Drought Susceptibility Index and Correlation of Soybean Based on Yield And Yield Component

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Abstract. The objectives of this study were to know drought susceptible and resistant varieties of soybean-based on the average value of drought susceptibility index and correlation of yield and yield components traits under drought stress condition. This study was conducted using an experimental method and was laid out using Factorial Completely Randomized Design (CRD), two factors with three replicates of each experimental unit. Factor 1 soybean variety consists of 7 genotypes: Lawit, Sibayak, Kaba, Pangrango, Seulawah, Nanti, and Burangrang, and factor 2 drought stress condition: no drought stress (reasonable condition), drought stress during the vegetative phase, drought stress during the generative phase, and drought stress during vegetative and generative phases. Yield component traits observed were the number of pod per plant, number of empty pod per plant, number of filled pod per plant, number of seeds per plant, the weight of 100 dry seeds, and seed weight per plant. Based on the results of the study, it can be concluded that: 1). Variety of Sibayak and Nanti, were classified as resistance to drought stress either during the vegetative phase, generative phase, or continuous drought. 2). The highly significant positive correlation of among yield and yield components of soybean under drought stress were: seed weight per plant - number of pods, seed weight per plant - number of filled pods, and seed weight per plant - number of seed per plant, while highly significant negative correlation occurred in the character of flowering date - 100 seed weight.

1. Introduction
Soybean (Glycine max (L.) Merrill) is one of the most important crops as a source of functional food in Indonesia, since soybean seeds have high nutritional content. In 100g of soybean contained 35% protein, 18% fat, 35% carbohydrate, 8% water, and 330 calories [1–3].

Every year in Indonesia, soybean seeds demand increases along with the improvement of population and per capita income. Hence, additional soybean supply required to be imported because national production can not fulfill these needs [4]. Strategies to increase national soybean production are extensification through expanding the soybean cultivation area and intensification through enhancing the soybean productivity [5,6].
In 2016, the total harvesting area of soybean was 589,420 ha, and production was about 887,540 tons, fluctuated, and tended to decrease around 4-7% in 2015. It was estimated that Indonesia needs to import about 1.91 million tones in 2020 [7].

To reduce dependence on soybean imports in Indonesia can be done by accelerating production in the country through the expansion of planting areas that need attention, especially dryland resources because of the limited fertile land that can be used. Therefore, efforts to improve varieties that excel in an optimal environment once excelled at the suboptimal environment is one of the objectives in breeding programs [8]; [9].

Plants under natural conditions, as well as agricultural cultivation, often experience stress due to environmental conditions (environmental stresses) such as drought stress. Drought stress is one of the unfavorable external factors (environmental or abiotic stress) that affect the crop. Stress is usually measured by the resistance of crop, production, plant growth, crop quality, or included in the assimilation of the main ones. Based on estimates, the effects of drought stress affects 22-60% of crop productivity. Kisman [10] reported that the higher the index susceptible to drought (drought susceptibility index, DSI), the more sensitive of these varieties to drought, this is indicated on the amount of difference or change in the number of pods per plant on each variety between normal conditions and drought, so there is a drop in the number of pods in drought conditions.

The Materials And Method resistance of plants to drought stress is a complex phenomenon both in physiology and genetics. A drought-tolerant plant has the ability to continue its functions under limited water conditions. For that, we need soybean varieties or soybean lines that are tolerant of the stress [8].

Based on the description above, a study on the "Drought Susceptibility Index and Correlation of Soybean (Glycine max (L.) Merrill) Based on Yield and Its Component," has been done.

This study aims to determine the level of drought susceptible index and correlation based on yield and yield components of some soybean varieties in drought stress conditions. The results of this study are expected to be useful as a material consideration and information in efforts to increase soybean production on dry land, as well as the improvement of yield and yield components in soybean breeding program to obtain high-yielding soybean varieties. It can also be used as a reference for future studies.

The study was conducted by using the experimental method, and the experimental unit was laid out based on the completely randomized design (CRD) in the greenhouse of the Agriculture Faculty of the University of Mataram. The experimental units were comprised of two factors: the factor of soybean variety (V) and drought stress exposed in various growth phases (D). Soybean variety factor consists of seven varieties as follows: V1 = Lawit, V2 = Sibayak, V3 = Kaba, V4 = Pangrango, V5 = Seulawah, V6 = Nanti, and V7 = Burangrang. The factor of drought stress at various growth phases (D) consists of six levels: D0 = control (no drought stress), D1 = Drought during the vegetative phase, D2 = Drought during the generative phase, D3 = Drought stress during the vegetative stage until the end of pod filling. Each combination treatment was repeated three times so that there were 84 experimental units (pots).

