Yield components of the M7 Kipas Putih mutant soybean

Zuyasna*, E Hayati, Y Ghufrani, A Marliah, B Basyah, Nura
Agrotechnology Department, Universitas Syiah Kuala, Jalan Tgk. Hasan Krueng Kalee 3, Darussalam-Banda Aceh 23111, Indonesia

*Email: zuyasna@unsyiah.ac.id

Abstract. This study aimed to obtain the homogeny of M7 soybean lines in an effort to release new high yielding varieties. The research was conducted in Lamsidaya village, and the observation of yield components was carried out at the Plant Breeding Laboratory, Faculty of Agriculture, Universitas Syiah Kuala. This study did not use an experimental design, so that the quantitative characters were observed individually from each plant, then analyzed by estimating the heritability broad sense value and the progress of selection. The material used were var. Kipas Putih and var. Dega1 as control, eight of 7th generation Kipas Putih mutant lines (B4, B7, B10, B12, B13, B15, B18 and B22). All genotypes were planted in rectangular plot 10 m x 1 m, drainage 50 cm, and planting distance 50 cm x 30 cm. Plants were maintained in accordance with the recommendation for soybean cultivation from Balitkabi, and fertilizer NPK (16:16:16) was given 200 g/plot (200 kg/ha). Parameters observed included plant height, flowering time, harvest time, number of productive branches, total number of pods per plant, number of filled pods per plant, seed weight per plant, weight of 100 seeds, seed weight per plot, and yield potential. All quantitative characters indicated increase on selection except for the character of plant height, percentage of filled pods and weight of 100 seeds because the heritability value was low. The B18 line has the potential to become a new high yielding variety because it has a high yield potential (3.02 tons ha⁻¹) with a large seed size compared to the other seven mutant lines and is also higher than the parent Kipas Putih and var Dega 1 varieties.

1. Introduction
Base on the data from the Central Statistics Agency shows that Indonesia's soybean imports throughout the first semester of 2020 reached 1.27 million tons or US$ 510.2 million or equivalent around Rp 7.52 trillion (exchange rate of Rp 14,700). A total of 1.14 million tons of soybean import came from the United States (US). Meanwhile, when viewed from previous years, total soybean imports reached 2.67 million tons in 2017, about 2.58 million tons in 2018 and 2.67 million tons in 2019 [1].

So far, national soybean farmers faced with various problems that prevent their production of soybeans from being fully absorbed by the market, such as quality and prices that cannot compete with imported soybeans. According to Felippa, Head of Research Centre for Indonesian Policy Studies (CIPS), several things affect the low productivity of national soybeans. The first is the climatic factor. Soybean is a plant that is actually a sub-tropical plant, so that growth in tropical areas such as Indonesia is not optimal. Soybean production businesses in Indonesia must adapt to cropping patterns and rotations. Therefore, it is important to increase the productivity and quality of national soybeans [1].
There are several ways to increase soybean production, namely by improving the optimal plant cultivation system, which includes the use of quality seeds from superior varieties, controlling plant pests and diseases, regulating irrigation and cultivation, and also applying fertilization techniques. Efforts to obtain superior varieties of soybeans can be obtained through plant breeding activities. Plant breeding can improve and increase the genetic potential of plants so that new plants obtained the superior to previous plants with better characters and can adapt to certain agroecosystems.

Breeding activities on soybeans directed to improve yield potential and agronomic characters, increase seed composition, increase tolerance to abiotic stress, and tolerance to herbicides, as well as improve resistance to pests and diseases [2]. Therefore, induction and exploitation of genetic diversity is an established genetic approach in crop improvement.

Plant breeding techniques, mutagenesis, biotechnology, genetic engineering, and molecular breeding have played a pivotal role in exploiting available germplasm resources for developing improved cultivars [3]; [4]. In this regard, mutagenesis offers as a simple and effective means of inducing genetic variation. A single induced mutant can have several desirable traits, e.g., disease resistance, high yield, quality, plant architecture, and abiotic stress tolerance. Mutants usually obtained by using radiation, chemicals, T-DNA or transposons [5]. Physical mutagens have yielded the majority of mutant varieties, and gamma rays mostly used followed by other radiation methods [6].

