Identification of soybean genotypes adaptive to tropical area and suitable for industry

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Abstract. Soybeans in Indonesia are mostly used for raw material of tempeh industry. This study aims to identify 150 soybean genotypes for their suitability for raw materials of tempeh and adaptability to be developed in tropical area of Indonesia. The research material consisted of 150 soybean genotypes. The field research was conducted in Malang from February to May 2016, using a randomized block design with two replicates. The identification of 150 soybean genotypes showed 30.67% of super early maturity (<75 days), 50% of early maturity (76 - 79 days), and 19.33% were medium maturity (80 - 90 days). In the group of super early maturity, 11 genotypes were yielded between 3.01 - 3.69 t/ha and the 100 seed weight ranged from 15.27 - 20.18 g. In the early maturity group, there were 23 genotypes with seed yields between 3.01 - 3.66 t/ha, and the 100 seed weight ranged from 13.90 - 20.23 g. In Indonesia, tempeh industry requires soybeans with large seed size. In this research, G511H/Anj//Anj////Anjs-8-5 was suitable to be developed in Indonesia's tropical climate and also preferred by industry for tempeh raw material due to its high yield, super early days to maturity, and large seed size.

Keywords: early days to maturity, large seed size, tempeh, tropical soybean

1. Introduction
Soybean cultivation in Indonesia is unique because it can be planted throughout the season, which starting from the beginning of the rainy season, the beginning of the dry season, and the end of the dry season. Soybean consumption in Indonesia reached 7.62 kg/capita/year [1]. Processed soy-based food in Indonesia has large variation, for example tempeh tofu, soy sauce, milk, tauco etc, and of a wide range of soybean food products in Indonesia, tempeh and tofu are the most popular foods. Based on Susenas data [2], the level of tempeh consumption in Indonesia reached 6.95 kg/capita/year. So far, Indonesia still import soybean about 67.28% or as many as 1.96 million tons to meet the domestic demand.

Soybean characteristics are vary in each type of processed food products. Soybean for tofu raw material is more determined by characteristic of high starch content, whereas the industry prefers soybean with large seed size for the tempeh raw material. Soybean seed differences are vary between soybean production centers in the world. In Indonesia, the size of the soybean seeds is divided into three groups, i.e. small seeds (<10 g/100 seeds), medium (10 - 14 g/100 seeds), and large seeded (> 14 g/100 seeds). A research by Krisdiana [3] showed that about 93% of tempeh producers prefer soybeans with yellow seed color and large seed size, because it produced a brighter colored tempeh and larger volume. According to Ginting [4], several superior varieties of soybeans in Indonesia can deliver tempeh which have similar quality with imported ones, and also frequently showed a higher
protein content. Moreover, Antarlina et al. [5] reported that soybean seed size could be a determinant factor of tempeh quality because it showed positive correlation with tempeh weight ($r = 0.86^{**}$) and tempeh volume ($r = 0.95^{**}$). The relationship between seed size and tempeh appearance was also reported by Astawan et al. [6] that the tempeh produced from Grobogan soybean varieties (large seed size) has the similar water, protein, and oil content with those of produced from imported soybeans which have seed size of 16-18 g/100 seeds. Research on four Brazilian soybean cultivars conducted by Bavia et al. [7] showed that the protein in tempeh increase from 36.16% of the seed protein to 43.16% in soybean protein. Thus, the processed soybean for tempeh become a potential source of protein for humans.

Soybean seed size as a determinant of quality of tempeh, was genetically controlled. Thus, an effort to increase seed size through genetic modification will provide a high chance of success. Liang et al. [8] reported that seed morphological traits, such as seed length, seed width, and seed height, were associated with seed weight and also affect the morphological quality of the seeds. The development of soybean for the provision of raw material of tempeh industry for tropical condition of Indonesia, is recommended not only based on seed size but also pay attention on the character of early days to maturity. This is due to soybeans are planted three times a year in Indonesia. Krisnawati & Adie [9] did simultaneously selection on both of large seed size (>15.8 g/100 seeds) and high seed yield (>2.53 t/ha) and obtained eight selected genotypes. Vollman et al. [10] stated that selection of early maturing soybean genotypes with improved seed protein content appears to be feasible and was limited by the moderately negative correlation between protein content and seed yield. Various studies on plant age have been widely reported. It was also reported that an increase in the number of flowers at the beginning of the flowering phase will potentially increase the number of pods and seeds at maturity phase [11].

The availability of soybean cultivars which suitable for raw material of tempeh and also adaptive in tropical area are important to meet the users’ preference. The objective of the research was to identify 150 soybean genotypes for their suitability for raw materials of tempeh and adaptability to be developed in tropical area of Indonesia.

