SEED DETERIORATION PATTERN OF FOUR BAMBARA GROUNDNUT LANDRACES (*Vigna subterraneasubterranean* (L) Verdc) IN OPEN STORAGE SYSTEM

Pola Deteriorasi Benih Empat Lanras Kacang Bambara (Vignasubterranea (L) Verdc) pada Sistem Penyimpanan Terbuka

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ABSTRAK

Kacang bambara (*Vigna subterranea* (L.) Verdc) merupakan tanaman yang potensial dikembangkan di Indonesia dan baru dibudidayakan satu kali setahun, sehingga diperlukan penyimpanan benih yang tepat. Penelitian ini bertujuan untuk mendapatkan pola deteriorasi benih empat lanras kacang bambara yang disimpan dalam kemasan dengan permebialitas berbeda pada sistem penyimpanan terbuka selama 6 bulan. Penelitian dilaksanakan sejak November 2015 hingga Juli 2016 di Laboratorium Teknologi Benih, IPB. Tahapan penelitian adalah: penghitungan permeabilitas kemasan, penyimpanan benih, penyusunan dan fiting pola persamaan deteriorasi benih. Kemasan yang digunakan dalam penelitian adalah alumunium foil, plastik polyprophylane (PP) dan karung plastik yang telah diukur permeabilitasnya. Hasil penelitian menunjukkan deteriorasi benih empat lanras kacang bambara pada permeabilitas kemasan berbeda mempunyai pola sigmoid dengan persamaan: y = a / {1 + exp (x + b) / c)}. Pola deteriorasi benih berdasarkan DB dan DHL dengan laju penurunan cepat terjadi pada lanras Sumedang yang dikemas dalam karung plastik, menunjukkan waktu simpan lebih pendek. Laju penurunan lambat pada lanras Gresik yang dikemas dalam alumunium foil, hal ini menunjukkan waktu simpan lebih panjang.

Kata kunci: kacang bambara, lanras, permeabilitas, sigmoid, waktu simpan

ABSTRACT

Bambara groundnut (Vigna subterranea (L.) Verdc) is a potential commodity to be developed in Indonesia, however, the production is done only once a year, therefore, it needs proper seed storage. The aim of this research was to study seed deterioration patterns of four bambara groundnut landraces stored in packages with different permeability in an open storage system for up to 6 months. This experiment was conducted from November 2015 to July 2016 at Seed Technology Laboratory, Department of Agronomy and Horticulture, IPB. Stages of experiment as follow: calculation of packaging permeability, seed storage, preparation and fitting data to regression equation.The packaging used in the study is aluminum foil, pp plastic and plastic sacks which have measured its permeability. The result showed that the seed deterioration of four bambara groundnut landraces in three packaging permeability has common sigmoidpattern with equation model: y = a / {1 + exp ((x + b) / c)}. The seed deterioration pattern based on SG and EC variables with the faster rate of decline occurred in Sumedang landrace packed in plastic sack (permeability = 1.4681 g/day m^2 mm/ Hg), thus having a shorter storability. The slower rate of decline occurred in Gresik landrace packed in aluminum foil (permeability = 0.098 g/day m^2 mm/Hg), this means that it has a longer storability..

Key words: *vignasubterranea (L.) Verdc, landraces, permeability, sigmoid, storability*

INTRODUCTION

Bambara groundnut (Vigna subterranea (L) Verdc) cultivation in Indonesia was begun at the beginning of 18th century (Redjeki *et al.*, 2013), but up to now, the government has not yet released any superior variety of bambara groundnut. Bambara groundnut contains high nutrients, which include 17-25% protein, 46-65% carbohydrate (Mabhaudhi *et al*. 2013), 5.88% fat, 10.43% water, and 3.03% ashes (Redjeki 2007), as well as calcium, phosphor, iron, and vitamin B1 (Suwanpraset *et al*. 2006).

Seeds used by the farmers for the cultivation are still derived from their own farming. In general, bambara groundnut seeds are only available from March to June. It is due to life span of bambara groundnut ranges between 17 WAP (weeks after planting) and 18 WAP, depends on the weather condition (Ilyas and Sopian 2013; Redjeki 2007), moreover, life span of some landraces is about 6 months (Toure *et al*. 2012), so that cultivation of bambarag roundnut could not be done year-round. The yielded seeds were stored in order to be planted in the next planting season, and duration between planting seasons require proper storage to maintain high viability of the seeds.

