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Araştırma Makalesi (Research Article)

Seed Storability and Genetic Parameters Estimation on Accelerated Aging Seed of Argomulyo Soybean (*Glycine max* (L.) Merr.) Mutant Lines

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Abstract: Seed storability of 22 selected soybean mutant lines from Argomulyo population irradiated by gamma ray were assessed by rapid aging tool, APC-IPB 77-1MM. Seed viability and vigor parameter observed due to genetic factors. The 90% ethanol was applied for 20, 40, 60 and 80 min as accelerated aging test. M100-96-53-6 was estimated that has good storability with less seed deterioration rate expressed by slow slope of germination percentage, germination speed and electrical resistance value after 20-80 min of chemical accelerated aging. Electrical resistance (ER) test could be as alternative and a substitute of electrical conductance (EC) test as alternative of vigor test. The high heritability and moderate to high genetic advance were noted on all parameters except moisture content. Germination percentage and germination speed could be reviewed for early stage selection to improve traits at the next generation based on R-square value of regresion and genetic parameters obtained.

Hızlandırılmıs Yaşlandırma Yapılan Argomulyo Soybean (*Glycine max* (L.) Merr.) Mutant Hatlarına Ait Tohumların Depolanabirliği ve Genetik Parametrelerinin Belirlenmesi**

Makale Bilgileri

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Anahtar Kelimeler
Etanol,
Genetik,
Baklagil,
Canlılık,
Vigor (Güç)

Özet: Gama ışını ile ışınlanmış olan Argomulyo popülasyonundan seçilen 22 soya fasulyesi mutant hatlarının tohum depolanabilirliği, APC-IPB 77-1MM olarak bilinen hızlı yaşlandırma aleti ile değerlendirilmiştir. Hızlandırılmış yaşlandırma testinde 20, 40, 60 ve 80 dakika içinde uygulanarak % 90 etanol kullanılmıştır. M100-96-53-6 'nın 20-80 dakika kimyasal hızlandırılmış yaşlandırma yapıldıktan sonra tohumun çimlenme oranı, çimlenme hızı ve elektriksel direnç değerinde yavaşlama eğilimi gösterilerek daha az tohum bozulma oranının yanı sıra iyi depolanabilirliğe sahip olduğu tahmin edilmiştir. Vigor (güç) testi için elektrik iletkenliği (EC) testi yerine bir alternatif olarak elektrik direnci (ER) testi kullanılabilmektedir. Nem içeriği hariç tüm parametrelerde bitkilerin kalıtım derecesi yüksek ve genetik ilerleme orta ila yüksek olduğu kaydedilmiştir. Regresyonun elde edilen R-kare değeri ve genetik parametreler değeri bakımından sonraki nesilde özellikleri iyileştirme amacıyla seçime (seleksiyona) ilk aşama için tohumun çimlenme oranı ve çimlenme hızı gözden geçirilebilmektedir.

** This article extracted from B.Sc. thesis of Siti MAESAROH.

1. Introduction

Soybean, as source of functional food, containing about 37% of vegetable protein is one of the important legume crops in Indonesia with 0.539 million tons in 2017 (Ministry of Agriculture, 2018). It can be used as raw material due to about 25% of its oil content (Pereira et al., 2011). The supply of soybean in Indonesia is only about 30% of national demand per annum due to low productivity with 1-1.5 ton/ha productivity. National production is reducing day after day with every increase in the national (BPS, 2015).

High production and productivity to achieve soybean self-sufficiency must be supported by supplying superior varieties with high quality seeds. Mutation breeding providing a source of genetic variation by developing and increasing genetic variability through mutation induction is necessary for improving crop yield and quality (Shu et al., 2011).

Deterioration of soybean seed is faster than cereals crop seed due to high protein and fat contents (Lisjak et al., 2009). Sofalian et al. (2015) noticed that polymorphism of storage protein on seed of soybean genotypes could be used as for selection. Soybean seed viability among cultivars showed gradual decreasing with increasing storage periods up to six months (El-Abady et al., 2012). Mbofung et al. (2013) noted that soybean seed viability expressed by germination percentage was affected by environmental factors during storage.

The Accelerated Aging (AA) test that established an injurious environmental condition (high temperature and relative humidity) for a specific period is applied in the chamber to evaluate the storability of seed lots (Gupta, 1993). The effectivity and good accuracy of accelerated aging with high temperature and RH for minimum 24 hours had been noted to predict relative storability and field emergence of soybean (TeKrony and Egli, 1997; Torres et al., 2004; Shivasharanappa et al., 2017**).** Demir and Mavi (2007) also noted the utilization of accelerated aging on melon seed lots for predicting seedling emergence.

MPC IPB 77-1, a rapid aging machine that had been introduced by Sadjad et al. (1982) is used to estimate seed storability by chemical aging of 95% ethanol. It has been developed to MPC IPB 77-1 M which provide shorter time of chemical accelerated aging test (Sadjad, 1991). The modified rapid aging tool of APC IPB 77-1MM from MPC IPB 77-1 M can be used to accelerate the deterioration of seeds with chemical or physical accelerated aging (Suhartanto, 1994). It has 60% smaller size chamber than previous model which can avoid vapor leakage lead to direct contact of seeds with vapor. The APC IPB 77-1 MM has been designed by placing the seeds in a non-stationary state and allowing for gradually seed devigoration.

Electrical conductivity (EC) test is one of tool to determine seed vigor loss (Gupta, 1993). The using conductivity meter for testing vigour seed is sometimes limited in the university's seed laboratory due to its availability. Electrical conductivity of solution can be obtained by measuring its resistance which has positive correlation with resistivity value. Electrical resistivity is described as reciprocal of conductivity (Heaney, 2003 and 2014). The use of ohmmeter as a resistance measurement tool is quite easy, practical and cheap.

