Comparison study of growth and yield of three soybean varieties on acid upland soil of South Lampung

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Abstract. Lampung is mostly occupied by marginal acid upland soils. However, applying of suitable technology innovations could improve the soybean productivity in this marginal land. Until now, only a few field studies have been conducted on the adaptability of new soybean varieties in acid upland soils of Lampung. Therefore, present study’s objectives were to compare the agronomic performance and the yield of three soybean varieties on an acid upland soil of South Lampung. As the treatments, the three soybean varieties were Anjasmoro, Grobogan, and Dering 1. The research was set in a Completely Randomized Design with four replications. The results showed that in general, based on the agronomic performance, the Anjasmoro variety was more adaptable compared with Grobogan and Dering 1 variety. This might be related to the number of effective nodules in the rooting system of Anjasmoro variety which was higher than that of Grobogan and Dering 1 varieties. In addition, the Anjasmoro variety had the highest yield as 2.60 t ha⁻¹ than that of the Grobogan and Dering 1 varieties as 2.33 and 1.99 t ha⁻¹, respectively.

1. Introduction
Soybean is an important source of food, protein, and the main ingredient of the tofu and tempeh industries consumed by most of the Indonesian people. However, more than 60% that soybean still needs to be imported from other countries [1]. Indonesia’s soybean imports reached 2.67 million tons in 2019 [2]. To reduce its dependence on imported soybean, Indonesia’s Ministry of Agriculture aims to enhance domestic soybean production. Soybeans have been included in the government's list of strategic food commodities.

Lampung as a soybean production centre has high potential dry land, but it has a major problem with soil acidity. The main problem faced is the effectiveness of fertilization and the low nutrients availability in the soil. The low effectiveness of fertilization, especially P fertilizer due to P fixation by alumina silicate compounds, especially on acid soils found in Lampung [3].

However, by application of suitable technology innovations, these marginal land areas have great potency for increasing national soybean production [4]. Until now, only a few field studies have been conducted on the adaptability of new soybean varieties on acid upland soils of Lampung. Information on the most suitable and adaptable soybean varieties on acidic dry land in Lampung is important for the development and improvement of soybean production. The objectives of the present study were to compare the agronomic performance and the yield of three soybean varieties, namely Anjasmoro, Grobogan, and Dering 1 on an acid upland soil of South Lampung. This study would be useful to determine suitable recommendations for developing soybean production in Lampung.
2. Materials and methods

This study was conducted on upland soil at the Research Station of Assessment Institute for Agricultural Technology, Tegineneng, South Lampung, from January to April 2016. The climatic data during the experiment is presented in Table 1 [5]. The chemical and the physical properties of the soil in the experimental site is shown in Table 2.

Table 1. Climatic data during the experiment of three soybean varieties in Tegineneng, South Lampung in 2016.

| Month    | Temperature (°C) | Relative humidity (%) | Rainfall rate (mm) | Light intensity (hours) |
|----------|------------------|-----------------------|-------------------|------------------------|
| January  | 27.52            | 84.25                 | 327.80            | 6.10                   |
| February | 27.13            | 84.72                 | 294.50            | 5.09                   |
| March    | 27.59            | 85.26                 | 294.90            | 5.51                   |
| April    | 27.42            | 86.93                 | 195.70            | 4.87                   |

Table 2. Selected chemical and physical properties of acid upland soil of Tegineneng, South Lampung, prior to the trial (0 to 10 cm depth).

| No | Parameter          | Value | Criteria |
|----|--------------------|-------|----------|
| 1  | pH H2O             | 4.60  | Acid     |
| 2  | % Organic carbon   | 1.62  | Low      |
| 3  | % Nitrogen         | 0.11  | Low      |
| 4  | Available P, Bray-l P (ppm) | 21.57 | Very High |
| 5  | Available K Morgan (ppm) | 18.22 | Low      |
| 6  | Potential P (mg P2O5 100 g⁻¹) | 35.78 | Moderate |
| 7  | Potential K (mg K2O 100 g⁻¹) | 40.55 | Moderate |
| 8  | Exchangeable acidity (cmol kg⁻¹) | 0.11 | Low |
| 9  | K-exchangeable (cmol kg⁻¹) | 0.68 | Low |
| 10 | Na-exchangeable (cmol kg⁻¹) | 0.56 | Low |
| 11 | Ca-exchangeable (cmol kg⁻¹) | 5.28 | Low |
| 12 | Mg-exchangeable (cmol kg⁻¹) | 0.83 | Very Low |
| 13 | CEC (cmol kg⁻¹)    | 8.86  | Low      |

