# Effect of Planting Dates on Growth, Yield, and Phenology of Different Soybean Lines Grown Under Tidal Swamp Land

**Heru Kuswantoro**

*Indonesian Legume and Tuber Crops Research Institute, Indonesian Agency for Agricultural Research and Development, 12540 Malang, Indonesia*

## ABSTRACT

The water availability in tidal swamp land type C is similar to the rain-fed area. However, waterlogging may occur if the irrigation system is not good. This experiment aimed to study the effect of different planting dates in growth, yield, and phenology of different soybean lines grown under tidal swamp land. A randomized complete block design was repeated four times, each planting date differed 46 days apart. Interaction of genotype and planting date were demonstrated by days to flowering and days to maturity. Different response on days to flowering and days to maturity showed that the tested genotypes had phenological adaptation on a particular planting date. No interaction was shown by other agronomical traits, even though the genotypes were significantly different. Most of the lines had similar seed yield to the control varieties. The genotype of Menyapa (G12) had the largest number of filled pods, but the seed size was the smallest. Consequently, the seed yield of G12 was lower than the genotypes with the slightly lower number of filled pods and larger seed size. The shortest maturity genotypes of Tgm/Brg-584 (G10) also showed similar seed yield to the control varieties. Seed size is substantially responsible for the performance of seed yield. The most promising lines was Snb/1087-148-2-1 (G4), because this line had high yield and large seed size. Interaction in phenological response reflecting in days to flowering and days to maturity was not followed by agronomical traits suggesting that the effect of phenological traits to agronomical traits is weak. Therefore, the soybean promising lines can be grown at those two planting dates.

*Keywords:* Growth, phenology, planting date, soybean, tidal swamp land, yield

## INTRODUCTION

Soybean is a staple food and is the third after rice and corn in Indonesia. By 2015, Indonesia's consumption of soybean-based products reached 6.12 kg/capita/year (Pusat Data dan Sistem Informasi Pertanian, 2016). Usually, soybean is used in food products such as tempeh, tofu, soy sauce, and soymilk. The requirement for soybean for food consumption cannot be fulfilled from domestic production. In 2015, soybean production reached 9,63,183 tons, but the soybean imports were much larger at 2,256,931 tons (Pusat Data dan Sistem Informasi Pertanian, 2016). This condition is worsened by the shrinkage of harvested area, whereby the area of soybean harvest in 2016 was about 589 thousand ha (Pusat Data dan Sistem Informasi Pertanian, 2016), while it was about 614 thousand ha in 2015 (Badan Pusat Statistik, 2017a) which meant a decrease of about 4%. However, even though the harvested area decreases, soybean production can still be maintained if the productivity increases. In 2015, there was an increase of soybean productivity to 15.68 ku/ha (Badan Pusat Statistik, 2017b) of which the production was maintained in that year although the harvested area declined.

The progressive of non-agricultural sector development in Indonesia causes a decrease in the availability of arable land. This condition forced agricultural land to shift to less fertile land. Many suboptimal lands in Indonesia, including tidal swamp land covers 20,192 million ha (Alihamsyah et al., 2003). There are four types of tidal swamp land, namely type A, B, C, and D. Types A and B face excess water stress. Type A is logged at large and small tidal period, while type B is logged only at large tidal period. Types C and D are not logged by the water. Type C is the tidal land where the ground water limit is <50 cm below the ground surface, while type D has ground water limit >50 cm below the ground surface. However, in a bad irrigation system, the type C can also face water excess that leads to rhizospheric hypoxia which affect the root morphological traits (Jitsuyama, 2015, 2017), hinder root development and plant growth at the seedling stage (Suematsu, Abiko, Nguyen, & Mochizuki, 2017), and finally decreases seed yield (Kuswantoro, 2015a; Nguyen et al., 2012). Besides the excess water, the low pH is also a problem in this soil. Deficiency in macronutrients and toxicity in micronutrients can be experienced by plants in this soil (Fageria & Nascente, 2014), such as a deficiency in nitrogen (Thomas, Ayarza, & Lopes, 2000), phosphorus (Zheng, 2010), and aluminum toxicity (Zheng, 2010).