The research aims are to estimate seed storability of soybean mutant lines with chemical accelerated aging by utilizing APC IPB 77-1MM, check effectivity of electrical resistance measuring for vigor test and determine genetic parameters value for supporting selection.

2. Material and Methods

The soybean line seeds of M7 population harvested at the same time were dried at 105±3 ^{o}C for 24 h to determine seed moisture content in the beginning and after accelerated aging treatment (ISTA, 2007). The selected lines of M7 population were used in respect to M7 population which is generally used as advanced yield potential trial due to their stability and uniformity to get promising new variety.

The seeds moisturized between paper towel for 12 h were used for chemical accelerated aging with 95% ethanol vapor using Rapid Aging Tool (APC IPB 77-1MM) during different levels of treatment durations (20, 40, 60 and 80 min). Each of twenty-five treated seeds were placed between moist paper towel. The seeds rolled paper towel were germinated in growth cabinet at 24±1 ^{o}C under dark conditions for 5 days.

Figure 1. Sample soybean seeds for accelerated aging test.

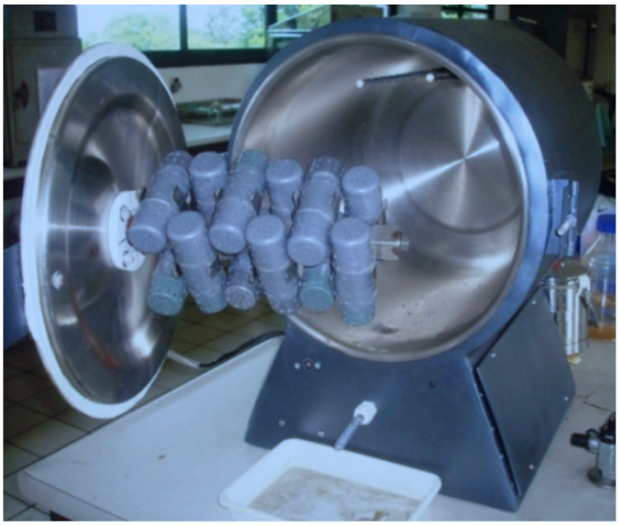

Figure 2. Rapid aging tool of APC IPB 77-1MM.

2.1. Measurement

Germination percentage (GP)

Germination percentage one of standard germination test is simple to measure seed viability. Evaluation of normal seedlings (2 mm radicle) was observed on the fifth day of standard germination test. The degree of complete germinated seed over germination period was expressed as percentage following Bewley and Black (1994):

$$GP\ (\%) = \frac{\Sigma ni}{N}\ x\ 100\% \tag{1}$$

With GP (%) = germination percentage, n = the number of normal germinated seeds at "i" day, N= the total number of incubated seeds per test.

Germination speed (GS)

Speed of germination, a direct measure of seed vigor can be expressed by germination index on one hundred seeds (from partial germination counts with percentages instead of counts) was calculated using Equation 2 (Gupta, 1993).

$$\mathrm{GI} = \frac{\text{number of normal seedling}}{\text{days to first count}} + \ldots + \frac{\text{number of normal seedling}}{\text{days to final count}} \tag{2}$$

Electrical resistance

The resistivity can be found by measuring resistance and physical dimension of material. Conductivity value can be calculated by inversing resistivity value (Heaney, 2003 and 2014).

$$\rho = \frac{R\,w\,h}{l} \tag{3}$$

with ρ is resistivity, R is resistance and w (width), h (heigth) and l (length) are physical dimension

$$\sigma = \frac{1}{\rho} \tag{4}$$

with σ is conducitivity.

Measurement of the electrical resistance (R) value of seeds used an electrical resistance meter (Ohmmeter). Twenty-five (25) seeds were soaked for 24 h in 100 ml of distilled water. After 24 h the seeds were stirred to ensure mixing and electrical resistance value was measured.

2.2. Statistical analysis

The experiment was designed in a Nested Plot Design with 22 soybean lines and two control varieties (Argomulyo as *wildtype* and Tanggamus as acid-tolerant variety) nested within five period of accelerated aging in 0, 20, 40, 60 and 80 min were distributed in to 3 replications. The percentage data were transformed by Arcsine transformation (Steel and Torrie, 1980) before the analysis of variance using computer statistical software "SAS'' and difference among the means were made using t-Dunnet. Pearson Correlation coefficient and regression among germination parameters were analyzed using computer statistical software "MINITAB 14''.

Table 1. ANOVA models and estimate of variance components

Source of variation	Degrees of freedom	Mean squares	E(MS)
Duration	d-1	M5	$\sigma^2_e + g.\sigma^2\ r/_d + gr\,\sigma^2_g$
Rep (Duration)	d(r-1)	M4	$\sigma^2_e + g.\sigma^2\ r/_d$
Genotype	g-1	M3	$\sigma^2_e + r.\sigma^2_{g*d} + r.d\,\sigma^2_g$
Genotype*Duration	(g-1)(d-1)	M2	$\sigma^2_e + r.\sigma^2_{g*d}$
Error	d(g-1)(d-1)	M1	σ^2_e

Note: d (duration), g (genotype), r (replication) E (expected) (Annicchiarico, 2002).

Estimation of variance componetns were calculated by using formula (Syukur et al., 2012):

Phenotypic variance (σ^2_p) $= \sigma^2_g + \sigma^2_{g*e} / d + \sigma^2_e / rd$ (5)

Genotypic variance (σ^2_g) $= (M3\text{-}M2) / rd$ (6)

Interaction variance (σ^2_{g*e}) $= (M2\text{-}M1) / r$ (7)

Environmental variance (σ^2_e) $= M1$

With r (replication), d (duration), and M1-M3 (mean square).

Heritability (h^2) was calculated using formula described by Tinker (2008) and categorized by Stansfield (1991):

$$h^2_{bs} = \sigma^2_g / \sigma^2_p \tag{8}$$

h^2_{bs} : Broad sense heritability
σ^2_g : Genetic variance
σ^2_p : Phenotypic variance.

Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) were determined by a formula suggested by Singh and Chaudhary (1985) as:

$$PCV\ (\%) = (\sqrt{\sigma^2_p} / \bar{X}) \times 100\ \% \tag{9}$$

$$GCV\ (\%) = (\sqrt{\sigma^2_g} / \bar{X}) \times 100\ \% \tag{10}$$

with $\bar{X}$ (sample mean of character).

Genetic advance (GA) and percentage of means (GAM) was computed according to Johnson et al. (1955) and Singh and Chaudhary (1985):

$$GA = K \times \sqrt{\sigma^2_p} \times h^2_{bs} \tag{11}$$

$$GAM\ (\%) = (GA / \bar{X}) \times 100\% \tag{12}$$

Where, K = 2.06 with assumption of 5% selection intensity for the respective trait.

3. Results and Discussion

3.1. Moisture Content

The initial moisture content among soybean mutant lines were uniform with values 8-9%. These moisture content values are recommended for storing of soybean seeds that have high protein content. The uniformity of seed water content is important to get standardization and to obtain greater reliability. The results confirm that high humidity level on seeds could be influenced by accelerated aging that leads to lowering or reduction seed quality (Marcos Filho, 2015). The uniform seed moisture contents of 29-34% were noted after moisturizing and decreased between 28-31% after accelerated aging of each duration in contrast to Toledo et al. (2011) who reported uniformity of seed moisture content in each exposure duration and their increasing after time passed. Imaniar (2012) notified that decreasing moisture content after chemically accelerated aging is caused by replacement of water by ethanol which is easy-accessable in binding water molecules and lead entering ethanol into seeds. While the increasing moisture content after physical accelerated aging is caused by entering water vapor into seeds.

3.2. Seed Viability and Vigor

There was a significant ($p < 0.05$) different effect between the interaction of accelerated aging duration and genetics on seed germination of soybean mutant lines (Table 2). Performance of manually harvested soybean mutant lines seeds have high initial seed viability. They showed more than 80% of germination percentage in the beginning (0 min) without application of increased accelerated aging. However, germination percentage decreased by increasing the duration of chemical accelerated aging on soybean mutant lines in agreement with Imaniar (2012). Mohammadi et al. (2011) noted decreasing germination percentage, germination rate and the normal seedling percentage that indicate seed deterioration of soybean.

The different responses among soybean lines during accelerated aging period in agreement with Mustika et al. (2014) who noted difference of decrease rate of germination on Anjasmoro and Wilis varieties treated by physical accelerated aging. M100-96-53-6 line had a significantly higher germination percentage of 80% than Argomulyo on 60 min and 80 min of a duration of chemical accelerated aging. Germination percentage of M100-29A-42-15 line was noted significantly higher than Argomulyo and germination percentage of M200-20-52-3 line was noted significantly less than Argomulyo and Tanggamus on 60 min of accelerated aging duration. They indicated high seed longevity of M100-96-53-6 line and low seed longevity of M200-20-52-3 line due to seed viability after accelerated aging. It can be predicted that M100-96-53-6 line and M200-20-52-3 line have good and bad storability respectively. These differences expressed by germination percentage on soybean mutant lines might be related to genetic, structural characteristics and chemical composition, as confirmed by Sheidaei et al. (2014).

Table 2. Effect of accelerated aging duration and soybean mutant lines on germination percentage

Mutant lines	Duration of accelerated aging (min)				
	0	20	40	60	80
	Percentage (%)				
M50-97-8-12	93.3	90.0	87.3	80.7	48.0
M50-78-9-13	94.7	95.3	89.3	62.7	34.7^{t-}
M50-45-9-12	88.0	83.3	86.7	80.0	56.7
M100-96-53-7	96.7	92.0	83.3	82.0	60.0
M100-96-53-6	92.7	90.0	92.0	91.3^{a+}	87.3^{a+}
M100-46-44-6	89.3	84.0	77.3	71.3	56.7
M100-29A-42-15	95.3	89.3	92.0	92.7^{a+}	72.7
M100-29A-42-14	94.0	91.3	81.3	61.3	32.0^{t-}
M100-29A-42-10	88.7	86.0	88.7	80.0	70.0
M150-69-47-2	88.7	85.3	75.3	72.7	36.7^{t-}
M150-40-65-5	86.7	83.3	72.7	44.7	19.3^{t-}
M150-29-44-10	95.3	87.3	81.3	81.3	63.3
M150-24-48-2	92.0	86.0	80.7	58.7	18.0^{t-}
M200-93-49-13	94.0	91.3	84.0	84.7	65.3
M200-79A-50-5	88.7	84.7	84.7	77.3	62.7
M200-64-51-2	89.3	86.0	86.0	62.7	45.3
M200-62-54-4	94.7	91.3	72.0	66.0	34.0^{t-}
M200-39-69-6	82.0	67.3	64.7	45.3	24.7^{t-}
M200-20-52-3	96.0	88.7	71.3	17.3^{at-}	10.0^{t-}
M200-20-52-11	98.0	96.0	86.0	85.3	65.3
M200-13-47-5	87.3	84.7	72.7	47.3	22.0^{t-}
M200-6B-58-7	85.3	84.0	76.7	66.0	36.0^{t-}
Argomulyo	**85.3**	**72.0**	**74.0**	**55.3**	**34.7**
Tanggamus	**94.0**	**90.7**	**87.3**	**78.0**	**85.3**

Means followed by the **a** letter within a column differ significantly of Argomulyo and **t** letter within a column differ significantly of Tanggamus at 5% level with Dunnet-test, (-) = less than, (+) = higher.