The soybean seeds were obtained from Indonesian Legumes and Tuber Crops Research Institute, East Java. The treatments were three soybean varieties, namely Grobogan (V1), Anjasmo (V2) and Dering 1 (V3). The treatments were arranged in a Completely Randomized Design with four replications. The three varieties represent three soybean seed sizes as large, medium and small, respectively. The harvest age for the three varieties were 79 to 90 days after planting. The cultivation method and fertilizer dosages (75 kg urea ha⁻¹, 100 kg SP-36 ha⁻¹, and 100 kg KCl ha⁻¹) were adjusted to the farmer’s method. The distance between treatments was 10 meters. The planting method was by dibble planting, with a spacing of 40 cm x 20 cm and two seeds per planting hole.

Observations in the vegetative phase were carried out until flowering stage. Parameters observed included plant height and leaf diameter at 20 days after planting, and the number of root nodules at 35 days after planting. Parameters observed in the generative phase were days to flowering, and maturity, number of branches, empty pods, and damaged pods per plant, total number of pods, weight of dry stover and 100 seeds, and grain yield. Production data were then converted to t ha⁻¹. The harvesting was carried out when the plant leaves had fallen off, and the pod colours turned to yellow or brown and dried up. The harvesting was conducted at 09.00 AM, by cutting the base of the plant with a sickle, except for harvest samples by pulling out the plant carefully. The soybean stover was collected.
in a dry place on a plastic mat. Post-harvest handling included drying, threshing, cleaning and storing seeds. The data were calculated using the analysis of variance (ANOVA) and mean values were compared by Duncan’s test ($P<0.05$).

3. Results and discussion

3.1. Vegetative growth observations

The observations results at 20 days after planting (DAP) showed that Anjasmo variety had a higher plant height and was significantly different compared to Grobogan and Dering 1 varieties. The average leaf diameter of the three varieties was not significantly different. The number of productive branches per plant in Dering 1 variety was higher than those of Grobogan and Anjasmo varieties (Table 3, Figure 1).

| Variety    | Plant height (20 days) (cm) | Plant height (85 days) (cm) | Leaf diameter (cm) | Number of productive branches per plant |
|------------|-----------------------------|-----------------------------|--------------------|-----------------------------------------|
| Grobogan   | 24.5 ±2.5 a                 | 39.2 ±1.2 a                 | 4.8 ±0.7 a         | 3.6 ±0.5 a                              |
| Anjasmo    | 23.3 ±1.9 a                 | 76.2 ±3.3 b                 | 5.1 ±0.2 a         | 4.0 ±0.6 a                              |
| Dering 1   | 23.6 ±2.2 a                 | 61.8 ±3.1 c                 | 4.4 ±0.7 a         | 5.4 ±0.5 b                              |

The means followed by different letters indicate statistically significant differences (Duncan, $P<0.05$).

The soybean growth is influenced by the availability of nutrients and irrigation [6]. In general, Anjasmo variety had a higher plant performance character compared to Grobogan and Dering 1 varieties. The soybean planting is more suitable in the rainy season for the growth and the yield. Dering 1 variety was designed to be drought tolerant so it did not show the best performance for planting in the rainy season. The observation on the number of plant nodules was conducted by destructive sampling at 35 days after planting. The number of root nodules of Anjasmo variety was higher than those of Grobogan and Dering 1 varieties (Table 4).
Table 4. Number of root nodules and number of pods of the three soybean varieties.