Farmers used to store the bambara groundnut in cans with scouring sands, which is intended to maintain low water content, to avoid the infestation of fungi and insects. According to Justice and Bass (2002), water content and temperature of storage are important factors that affect life span of the seeds, as well as chemical contents in the seeds, initial viability, water content of the seeds, temperature of the storage space, and diverse packaging materials (Hasbianto 2012). Carbohydrate as dominant chemical composition of bambara groundnut has enabled the seeds tobe stored longer than other legumes.

Estimation of bambara groundnut vigor for storability plays important role in estimating its storability, since vigor of storability has closely related to complex deterioration process of the seeds (Copeland and McDonald, 2001). Such deterioration of seeds occurs during the storage periods, both open storage and controlled storage. Seeds deterioration is affected by many factors, both internal and external factors (Copeland and McDonald 2001). According to Justice and Bass (2002), internal factors that affect on seed deterioration include initial viability of seeds, water content of seeds, and genetic factors (for example, varieties, seed size, testa permeability, chemical composition of seeds), while the external factors include physical environment (temperature, relative atmospheric humidity, atmosphere) and biotic (virus, fungi, bacteria, and pest). Information about storability of bambara groundnut and the packaging ability to maintain viability of the seeds within longer period of storage, is still limited.

Objective of this experiment was to obtain seed deterioration pattern of four bambara groundnut landraces on three different permeability packaging for six months of open storage.

MATERIALS AND METHODS

Experiment of seed storage was conducted from November 2015 to July 2016 at Seed Technology Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. Stages of experiment are as follow: 1) calculation of packaging permeability, 2) seed storage, 3) arranging the equation of deterioration patterns, and 4) fitting equation model of deterioration patterns.

Bambara groundnut seeds, which were used, comprise of four landraces: Sumedang (harvested in April 2015), Sukabumi (harvested in May 2015), Gresik (harvested in April 2015), and Tasikmalaya (harvested in June 2015). Seed germination, electrical conductivity, and moisture content of the seeds were tested before they are stored in the room storage at ± 20^{o}C and ±RH 60%.

Calculation of Packaging Permeability

The packaging permeability is measured by ASTM D895-79 method (whole bag desiccant method, (Arpah 2007)). Desiccant (silica gel) was dried in oven at 105^{o}C for three hours, and then incubated in desiccators for 30 minutes and after that ± 20 g desiccant was put into the packaging, in which its surface area has been measured first. Packaging, which was filled with desiccant, was kept in incubator at ± 44^{o}C and RH ±99% for 14 days. Weight of desiccant is weighed everyday and a correlation curve is drawn between desiccant weights against time (day), so that the daily absorbed water values are obtained. The permeability values are counted using Moyls's equation in Arpah (2007) as follow :

$$\text{Packaging permeability} = \frac{n/t}{A\,(RH_{out} - RH_{in})P_o}$$

Whereas n/t (amount of the absorbed water per day, g/day), A (surface area of packaging, m^2), RH_{out} (RH outside the packaging, %), RH_{in} (RH inside the packaging, %) and Po (saturated vapor pressure, mmHg).

Seeds Storage

The experiment was arranged using randomized complete design by nested packaging permeability factor in storage period. The packaging permeability values comprise of three levels, such as aluminum foil (alfoil), plastic polyprophylane (PP), and plastic sack (*karplas*). Storability comprises of seven stages, such as 0, 1, 2, 3, 4, 5, and 6 months. Combination of treatment has three replications, and each unit of experiment includes 250 seeds that are stored in open storage (kept under room temperature). Daily RH and temperature of the storage space are measured everyday using thermohygrometer (Elitech RC4HA/C(UK)). The observed variables include seed germination (SG) and electrical conductivity (EC). Experiment on seeds storage was conducted against four bambara groundnut landraces, such as Sumedang, Sukabumi, Gresik, and Tasikmalaya landraces.

Arranging the Equation Pattern of Seed Deterioration

Arrangement of the seed deterioration equation pattern was initiated by the establishment of dispersion diagram. Such dispersion diagram describes the testing values of the seed deterioration variables during storage, in which the horizontal axis or abscissa (x) is for duration of storage (month) and vertical axis or coordinate (y) is for seed deterioration variables (seed germination, electrical conductivity). Such dispersion diagram will be used to estimate proper equation pattern through non linear regression analysis with sigmoid function. Deterioration pattern is established for each landrace and packaging permeability (types of packaging).

Fitting of Seed Deterioration Pattern to Equation

Fitting the deterioration to equation was intended to estimate conformity between deterioration equation pattern and results of the seed test during the storage. The fitting was conducted by comparing the equation outcomes pattern along with criteria entering the pattern in each deviation standard of the test values during the seeds storage.