In the preparation of planting media, the entisol soil was taken from the fields of farmers in the area of Perampuan village, Labuapi district, in West Lombok regency was dried for a week, then sieved with a sieve with a diameter of 6 mm, cleaned from the garbage of plant roots, etc. The 7 kg of the sieved soil was filled into the pot with the above circle diameter of 23 cm, bottom diameter of 18 cm, and pot height of 25 cm as an experimental unit. The experimental units were arranged with a distance of 25 x 25 cm. A day before planting, the soil was given basic fertilizer urea, SP36, and KCl at a dose of 1/3 of the full dose of 50 kg urea, 100 kg SP36, and 50 kg of KCl per hectare.

The soybean seeds were then planted after seed treatment of Marshall 25 ST with a dosage of 15 g/kg of seeds to prevent the seeds fly attack. Three soybean seeds with a depth of 2 cm were planted with a system of direct planting. At one week of plant age, thinning of plants was done by leaving two healthy plants per pot, a plant sample for observation of the yield and yield components, another for destructive plant sample.

Fertilization of urea, SP36, and KCl was done in three times, before planting, nine days after planting, and 29 days after planting with the dose of 1/3 of the whole dosages.
Harvest was done when most of the soybean pods matured as shown by the change of pod color from green to yellow-brown, and also stem slightly brown and bare.

Drought stress treatment exposed at various growth stages of soybean plants, as follows:
- Control (no drought stress): the plants under normal conditions (100% of field capacity) until harvest.
- Drought stress during the vegetative phase: the plants under drought stress (50% field capacity) for 2 weeks after planting (WAP) until the age of 5WAP (before entering the flowering phase), then the plants were conditioned to no drought stress until harvest.
- Drought stress during the generative phase: the plants under drought stress (50% field capacity) since 6 WAP then given drought stress (50% field capacity) until the age of 8 MST (entering the pod filling phase), then the plant under normal conditions until harvest.
- drought stress that continues during the vegetative phase until the end of pod filling then plants under normal conditions until harvest.

Controlling drought stress conditions with the levels of 50% field capacity of soil moisture content was done by method of weighting, as well as methods used by [11].

Variables observed in this study were: flowering date, harvesting date, number of pods, number of filled pods, number of empty pods, number of seeds per plant, the weight of 100 seeds, seed weight per plant. The observation of the parameters was done as follows:
- Flowering date (DAP): observed when 80% flowering in each individual plant.
- Harvesting date (DAP): observed when about 80% of pods have been showing mature with a brownish color on each individual plant.
- Number of pods (pod), observed by counting the number of pods produced.
- Number of filled pods (pod): observed by counting the number of pods contain normal seeds.
- Number of empty pods (pod): observed by counting the number of pods contain no seed.
- Number of seeds per plant (seed): observed by counting the number of seeds per individual plant.
- Seed weight per plant (g): observed by weighting of dry seeds per plant.
- Weight of 100 grains of seeds (g): observed by weighting of 100 dry seeds.
- It also carried out such an analysis: drought susceptibility index (DSI) and correlation coefficient.

Drought susceptibility index (DSI) was calculated using Fischer and Maurer [12] formula:

\[ DII = 1 - \frac{Xs}{Xi} \]

where,

\( DII \) = drought intensity index
\( Xs \) = the average value of all genotypes under drought stress conditions
\( Xi \) = the average value of all genotypes under no drought stress conditions

Value of more than 0.7 indicates severe drought stress.

Furthermore, drought susceptibility index (DSI) is calculated as follows:

\[ DSI = \left(1 - \frac{Ys}{Yi}\right)/DII \]

where,

\( Ys \) = the average value of specific genotypes under drought stress conditions
\( Yi \) = the average value of particular genotypes under no drought stress conditions

DSI > 1 = sensitive to drought stress; DSI < 1 = resistant to drought stress

The cithe Correlation coecfeicent was calculated using formula used by [13]:

\[ r = \frac{\frac{\sum xy}{n} - \frac{\sum x \sum y}{n}}{\sqrt{\left(\frac{\sum x^2}{n} - \left(\frac{\sum x}{n}\right)^2\right) \left(\frac{\sum y^2}{n} - \left(\frac{\sum y}{n}\right)^2\right)}} \]
where:
\( r \) = correlation coefficient
\( n \) = number of replication

2. Results And Discussion

2.1. Drought Susceptibility Index (DSI)

Drought susceptibility index (DSI) is used to determine genotypes resistant and susceptible to drought stress conditions. The magnitude of the drought susceptibility index of each variety exposed during the active vegetative phase is shown in Table 1. Table 2 showed the drought susceptibility index during the generative phase, and Table 3 showed the drought susceptibility index during the continuous drought from vegetative till generative phases.