A significant ($p < 0.05$) different effect was noted between the interaction of accelerated aging duration and genetic on germination speed of *soybean mutant lines* (Table 3). The decline in seed vigor expressed by germination speed values was noted on all soybean mutant lines. The increasing duration of accelerated aging caused reduction of germination speed in agreement with Mohammadi et al. (2011) and Rastegar et al. (2011). Summarily, accelerated aging decreased both germination percentage and germination speed of soybean similar to Imaniar (2012) who noted the loss of germination percentage and germination speed of Anjasmoro soybean variety seeds due to chemical and physical accelerated aging.

Generally, non-significant germination speed values of soybean mutant lines were higher than Argomulyo and lower than Tanggamus in each duration of accelerated aging. M100-96-53-6 line had a higher significant germination speed value than Argomulyo and closed to Tanggamus that indicated its ability to germinate faster and higher. According to germination speed value, M100-96-53-6 line has been estimated that is more vigorous and has good storability than other lines.

There were significant electrical resistance values among soybean mutant lines which are less than Argomulyo and Tanggamus in each duration of accelerated aging (Table 4). A few soybean mutant lines had a higher electrical resistance value than Argomulyo at 20 min of accelerated aging duration. The increasing duration of accelerated aging decreased the electrical resistances value of all soybean mutant lines. Decreasing electrical resistances values might be caused by membrane damage or loss of membrane integrity led to electrolyte leakage. The increasing ionic concentration of seed soaking solution contributed to higher conductivity. It means that decreasing electrical resistances followed by decreasing electrical resistivity led to increasing electrical conductivity on solution as confirmed by Heaney (2003 and 2014).

Table 3. Effect of accelerated aging duration and soybean mutant lines on germination speed

Mutant lines	Duration of accelerated aging (min)				
	0	20	40	60	80
M50-97-8-12	42	34	29	24	14^{t-}
M50-78-9-13	44	35	29	20	11^{t-}
M50-45-9-12	45	31	30	26	19
M100-96-53-7	42	33	28	28	20
M100-96-53-6	45	32	31	30	29^{a+}
M100-46-44-6	36	31	25	24	17
M100-29A-42-15	44	34	31	30	23
M100-29A-42-14	44	35	28	19	12^{t-}
M100-29A-42-10	44	32	31	24	24
M150-69-47-2	34	35	26	23	15^{t-}
M150-40-65-5	34	31	26	17	6^{t-}
M150-29-44-10	43	30	28	25	21
M150-24-48-2	42	32	26	18	7^{t-}
M200-93-49-13	40	34	25	28	23
M200-79A-50-5	40	29	27	25	20
M200-64-51-2	41	30	29	21	17
M200-62-54-4	50	35	25	20	9^{t-}
M200-39-69-6	36	23^{t-}	21^{t-}	14	8^{t-}
M200-20-52-3	44	31	24	4^{t-}	3^{t-}
M200-20-52-11	46	33	30	28	21
M200-13-47-5	42	30	25	15	9^{t-}
M200-6B-58-7	39	27	26	22	12^{t-}
Argomulyo	**38**	**27**	**24**	**17**	**13**
Tanggamus	**44**	**41**	**34**	**27**	**30**

Means followed by the a letter within a column differ significantly of Argomulyo and t letter within a column differ significantly of Tanggamus at 5% level, (-) = less than, (+) = higher.

The unexpected data on untreated soybeans seeds which are showing values lower than 20 min treatment seeds might be caused by seed genetic as genetic variability and purity, size and weight (physical) uniformity and purity and less environmental factor. Although used seeds of M7 were selected from same seed lot, mentioned reasons might influenced on measuring electrical resistance between untreated seeds and 20 min treatment seeds. Each lot has its own characteristics led to seeds which have a common genotype might vary in their vigor depending on the maternal environment and their harvest and handling (Finch-Savage and Bassel, 2016). Each seed of seed lot which are produced and handled at the same time might have varying in vigor due to its own characteristic (Kuswanto, 2007). These unexpected data have been also suggested due to soaking time inaccuracy. The soaking time on untreated seeds might be slightly over 24 hours led to increasing the amount of electrolyte leakage impacted to low electrical resistance value. Hartati (2019) reported that the increasing soaking time on sesame seeds caused the increasing electrical conductivity.

3.3. Effectivity of utilization electrical resistance

A significant and strong positive correlation was noted between electrical resistance and other parameters (Table 5). It indicated that value of evaluated parameters increased with increasing electrical resistance value. It is indicated that resistivity value correlated positively with resistance value on same measured solution of soybean. It is also estimated that a solution which has high resistivity will has low conductivity in agreement with Heaney (2003 and 2014). Oktaviani (2012) verified that conductivity value had a negative correlation with germination percentage and germination speed on black soybean.

Table 4. Effect of accelerated aging duration and soybean mutant lines on electrical resistance