In 2013, Zuyasna and friends radiated the Kipas Putih var. using gamma ray, and after selecting several lines, found that some of these mutant lines have the potential to be as superior varieties because they are designed to have adaptive properties and high yield [7]. Kipas Putih var. is one of Aceh's local soybean varieties, which released on November 3, 1992. This variety has an average yield potential of 1.69 tons ha\(^{-1}\) of dry seeds; however, it is categorized to the small seed group with a weight of 100 seeds of 12 g. This variety contains 35% protein and 20.5% fat content. The Kipas Putih var. is tolerant to leaf rust (Phadankopsora pachirhyzi Syd.) and has the characteristics not easily fall. The Kipas Putih var. can also adapt well to dry land and rain fed rice fields [8].

The aim of this research is to obtain homogeneity mutant’s Kipas Putih in order to get new soybean variety that adaptable in Aceh. We currently selected of eight M\(_7\) generation Kipas Putih mutant lines (B4, B7, B10, B12, B13, B15 and B22) in expectations to release one of the new soybean varieties that superior from the original varieties or parent and uniform. On this research, we also used Dega 1 var., one of the national varieties. Dega 1 var. released in 2016, and this superior variety is higher in yield potential and average yields than Grobogan and Baluran varieties. Dega 1 var., it also early mature and large seeds size about 22 g per 100 of seeds.

2. Materials and methods

2.1. General condition
This research was conducted in Lamsidaya Village, Darul Imarah District, Aceh Besar District from March 2020 to October 2020. Observations of yield components were carried out at the Plant Breeding Laboratory, Faculty of Agriculture, Universitas Syiah Kuala. The materials used were var. Kipas Putih and var. Dega 1 as control, eight of 7\(^{th}\) generation Kipas Putih mutant lines (B4, B7, B10, B12, B13, B15, B18 and B22). As a complement for soybean cultivation, we used organic cow fertilizer, NPK Mutiara fertilizer, rice husk ash, Rhizobium sp. (Rhizoka), furadan, herbicide and Decis.

The research area was located in Lamsidaya Village, Darul Imarah - Aceh Besar District. The land was previously used as a duck farm managed by the landowner from late 2017 to middle 2018. The land was left for about two years until the land plowed again on March 30, 2020. Planting was carried out in mid-June 2020, the weather in the field is classified as hot with erratic rains so that it requires watering twice a day, in the morning and afternoon.
2.2. Land preparation
The land was cleaned from weeds and unwanted inorganic materials. Then ploughing and loosening the soil. Plot with rectangular made with a size of 10 m x 1 m, drainage 50 cm and planting distance 50 cm x 30 cm. Then manure was given 20 kg/plot (20-ton ha⁻¹) one week before planting by spreading it. NPK compound fertilizer was given 200 g/bed (200 kg ha⁻¹) 2 weeks after planting (2 WAP) by sowing it between plant rows and then covering it again with soil.

2.3. Soybean cultivation
Planting seeds after spreading the soil with cow manure. The seeds are soaked in the water and those that sinks were taken for planting, but before planting those seeds were greased with Rhizoka. Planting seeds was one seed in each hole with a planting distance of 50 cm x 30 cm, and then the planting hole covered with rice husk ash.

2.4. Maintenance
Maintenance of soybean plants includes watering, replanting, weeding and controlling pests and diseases. Watering was carried out every day in the morning and evening. Watering also adjusted to the conditions of the land in the field. At the age of 6 days after planting, we replant those that do not grow. Soil hoarding around the plant was done when the plant has started to grow to improve aeration (air circulation) and regulation of soil that is too watery, creates loose soil conditions around the plant, provides a better root environment, and covering roots that appear above the soil surface. Weed control was done manually by pulling out weeds using a knife or machete. Pest and disease control was carried out once a week using Decis brand pesticides to prevent pest and disease attacks from getting worse during the production phase.

2.5. Roguing in the field
Roguing is the activity of identifying and eliminating deviant activities. The purpose of rouging is to maintain the purity and genetic quality of a variety. Negative mass selection or rouging was carried out three times, in the germination phase (juvenile), flowering phase and ripe phase. In each selection phase we observed the characters of the colour of the hypocotyl, in the flowering phase was observed the colour of flowers and feathers and the color of the pod in the ripe phase.

2.6. Harvest
Harvesting was carried out after the plants show the conditions of the harvest criteria, the leaves have turned 85% to yellow; the pods are brown and completely hardened. Harvesting was done by pulling or cutting the plants using a sickle.