Table 1. Drought susceptibility index (DSI) of soybean varieties exposed during the active vegetative phase.

| varieties     | Drought Susceptibility Index (DSI) | Total | Average |
|---------------|-----------------------------------|-------|---------|
|               | JP      | JPI    | JBPT   | BB      |       |        |
| Lawit         | 1.64    | 1.45   | 1.01   | 0.15    | 4.25  | 1.06   |
| Sibayak       | 0.14    | 0.14   | 1.31   | 0.72    | 2.31  | 0.58   |
| Kaba          | 1.36    | 1.33   | 1.31   | 0.92    | 4.92  | 1.23   |
| Pangrango     | 1.95    | 2.07   | 2.14   | 1.42    | 7.58  | 1.90   |
| Seulawah      | 0.27    | 0.17   | -1.14  | 1.52    | 0.82  | 0.21   |
| Nanti         | 0.72    | 0.86   | 1.20   | 0.69    | 3.47  | 0.87   |
| Burangrang    | 1.10    | 1.03   | 1.60   | 0.34    | 4.07  | 1.02   |

where: JP = number of pods; JPI = number of filled pods; JPH = number of empty pods; JBPT = number of seeds per plant; BB = seed weight per plant.

Drought susceptibility index of each variety exposed during the active vegetative phase as shown in Table 1 showed that four varieties were susceptible as indicated by DSI > 1, namely Lawit (DSI=1.06), Kaba (DSI=1.23), Pangrango (DSI=1.90), and Burangrang (DSI=1.02), while three varieties were resistant to drought stress during vegetative phase since DSI < 1, namely Sibayak (DSI=0.58), Seulawah (DSI=0.21), and Nanti (DSI=0.87). The high value of DSI (DSI>1) of Lawit, Kaba, Pangrango, and Burangrang was due to the high value of DSI on the characters of whole number pods, a number of filled pods, and a number of seeds per plant and also seed weight per plant for Pangrango particularly. While Sibayak, Seulawah, and Nanti varieties were relatively resistant to drought stress since the DSIs value was smaller than one and was mostly determined by low DSI of character total number of pods, a number of filled pods, and seed weight per plant.

Table 2 showed that three varieties were classified as sensitive to drought stress based on the value of drought susceptibility index (DSI) during the generative phase, namely Lawit (DSI=1.23), Kaba (DSI=1.12) and Seulawah (DSI=1.04). The relatively high value of the DSIs was mostly determined by the high DSI on the character of a number of pods, number of filled pods, and seed weight per plant. Sibayak, Pangrango, Nanti, and Burangrang was relatively resistant to drought stress during the generative phase since the DSIs value was smaller than one and was mostly determined by low DSI of character total number of pods, number of filled pods, number of seeds per plant, and seed weight per plant. According to Dornbos et al. [14] and Vieire et al. [15], drought stress that occurs during the generative growth, as when pod filling, will reduce production. Scott et al. [16] also reported that drought stress could also decrease seed weight because the weight of the seeds is strongly influenced by the amount of water supplied in the growing season.

Table 2. Drought susceptibility index (DSI) of soybean varieties exposed during the generative phase.

| varieties     | Drought Susceptibility Index (DSI) | Total | Average |
|---------------|-----------------------------------|-------|---------|
|               | JP      | JPI    | JBPT   | BB      |       |        |
| Lawit         | 1.64    | 1.62   | 1.01   | 0.15    | 4.25  | 1.06   |
| Sibayak       | 0.14    | 0.14   | 1.31   | 0.72    | 2.31  | 0.58   |
| Kaba          | 1.36    | 1.33   | 1.31   | 0.92    | 4.92  | 1.23   |
| Pangrango     | 1.95    | 2.07   | 2.14   | 1.42    | 7.58  | 1.90   |
| Seulawah      | 0.27    | 0.17   | -1.14  | 1.52    | 0.82  | 0.21   |
| Nanti         | 0.72    | 0.86   | 1.20   | 0.69    | 3.47  | 0.87   |
| Burangrang    | 1.10    | 1.03   | 1.60   | 0.34    | 4.07  | 1.02   |

where: JP = number of pods; JPI = number of filled pods; JPH = number of empty pods; JBPT = number of seeds per plant; BB = seed weight per plant.
Table 2. Drought susceptibility index (DSI) of soybean varieties exposed during the generative phase.