Mutant lines	Duration of accelerated aging (min)				
	0	20	40	60	80
	Ohm (Ω)				
M50-97-8-12	21.33^{t-}	25.50^{a+}	17.33^{t-}	16.17	12.33^{t-}
M50-78-9-13	21.00^{t-}	22.67^{t-}	17.33^{t-}	15.17^{t-}	11.33^{t-}
M50-45-9-12	20.00^{t-}	24.67	18.33	14.83^{t-}	12.50^{t-}
M100-96-53-7	21.33^{t-}	24.00^{t-}	16.00^{t-}	15.50^{t-}	12.42^{t-}
M100-96-53-6	22.33	23.17^{t-}	17.00^{t-}	17.00	15.00
M100-46-44-6	20.67^{t-}	22.00^{t-}	15.67^{t-}	15.83	12.83
M100-29A-42-15	22.33	23.67^{t-}	17.67^{t-}	16.50	13.83
M100-29A-42-14	19.83^{t-}	24.67	13.17^{t-}	13.83^{t-}	11.00^{t-}
M100-29A-42-10	21.00^{t-}	26.00^{a+}	18.67	15.67^{t-}	14.17
M150-69-47-2	20.33^{t-}	21.67^{t-}	17.00^{t-}	15.83	11.00^{t-}
M150-40-65-5	21.00^{t-}	24.33	17.00^{t-}	13.67^{t-}	10.50^{t-}
M150-29-44-10	20.33^{t-}	23.33^{t-}	16.83^{t-}	15.83	12.50^{t-}
M150-24-48-2	21.67^{t-}	24.50	16.00^{t-}	15.00^{t-}	9.67^{t-}
M200-93-49-13	20.00^{t-}	25.33	16.67^{t-}	16.00	13.00
M200-79A-50-5	20.67^{t-}	23.67^{t-}	15.83^{t-}	15.50^{t-}	12.83
M200-64-51-2	18.83^{at-}	24.33	19.00	14.83^{t-}	11.33^{t-}
M200-62-54-4	21.33^{t-}	26.00^{a+}	16.67^{t-}	14.50^{t-}	9.83^{t-}
M200-39-69-6	21.50^{t-}	22.67^{t-}	15.67^{t-}	13.67^{t-}	11.33^{t-}
M200-20-52-3	20.00^{t-}	24.00^{t-}	17.17^{t-}	13.17^{t-}	8.83^{at-}
M200-20-52-11	20.00^{t-}	24.17^{t-}	17.00^{t-}	15.17^{t-}	12.00^{t-}
M200-13-47-5	19.83^{t-}	21.50^{t-}	17.17^{t-}	13.17^{t-}	8.75^{at-}
M200-6B-58-7	20.83^{t-}	19.67^{t-}	17.83^{t-}	14.83^{t-}	11.67^{t-}
Argomulyo	**23.33**	**20.33**	**17.17**	**15.67**	**13.17**
Tanggamus	**26.67**	**29.33**	**22.67**	**18.67**	**16.17**

Means followed by the a letter within a column differ significantly of Argomulyo and t letter within a column differ significant of Tanggamus at 5% level, (-) = less than, (+) = higher.

Table 5. Correlation between electrical resistance value and other parameters

Parameters	Germination percentage	Germination speed	Moisture content
Electrical resistance	0.634 0.001**	0.729 0.000**	-0.231 0.279^{ns}

Note: ** significant at 1% level.

3.4. Regression analysis

Increasing duration of accelerated aging was inverse of reduction seed viability and seed vigor showed by negative regression coefficient on soybean mutant lines. In this condition, a high R-squared value showed a higher loss of viability and vigor. The M100-96-53-6 line had good seed viability and vigor as an indicator of good seed storability due to low R-squared value compared to other soybean mutant lines (Figure 3-5). On the contrary, high R-squared values were noted on M200-20-52-3 line that indicated bad seed storability.

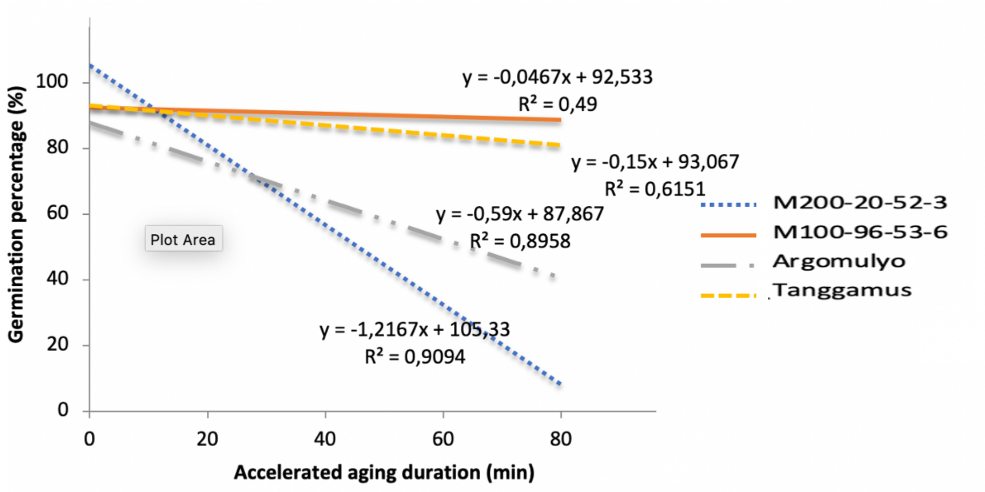

Figure 3. Relation between accelerated aging duration and germination percentage.

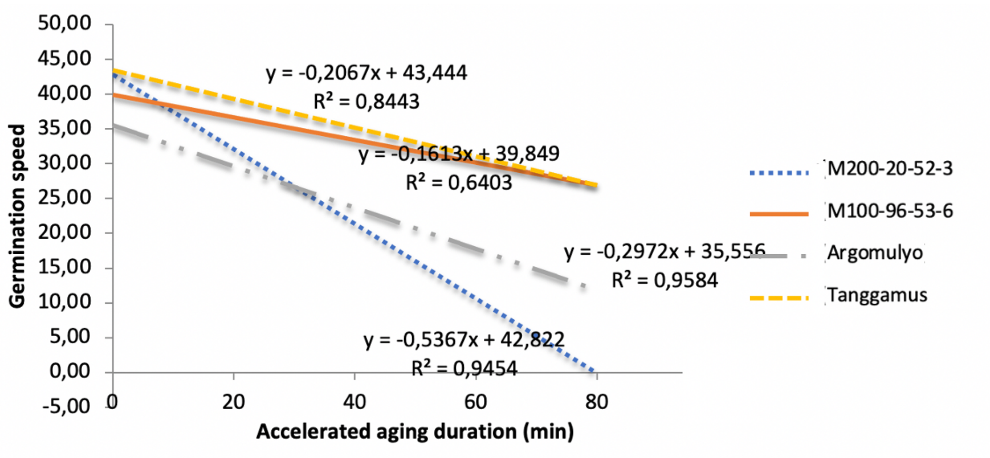

Figure 4. Relation between accelerated aging duration and germination speed.