| Variety    | Number of root nodules per plant (±SE) | Total number of pods (±SE) | Number of filled pods (±SE) | Number of empty pods (±SE) | Number of damaged pods (±SE) |
|------------|----------------------------------------|----------------------------|-----------------------------|---------------------------|-----------------------------|
| Grobogan   | 74 ±8.4 a                              | 96 ±6.0 a                  | 76 ±12.6 a                  | 9 ±2.3 a                  | 16 ±4.3 a                   |
| Anjasmoro  | 85 ±8.2 a                              | 196 ±8.2 a                 | 158 ±14.1 b                 | 21 ±4.5 b                 | 17 ±2.1 a                   |
| Dering 1   | 27 ±3.1 b                              | 188 ±3.7 b                 | 139 ±18.6 b                 | 26 ±4.2 b                 | 23 ±7.4 a                   |

The means followed by different letters indicate statistically significant differences (Duncan, P<0.05).

The Anjasmoro variety had the highest number of root nodules and mostly in red colour indicating that Rhizobium bacteria were active in soybean plants [6]. Effective nodules generally have pink colour due to the leghemoglobin content. Leghemoglobin is an essential component for nitrogen fixation by legumes and produced as result of a d symbiotic association between bacteria and plant. Meanwhile, white root nodules indicate that Rhizobium is inactive. Ineffective nodules are generally small size and contain a network of bacteria that cannot develop due to the abnormalities in their structure and low ability to fix nitrogen [6]. The number of pods in Anjasmoro variety was higher than those of Grobogan and Dering 1 varieties. The number of damaged pods was affected by the level of pest attacks such as sucking pests on soybean.

3.2. Generative growth observations

Grobogan variety had shorter flowering and harvesting ages compared to Anjasmoro and Dering 1 varieties (Table 5; Figure 2).

Table 5. Days to flowering and days to maturity of three soybean varieties.

| Variety    | Days to flowering (days) (±SE) | Days to maturity (days) (±SE) |
|------------|-------------------------------|-------------------------------|
| Grobogan   | 30 ±1.4 a                     | 79 ±0.6 a                     |
| Anjasmoro  | 33 ±1.7 a                     | 90 ±0.6 b                     |
| Dering 1   | 33 ±0.6 a                     | 90 ±0.6 b                     |

The means followed by different letters indicate statistically significant differences (Duncan, P<0.05).

The Anjasmoro variety had the highest yield (2.60 t ha⁻¹) compared to the Grobogan and Dering 1 varieties producing 2.33 and 1.99 t ha⁻¹, respectively (Table 6).

Table 6. Weight of 100 seeds character of the three soybean varieties.

| Variety    | Weight of 100 seeds (±SE) |
|------------|---------------------------|
| Grobogan   | 18 ±1.2 g 100 seeds⁻¹     |
| Anjasmoro  | 16 ±1.0 g 100 seeds⁻¹     |
| Dering 1   | 20 ±2.1 g 100 seeds⁻¹     |

The results in Table 6 showed that the Grobogan variety had larger seeds (±18 g 100 seeds⁻¹), indicating that they were more responsive to nutrient and water deficiencies. With adequate nutrition and irrigation, Grobogan variety will produce maximum production, and vice versa. The Anjasmoro variety had medium seeds (±16 g 100 seeds⁻¹), but more adaptable and tolerant on acid dry land, therefore the production yield was higher than that of Grobogan variety. The Dering 1 variety has...
small seeds (±12 g 100 seeds⁻¹) and a drought tolerant character. In optimal environmental conditions, the weight of seeds produced was lower than those of Anjasmoro and Grobogan. The Anjasmoro variety showed higher yield and better agronomic appearance compared to Grobogan and Dering 1 varieties. These results were most likely also due to the ability of Anjasmoro variety to produce a higher number of effective nodules in the rooting system on acid upland soil of the present study than those of Grobogan and Dering 1 varieties.