Generally, in subtropics, planting dates are associated with maturity groups (Nyagumbo, Mkuhlani, Mupangwa, & Rodriguez, 2017; Salmerón et al., 2016). In the tropics like Indonesia, the maturity group is relatively unaffected, since the length of the day is somewhat similar. This planting date is closely related to temperature and light that can affect the growth and yield of soybeans (Arslanoglu & Aytac, 2010). The main problem of planting date in the tropics is the availability of water,

such as the rain-fed area. It is also a problem in soybeans grown on land with uncertain water availability, where in some cases a puddle occurs when water shortages occur. Soybean cultivation in tidal swamp area is done in type C. Soybean cultivation is carried out during the rainy season whereby soybeans can receive water from the rain for growth and development. Although there is water in the dry season, the water is so acidic that it cannot be used for soybean watering. In the rainy season, it is still dependent on the occurrence of waterlogging within the land with poor drainage problems. Lack of water is more influential on soybean growth as compared to soil acidity (Kuswantoro & Zen, 2013) because water is the essential for plant growth.

Soybean cultivation in tidal swamp land type C is generally grown during the rainy season because the tidal condition is unable to rise through the soil because the water table is about 50 cm below the soil surface. Different rainfall during the plant growth and development will affect plant performance expressed in phenological and agronomical respones. Therefore, planting date can influence phenological and agronomical traits. This study was to investigate the effect of different planting dates in growth, yield, and phenology of different soybean lines grown under tidal swamp land.

## MATERIALS AND METHOD

### Experimental Site

The research site was in the village of Sari Makmur and Dadahup district, Kuala Kapuas regency, Central Kalimantan province, Indonesia. This site had a latitude of 2°39′33″ N, and a longitude of 114°28′16″ E.

### Experimental Design

The experimental design used in each planting date was a randomized complete block design that was repeated four times. There were two factors in this study. The first factor was the planting date consisted of two planting dates, D1 and D2, where D1 was planted on the 6th of April 2014 and D2 was planted on the 22nd of May 2014, with 46 days from the day when D1 was planted. The second factor was the genotype which consisted of 12 genotypes as described in plant materials.

### Plant Materials

The research material consisted of ten soybean promising lines, that is, Snb/1087-147-2-2 (G1), Snb/1087-147-2-7 (G2), Snb/1087-148-1-5 (G3), Snb/1087-148-2-1 (G4), Snb/1087-148-2-10 (G5), Snb/1087-148-2-3 (G6), Snb/1087-210-1-1 (G7), Sby/Pdm-651 (G8), Snb/1087-210-4-12 (G9), Tgm/Brg-584 (G10), and two control varieties of Lawit (G11) and Menyapa (G12). The promising lines of Snb/1087 were derived from the crossing of Sinabung variety and the genotype of MLGG 1087. Sinabung is a variety with high agronomical traits in an optimal land and MLGG 1087 is a genotype that is tolerant to acid tidal-swamp land. Sby/Pdm-651 was derived from the selection of Sibayak and Panderman crossing. Sibayak is an acid dry land tolerant

variety, and Panderman is a large seeded optimal land variety. Tgm/Brg-584 was obtained from the selection of Tanggamus and Burangrang crossing. Tanggamus is also acid dry land tolerant variety and Burangrang is an optimal land variety with large seed and early maturity. The two control varieties are the varieties for acid tidal swamp land (Balitkabi, 2009).

## Soil Properties

The soil type in this experimental site was organosols with pH of 4.4. This soil pH includes in extremely acidic. Exchangeable Al and H were 12.9 and 10.7 me $(100 \text{ g})^{-1}$, respectively. The other soil properties were presented in Table 1.

Table 1
*Soil properties of the experimental site*

| Soil properties | Value |
|---|---|
| pH | 4.4 |
| N (%) | 0.29 |
| Fe (ppm) | 2679 |
| Mn (ppm) | 0.27 |
| Cu (ppm) | 20.02 |
| Zn (ppm) | 51.81 |
| K (me $(100 \text{ g})^{-1}$) | 0.53 |
| Na (me $(100 \text{ g})^{-1}$) | 0.44 |
| Ca (me $(100 \text{ g})^{-1}$) | 0.74 |
| Mg (me $(100 \text{ g})^{-1}$) | 0.40 |
| CEC (me $(100 \text{ g})^{-1}$) | 26.03 |
| $Al_{ex}$ (me $(100 \text{ g})^{-1}$) | 12.9 |
| $H_{ex}$ (me $(100 \text{ g})^{-1}$) | 10.7 |

## Planting

Before planting, the soil was ploughed and then flattened. Drainage canals were made every 4.5 m with 20 cm depth and 40 cm width. The planting space was 40 cm × 15 cm, two plants per hill. Every soybean line was grown on 2.4 m × 4.5 m.