2.7. Observation parameter
Observation for quantitative characters of soybean mutant lines included; plant height (cm), flowering age, harvest age, number of productive branches, number of pods per plant, number of filled pods, percentage of filled pods, number of seeds per plant, seed weight per plant (g), weight of 100 seeds (g), weight of seeds per plot (g) and yield potential (tons ha⁻¹).

2.8. Genetic parameter estimation data analysis
Quantitative observation data were analysed by estimating the heritability value and the predictive value of selection progress. Heritability is the ratio between the diversity caused by genetic factors (inherited characters) and with the diversity caused by environmental factors. This study uses broad sense heritability (h²bs) calculated by the method of Kalton, Smit and Leffel, based on the formula:

\[ h^2_{\text{(bs)}} = \frac{\sigma^2_{S1} - \sigma^2_{S0}}{\sigma^2_{S1}} \times 100\% \]  

\( h^2_{\text{(bs)}} = \text{heritability} \)
S0 = variety of parent varieties of soybeans
S1 = variety derived from mutation of soybean plant

Classification of broad meaning heritability values were determined as low ($h^2 < 0.2$), medium (0.2 $h^2 < 0.5$) and high ($h^2 > 0.5$).

Selection progress is the difference between the mean value of the offspring of the selection and the mean value of the selected population. The estimated value of genetic progress was calculated based on the formula:

$$G = \hat{i} \cdot H \cdot \sigma_p$$  \hspace{1cm} (2)

In this study, the intensity of the selection was 10% with a value of $= 1.76$.

3. Results and discussion

3.1 Plant height, flowering age, and harvest age

The Centre for Plant Variety Protection (PPVT) in 2007 has divided the height criteria for soybean plants, namely short (15-50 cm), medium (50-68 cm), and tall (>68 cm). All soybean mutant lines had a plant height of >68 cm so that they could be classified in the tall plant. This criterion was also shown in the elder Kipas Putih variety, but in the comparison variety Dega 1, the plant height only reached 59.22 cm, so it was classified in the medium criteria.

The flower age is determined based on the appearance of flowers as much as 50% in a soybean population. The criteria for flowering age are very early (<25 days), early (25-30 days), medium (31-35 days), deep (35-40 days), very deep (>40 days). This is not much different from the opinion of Sharah [9], which states that soybeans in Indonesia generally flower at the age of 25-40 days. Elderly var Kipas Putih was categorized as the very late crop to harvest (90 DAP), while var Dega 1 was categorized as early harvest (77 DAP). Based on the observations, eight soybean mutant lines categorized as late and very late to flower and harvest. This is in accordance with Sibarani et al., [10] who stated that the harvesting age of each plant genotype depends on the flowering age and also the genetic factors of each genotype. The plant height, flowering age, and harvest age is shown in table 1.

| No. | Genotype     | Plant height ± Sd | Flowering time ± Sd | Harvesting time ± Sd |
|-----|--------------|-------------------|---------------------|----------------------|
| 1.  | Mutant B4    | Tall (103.3 ± 14.6) | Very late (41 ± 2.0) | Very late (94 ± 1.2) |
| 2.  | Mutant B7    | Tall (111.5 ± 15.4) | Late (40 ± 2.2)     | Late (92 ± 1.8)      |
| 3.  | Mutant B10   | Tall (107.1 ± 14.2) | Very late (41 ± 1.0) | Very late (92 ± 1.7) |
| 4.  | Mutant B12   | Tall (102.3 ± 15.7) | Very late (41 ± 0.7) | Very late (91 ± 1.4) |
| 5.  | Mutant B13   | Tall (89.7 ± 10.7)  | Very late (41 ± 0.8) | Very late (92 ± 1.9) |
| 6.  | Mutant B15   | Tall (107.4 ± 12.1) | Late (40 ± 1.1)     | Late (91 ± 1.7)      |
| 7.  | Mutant B18   | Tall (106.2 ± 16.0) | Late (40 ± 2.0)     | Late (92 ± 1.7)      |
| 8.  | Mutant B22   | Tall (96.7 ± 13.1)  | Late (40 ± 1.1)     | Late (92 ± 2.0)      |
| 9.  | Kipas Putih  | Tall (88.7 ± 26.7)  | Very late (42 ± 1.5) | Very late (90 ± 0.0) |
| 10. | Dega 1       | Medium (59.22 ± 10.0) | Early (27 ± 1.1)    | Early (77 ± 3.2)     |

Table 1 shows a mutant strain of Kipas Putih has a flowering age ranging from 40-41 days after planting. Lines that flower earlier are more likely to be harvested sooner as well. Based on the research results, mutant lines that have criteria very late to flower will be harvested too late. Sumarno and Manshuri [11] reported that soybeans in Indonesia generally flower around 25-40 days.