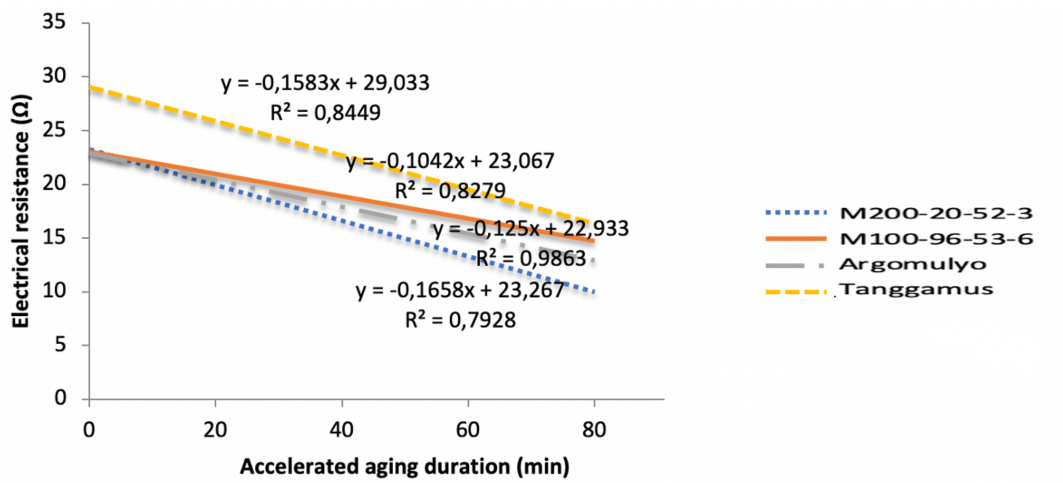

Figure 5. Relation between accelerated aging duration and electrical resistance.

3.5. Variance components and genetic parameters

Variance components of germination parameters showed Table 6 and were calculated by using formulas in Table 1. According to Stansfield (1991), the high heritability (> 0.5) was noted on germination percentage, germination speed and electrical resistance, while moisture content was categorized to moderate heritability (0.2-0.5) (Table 6). This high heritability implied that the heredity regressed < 30% toward the mean of previous generation and characters were mostly influenced by the genotype. Kalpande et al. (2015) also noted the high heritability estimate on germination seed, electrical conductivity and vigor index of sorghum landraces.

The high to low GA of this study were noted on germination percentage, germination speed, electrical resistance value and moisture content respectively. High genetic advance as percentage of mean (GAM) on germination percentage and germination speed (> 20%), moderate on electrical resistance value (10-20%) and low on moisture content (≤10%) were noted in accordance with Johnson et al. (1955). Additive genes action was suggested on germination percentage and germination speed expressed by high heritability with moderate to high values of GA in agreement with Naik et al. (2016) and Joshi et al. (2018) who noted additive gene and non-additive gene effects on soybean yield traits. Whereas non-additive gene action was indicated on the moisture content expressed by moderate heritability with low genetic advance. Kalpande et al. (2015) also suggested the high heritability with low genetic advance showed a non-additive effect that was most influenced by environmental than genotype on germination percentage and vigor seed of sorghum landraces. It had been notified effectivity and reliability of using a combination of heritability with genetic advance over mean (GAM) to predict the progress of selection. The combination of the high heritability and moderate to high genetic advance provide variation sources and improvement of the traits in the selection process (Jain et al., 2018). In this study, germination speed, germination percentage and electrical resistance value could be considered as criteria in sequence for selecting soybean mutant lines in consequence of the appearance of a character that is influenced by genetic and less environmental factor.

Table 6. Variance components and genetic parameters on seed viability and vigor of soybean mutants lines

Parameters	Mean	σ^2_e	σ^2_g	σ^2_{g*e}	σ^2_p	h^2_{bs}	GCV	PCV	GA	GAM
Germination Percentage (GP)	75.00	169.58	76.99	45.90	97.47	0.79	11.70	13.16	16.06	21.42
Germination speed (GS)	27.81	29.43	11.13	3.99	13.89	0.80	12.00	13.40	6.15	22.12
Moisture content (MC)	29.99	3.15	0.13	0.11	0.36	0.35	1.18	2.00	0.43	1.45
Electrical resistance	17.86	2.49	1.30	0.58	1.58	0.82	6.39	7.05	2.13	11.93

Note: σ^2_e (environmental variance), σ^2_g (genotypic variance), σ^2_{g*e} (interaction of genotypic and environmental variance), σ^2_p (phenotypic variance), h^2_{bs} (broad sense heritability), GCV (genotypic coefficient of variance), PCV (phenotypic coefficient of variance), GA (genetic advance), GAM (GA as percentage of means).

According to Deshmukh et al. (1986) classification, medium PCV and GCV of germination percentage and germination speed (10-20%) and low PCV and GCV on remaining parameters (< 10%) with smaller differences were observed in this study. The higher PCV than GCV with small differences between PCV and GCV indicated that these parameters are less influenced by the environment in phenotypic expression in agreement with Kalpande et al. (2015) and Ali et al. (2016). The parameters had medium PCV and GCV with smaller differences that might be effective for selection. Similarly, Tuhina-Khatun et al. (2015), Ali et al. (2016) and Kuswantoro et al. (2018) mentioned the effectivity of selection due to the high or medium of PCV and GCV with narrow differences.

4. Conclusion

Diversity in seed storability of soybean mutant lines was influenced by most of the genetic and some degree of environmental factors. M50-45-9-12, M100-29A-42-10, M100-29A-42-15, M100-96-53-6, M100-96-53-7, M200-93-49-13 and M200-20-52-11 lines had been estimated good seed storability and M200-13-47-5 and M200-20-52-3 lines had poor estimated seed storability compared to Argomulyo as wild type based on germination percentage, germination speed and electrical resistance value. M100-96-53-6 and M200-20-52-3 lines deteriorated to the slowest and fastest as expressed on the slope graph. Beside using electrical conductivity value, electrical resistance value could be used as an alternative method to evaluate seed vigor test. It is also recommended to compare electrical conductivity value and electrical resistance to confirm the validity.