## Cultural Practice

Fertilizer of 250 kg/ha Phonska, 100 kg/ha SP36, and 1 ton/ha organic fertilizers were provided throughout the planting time. Weed control was done manually at ages 2 and 4 weeks after planting. Watering was carried out based on the rainfall as stated in Table 2.

Table 2
*Weather data of the experimental site from April to September 2014*

| Month | Minimum temperature (°C) | Maximum temperature (°C) | Average temperature (°C) | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|
| April | 24.1 | 32.8 | 27.5 | 84.6 | 575.2 |
| May | 24.3 | 32.6 | 27.8 | 84.7 | 223.0 |
| June | 24.1 | 32.5 | 27.5 | 86.2 | 207.5 |
| July | 23.3 | 32.7 | 27.4 | 82.9 | 41.0 |
| August | 23.1 | 32.7 | 27.1 | 81.0 | 62.3 |
| September | 23.0 | 33.4 | 27.6 | 77.0 | 120.9 |

## Weather Data

The average temperature of this site was around 27°C, while the humidity ranged between 77.0% and 86.2%, whereas the minimum and maximum humidity was in September and June 2014, respectively. The rainfall in April was the highest (575.2 mm), while the rainfall in July was the lowest (41.0 mm). Weather data of the experimental site were presented in Table 2.

## Data Collection

Observations were carried out for the days to flowering, days to maturity, weight of 100 seeds, and seed yield. These four traits were observed based on the population of plants per plot. Besides these four traits, plant height, number of reproductive nodes, and number of filled and unfilled pods were observed. These traits were recorded based on ten sample plants.

## Statistical Analysis

The data were analyzed using statistical software of PKBT STAT 1.0 for the analysis of variance. When the analysis of variance for a trait was significant, multiple comparisons were performed with least significant difference at 5% (LSD 5%) significance level using the same software.

## RESULTS AND DISCUSSION

Analysis of variance revealed that interaction between genotype and planting date was shown on days to flowering and days to maturity. The other agronomical traits had no interaction, but they showed differences in the genotypes. However, the agronomical traits with no interaction were also not affected by planting date (Table 3). Genotype × planting date interaction on days to flowering and maturity indicated that a genotype has a different response when grown on a different planting date. The interaction on days to flowering and maturity reflects the phenological adaptation of a genotype on a certain planting date. The differences of plant phenological development phase as well as genotype × environment interaction can result in the variability of plant development (Junior et al., 2015 ).

Table 3
*Mean square of agronomical traits*

| Agronomical trait | Date | Rep. × Date | Genotype | G × Date |
|---|---|---|---|---|
| Days to flowering (days) | 102.09** | 1.25 | 14.58** | 5.80** |
| Days to maturity (days) | 228.17** | 2.02* | 31.25** | 6.37** |
| Plant height (cm) | 0.13 | 255.41 | 496.51** | 2.98 |
| Number of branches per plant | 0.00 | 0.49* | 1.19** | 0.00 |
| Number of reproductive nodes per plant | 0.01 | 19.79** | 55.47** | 0.00 |
| Number of filled pods per plant | 0.84 | 66.08** | 131.65** | 1.36 |
| Weight of 100 grains (g) | 0.20 | 0.70 | 8.38** | 0.16 |
| Seed yield (t/ha) | 0.66 | 0.32** | 0.11** | 0.01 |