3.2. Number of productive branches and number of pods per plant

Productive branches are branches that produce pods on each plant. The total number of pods is the result of the sum of the number of filled pods and empty pods. The average number of productive branches of
the Kipas Putih mutant line ranged from 17-28 productive branches that produced pods, while the average number of pods per plant in the Kipas Putih mutant line ranged from 189-374 pods per plant. The highest number of productive branches was found in the B15 line, which was 28 branches compared to the elder Kipas Putih variety and the comparison variety Dega 1, while the highest number of pods per plant was found in the B12 line, which was 374 pods compared to the elder Kipas Putih variety and the comparison variety Dega 1. Branch yield and total pod number of each mutant strain of Kipas Putih soybean show in table 2.

### Table 2. Number of productive branch and number of total pod soybean plant.

| No. | Genotype       | Number of productive branches ± Sd | Total pods per plant ± Sd |
|-----|----------------|------------------------------------|---------------------------|
| 1.  | Mutant B4      | 17 ± 7.9                           | 193 ± 95.7                |
| 2.  | Mutant B7      | 18 ± 8.4                           | 189 ± 86.5                |
| 3.  | Mutant B10     | 24 ± 9.3                           | 257 ± 127.9               |
| 4.  | Mutant B12     | 22 ± 12.3                          | 374 ± 273.8               |
| 5.  | Mutant B13     | 19 ± 8.3                           | 325 ± 144.8               |
| 6.  | Mutant B15     | 28 ± 11.6                          | 272 ± 120.7               |
| 7.  | Mutant B18     | 18 ± 8.0                           | 227 ± 119.9               |
| 8.  | Mutant B22     | 19 ± 7.8                           | 271 ± 176.6               |
| 9.  | Kipas Putih    | 10 ± 4.6                           | 130 ± 99.9                |
| 10. | Dega 1         | 8 ± 3.0                            | 88 ± 40.6                 |

The environment can affect the number of productive branches. The number of plant branches is reduced if the plant is in environmental conditions experiencing drought stress [10]. According to table 2, the number of productive branches can affect the number of pods per plant, the number of filled pods, the percentage of filled pods, and the number of seeds per plant. The more productive branches, the more pods per plant so that the number of seeds per plant also increases.

### 3.3. Filled pod, percentage of filled pods, and number of seeds per plant

The Kipas Putih soybean mutant line had an average number of filled pods ranging from 130-278 filled pods per plant. The elder Kipas Putih variety had an average number of filled pods less than the mutant line, which was 69 pods and the Dega 1 variety only had an average number of 48 pods filled. The data on the number of filled pods, the percentage of filled pods and the number of seeds per plant shows in table 3.

### Table 3. Filled pod, percentage of the filled pod, and number of seeds per plant.

| No. | Genotype       | Filled pod ± Sd | Percentage of filled pod ± Sd | Number of seeds per plant ± Sd |
|-----|----------------|-----------------|------------------------------|-------------------------------|
| 1.  | Mutant B4      | 135 ± 70.6      | 70% ± 10%                    | 249 ± 148                     |
| 2.  | Mutant B7      | 130 ± 68.3      | 68% ± 12%                    | 238 ± 133                     |
| 3.  | Mutant B10     | 190 ± 98.9      | 74% ± 12%                    | 369 ± 198                     |
| 4.  | Mutant B12     | 268 ± 212.3     | 73% ± 8%                     | 529 ± 433                     |
| 5.  | Mutant B13     | 278 ± 130.8     | 85% ± 10%                    | 527 ± 260                     |
| 6.  | Mutant B15     | 201 ± 89.8      | 74% ± 10%                    | 374 ± 178                     |
| 7.  | Mutant B18     | 164 ± 86.4      | 73% ± 13%                    | 301 ± 167                     |
| 8.  | Mutant B22     | 199 ± 137.4     | 74% ± 10%                    | 360 ± 264                     |
| 9.  | Kipas Putih    | 69 ± 59.7       | 51% ± 21%                    | 171 ± 128                     |
| 10. | Dega 1         | 48 ± 24.7       | 50% ± 13%                    | 89 ± 55                       |

The percentage of filled pods is the result of the number of filled pods per total number of pods multiplied by 100%. Eight mutant lines of Kipas Putih soybean had a higher average number of seeds.
per plant than the elder Kipas Putih and Dega 1 varieties, ranging from 238-529 seeds per plant. The highest number of filled pods was found in line B13, which was 278 pods (85%) and the lowest was found in line B7, which was 130 pods (68%). The highest number of seeds per plant was found in the B12 line (529 seeds) and the lowest was in the B7 line (238 seeds).