2. Methodology

2.1. Research material

The research materials were 150 soybean genotypes which consisted of 145 genotypes as a result of crosses, and five soybean varieties (Grobogan, Burangrang, Anjasmo, Argomulyo and Dega 1).

2.2. Field study

The research study was conducted in Kendalpayak Research Station (Malang, East Java, Indonesia) which located at 8° 049645” South Latitude until 112° 625592” East Longitude, 445 m above sea level, C2 climate type of Oldeman system, and the 2191 mm/year of mean annual rainfall intensity. The study was performed from February to May 2016 in the lowland (paddy field) after rice planting. The experiment was arranged in randomized complete block design with two replicates. The plot size was 1.2 × 4.5 m, 40 cm × 15 cm plant spacing, two seeds per hill. Plants were fertilized by 250 kg Phonska/ha + 100 kg SP36, and 1 t/ha organic fertilizer which applied entirely during planting. The land used in the study was wetland from former rice paddy field. The drainage channel was made prior planting to maintain the optimum soil moisture. The weed, pest, and disease were controlled optimally. The plant harvest was done when 90% pods reach maturity.

2.3. Observation

Parameter observed was included seed yield, days to maturity, 100 seed weight, and the supporting characters which consisted of plant height, number of branches, number of nodes, number of filled pods, and number of empty pods [9].
3. Result

The performance of main characters (seed yield, days to maturity, and 100 seed weight) and the supporting characters (plant height, number of branches, number of nodes, number of filled pods, and number of empty pods) were significantly influenced by the differences of genotypes used (Table 1). It indicates that each soybean genotype produce different value of main and supporting characters.

Table 1. Analysis of variance for main and supporting characters of 150 soybean genotypes. Malang. 2016.

| Character                  | Mean Square Replication | Genotype         | CV (%) |
|----------------------------|-------------------------|------------------|--------|
| Main characters:           |                         |                  |        |
| Seed yield (t/ha)          | 28.5825 **              | 0.3447 **        | 18.46  |
| Days to maturity (day)     | 88.5633 **              | 11.8503 **       | 2.50   |
| 100 seed weight (g)        | 10.3788 **              | 5.5558 **        | 7.52   |
| Supporting characters:     |                         |                  |        |
| Plant height (cm)          | 1992.8021 **            | 112.7910 *       | 16.25  |
| Number of branches/plant   | 1.7710 ns               | 1.0804 **        | 29.09  |
| Number of node/plant       | 1.6133 ns               | 3.1714 *         | 14.51  |
| Number of filled pod/plant | 1.4145 ns               | 193.4303 **      | 23.29  |
| Number of empty pod/plant  | 0.0385 ns               | 2.5096 **        | 37.47  |

** = significant at 1% probability level (p < 0.01), * = significant at 5% probability level (p < 0.05), ns = not significant, CV = coefficient of variation.

The descriptive statistic showed that the seed yield of 150 genotypes was ranged from 0.91 – 3.08 t/ha (average of 2.31 t/ha). The days to maturity was vary from 73 – 84 days (average of 77 days), whereas for 100 seed weight was between 13.07 to 22.65 g (average of 16.60 g/100 seeds) (Table 2). Those three characters are classified as main characters to support soybean development in the tropical area of Indonesia for tempeh raw material.

The supporting characters, i.e. plant height was ranged from 33.70 – 74.00 cm (average of 55.45 cm), the range of number of branches was 0.70 – 5.30 branches (average of 2.88 branches/plant), the range of number of nodes was 7.50 – 15.50 nodes/plant (average of 10.19 nodes/plant). Character of number of pod/plant was divided into number of filled pod (which ranged from 22.70 – 81.80 filled pods and with an average of 39.89 pods/plant) and number of empty pods which ranged from 0.10 to 8.70 empty pods (average of 1.39 empty pods/plant) (Table 2). The performance of main and supporting characters in this study showed that the plant growth was optimal and the variability of morphological characters were vary between genotypes.

Table 2. Descriptive statistic of main and supporting characters of 150 soybean genotypes. Malang. 2016.

| Character                  | Mean | Minimal value | Maximal value | Standard deviation |
|----------------------------|------|---------------|---------------|--------------------|
| Main characters:           |      |               |               |                    |
| Seed yield (t/ha)          | 2.31 | 0.91          | 3.08          | 0.41               |
| Days to maturity (day)     | 77   | 73            | 84            | 2.43               |
| 100 seed weight (g)        | 16.60| 13.07         | 22.65         | 1.66               |
| Supported characters:      |      |               |               |                    |
| Plant height (cm)          | 55.45| 33.70         | 74.00         | 7.48               |
| Number of branches/plant   | 2.88 | 0.70          | 5.30          | 0.73               |
The preference of tempeh industry is large seeded soybean variety. The grouping of 150 soybean genotypes based on their seed size was classified into three groups, i.e. seed size less than 14 g/100 seeds, size between 14 – 16 g/100 seeds, and seed size over 16 g/100 seeds (Table 3). Based on those grouping, this study has obtained five soybeans with seed size less than 14 g/100 seeds, 51 genotypes of sees size between 14 – 16 g/100 seeds, and 94 genotypes with seed size over 16 g/100 seeds. Those seed size are suitable for raw material of tempeh, and also have a similar size with imported variety.