The interaction between genotype and planting date on days to flowering revealed that G1, G2, G7, and G9 had longer days to flowering on D1 than D2. These four genotypes were not significantly different to the two control varieties (G11 and G12) (Figure 1). Days to flowering at D1 were longer than that of D2. The shortest days to flowering was shown by G8 and G10 at D2. The longer duration of days to flowering was due to the high level of the rainfall (Table 2) at D1 than that for D2. At high rainfall, days to flowering is longer. This is related to crop adaptation, in which the plant develops a good vegetative period when water is fully available. The development of vegetative traits, especially leaves, is needed as it assimilates source in the development of generative organs. Candoğan and Yazgan (2016) also reported a similar case in which there was an increase in days to flowering when there was a rise in rainfall. Solar radiation also plays a major role in days to flowering due to the lack of solar radiation which resulted in prolonged days to flowering (Yin, Olesen, Wang, Öztürk, & Chen, 2016). In the subtropics region, the development of vegetative organs was reported due to the differences in photoperiods (Dogra, Kaur, & Srivastava, 2015; Spehar Francisco, & Pereira, 2015). Benlahbil, Zahidi, Bani-Aameur and El Mousadik (2015) stated that extended days to flowering might be as a strategy in minimizing reproductive failure. However, the two control varieties showed consistent values between the two planting dates. The response of these control varieties was different than the other promising lines. It may be due to the lower phenotypic plasticity of these two control varieties. Plasticity is needed in plant adaptation, whereby plants with higher adaptive plasticity may be able to survive better in a new environment (Gratani, 2014).

Days to maturity of all tested genotypes were longer at D2 than that for D1, except G10 showed no significant difference at
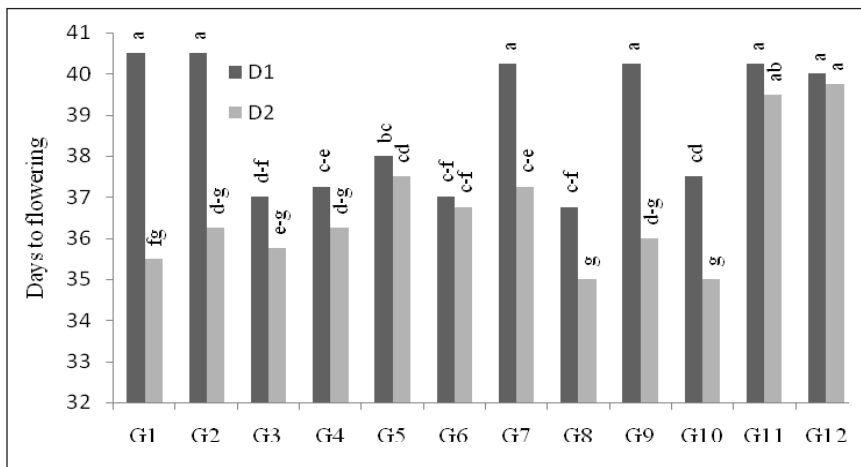


*Figure 1.* Days to flowering of twelve soybean genotypes at different planting dates

the two planting dates. The longest days to maturity were demonstrated by the two control varieties at D2, while the shortest was shown in G10 at the two planting dates (Figure 2). The longer days to maturity is due to the high rainfall during the reproductive phase. In this study, the rainfall during the reproductive phase at D1 was lower as compared to D2 (Table 2). Kuswantoro and Zen (2013) also reported similar results for the acidic dryland. The highest responses were shown in the control varieties of which these two varieties had 5 days difference of maturity between D1 and D2. The response of ten promising lines was lower than the control varieties, reflecting that promising lines had lower plasticity and more stable in days to maturity. Phenotypic plasticity in days to maturity is lower than days to flowering. This may be related to the duration of filling pods triggered by solar radiation. Iqbal et al. (2010) reported no differences in the two different growing

seasons, with the number of different rainfall in days to flowering and days to maturity. This is in contrast to Zhang et al. (2015) in a study of the soybeans grown in subtropics, where narrow differences were found on days to flowering trait, but wide differences were observed on days to maturity trait. The duration of a vegetative and reproductive period can be influenced by photoperiod, temperature, and rainfall (Hu et al., 2012).

