Yield and yield component performance of soybean promising line in upland during the rainy season

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Abstract. Soybean development in dry land during the rainy season not only contributes to soybean production but also has the potential to be a source of seeds. The research aimed to identify the yield and yield component performance of soybean promising line at upland in the rainy season. A total of fourteen soybean promising lines and two check cultivars were evaluated for their yield and yield components in Blitar and Malang. The field experiments were conducted in each location during the rainy season 2021 using a randomized block design with four replicates. A significant GEI was found on the plant height, number of branches/plant, number of nodes/plant, number of filled pods/plant, and 100 seed weight. The Blitar location indicated resulting in the optimum yield and yield components of the tested promising lines. The average yield in Blitar was 2.81 t/ha (an average of 2.07 – 3.60 t/ha) and in Malang was 2.16 t/ha (an average of 1.52 – 3.18 t/ha). The number of branches and number of nodes has significant roles in determining the seed yield in soybean. Two genotypes with consistently high yield in Blitar and Malang are recommended to be evaluated in further advanced yield trials in different environments.

1. Introduction

The soybean cultivation system in Indonesia is distinct from that of other countries. Soybean can be grown in different growing seasons and on different types of land. Soybeans are planted in dry land at the beginning or end of the rainy season, whereas in paddy fields, soybeans are planted after rice following the cropping pattern of rice-soybean or rice-paddy-soybean. When considering the soybean cultivation pattern, thus soybean farming in dryland has the potential to supply seeds for the soybean cultivation in the wetland.

Soybean cultivation on dry land in Indonesia is distinguished by the fact that it takes place during the rainy season, as the irrigation source is rainwater. The presence of adaptable soybean varieties in this environment is important for increasing national soybean production. Every plant, including soybean, has an adaptation limit to a specific environment. Soybean seed yield is a complicated trait that is influenced by a variety of agronomic characteristics, genetic control, and environmental factors [1,2]. A study of nine soybean genotypes conducted in eight soybean production centers in Indonesia showed that the environment for soybean cultivation could be divided into two mega-environments, with each genotype had adaptability in each environment [3]. A study revealed that the environment had the greatest impact on soybean yields (51.45%), followed by genotype (3.24%) and the G × E interaction (14.59%) [4]. In another study, the G × E interaction has the greatest contribution to the total variance of the seed yield in soybean, followed by environment and genotype [5]. In the bread wheat, the highest
variation was determined by environment effect (90.76%), followed by genotype (7.12%) and environment effect (2.5%) [6]. A similar pattern was also reported in rice [7]. Differences in the role of genotype, environment, and their interaction on seed yield and yield components in soybeans are determined by the genotype's genetic composition, environmental characteristics, as well as management practices [2,8]. An evaluation by Mudibu et. al. [9] on 40 soybean genotypes in Congo for two years revealed that soybean yield was strongly determined by the number of pods and number of seeds, and based on this evaluation, the DR-Congo genotype was identified as the most suitable to be developed in the Congo environment. Another study reported that the number of pods, the weight of 100 seeds, and 50% flowering age have a direct influence on soybean yield [10]. High-yielding soybean genotypes were characterized by a tall plant, lots of pods, and a high yield index [11].

In Indonesia, a study on the 150 soybean genotypes found a genotype (G511H/Anj//Anj///Anj///Anj///Anj-8-5) that has been identified as a high producing genotype that is also according to the consumers’ preferences, due to its early maturation and large seed size [12]. The effect of tillage combined with cropping patterns of soybean and cerealia was studied in Brasilia, and it was discovered that no-tillage and minimum tillage gave higher soybean yield than optimum tillage [13]. Identification of superior soybean genotypes in Zambia obtained a yield mean score of 1239 Kg/ha, and TGX 1988-22F was the highest yielding genotype with 1517 kg/ha [14].

The research aimed to identify the yield and yield component performance of soybean promising line at upland in the rainy season.