Germination percentage, germination speed and electrical resistance could be considered to select lines having good quality seeds with estimated storability values as a step of plant breeding purposes. To evaluate seed performances, selected good lines of accelerated aging might be compared to natural dry storage following field emergence test.

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References

Ali, A., Khan, S. A., Ehsanullah, Ali, N., & Hussain, I. (2016). Estimation of genetic parameters in soybean for yield and morphological characters. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinery Sciences, 32(2),* 162-168.

Annicchiarico, P. (2002). *Genotype X Environment Interactions-Challenges and Opportunities for Plant Breeding and Cultivar Recommendations*. Roma, Italy: Food and Agriculture Organization of The United Nations.

Bewley, J. D., & Black, M. (1994). *Seeds: Physiology of Development and Germination*. New York, USA: Plenum Press.

BPS. (2015). *Statistik Indonesia- Statistical Yearbook of Indonesia 2015*. Jakarta, Indonesia: Badan Pusat Statistik. (in Indonesian language)

Demir, I., & Mavi, K. (2008). Controlled deterioration and accelerated aging tests to estimate the relative storage potential of cucurbit seed lots. *Hort Science, 42(6),* 1431-1435.

Deshmukh, S. N., Basu, M. S., & Reddy, P. S. (1986). Genetic variability, character association and path coefficient analysis of quantitative traits in *Virginia bunch* varieties of groundnut. *Indian Journal of Agricultural Science, 56,* 515-518.

El-Abady, M. I., El-Emam, A. M. M, Seadh, S. E, & Yousof, F. I. (2012). Soybean seed quality as affected by cultivars, threshing methods and storage periods. *Research Journal of Seed Science, 5(4),* 115-125.

Finch-Savage, W.E., & Bassel, G. W. (2016). Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany, 67(3),* 567-591.

Gupta, P. C. (1993). Seed Vigour Testing. In P. K. Agrawal (Ed.), *Handbook of Seed Testing* (pp. 242-249). New Delhi, India: Ministry of Agriculture.

Hartati P. 2019. Hu*bungan deteriorasi dengan umur simpan benih melalui penggunaan indiktor pengujian viabilitas dan vigor pada benih wijen* (*Sesamum indicum* L.) (Correlation between deterioration and the age of seed storage by using indicator of viability and vigor test in sesame seeds (*Sesaman indicum* L.)). (Master Thesis). Fakultas Pertanian, Universitas Sumatra Utara. 73 pages (in Indonesian language)

Heaney, M. B. (2003). Electrical Conductivity and Resistivity. In G. B. John (Ed.), *Electrical Measurement, Signal Processing and Displays* (Chapter 7, pp. 1-14). USA: CRC Press.

Heaney, M. B. (2014). Electrical Conductivity and Resistivity. In G. W. John and H. Eren (Eds.), *Measurement, Instrumentation, and Sensors Handbook: Electromagnetic, Optical, Radiation, Chemical, and Biomedical Measurement, 2nd Edition* (Chapter 26). USA: CRC Press.

Imaniar, A. (2012). *Pemanfaatan alat pengusangan cepat (APC) IPB 77-1MM untuk pendugaan vigor daya simpan benih kedelai* (*Glycine max* (L). Merr.). (B.Sc), Agronomy and Horticulture Departement, IPB University, Bogor, Indonesia. (in Indonesian language)

ISTA. (2007). *International Rules For Seed Testing*. Bassersdorf, Switzerland: International Seed Testing Association.

Jain, R. K., Joshi, A., Chaudhary, H.R., Dashora, A., & Khatik, C.L. (2018). Study on genetic variability, heritability and genetic advance in soybean [*Glycine max* (L.) Merrill]. *Legume Research, 41(4),* 532-536.

Johnson, H.W., Robinson, H.F., & Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal, 47,* 314-318.

Joshi, D., Pushpendra, Singh, K., & Adhikari, S. (2018). Study of genetic parameters in soybean germplasm based on yield and yield contributing traits. *International Journal of Current Microbiology and Applied Sciences, 70(1),* 700-709.

Kalpande, V. V., Khade, P. A., Ghorade, R.B., Dange, A., & Thawari, S. B. (2015). Genetic variability, heritability and genetic advance for seed quality parameters in some of the land races of Sorghum. *The Bioscan, 10(2),* 719-721.

Kuswanto. 2007. Teknologi Pemrosesan Pengemasan dan Penimpanan Benih. Yogyakarta: Kanisius. 250p. in Indonesian language

Kuswantoro, H., Artari, R., Rahajeng, W., Ginting, E., & Supeno, A. (2018). Genetic variability, heritability, and correlation of some agronomical characters of soybean varieties. *Biosaintifika, 10(1),* 9-15.

Lisjak, M., Wilson, I. D., Civale, L., Hancock, J. T., & Teklić, T. (2009). Lipid peroxidation levels in soybean (*Glycine max* (L.) Merr.) seed parts as a consequence of imbibition stress. *Poljoprivreda, 15(2),* 32-37.

Marcos-Filho, J. (2015). *Seed Physiology of Cultivated Plants*. 2nd ed. Londrina, Brazil: Abrates.

Mbofung, G. C. Y., Goggi, A. S., Leandro, L. F. S., & Mullen, R. E. (2013). Effects of storage temperature and relative humidity on viability and vigor of treated soybean seeds. *Crop Science, 53,* 1086-1095.

Ministry of Agriculture. (2018). Statistik Pertanian 2018. Kementrian Pertanian Republik Indonesia, Jakarta. 427s. (in Indonesian language)

Mohammadi, H., Soltani, A., Sadeghipour, H. R., & Zeinali, E. (2011). Effect of seed aging on subsequent seed reserve utilization and seedling growth in soybean. *International Journal of Plant Production, 5(1),* 65-70.