There was no difference between D1 and D2 on plant height trait. The highest plant height was shown in G12 (Figure 3). Plant height is important in soybean because it is the main trait that can indicate a plant growing in normal or stress conditions. Plant height in acid soil is lower than that in normal condition. It is because the low availability of nitrogen reduces the plant growth in acid soil (Thomas et al., 2000). However, plant height is greatly affected by the water availability than the acidity (Kuswantoro & Zen, 2013). Even
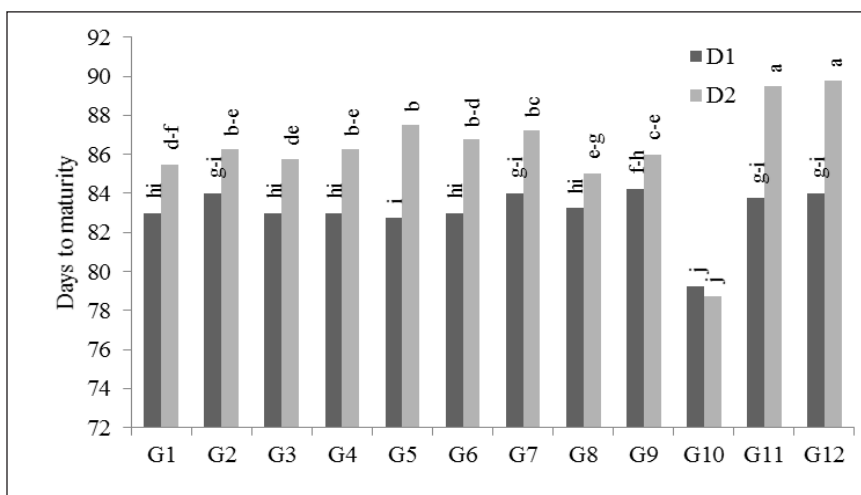


*Figure 2*. Days to maturity of twelve soybean genotypes at different planting dates
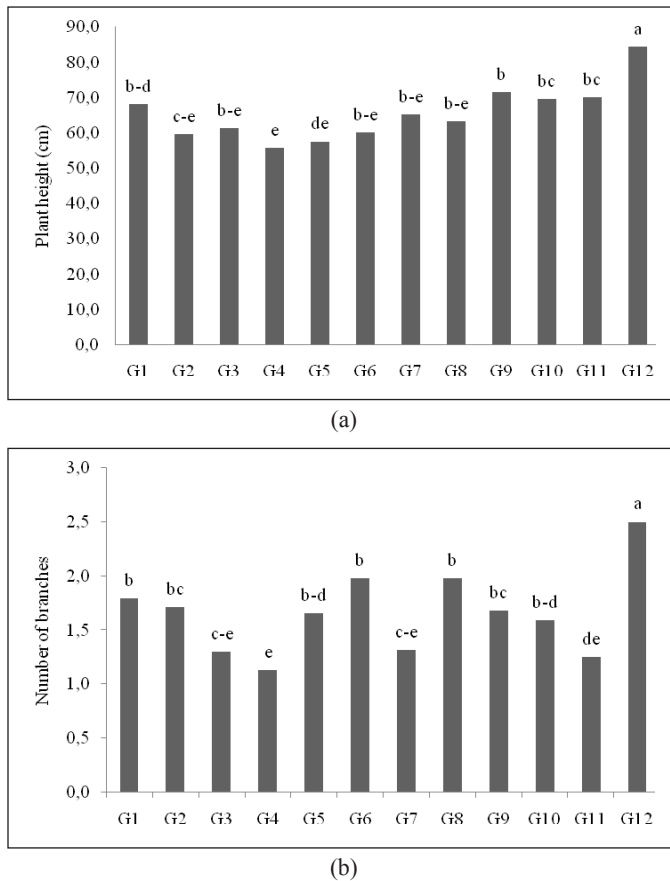
(a)



(b)

*Figure 3.* Means of : (a) plant height; and (b) number of branches of twelve soybean genotypes at different planting dates

though it is grown in normal condition, the plant height decreases more than that in acidic soil when there is a lack of water (Kuswantoro, Zubaidah, & Sulisetijono, 2014; Kuswantoro, 2015b). The increase in plant height during rainy season is also due to the ultraviolet radiation exclusion, which lengthens the soybean internodes (Zhang et al., 2014).