| varieties      | Drought Susceptibility Index (DSI) | Total | Average |
|----------------|------------------------------------|-------|---------|
|                | JP       | JPI   | JBPT   | BB     |         |         |
| Lawit          | 1.28     | 1.27  | 1.28   | 1.11   | 4.94    | 1.23    |
| Sibayak        | 0.61     | 0.60  | 0.87   | 0.67   | 2.75    | 0.69    |
| Kaba           | 1.01     | 1.33  | 0.94   | 1.19   | 4.47    | 1.12    |
| Pangrango      | 0.71     | 0.91  | 0.95   | 0.81   | 3.37    | 0.84    |
| Seoulawah      | 1.18     | 1.06  | 0.83   | 1.07   | 4.14    | 1.04    |
| Nanti          | 1.06     | 1.08  | 0.98   | 0.86   | 3.97    | 0.99    |
| Burangrang     | 0.89     | 0.83  | 0.10   | 1.27   | 3.09    | 0.77    |

where: JP = number of pods; JPI = number of filled pods; JPH = number of empty pods; JBPT= number of seeds per plant; BB = seed weight per plant.

In Table 3, there were two varieties were seems to be relatively susceptible to continuous drought stress, namely: Pangrango (DSI=1.18) and Seoulawah (DSI=1.05), and five varieties were classified as resistant varieties, namely: Sibayak (DSI=0.31), Burangrang (DSI=0.79), Kaba (DSI=0.88), Lawit (DSI=0.89), and Nanti (DSI=0.90), mostly due to lowest value of DSI on the character of a number of the filled pod.

Table 3. Drought susceptibility index (DSI) of soybean varieties exposed during the vegetative phase until the generative phase.

| varieties      | Drought Susceptibility Index (DSI) | Total | Average |
|----------------|------------------------------------|-------|---------|
|                | JP       | JPI   | JBPT   | BB     |         |         |
| Lawit          | 0.91     | 0.48  | 1.19   | 1.00   | 3.58    | 0.89    |
| Sibayak        | 0.66     | -0.26 | 0.66   | 0.17   | 1.23    | 0.31    |
| Kaba           | 0.97     | 0.05  | 0.93   | 1.57   | 3.52    | 0.88    |
| Pangrango      | 0.90     | 1.11  | 0.96   | 1.76   | 4.73    | 1.18    |
| Seoulawah      | 1.24     | 0.31  | 1.32   | 1.32   | 4.18    | 1.05    |
| Nanti          | 1.13     | 0.26  | 1.12   | 1.07   | 3.59    | 0.90    |
| Burangrang     | 1.04     | 0.12  | 0.96   | 1.03   | 3.14    | 0.79    |

where: JP = number of pods; JPI = number of filled pods; JPH = number of empty pods; JBPT= number of seeds per plant; BB = seed weight per plant.

Among the seven varieties tested, Sibayak and Nanti, two varieties were classified resistance to drought stress in all drought stress either during the vegetative phase, generative phase, or continuous drought, while some other varieties were resistant or susceptible depend on the growth stage of drought stress exposed. Differences in susceptibility index of drought (DSI) can be detected from the magnitude of reduction of yield or yield components of each variety under drought stress compared to normal conditions. Kisman [10] reported that there was a significant decrease in the number of pods per plant of soybean under drought conditions. The magnitude of the difference or change in the number of pods per plant on each variety between normal and drought conditions as indicated by the index of susceptible to drought (drought susceptibility index, DSI). The higher DSI of these varieties are more sensitive to drought, and the lower DSI of these varieties are more tolerant to drought. According to Baihaki [17], tolerant varieties to drought stress is indicated by a smaller difference of yield between in normal condition and in drought condition.