Seed Germination Testing after the Seeds Being Stored

After being stored, SG of the seeds were measured in accordance with percentage of normal seedling (NS) on first and final count. SG test was done by germinating 50 seeds of each accession in the seedling beds, which were filled with sands as the medium and had three replications, were put in a chamber at 25^{o}C. SG is calculated using the equation below (ISTA 2014):

$$SG(\%) = \frac{\sum NS\ I + NSII}{\sum seeds} x\ 100\%$$

Whereas NS I = observation on germinate at 5th day, NS II= observation on germinate at 10th day.

Electrical Conductivity Testing after the Seeds Being Stored

Electrical conductivity (EC) on each accession was made by three replications, 25 seeds each. Seeds were weighed and then put them in a jar, which was filled with aquadest, and then incubated for 24 hours at 20^{o}C. EC calculation uses the equation below (ISTA 2014):

EC = µS.cm-1/g

$$\frac{\text{conductivity of sample} - \text{blanko } (\mu S.cm - 1)}{\text{Weight of seeds per replication (g)}}$$

RESULT AND DISCUSSION

Packaging Permeability

Packaging permeability is ability of the packaging to release vapor that could permeate the packaging (PB Depdiknas 2008). Low permeability indicates fewer vapors that could permeate the packaging and hit the seed's surface within the packaging. Results of calculation against the packaging permeability, which were used in the experiment, were based on Moyls' equation as presented in Table 1.

Tabel 1 showed permeability of aluminum foil (0.0981 g/day m^2 mm/Hg), plastic PP (0.1572g/day m^2 mm/Hg), and plastic sack (1.4681g/day m^2 mm/Hg). Aluminum foil has the lowest permeability, and followed by plastic PP, and plastic sack. Plastic sack has porous, which enable the vapor absorption, which means that plastic sack is easily permeable than aluminum foil and plastic PP (Arizka and Daryatmo 2015). Hasbianto (2012)

Table 1. Permeability values of packaging type using Moyl's equation

Variable	Type of packaging		
	Aluminum foil	Plastic PP	Plastic sack
n/t (g/day)	0,0217	0,0364	0,3021
A (m^2)	0,0043	0,0045	0,0040
Permeability (g/day m^2/mm Hg)	0,0981	0,1572	1,4681

Notes: RH incubator: 71,27%, Temperature: 44 °C, P_0: 72.18 mm Hg (saturated vapor pressure at 44°C based on Bennefield et al. 1982) suggested that packaging permeability values may affect the stored-water content of the seeds. The lower permeability, the slower increase of moisture content (MC) of the seeds, so that it will prolong the storability.

Seeds Storage

Seeds, which were used in this research were harvested between April – June 2015, and post-harvest time, the seeds were processed by the farmers. The seeds were tested before they are kept in storage space at 20°C and RH 60% (Table 2).

Seeds, which were used in this research, had been kept in open storage for 5 months (April to August) by the farmers before they were applied in November 2015. During seeds storage, SG and EC were tested, and then seed deterioration patterns were made on each landrace and packaging permeability.

SG Variable after the Seeds being Stored

Behavioral pattern of SG during storage on all landraces and packaging permeability based on nonlinear regression analysis has sigmoid equation. It conformed to research by Walter *et al.* (2010), seeds deterioration is described by sigmoid correlation between viability and time, even though no significant change was found on seed vigor, but faster rate of death was occurred. The equation that match with the pattern formed is as follows (Birch 1999):

$$y = a / (1 + \exp^{((x + b)/c)})$$

For a, b, and c are constant, x is storage period (month) and y is seed deterioration variables (SG and EC). Results of regression analysis are presented in Table 3.

Equation of SG behavior was followed by descriptive fitting that used standard of deviation. Descriptive fitting was shown from lines that enter to ranges of deviation standard on point of the observation. Results of fitting are presented in Figure 1.

Figure 1 showed that dominantly, lines that resulted from the equation pattern were included in range of the deviation standard on each point of observation.