2. Materials and Methods

2.1. Research material

This study used 14 soybean promising lines and two check cultivars (Anjasmoro and Dega 1). The promising lines were developed using several parentals (Table 1).

| No | Genotype                  | Remark                               |
|----|---------------------------|--------------------------------------|
| 1  | G511H/Anj/Anj/Anj/Anj-8-5| Backcross of Anjasmoro with G511H   |
| 2  | G511H/Anj/Anj/Anj/Anj-4  | Backcross of Anjasmoro with G511H   |
| 3  | Arg/Ljtg/Sbg-3           | Single cross of Argomulyo with Lokal Jateng and Sinabung |
| 4  | G511H/Anj-1              | Single cross of G511H with Anjasmoro|
| 5  | G511H/Anj/Anj/Anj-3       | Backcross of Anjasmoro with G511H   |
| 6  | G511H/Anj/Anj/Anj-6-13    | Backcross of Anjasmoro with G511H   |
| 7  | G511H/Arg/Arg/Arg/Arg/Arg-44-7 | Backcross of Argomulyo with G511H |
| 8  | Mutiara/Argomulyo-25    | Single cross of Mutiara with Argomulyo |
| 9  | Arg/Ljtg/Sbg-12          | Single cross of Argomulyo with Lokal Jateng and Sinabung |
| 10 | Grobogan/G100H/Anj-3      | Single cross of Grobogan with G100H |
| 11 | G511H/Anj/Anj/Anj-5-5     | Backcross of Anjasmoro with G511H   |
| 12 | Ljtg/Sbg/Argomulyo-3     | Single cross of Lokal Jateng with Sinabung and Argomulyo |
| 13 | G511H/Arg/Arg/Arg/Arg/Arg-44-6 | Backcross of Argomulyo with G511H |
| 14 | Argopuro/G100H-4         | Single cross of Argopuro with G100H |
| 15 | Anjasmoro                | Released variety                     |
| 16 | Dega 1                   | Released variety                     |

2.2. Field experiment and observation

The field research was carried out on dry land in Blitar and Malang from January to April 2021. Rainwater was used predominately for irrigation. Before planting, the soil was optimally managed, and pre-growing herbicides were applied. Drainage channels were made between treatment rows. The study was carried out in each location using a randomized block design, with genotypes as treatment, and each genotype was repeated four times. Each genotype was planted on a 2 m × 4.5 m plot, and the spacing was 40 cm × 15 cm, two plants per hill. Manure has been spread over the planting hole. Fertilization with 250 kg Phonska and 100 kg SP36, applied entirely at planting time. Pests, diseases and weeds was...
controlled intensively. Data on each location were observed on the days to flowering, days to maturity, plant height, number of branches, number of nodes, number of filled pods, number of empty pods, 100 seed weight, and seed yield.

2.3. Data analysis
The data from two locations were analyzed using the combined analysis of variance using the SAS software version 9.1.3 for Windows [15]. The relationship among agronomic traits was investigated based on the average data from two locations, using the Pearson correlation, and visualized by the R package corrplot using the RStudio program [16].

3. Results and Discussion

3.1. Combined analysis of variance
The combined analysis of variance showed a significant interaction for genotype effect in all characters studied, except the amount of branches/plant. A significant interaction between genotype with location (GEI) was found for the plant height, number of branches/plants, number of nodes/plants, number of filled pods/plant, and 100 seed weight. There was no significant GEI on yield, indicating that the seed yield was not affected by the GEI.

| Character                     | Mean Square | Replication/E | Location (E) | Genotype (G) | G × E |
|-------------------------------|-------------|---------------|--------------|--------------|-------|
| Days to flowering (day)       | 0.1406      | 0.0001**      | 23.5979**    | 0.0001**     |
| Days to maturity (day)        | 1.8828      | 0.0078**      | 20.7911**    | 0.0244**     |
| Plant height (cm)             | 203.7187    | 19750.7812**  | 951.6312**   | 418.5812**   |
| Number of branches/plants     | 9.3098      | 244.7578**    | 2.8768ns     | 3.1411*      |
| Number of nodes/plants        | 195.9036    | 2619.0703**   | 77.5786**    | 61.5369*     |
| Number of filled pods/plant   | 1571.3619   | 58524.7578**  | 474.6661*    | 453.6911*    |
| Number of empty pods/plant    | 0.4787      | 106.9270**    | 1.7138*      | 1.3034ns     |
| 100 seed weight (g)           | 11.3129     | 402.4639**    | 9.4547**     | 7.9277**     |
| Seed yield (t/ha)             | 1.3117      | 13.6372**     | 1.3701**     | 0.5365ns     |

** = significant at 1% probability level (p < 0.01), * = significant at 5% probability level (p < 0.05), ns = not significant

3.2. Plant age characters
The character of plant age has become one of the important agronomical characteristics for soybean improvement in the tropics. This is due to the fact that soybeans are grown in a series of annual cropping patterns, such as rice-paddy-soybean. As a result, the plant age factor, particularly the days to maturity, is crucial.