Number of branches also did not differ between the two planting dates. The number of branches in this study were <2 branches per plant. This is lower than Kuswantoro

(2017), which reported a mean of 2.3 branches per plant on another tidal land. It indicates that the number of branches is more affected by the characteristic of the genotypes and not dependent on the maturity group (Junior et al., 2015). However, number of branches is influenced by planting space, where wider planting space leads to a higher number of branches (Güllüoğlu, Bakal, & Arioğlu, 2016). The branches are located on the plant stem. Therefore, plant height and the number of branches mostly have a similar pattern of

which the highest number of branches per plant was also shown in G12, while the lowest was shown in G4 (Figure 3). This similar pattern confirms the important role of plant height. Jain, Srivastava, Singh, Indapurkar and Singh (2015) reported that plant height and the number of branches had a significant correlation. The higher internodes may provide a higher chance for the plants to form more branches.

A reproductive node is any node with one or more pods. This node is important because it supports the yield through the number of pods. Different planting dates did not affect the number of reproductive nodes, but number of reproductive nodes was more affected by the genotypes (Table 3; Figure 4). The highest number of reproductive nodes were achieved by G12 followed by four similar lines of G1, G5, G6 and G8, while the lowest was reached by four similar lines of G3, G4, G7, and G11 (Figure 4). A similar pattern was shown by the number of filled pods. However, G4, one of lines with the lowest number of reproductive nodes, showed the higher number of filled pods. It
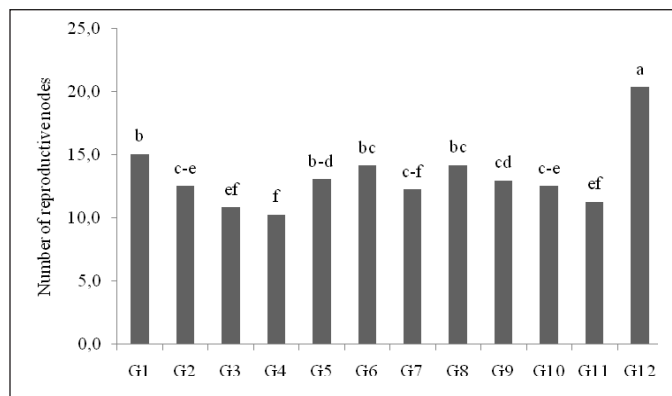


(a)
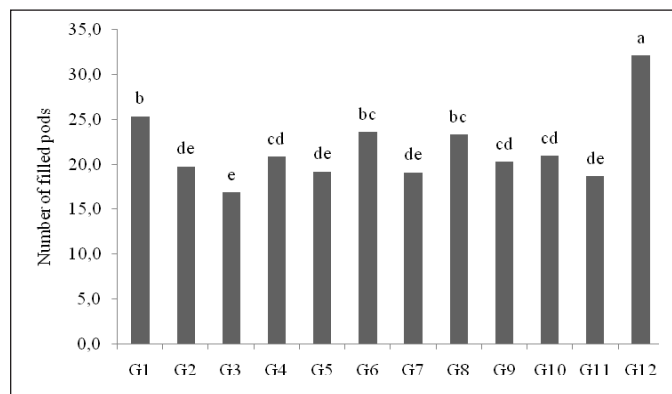


(b)

*Figure 4.* Means of number of reproductive nodes and number of filled pods of twelve soybean genotypes at different planting dates

may be due to this genotype of which there were more filled pods per reproductive nodes than other genotypes. Also, the similar pattern was shown by plant height. The relationship between plant height, number of reproductive nodes, and number of nodes may be due to the effect of planting date on the number of nodes, especially on nodes forming at V9 growth stage and the flowers decreasing in the R2 growth stage (Junior et al., 2015). The decrease in flowers may be due to the increase in abscission on the flower attributes and due to the pollination and seed development failures (Hoque, Hassan, Khan, Khatun, & Baten, 2015).

Seed size was measured from weight of 100 seeds. Seed size was not significantly different between the planting dates but differed significantly between genotypes (Table 3). The line of G4 had the largest seed size, while the G12 line had the smallest seed size (Figure 5). Differences
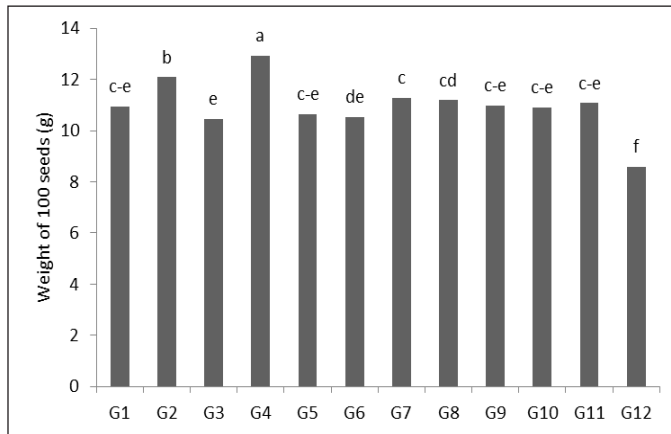