Seed weight per plant and weight of 100 seeds per plant are characters that affect productivity. Plant seed weight is the overall weight of the seeds produced by each soybean plant, while the weight of 100 seeds per plant is obtained by weighing the selected 100 seeds from each plant expressed in grams (g). The weight character of 100 seeds per plant is used as a measure to determine the size of soybean seeds whether it categorized as the large, medium, or small seed.

Soybean seed size divides into 3 criteria based on the weight of 100 seeds. The large seed if >14 g/100 seeds, the medium seed if 10-14 g/100 seeds, and the small seed if <10 g/100 seeds [12]. The average weight of 100 seeds per plant in the eight mutant lines of Kipas Putih soybean ranged from 12.0-14.9 g. The medium seed category was found in lines B4, B10, B13 and B22, and the large seeds are found in lines B7, B12, B15 and B18. Data on the performance of seed weight per plant and weight of 100 seeds per plant shows in table 4.

| No. | Genotype  | Seed weight per plant ± Sd (g) | Weight of 100 seed ± Sd (g) |
|-----|-----------|--------------------------------|-----------------------------|
| 1.  | Mutant B4 | 34.62 ± 19.6                   | 14.0 ± 1.6                  |
| 2.  | Mutant B7 | 35.5 ± 19.2                    | 14.6 ± 1.2                  |
| 3.  | Mutant B10| 48.2 ± 24.7                    | 13.5 ± 1.8                  |
| 4.  | Mutant B12| 61.5 ± 39.6                    | 14.1 ± 2.3                  |
| 5.  | Mutant B13| 53.3 ± 23.4                    | 12.0 ± 1.2                  |
| 6.  | Mutant B15| 56.1 ± 26.8                    | 14.6 ± 1.7                  |
| 7.  | Mutant B18| 45.3 ± 24.9                    | 14.9 ± 2.3                  |
| 8.  | Mutant B22| 39.8 ± 29.0                    | 12.3 ± 2.7                  |
| 9.  | Kipas Putih| 16.10 ± 13.8                  | 13.5 ± 5.4                  |
| 10. | Dega 1    | 18.33 ± 11.79                  | 22.3 ± 8.6                  |

Based on the table above, it shows that the highest seed weight per plant is the B12 line (61.5 g) and the lowest seed weight per plant is the B4 line (34.62 g). The highest weight of 100 seeds per plant is the B18 line (14.9 g) and the lowest weight is the B13 line (12.0 g). The number of filled pods also influenced the character of seed weight per plant). The seed weight per plant is one of the characters that gives a greater role to soybean diversity compared to other characters [13].

3.4. Seed weight per plot and yield potential

Seed weight per plot is the total weight of all plants in each line that weighed for each plant. Yield potential is the yield calculated based on land area per ha divided by area per plot multiplied by seed weight per plot using the formula: (area per ha)/(area per plot) x weight per plot, the data as shown in table 5.

Table 5 shows that the yield potential of Kipas Putih elders in this study only reached 1.07 tons ha⁻¹, which means that it is very much different from the yield potential mention in the description of the Kipas Putih variety (1.69 tons ha⁻¹). This probably because the Kipas Putih planted in this study could not grow optimally compared to other mutant lines and also occurred for the Dega 1 variety. Based on the above data, it was found that the seed weight per plot ranged from 995.6 - 2505.2 g, while the yield potential ranged from 1.00 to 2.51 tons ha⁻¹. The B13 line had the highest seed weight per plot and yield potential compared to the two comparison varieties as well as several other mutant lines of Kipas Putih soybean. The yield potential of Kipas Putih soybean mutant lines increased compared to the yield potential of the elder Kipas Putih variety and the comparison variety Dega 1. This indicated that the
character of seed weight per plant and seed weight per plant plot had increased which affected soybean productivity. The yield potential of the Kipas Putih mutant line determined by plant height, number of productive branches, number of pods as well as weight and size of seeds.

