and Wilis (Table 2). A study by Carpenter and

Board suggested a close relationship between the number of branches and the number of reproductive nodes,[6] where greater branch dry matter per plant created more branch nodes, branch reproductive nodes, and branch pods. Reproductive nodes lay in the branch of the plant.

In this study, Tanggamus and Wilis, which had the highest number of reproductive nodes, also had the highest number of branches. The number of reproductive nodes will affect pod number. As a result, pods per reproductive branch node will also affect grain yield.[6]

The highest number of filled pods per plant was achieved by Tanggamus. Statistically, there are three lines that had a number of filled pods equivalent to Tanggamus, *i.e.* SJ-5/Msr.99.5.4.5-1-6-1, SC2P2.99.5.4.5 and SC5P2P3.5.4.1-5-1-6-1 (Table 3). The highest number of unfilled pods was reached by SJ-5/Msr.99.5.4.5-1-6-1. The number of filled pods in this study was lower than the number of filled pods in another study (with the same materials).[16] This occurred because the soil pH in this study was lower (pH 4.70) than soil pH (4.89) in the other one.[16] If compared to lower pH studies with less irrigation conditions,[17] this study shows higher number of filled pods. However, when it is compared to lower pH studies with sufficient irrigation conditions,[17] the number of filled pods in this study is lower. Deleterious effect of low pH and low nutrient supply lead acid soil to suppress the number of filled pods.[18,19] In addition, water deficit might induce pod abortion during pod development,[20] leading to a decreasing number of filled pods.

With the relatively high number of filled and unfilled pods, SJ-5/Msr.99.5.4.5-1-6-1 line had the higher number of total pods with respect to the other lines. Unfilled pods are the ones that have no seed because the seed formation is hampered due to the unfavorable environmental conditions. Therefore, in a better environmental condition, SJ-5/Msr.99.5.4.5-1-6-1 may achieve higher yield because the pods filling may proceed perfectly and the unfilled pods would have became filled pods. However, the number of unfilled pods can also be higher if the genetic factor is more influential. The variability of unfilled pods number was due to the genetic constitution, which suggested that genetic factors had higher effect than environment, as stated by Sahay *et al.*[21] since broad-sense heritability of unfilled pods was high (93.1%).

In general, the flowering ages of tested genotypes were almost the same, which were between 38-40 days. This result does not differ when compared to other studies conducted in optimal conditions, but it is different if compared to drought condition.[17] Differences occurred at the maturity age ranging from 82-87 days. The earliest maturity age shown by Wilis while the longest maturity age shown by

Table 1. Soil properties of Restu Baru village, Rumbia Regency, Central Lampung, Indonesia.

Soil properties	Value	Criteria
pH (H_2O)	4.70	Very strong acid*
$C_{organic}$ (%)	2.01	Medium°
N (%)	0.066	Very low°
P_2O_5 BI (ppm)	1.30	Very low°
K (me.100 g^{-1})	0.42	Medium°
Ca (me.100 g^{-1})	3.24	Low°
Mg (me.100 g^{-1})	0.64	Low°
CEC (me.100 g^{-1})	7.22	Low°

According to *USDA and °Soepraptohardjo.[11,12]

Table 2. Number of branches per plant, and number of reproductive nodes per plant of acid-adaptive soybean promising lines in Central Lampung, Indonesia.

Genotype	Branches per plant	Reproductive nodes per plant
SC2P2.99.5.4.5-1-6-1	9.0^{bc}	29.5^{b}
SC5P2P3.23.4.1-3-28-3	8.3^{c}	24.5^{ce}e
SC2P2.151.3.5.1-10	9.0^{bc}	23.8^{ce}e
SC5P2P3.5.4.1-5	8.3^{c}	23.8^{ce}e
SC5P2P3.23.4.1-5	8.5^{bc}	19.8e
SC5P2P3.48.31.1-10	8.8^{bc}	23.8^{ce}e
SJ-5/Msr.99.5.4.5-1-6-1	9.8^{bc}	24.8^{bce}
Msr/SJ-5.21.3.7-3-27-1	8.3^{c}	23.3^{ce}e
Msr/SJ-5.23.4.1-3-28-3	8.3^{c}	22.5^{e}e
Msr/SJ-5.23.4.1-5	8.3^{c}	24.0^{ce}e
Wilis	10.3^{b}	27.5^{bc}
Tanggamus	12.3^{a}	34.8^{a}
LSD 5%	1.87	4.94

Value in the same column ane followee by the same letter was not significantly different at LSD 5%.

Table 3. Number of filled pods per plant and number of unfilled pods per plant of acid-adaptive soybean promising lines in Central Lampung, Indonesia.

Genotype	Filled pods per plant	Unfilled pods per plant
SC2P2.99.5.4.5-1-6-1	69.8^{abc}	7.5^{bcd}
SC5P2P3.23.4.1-3-28-3	63.3^{bcd}e	6.8^{cd}
SC2P2.151.3.5.1-10	65.0^{bcd}	9.5^{b}
SC5P2P3.5.4.1-5	73.3^{ab}	7.0^{cd}
SC5P2P3.23.4.1-5	51.0e	8.3^{bc}
SC5P2P3.48.31.1-10	65.5^{bcd}	6.0^{cd}
SJ-5/Msr.99.5.4.5-1-6-1	74.3^{ab}	13.8^{a}
Msr/SJ-5.21.3.7-3-27-1	57.8^{cd}e	5.8^{d}
Msr/SJ-5.23.4.1-3-28-3	54.5^{d}e	5.5^{d}
Msr/SJ-5.23.4.1-5	58.3^{cd}e	6.3^{cd}
Wilis	65.3^{bcd}	7.3^{bcd}
T^{a}ngg^{a}mus	82.3^{a}	7.5^{bcd}
LSD 5%	13.89	2.42