Table 2. Initial data of seeds before seeds storage

Variable	Landrace			
	Smedang	Skbumi	Gresik	Tkmalaya
SG (%)	89	96	96	93
EC ($\mu S.cm^{-1}.g^{-1}$)	0,9	0,9	2,5	1,4
MC (%)	9,6	10,1	10,1	10,2

Notes: SG = seed germination, EC = electrical conductivity, MC = moisture content

Table 3. Results of exponential equation for DB variable

Landrace	Type of Packaging	Equation	SG(%) at 6th month	
			Testing	Equation
Sumedang	Alfoil	$y = 91.8664/(1+\exp^{((x-5.43623)/1.61247)})$	56	55.9
	PP	$y = 92.6205 / (1 + \exp^{((x - 6.32146) / 2.01133)})$	45	44.8
	Plastic sack	$y = 89.0609 / (1 + \exp^{((x - 4.0322) / 1.19404)})$	37	36.0
Sukabumi	Alfoil	$y = 749.343/ (1 + \exp^{((x + 16.5948) / 4.93457)})$	77	78.3
	PP	$y = 679.448/ (1 + \exp^{((x + 30.0652) / 16.219)})$	60	68.0
	Plastic sack	$y = 2921.14/ (1 + \exp^{((x + 88.689) / 193.493)})$	59	59.2
Gresik	Alfoil	$y = 96.4466/ (1 + \exp^{((x - 2.99022) /0.778764)})$	79	79.8
	PP	$y = 96.8416 / (1 + \exp^{((x - 2.43074) /0.829985)})$	77	77.7
	Plastic sack	$y = 1597.45 / (1 + \exp^{((x + 15.7881) / 3.84057)})$	75	73.9
Tasikmalaya	Alfoil	$y = 1262.28/ (1 + \exp^{((x + 48.0952) / 88.662)})$	62	63.1
	PP	$y = 3433.46 / (1 + \exp^{((x + 78.3115) /189.719)})$	48	49.8
	Plastic sack	$y = 135.281 / (1 + \exp^{((x - 4.04914) / 4.31028)})$	41	40.6

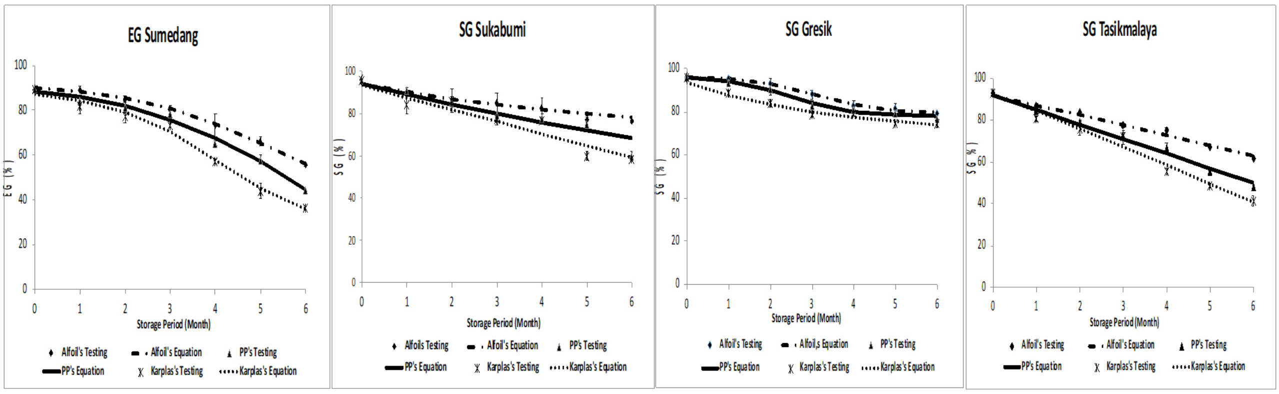

Figure 1. Fitting of the seed deterioration equation pattern with results of testing onSG variable

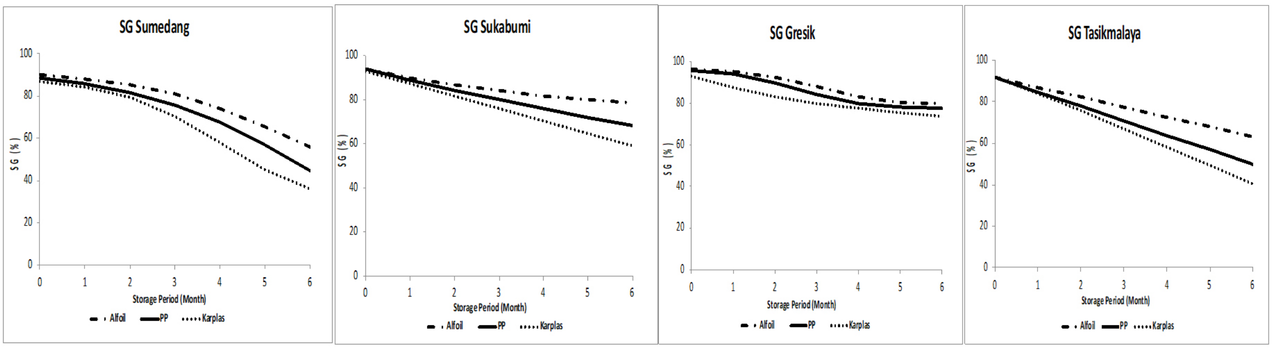

Figure 2. Seed deterioration behavior pattern with SG variable

It prevails on all landraces and all packaging that being used and it shows no difference between patterns resulted from equation and testing. Seed deterioration patterns with SG variable are presented in Figure 2.