The variation of days to flowering was relatively equal in both locations, however, the days to flowering among genotypes differed. The days to flowering ranged from 29-36 days in Blitar and 29-35 days in Malang (Figure 1a). The average days to maturity in Blitar and Malang was around 81 days, while the range of days to maturity in Blitar was 78-84 days, while in Malang was 78-83 days (Figure 1b). Dega 1 is a soybean variety that matures in 71 days. However, if grown during the rainy season, the days to maturity increases to 79 days. Four promising lines with a similar maturing day as Dega 1 were identified in this study. In comparison to Anjasmoro, the other promising lines matured earlier (84 days).
3.3. Plant growth characters

Plant height, number of branches, number of nodes/plants, number of filled pods/plant, and number of empty pods/plants were defined as growth characters in this study (Figure 2a-2e). The average plant height in Blitar (70.81 cm) was higher than the average plant height in Malang (45.97 cm), indicating that the Blitar location resulted in a good growth plant performance.
3.4. The performance of yield characters

The seed yield characters are represented by the seed size (100 seed weight) and seed yield (Figure 3a and 3b, respectively). All soybean genotypes evaluated at the two locations were categorized as large seeds, with an average of 18.30 g/100 seeds in Blitar and 15.00 g/100 seeds in Malang. Seed size is an important characteristic in Indonesia since most soybeans are used as raw materials for the tempeh industry, which requires large seed (> 14g/100 seeds).

Seed size in an optimal environment, such as Blitar, ranged from 17.11 to 22.46 g/100 seeds. The seed size of Dega 1, which was usually large, was only around 17.11 g/100 seeds in this study. There were six promising lines with a larger seed size than Anjasmoro (17.81 g/100 seeds) among the 14 promising lines tested in Blitar. On the contrary, in Malang, Dega 1 showed maximum seed size (18.16 g/100 seeds), while Anjasmoro showed a seed size of 15.70 g/100 seeds. When comparing the seed size performance among genotypes, all of the examined lines were smaller than Dega 1, with three promising lines having higher seed sizes than Anjasmoro.

Seed yield is an important economic factor in soybean. In Blitar, the average grain yield was 2.81 t/ha (range 2.07 – 3.60 t/ha), while in Malang, the average grain yield was 2.16 t/ha (1.52 – 3.18 t/ha) (Figure 3b). There are six genotypes at the Blitar location, including Anjasmoro, which can produce more than 3.0 t/ha. In Malang, one genotype had a seed yield of more than 3.0 t/ha. In Malang, one genotype had a seed yield greater than 3.0 t/ha. On average, two genotypes produced seed yields greater than 3.0 t/ha, indicating that both genotypes were able of producing optimal yields in two locations.
When comparing the performance of seed yields in two locations, it suggested that Blitar was quite effective as an environment for soybean selection on dry land during the rainy season, because the Blitar location resulted in a higher average yield than the Malang location. Varietal adaptability to environmental fluctuations is important for the stabilization of crop production over both the regions and years [17]. A study on the yield stability and adaptability of lowland sorghum was also able to determine a suitable environment for selecting generally adapted lowland sorghum genotypes [18].

3.5. The characters for yield determinants
The relationship between yield and yield components is shown in Figure 4. The seed yield showed a significantly positive correlation with the number of branches/plant and the number of nodes/plant. Therefore, these traits may be more attributed to higher-yielding soybean. Although the seed yield does not show a positive correlation with the number of filled pods, however, the number of branches and number of nodes showed a significantly positive correlation with the number of filled pods. This indicated that an increase in the number of branches and number of nodes was strongly associated with an increase in the number of filled pods. These results of the study were in agreement with previous studies [19,20]. Another study found that the number of pods, plant height, and the number of reproductive nodes were important criteria for evaluating different soybean varieties and suggested that pod numbers/plant as the best selection criterion [21].

![Figure 4](image_url)

**Figure 4.** Pearson correlation among yield and yield components of 16 soybean genotypes.
The significant correlation was $<\pm 0.05$

4. Conclusion
Each soybean genotype shows a different response to environmental differences. Optimal seed yields were obtained at the dry land location of Blitar compared to the location of Malang, indicating that the Blitar location was more suitable to be used as a selection environment. The number of branches and number of nodes has significant roles in determining the seed yield in soybean which planted during the rainy season. Two genotypes with consistently high yields in Blitar and Malang were obtained, hence it is recommended that both genotypes be evaluated in further advanced yield trials at different environments.
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