Value in the same column and followed by the same letter was not significantly different at LSD 5%

Tanggamus (Table 4). The longest duration of pod filling period was shown by Tanggamus, that in this study had the earliest flowering age but the longest maturity age (49 days), while the shortest seed filling period was reached by Wilis (43 days). Usually, the longer generative phase varieties will produce higher grain yield.[13]

Grain size is expressed in weight of 100 grains. Largest grain size was indicated by SC5P2P3.48.31.1-10 lines that reached 14.22 g/100 grains (Table 4). In general, the ten tested lines had a larger grain size than both check varieties. Tanggamus was the genotype that had the smallest grain size. In this study, Tanggamus and Wilis showed smaller seed size than in the description,[22] suggesting that the two checks varieties showed grain size decreasing. All promising lines showed grain sizes higher than Wilis and Tanggamus, where there was one promising lines with seed size more than 14 g/100 grains *i.e.* SC5P2P3.48.31.1-10 (Table 4). The magnitude of grain size depends on grains filling rate,[23] but in this study Tanggamus varieties with the longest pod filling duration resulted the lowest weight of 100 grains. It is because photosynthate of Tanggamus was used for grains formation lead more number of grains, but smaller grain weight or grain size due to the photosynthate was partitioned on many grains.

The highest grain yield was shown by SC5P2P3.5.4.1-5 with 2.51 $t.ha^{-1}$. Another line having grain yield more than 2 $t.ha^{-1}$ was SJ-5/Msr.99.5.4.5-1-6-1.

The line of SC5P2P3.5.4.1-5 had the highest grain yield, because SC5P2P3.5.4.1-5 had a lot number of pods (73 filled pods) and relatively large grain (13.76 $g.100\ grains^{-1}$) than other lines. Some researchers reported that there were a significant correlation and a genetic correlation between grain yield and 100 grains weight.[24,25] Beside, a positive direct effect also found between 100 grains weight and grain yield.[26] As the check varieties, Wilis and Tanggamus had a high grain yield, *i.e.* 2.16 $t.ha^{-1}$ and 1.94 $t.ha^{-1}$ respectively in acid soil (Table 5). Therefore, these two varieties were effective to assess potential yield of tested lines in acid soil. In the two check varieties, grain yield was dominantly determined by the number of filled pods because the grain sizes of the two check varieties were smaller than those ten promising lines (Table 5).

Table 4. Flowering age and maturity age of acid-adaptive soybean promising lines in Central Lampung, Indonesia.

Genotype	Flowering age (days)	Maturity age (days)
SC2P2.99.5.4.5-1-6-1	39.5^{bc}	85.8^{b}
SC5P2P3.23.4.1-3-28-3	38.3e	84.0^{cd}
SC2P2.151.3.5.1-10	38.5^{d}e	83.8^{d}
SC5P2P3.5.4.1-5	39.8^{ab}	84.0^{cd}
SC5P2P3.23.4.1-5	39.8^{ab}	84.3^{c}
SC5P2P3.48.31.1-10	38.8^{de}	83.0^{e}
SJ-5/Msr.99.5.4.5-1-6-1	40.0^{ab}	85.8^{b}
Msr/SJ-5.21.3.7-3-27-1	38.8^{de}	84.0^{cd}
Msr/SJ-5.23.4.1-3-28-3	38.5^{de}	84.0^{cd}
Msr/SJ-5.23.4.1-5	40.3^{a}	85.0^{bc}
Wilis	39.0^{cd}	82.0f
Tanggamus	38.3^{e}	86.8^{a}
LSD 5%	0.67	0.47

Value in the same column and followed by the same letter was not significantly different at LSD 5%

Table 5. Grain size (100 grains weight) and grain yield of acid-adaptive soybean promising lines in Central Lampung, Indonesia.

Genotype	100 grain weight (g)	Grain yield (t.ha-1)
SC2P2.99.5.4.5-1-6-1	13.50^{ab}	1.84^{b}
SC5P2P3.23.4.1-3-28-3	13.53^{ab}	1.89^{b}
SC2P2.151.3.5.1-10	12.59^{abc}	1.86^{b}
SC5P2P3.5.4.1-5	13.76^{ab}	2.51^{a}
SC5P2P3.23.4.1-5	13.18^{ab}	1.88^{b}
SC5P2P3.48.31.1-10	14.22^{a}	1.86^{b}
SJ-5/Msr.99.5.4.5-1-6-1	13.63^{ab}	2.03^{b}
Msr/SJ-5.21.3.7-3-27-1	12.94^{ab}	1.77^{b}
Msr/SJ-5.23.4.1-3-28-3	12.57^{abc}	1.77^{b}
Msr/SJ-5.23.4.1-5	13.78^{a}	1.78^{b}
Wilis	11.59^{bc}	1.97^{b}
Tanggamus	10.52^{c}	2.04^{b}
LSD 5%	2.17	0.41

Value in the same column and followed by the same letter was not significantly different at LSD 5%

Conclusions

The highest grain yield was shown by SC5P2P3.5.4.1-5 with 2.51 t/ha, followed by SJ-5/Msr.99.5.4.5-1-6-1 with 2.03 t/ha. SC5P2P3.5.4.1-5 had the highest grain yield because it had a lot of pods and a relatively large grain size than the other lines. SJ-5/Msr.99.5.4.5-1-6-1 can be also developed in some areas that have similar soil and climate conditions. The number of filled pods affects more grain yield than other observed characters. Since Tanggamus and the other nine promising lines were statistically not different, all of the nine promising lines can be developed to obtained as many grain yield as Tanggamus.

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