| No. | Genotype       | Seed weight per plot (g) | Yield potential (ton ha⁻¹) |
|-----|----------------|--------------------------|----------------------------|
| 1   | Mutant B4      | 2042.3                   | 2.31                       |
| 2   | Mutant B7      | 1986.5                   | 2.36                       |
| 3   | Mutant B10     | 2361.1                   | 3.21                       |
| 4   | Mutant B12     | 1783.7                   | 4.10                       |
| 5   | Mutant B13     | 2505.2                   | 3.55                       |
| 6   | Mutant B15     | 2018.7                   | 3.74                       |
| 7   | Mutant B18     | 2040.4                   | 3.02                       |
| 8   | Mutant B22     | 995.6                    | 2.06                       |
| 9   | Kipas Putih    | 370.3                    | 1.07                       |
| 10  | Dega 1         | 1118.2                   | 1.31                       |

3.5. Heritability and prediction value of selection progress

The diversity contained in a plant character should be compared whether the diversity is caused by genetic factors (heritable characters) or the diversity is caused by environmental factors. The heritability of a plant will determine the progress of selection in that plant.

The high heritability value proves that the genetic factor of the plant is more influential than the environmental factor. Syukur et al. [3] said that if the value of heritability obtained is greater, then the value of selection progress is greater and the release of superior varieties will be faster. Data on heritability values in a broad sense and selection progress as shows in table 6.

| Genotype       | Criteria               | h²/bs | Category h²/bs | Selection progress |
|----------------|------------------------|-------|----------------|--------------------|
| Mutant B4      | Plant height           | 0.00  | Low            | 0.00               |
|                | Flowering time         | 0.42  | Medium         | 2.99               |
|                | Harvesting time        | 1.00  | High           | 2.50               |
|                | Number of productive branches | 0.67  | High           | 73.65              |
|                | Number of total pods   | 0.00  | Low            | 0.00               |
|                | Number of filled pod   | 0.20  | Medium         | 1721.21            |
|                | Percentage of filled pod | 0.00 | Low            | 0.00               |
|                | Weight of seeds per plant | 0.50 | Medium         | 338.22             |
|                | Weight of 100 seeds    | 0.00  | Low            | 0.00               |
|                | Number of seeds per plant | 0.21 | Medium         | 8099.28            |

| Mutant B7      | Plant height           | 0.00  | Low            | 0.00               |
|                | Flowering time         | 0.52  | High           | 4.44               |
|                | Harvesting time        | 1.00  | High           | 5.51               |
|                | Number of productive branches | 0.71  | High           | 88.03              |
|                | Number of total pods   | 0.00  | Low            | 0.00               |
|                | Number of filled pod   | 0.14  | Low            | 1160.95            |
|                | Percentage of filled pod | 0.00 | Low            | 0.00               |
|                | Weight of seeds per plant | 0.48 | Medium         | 314.19             |
|                | Weight of 100 seeds    | 0.00  | Low            | 0.00               |
|                | Number of seeds per plant | 0.02 | Low            | 711.81             |