Mustika, S., Suhartanto, M. R., & Qadir, A. (2014). Soybean seed deterioration using accelerated aging machine IPB 77-1 MM compared to natural storage. *Buletin Agrohorti, 2(1),* 1-10. (article in Indonesian language with an abstract in English)

Naik, S. M., Madhusudan, K., Motagi, B. N., Nadaf, H. L., Rao, M. S. L, Mugali, S., Gurumuthy, R., & Basavaraj, G. T. (2016). Genetic variability and association studies for seed yield and longevity with component traits in soybean [Gl*ycine max* (l.) Merill.]. *Ecology, Environment and Concervation*, S117-S122.

Oktaviani, K. A. (2012). *Studi genetik terhadap daya simpan kedelai hitam* (*Glycine Max* (L.) Merr.). Bachelor, Agronomy and Horticulture, IPB University, Bogor, Indonesia.

Pereira, R. G., Tulcan, O. E. P., Jesus Lameira, V., Espirito Santo, D. M., & Andrade, E. T. (2011). Use of soybean oil in energy generation, 301-320. http://Cdn.İntechweb.Org/Pdfs/22609.Pdf

Rastegar, Z., Sedghi, M., & Khomari, S. (2011). Effects of accelerated aging on soybean seed germination indexes at laboratory conditions. *Notulae Scientia Biologiace, 3(3),* 126-129.

Sadjad, S. (1991). Modifikasi mesin pengusangan cepat IPB 77-1. Laporan Akhir Hasil Penelitian. Fakultas Pertanian, Institut Pertanian Bogor. Bogor. 40 hal. (in Indonesian language).

Sadjad, S., Purnomohadi, M. B., Murniati, E., Suwarno, F. C., & Ilyas, S. (1982). Penelitian akurasi alat penduga daya simpan benih type IPB 77-1. Laporan Akhir Penelitian. Fakultas Pertanian, Institut Pertanian Bogor. 36 pp. (In Indonesian language).

Sheidaei, S., Abad, H. H. S., Hamidi, A., Mohammadi, G. N., & Moghaddam, A. (2014). Evaluation of soybean seed quality under long term storage. *International Journal of Biosciences, 5(3),* 214-219.

Shivasharanappa, S., Patil, S.R., Doddagoudar, V.K.K.R., Mathad, C., & Patil, R.P. (2018). Prediction of storability in soybean seeds through accelerated ageing technique [Glycine max (L.) Merill]. *Legume Research, 41(4),* 572-577.

Shu, Q. Y., Forster, B. P., & Nakagawa, H. (2011). Principles and Applications of Plant Mutation Breeding. In Q. Y. Shu, B.P. Forster, H. Nakagawa (Eds.). *Plant Mutation Breeding and*

Biotechnology (p: 30). Italy: Electronic Publishing Policy and Support Branch Communication Division, FAO.

Siavash Moghaddam, S., Rahimi, A., Noorhosseini, S., Heydarzadeh, S., & Mirzapour, M. (2018). Effect of seed priming with salicylic acid on germinability and seedling vigor fenugreek (*Trigonella Foenum-Graecum*). *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi*, *28(2),* 192-199.

Singh, R. K., & Chaudhary, B. D. (1985). *Biometrical Methods In Quantitative Analysis.* New Delhi, India: Kalayani Publishers.

Sofalian, O., Bandarian, P., Asghari, A., Sedghi, M., & Firoozi, B. (2015). Identification of seed storage protein polymorphism in some soybean (*Glycine max* Merril) genotypes using SDS-PAGE Technique. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 25(2),* 127-133.

Stansfield, W. D. (1991). *Theory and Problems of Genetics*. 2nd ed. New York, USA: Mc.Graw-Hill.

Steel, R. G., & Torrie, J. H. (1980). *Principles and Procedures of Statistics A Biometrical Approach*. 2nd ed. New York, USA: Mcgraw-Hill.

Suhartanto, M. R. 1994. *Studi sistem multiplikasi devigorasi secara fisik dan kimia pada kasus kemunduran viabilitas benih kedelai* (*Glycine max* L. Merr.) *akibat goncangan*. (Master). Program Pasca Sarjana, Institut Pertanian Bogor, Indonesia. 51 pp. (in Indonesian language).

Syukur, M., Sujiprihati, S., & Yunianti, R. (2012). *Teknik Pemuliaan Tanaman*. Bogor, Indonesia: Penebar Swadaya. (in Indonesian language).

TeKrony, D. M., & Egli, D. B. (1997). Relationship between Standard Germination, Accelerated Ageing Germination and Field Emergence in Soyabean. In: R. H. Ellis, M. Black, A. J. Murdoch, T. D. Hong (Eds). *Basic And Applied Aspects Of Seed Biology* (pp: 539-600). Boston: Kluwer Academic Publishers.

Tinker, N. A. (2008). Plant Breeding, Central Concept in Plant Breeding. In C. N. Stewart (Ed.). *Plant Biotechnology and Genetic* (pp: 51). Canada: A John Wiley & Sons, Inc. Publication.

Toledo, M. Z., Teixeira, R. N., Ferrari, T. B., Ferreira, G., Cavariani, C., & et al. (2011). Physiological quality and enzymatic activity of crambe seeds after the accelerated aging test. *Maringa, 33(4),* 687-694.

Torres, R.M., Vieira, R.D., & Panobianco, M. (2004). Accelerated aging and seedling field emergence in soybean. *Scientia Agricola, 61(5),* 476-480.

Tuhina-Khatun, M., Hanafi, M. M., Yusop, M. R., Wong, M. Y., Salleh, F. M., & et al. (2015). Genetic variation, heritability, and diversity analysis of upland rice (*Oryza sativa* L.) genotypes based on quantitative traits. *Biomed Research International*. Article ID 290861, 7 Pages.