The highest yield on the group less than 14 g/100 seeds was 2.52 t/ha. All genotypes in this group were have early days to maturity. In the group of 14 – 16 g/100 seeds, the highest yield was 2.93 t/ha, and the seed-size group over > 16 g/100 seeds produced the highest yield of 3.08 t/ha. On those three seed-size groups, the lowest yield was in the group with seed size less than 14 g/100 seeds. If we compared it with the performance of the supporting characters, it clearly seen that the larger seed size will resulted in more optimal supporting characters compared to those of in the group of less than 14 g/100 seeds.

G511H/Argomulyo-2 produced the highest yield in the seed-size group less than < 14 g with the days to maturity reached 76 days. The best yielded genotype in the group 14 – 16 g was G511H/Arg///Arg///Arg///Arg///Arg-30 (2.91 t/ha) with the days to maturity 76 days. In the seed-size group over 16 g/100 seeds, G511H/Anj///Anj///Anj///Anj///Anj-8 showed the highest yield (3.08 t/ha) with 75 days of maturity (Table 4). Thus, G511H/Anj///Anj///Anj///Anj///Anj-8 was identified as the best genotype, and suitable to be developed in Indonesia for raw material of tempeh.

### Table 3. Grouping of 150 soybean genotypes based on seed size. Malang. 2016.

| Seed weight (g/100 seed) | Descriptive statistic | SY.a | DM.b | PH.c | NB.d | NN.e | FP.f | EP.g |
|--------------------------|----------------------|------|------|------|------|------|------|------|
| < 14 g                   | Mean                 | 2.19 | 76.20| 55.32| 3.50 | 10.00| 39.44| 0.84 |
|                          | Minimal              | 1.70 | 74.00| 46.80| 2.20 | 9.00 | 34.20| 0.40 |
|                          | Maximal              | 2.52 | 79.50| 68.05| 5.30 | 11.00| 51.80| 1.20 |
|                          | Std                  | 0.28 | 2.11 | 7.59 | 1.02 | 0.71 | 6.41 | 0.32 |
| 14 – 16 g                | Mean                 | 2.32 | 77.54| 57.13| 3.07 | 10.53| 43.78| 1.45 |
|                          | Minimal              | 1.62 | 73.50| 33.70| 1.60 | 8.00 | 26.80| 0.40 |
|                          | Maximal              | 2.93 | 84.00| 74.00| 4.50 | 13.50| 77.20| 4.60 |
|                          | Std                  | 0.35 | 2.54 | 8.34 | 0.62 | 1.13 | 10.67| 0.88 |
| >16 g                    | Mean                 | 2.31 | 76.60| 54.54| 2.74 | 10.01| 37.80| 1.38 |
|                          | Minimal              | 0.91 | 73.00| 39.40| 0.70 | 7.50 | 22.70| 0.10 |
|                          | Maximal              | 3.08 | 82.50| 69.40| 5.00 | 15.50| 81.80| 8.70 |
|                          | Std                  | 0.45 | 2.31 | 6.80 | 0.73 | 1.30 | 8.76 | 1.24 |

.a Seed yield (t/ha)
.b Days to maturity (day)
.c Plant height (cm)
.d Number of branches/plant
.e Number of node/plant
.f Number of filled pod/plant
.g Number of empty pod/plant
Table 4. The best genotype on each seed-size group. Malang. 2016.

| Grouping | Genotype          | SS\(a\) | SY\(b\) | DM\(c\) | PH\(d\) | NB\(e\) | NN\(f\) | FP\(g\) | EP\(h\) |
|----------|-------------------|----------|---------|---------|---------|---------|---------|---------|---------|
| < 14 g   | G511H/Argomulyo-2 | 13.90    | 2.52    | 76      | 59.50   | 3.40    | 10.50   | 35.90   | 0.80    |
| 14 – 16 g| G511H/Arg//Arg///Arg//Arg-30-3 | 15.84    | 2.91    | 76      | 66.90   | 4.50    | 11.00   | 48.50   | 0.70    |
| >16 g    | G511H/Anj///Anj///Anj///Anjs-8-5 | 16.92    | 3.08    | 75      | 56.40   | 2.50    | 10.00   | 32.40   | 0.80    |

\(a\) Seed size\((g)\)
\(b\) Seed yield \((t/ha)\)
\(c\) Days to maturity \((days)\)
\(d\) Plant height \((cm)\)
\(e\) Number of branches/plant
\(f\) Number of node/plant
\(g\) Number of filled pod/plant
\(h\) Number of empty pod/plant