| Mutant B10     | Plant height           | 0.00  | Low            | 0.00               |
|                | Flowering time         | 0.00  | Low            | 0.00               |
|                | Harvesting time        | 1.00  | High           | 4.86               |
|                | Number of productive branches | 0.77  | High           | 117.32             |
| Mutant | Plant Height | Flowering Time | Harvesting Time | Number of Productive Branches | Number of Total Pods | Number of Filled Pods | Percentage of Filled Pods | Weight of Seeds per Plant | Weight of 100 Seeds | Number of Seeds per Plant |
|--------|--------------|----------------|-----------------|-------------------------------|----------------------|-----------------------|---------------------------|-----------------------------|-------------------|----------------------|
| B12    | 0.00         | 0.00           | 1.00            | 0.86                          | 0.87                 | 0.91                  | 0.00                      | 0.69                         | 0.00              | 0.56                 |
|        | Low          | Low            | High            | High                          | High                 | High                  | Low                       | Low                         | Low               | High                |
| B13    | 0.00         | 0.00           | 1.00            | 0.71                          | 0.53                 | 0.77                  | 0.00                      | 0.65                         | 0.00              | 0.74                 |
|        | Low          | Low            | High            | High                          | High                 | High                  | Low                       | Low                         | Low               | High                |
| B15    | 0.00         | 0.00           | 1.00            | 0.85                          | 0.33                 | 0.51                  | 0.00                      | 0.74                         | 0.00              | 0.46                 |
|        | Low          | Low            | High            | Medium                        | Medium              | High                  | Low                       | Medium                      | Low               | Medium              |
| B18    | 0.00         | 0.43           | 1.00            | 0.68                          | 0.31                 | 0.46                  | 0.00                      | 0.69                         | 0.00              | 0.38                 |
|        | Low          | Medium         | High            | High                          | Medium              | Medium                | Low                       | High                        | Low               | Medium              |
| B22    | 0.00         | 0.00           | 1.00            | 0.66                          | 0.68                 | 0.78                  | 0.00                      | 0.77                         | 0.00              | 0.75                 |
|        | Low          | Low            | High            | High                          | High                 | High                  | Low                       | High                        | Low               | High                |
Heritability values with high criteria ranging from 0.51-1.00 were found in the character of the flowering age (B7 line), the number of pods per plant (B12, B13, B22 lines), the character of the number of filled pods (B10, B12, B13, B15, B22 lines), character of number of seeds per plant (lines B10, B12, B13, B22), character of seed weight per plant in all lines except B4 and B7, character of harvest age, and character of number of productive branches in all mutant lines.

The high heritability value occurs because the environmental conditions are usually homogeneous, which indicates that the genetic diversity is higher than the environmental diversity. The high value of heritability in a broad sense is estimated by the uniformity of the research locations [14]. Barmawi et al. [15], stated that if the observed traits produce high heritability values, then selection can be applied appropriately to these traits.

In addition to heritability values with high criteria, there are also heritability values with low criteria, ranging from 0.00-0.14. The low heritability values were found in the character of flowering age (B10, B12, B13, B15, B22 lines), the number of pods per plant (B4 and B7 lines), the character of the number of filled pods in the B7 line, the character of the number of seeds per plant in the B7 line, character of plant height, character of percentage of filled pods in all mutant lines, and character of weight of 100 seeds in all mutant lines. Plant characters with low heritability values indicate that these characters are more influenced by environmental factors than genetic factors.

Characters that have high heritability values will make it easier to select these characters, so that the selected characters are relatively easy to pass down to the next generation. This study is in line with the research of Rahmah et al. [14] which reported that harvesting age has a high heritability value so that the selection to obtain soybean genotypes that have a uniform harvest age in the next generation will be easily inherited. Data on the progress of plant selection by 10% which had a positive value resulted in the number of productive branches per plant in all soybean mutant lines increasing, the number of filled pods per plant in all soybean mutant lines increased, the number of seeds per plant in all soybean mutant lines increased, and seed weight per plant increased. Crops in all mutant soybean lines increased which could affect soybean productivity. This is in line with the research of Barmawi et al., (2013) who reported that there was progress in selection on the character of the number of pods per plant and seed weight per plant.

According to Barmawi et al. [15] the success of the selection will be determined by the estimated value of heritability, because this value will indicate whether a character in a plant is influenced by genetic factors or environmental factors. The progress of selection in this study uses the formula $G = \frac{H \cdot p \cdot i}{100}$ where the value of $i$ is 1.76. There was no selection progress on the character of plant height, percentage of filled pods, and weight of 100 seeds due to the heritability value was low.

The line that has the potential as a candidate for the newest high yielding variety is B18. The B18 line has the potential to be a new high yielding variety because it has a high yield potential of 2.04 tons ha$^{-1}$ with large seed size compared to the other seven mutant lines and is also higher than the two comparison varieties Kipas Putih and Dega 1.

4. Conclusions

Several mutant soybean lines increase in yield potential compared to the parent var. Kipas Putih. All quantitative characters underwent selection progress except for the character of plant height, percentage of filled pods, and weight of 100 seeds due to the heritability value was low. Some of the best mutant lines that can be studied further because they have a much higher yield potential compared to the parent Kipas Putih variety are the B4, B10, B13, B15, and B18 mutant lines which are more than 2 tons ha$^{-1}$. The B18 line has the potential to become a new high yielding variety because it has a high yield potential (3.02 tons ha$^{-1}$) with a large seed size compared to the other seven mutant lines and is also higher than the elder Kipas Putih and var Dega 1 varieties.
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