Table 6. Weight of 100 seeds and grain yields of three soybean varieties.

| Variety   | Weight of 100 seeds (g) | Grain yield per ha (tons ha⁻¹) |
|-----------|-------------------------|-------------------------------|
| Grobogan  | 18.5 (±0.9) a           | 2.33 (±0.60) ab               |
| Anjasmoro | 16.0 (±1.4) b           | 2.60 (±0.11) a                |
| Dering 1  | 12.0 (±1.0) c           | 1.99 (±0.03) ab               |

The value followed by different letters indicate statistically significant differences (Duncan, P<0.05).

3.3. Correlation between agronomic characters

The total grain yield is influenced by other agronomic characters, such as maturity date, plant height, number of branches, number of pods and the number of root nodules, as well as the size of seeds (100 seed weight). Correlation analysis between agronomic characters is presented in Table 7.

Table 7. Correlation coefficient between agronomic characters in three soybean varieties.

| Charactersᵃ | DM | PH  | LD  | NB  | NN  | NP   | 100 SW |
|-------------|----|-----|-----|-----|-----|------|--------|
| PH          | 0.16 | $P=0.57$ |     |     |     |      |        |
| LD          | -0.09 | $P=0.73$ | 0.58* | $P=0.02$ |     |      |        |
| NB          | 0.55* | $P=0.03$ | 0.05 | $P=0.87$ | -0.36 | $P=0.18$ |        |
| NN          | -0.14 | $P=0.62$ | -0.19 | $P=0.49$ | -0.04 | -0.45 |        |
| NP          | 0.69* | $P=0.004$ | 0.22 | $P=0.44$ | -0.20 | 0.56* | 0.23   |
| 100 SW      | 0.19 | $P=0.52$ | 0.46 | $P=0.10$ | -0.01 | -0.33 | -0.05  | -0.017 |
| DF          | 0.50 | $P=0.06$ | -0.06 | $P=0.82$ | -0.42 | 0.80* | -0.45  | 0.30    | -0.91* |

ᵃ PH = plant height (cm); DM = days of maturity (days); LD = leaf diameter (cm); NB = number of productive branches per plant; NN = number of root nodules per plant; NP = total number of pods; 100 SW = seed weight (g 100 seeds⁻¹); DF = days to flowering (days).

Correlation analysis between agronomic characters (Table 7) indicated a significant positive correlation between leaf diameter and plant height, number of productive branches per plant and plant height, total number of pods and days of maturity, number of productive branches per plant and total number of pods, and days of flowering and number of productive branches per plant. Seed weight was negatively correlated with days of flowering. Seed production was positively correlated with the number of pods and the number of pods was correlated with plant height. The height of the plant causes an even distribution of light throughout the canopy, therefore the potential for photosynthesis will be maximum. The more photosynthate filling the pods will increase the weight of the seeds per plant [7,8].
The yield is a complex desirable traits inherited in a quantitative fashion [9-12]. The grain yield is influenced by many factors, including genetic and environmental factors. Phenotypic variations are the result of genetic variations and epigenetic effects due to environment variations [13-15].

The results showed that based on the agronomic performance, Anjasmoro variety was more adaptable compared with Grobogan and Dering 1 varieties. In addition, the Anjasmoro variety had a higher yield than those of the two other varieties. These results were related to the number of effective nodules in the roots of Anjasmoro variety which was higher than those in Grobogan and Dering 1 varieties as explained earlier, although planted on an acid upland soil.

The use of more adaptable and tolerant varieties on marginal lands will be more economically profitable [16]. Anjasmoro variety has better performance for planted on acid upland soil, compared to Grobogan and Dering 1 varieties. Anjasmoro variety has the potential to be developed and recommended to increase soybean productivity, especially in Lampung.

4. Conclusions

Three soybean varieties (Anjasmoro, Grobogan, and Dering 1) were analyzed for their agronomic performance on acid upland soil in South Lampung. The Anjasmoro variety had higher yields and was more adaptable compared to the Grobogan and Dering 1 varieties. Anjasmoro variety has better performance for planting on acid upland soil and has the potential to be developed and recommended to increase soybean productivity, especially in Lampung. These results were most likely due to the ability of Anjasmoro variety to produce a higher number of effective nodules on the rooting system than those of Grobogan and Dering 1 varieties on acid upland soils.

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