(a)
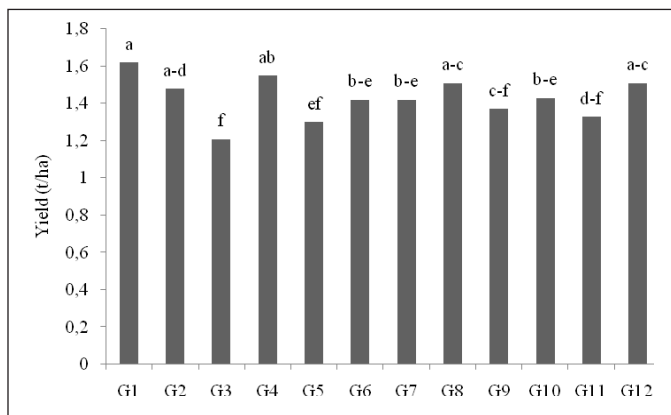


(b)

Figure 5. Means of weight of 100 seeds and seed yield of twelve soybean genotypes at different planting dates

in seed size are influenced by environmental conditions such as water availability (Hu & Wiatrak, 2012), soil acidity (Kuswantoro et al., 2014; Kuswantoro, 2015b) and air temperature (Hoque et al., 2015). In this study, there was no difference in soil acidity between planting dates because soybeans were grown in the same location. Air temperature also did not differ between planting dates, but the amount of rainfall was different. Heritability of seed size is high (Berger-Doyle, Zhang, Smith, & Chen, 2014; Kuswantoro, 2017), this means that seed size is not much influenced by the environmental factor. However, under very different environmental conditions, seed size will change (Kuswantoro et al., 2014; Kuswantoro, 2015b). In this study, the environmental changes were not extreme, so the size of the seeds on both planting dates was not significantly different. Differences in rainfall have no effect on seed size change. It may be implied from the amount of rainfalls being received in the pods filling period in the two planting dates that were not significantly different (Table 2).

Seed yields were not significantly different between the planting dates. The environmental differences in these planting dates had no effect on seed yield. Many reports suggested that the heritability of seed yields is low (Berger-Doyle et al., 2014, Kuswantoro, 2017) since the yield of the seeds is controlled by many genes. In this study, seed yield was not influenced by planting date × environment interaction whereby the differences in the environment might be less distinctive.

In the subtropical region, the effect of these seed yields is reported because of the difference in photoperiod (Spehar et al., 2015). Furthermore, the differences in planting dates are generally a combined effect of photoperiod, temperature, and rainfall (Hu & Wiatrak, 2012). However, the rainfall volume in reproductive phase is not always directly related to the yield in a location (Dogra et al., 2015). Nevertheless, there were seed yield differences between the soybean lines. The highest seed yield was achieved by G1, G2, G4, G8, and G12. The similar seed yield of G12 than G1 was due to the smallest seed size of G12 (Figure 5) even though G12 had the largest number of filled pods (Figure 4). It appears that seed size plays a significant role in the seed yield than the number of filled pods (Kuswantoro et al., 2014; Kuswantoro, 2015b). A soybean line that can maintain a large seed size will produce a greater seed yield.

**CONCLUSION**

Genotype × planting date interaction was presented in the days to flowering and days to maturity. The response of a genotype on those two traits differ when grown in diverse planting dates. There was a genotypic adaptation by changing phenological traits on a different planting date. The different phenological development due to genotype × environment interaction did not result in the differences of other plant development, whereby the six agronomical traits were more affected by the genotype rather than the environmental factor. The presence of interaction in phenological traits and the

absence of interaction on agronomical traits suggest that phenological traits had no effect on agronomical traits. Therefore, the tested soybean promising lines can be grown at those two planting dates.

## ACKNOWLEDGEMENTS

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