In general, plants will exhibit a certain drought susceptibility index when experiencing drought stress. Index of plant susceptible to drought stress is determined by the level of stress experienced and plant growth stages when experiencing stress. When the plants exposed to drought conditions, there are two kinds of responses that can improve water status: (1) the plant changes the distribution of assimilating to support root growth and increase the capacity of the roots absorb water and prevent the expansion of
leaves and number of leaves to reduce transpiration (2) plant adjusts the degree of stomatal opening to prevent water loss through transpiration [18].

2.2. Coefficient of correlation among yield and yield component
The coefficient of correlation indicates the level of relationship between two or more traits that depend on each other without weighting of which factor affects other factors either in genetic or non-genetic. According to Bari et al. [19], a correlation between two factors may be caused by environmental factors or genetic factors lead to phenotypic correlation and genotypic correlation.

Table 4 shows that all the characters of yield and yield components observed indicated various phenotypic correlation coefficient (ranging from -0.44 to 0.995). The high significant positive correlation coefficient (**) is shown in pairing characters of a number of empty pods - date of flowering (0.257**), number of empty pods - harvesting date (.414**), number of filled pods -number of pods (0.995**), number of seeds per plant -number of pods (0.858**), number of seeds per plant -number of filled pods (0.859**), 100 seed weight - flowering date (-0.441**), 100 seed weight - number of seed per plant (-0.038**), seed weight per plant - number of pods (0.694**), seed weight per plant - number of filled pods (0.687**), and seed weight per plant - number of seed per plant (0.673**). Positive correlations of some character pairs are caused by the action of the gene association (linkage) in which two or more genes are located in the same chromosome and tend to be heritage together, meaning that an increase in a character will be followed by a rise in other correlated characters. Soemartono et al. [20] reported that genetic causes of the correlation between characters are evidence of gene link (linkage), which affects two characters or the effect of the pleiotropic gene.

Highly significant negative correlation coefficients (- **) were also shown in Table 4 as indicated by 100 seed weight – flowering date (-0.441**) and 100 seed weight – number of seeds per plant (-0.038**). This means the increase of one character follows by the decrease of paired characters. According to Kasno [21], negative correlation indicates that some genes increase certain characters but decrease other paired characters.

Table 4. Coefficient of correlation among yield and yield component characters of soybean under drought stress conditions.

|       | UB  | UP  | JP  | JPH | JPI | JBPT | B100B | BB  |
|-------|-----|-----|-----|-----|-----|------|-------|-----|
| UB    | 1   |     |     |     |     |      |       |     |
| UP    | 0.189 | 1   |     |     |     |      |       |     |
| JP    | 0.244 * | 0.189 | 1   |     |     |      |       |     |
| JPH   | 0.257 ** | 0.414 ** | 0.257 * | 1 |     |      |       |     |
| JPI   | 0.226 * | 0.153 | 0.995 ** | 0.169 | 1 |      |       |     |
| JBPT  | 0.186 | 0.122 | 0.858 ** | 0.201 | 0.859 ** | 1 |       |     |
| B100B | -0.441 ** | 0.049 | -0.247 * | -0.057 | -0.252 * | -0.038 ** | 1 |     |
| BB    | -0.118 | 0.142 | 0.694 ** | 0.210 | 0.687 ** | 0.673 ** | 0.269 * | 1 |

Note: *) was significantly correlated to the level of 5%
Flowering date (UB), Harvesting date (UP), Number of pods (JP), Number of empty pods (JPH), Number of filled pods (JPI), number of seed per plant (JBPT), the weight of 100 seeds (B100B), and seed weight per plant (BB)

3. Conclusion and Suggestion
Based on the results and discussion above, it can be concluded that:
1. Based on the average value of drought susceptibility index (DSI) of yield and yield components of soybean, variety of Sibayak and Nanti, were classified resistance to drought stress either during the vegetative phase, generative phase or continuous drought.
2. The highly significant positive correlation of among yield and yield components of soybean under drought stress were: seed weight per plant - number of pods, seed weight per plant - number of filled pods, and harvest index (DSI).

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pods, and seed weight per plant - number of seed per plant, while highly significant negative correlation occurred in the character of flowering date - 100 seed weight.

Based on the conclusions above, it may be suggested that:
1. Sibayak and Nanti, two drought-resistant varieties may be developed in the drylands or during drought stress in dry seasons.
2. Improving yield or seed weight can be done by increasing the number of pods, the number of filled pods, and the number of seed per plant.

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