4. Discussion

The domestic soybean demand continues to increase as a result of the increasing population of Indonesia. Tempeh is one of the processed soybean products consumed by most of the Indonesian people. The fulfilment of soybean raw materials for industrial purposes is partly imported from other countries. The physical characteristic of imported soybeans is large seed size (about 16 g/100 seeds), and the size is in accordance with the preference of tempeh industry in Indonesia. The development of soybean to meet the needs of tempeh industry in Indonesia must have the requirements: (1) adaptive and productive in the tropical environment of Indonesia, (2) large seed size (> 14 g/100 seeds), and early days to maturity (<80 days).

Identification on 150 soybean genotypes showed that the performance of main characters (yield, 100 seed weight, and days to maturity) as well as supporting characters were differ between genotypes. Soybean seed size become the determinant of tempeh quality. The grouping of 150 soybean genotypes was based on seed size which measured through 100 seeds weight. It has classified into three groups, i.e. less than 14 g, between 14 – 16 g, and over 16 g. The result showed that most of soybean genotypes (94 genotypes) were in the seed-size group over 16 g, followed by 51 genotypes in the group of 14 – 16 g, and the rest (5 genotypes) were in the group of less than 14 g. Soybeans used in this study were derived from selection result of soybean germplasm crossing which aimed to increase the seed size and early maturing characters. Seed size is essential character to optimize the yield and also play important role in adaptation of a cultivar and influence to seed vigor [12]. Hu et al. [13] studied about seed length, seed width, and seed height as seed-size traits, and their ratios of these values as seed-shape traits of 184 recombinant inbreds lines and 219 cultivated soybean accessions. They reported that seed size traits, which are controlled by multiple genes in soybean, play an important role in determining seed yield, quality and appearance. Another research reported that the matured soybean seed size was simultaneously controlled by embryo, cytoplasm, and maternal effects [14]. Related to the soybean seed character, Sudaric & Vrataric [15] reported that the direct selection on higher number of seeds/plant and higher seed yield/plant would result in greater genetic advance in grain yield. The nutrient composition on soybean is determined by variety, location, climate, and the cultivation management.

The opportunity to obtain soybean cultivar adapted with tropical condition, especially in Indonesia, is widely open. In the group of 14 – 16 g/100 seeds, the range of seed yield was between 1.62 – 2.93 t/ha with days to maturity from 73 – 84 days; whereas in the seed-size group of over 16 g/100 seeds have range of seed yield between 0.91 – 3.08 t/ha and range of 73 – 82 days to maturity. If the limit of soybean productivity is determined by 3.0 t/ha, seed size > 14 g/100 seeds, and days to maturity < 80 days, then in the seed-size group of 14 – 16 g, G511H/Arg//Arg///Arg//Arg-30-3 was able to produce 2.91 t/ha with the days to maturity 76 days. In the seed-size group over 16 g/100 seeds, G511H/Anj///Anj///Anj///Anjs-8-5 was produce up to 3.08 t/ha with days to maturity around 75 days.
The requirement of agronomic character and soybean agro-ecosystem in the tropical area of Indonesia is different with other soybean production center countries. This is related to the existing growing season performed three times a year, i.e., in the beginning of rainy season (November/December), beginning of dry season (February/March), and dry season (June/July). A study on soybean in Argentina by Santachiara et al. [16] revealed that maturity groups (MG) III had a longer seed set period, received more incident radiation during that period, and captured more N compared to the MG V. A study in Thailand showed that the extension of days to flowering resulted in an increase of the yielding potential of early maturing [17].

The soybean variety development in Indonesia in the last five years has aimed to develop soybean early maturing varieties (< 80 days). The newest soybean variety in Indonesia, namely Detap 1 which released in 2017, is resistant to pod shattering, the average yield 2.70 t/ha, the 100 seed weight 15.37 g, and the days to maturity 78 days. Liu et al. [18] reported that the soybean breeding program during 82 years in China for character of days to maturity has successfully decrease the days to maturity from 140.3 days to 125.6 days, whereas the average yield increase from 1283.3 kg to 2310.7 kg. The identification of soybean genotypes that are not only adaptive to Indonesia's tropical climate, but also have early days to maturity and large seed size is important for the provision of soybean raw materials for tempeh industry.

5. Conclusion
The soybean genetic approach to produce variety with large seed size and maturity of early days to maturity have a relatively high chance of success. G511H/Anj//Anj///Anjs-8-5 with yield of 3.08 t/ha, early days to maturity (75 days), and large seed size (16.92 g/100 seeds) is potential to be developed in Indonesia's tropical climate to support the provision of raw materials of tempeh industry.

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