In general, seeds deterioration behaviors that are kept in plastic sacks have lower SG than other packaging during storage period. Low permeability of packaging (aluminum foil) showed the highest SG. According to Putro (2012), aluminum foil has longer storability than polypropylene. It is due to aluminum foil has lower water vapor transmission and water vapor transmission than polypropylene and plastic sack.

The fastest deterioration by SG variable occurred on Sumedang landrace, as shown by faster rate of decline than with other landraces. Seeds deterioration with sigmoid line pattern comprise of two declining rates, faster and slower. Both declining rate patterns are restricted by anomaly points as critical points of seeds viability period. Different forms of line patterns are determined by the amount constants, which construct the equation.

Seed deterioration behaviors of four landraces on those three packaging types have sigmoid declining pattern with different declining rates. These differences are determined by the constant values of a, b, and c as presented in Table 3. The higher constant value of a, the higher declining rate will be before anomaly point. The higher value of b will reduce the deterioration rate after anomaly point with higher vigor by the end of storage period. Constant value of c contributes in increasing deterioration rate after the anomaly point.

Anomaly points on SG behavioral patterns of Sumedang and Tasikmalaya landraces were between storage periods 2 and 3 months. It showed that during the storage, the seeds will decrease sharply that indicated shorter storability. Gresik and Sukabumi landraces showed different result, the declining rate was not so fast, which indicated longer storability.

SG of Gresik landrace to the end of storage period was still above 75%. Gresik landrace used in this research was the product of purifying (F7), while other three landraces were derived from culturing products by local farmers. It is presumed that it caused Gresik landrace has higher SG. Research by Pillay (2003) showed that bambara groundnut, which has passed through purification, had better viability than the seeds derived from culturing product by the farmers. Gresik landrace has smaller seeds than other three landraces. Rasyid (2012) suggested that smaller seeds of soybean have slower declining rate of quality, so that they have longer storability. Furthermore, storability is affected by water content, temperature of the storage space, and characteristics of seeds are affected by genetic and environmental interactions during maturity to the harvest time (Walters *et al.* 2010).

EC Variable after the Seeds being Stored

EC behavioral patterns on all landraces and packaging types are presented in Table 4. Such behavioral patterns establish sigmoid function with different constant values for each equation. Different constant affects on the resulted shape of the equation line pattern.

The resulted patterns of the equation and testing will be fitting based on standard of deviation. Results of fitting between testing and equation are presented in Figure 3.

Almost all lines of the equation results include within range of deviation standard on each point of observation during storage period. It indicates that behavioral pattern of EC resulted from the equation may describe behavioral pattern of EC during the test. Seed deterioration patterns with EC variable are presented in Figure 4.

EC behavior shows that the longer storability, the higher EC values will increase. The increase patterns of EC were different on those four landraces. Different landrace showed different response on EC increase,

Table 4. Results of exponential equation for EC variable

Landrace	Type of Packaging	Equation	EC(μS.cm^{-1}.g^{-1}) at 6thmo	
			Testing	Equation
Sumedang	Alfoil	$y = -56.5224 / (1 + \exp^{((x + 14.3287) / 6.02724)})$	7.0	6.5
	PP	$y = 0.463066 / (1 + \exp^{((x - 1.86725) / 0.801414)})$	6.6	6.4
	Plastic sack	$y = 1.37051 / (1 + \exp^{((x - 2.79974) / 0.802216)})$	11.7	12.0
Sukabumi	Alfoil	$y = 1.69665 / (1 + \exp^{((x - 2.3811) / 0.331344)})$	7.6	7.3
	PP	$y = - 149.075 / (1 + \exp^{((x + 14.5471) / 6.00079)})$	9.5	9.3
	Plastic sack	$y = - 4.84463 / (1 + \exp^{((x - 0.460923) / 1.24385)})$	9.3	9.0
Gresik	Alfoil	$y = - 104.229 / (1 + \exp^{((x + 8.57083) / 2.70785)})$	5.3	4.7
	PP	$y = - 103.985 / (1 + \exp^{((x + 15.0014) / 5.53204)})$	7.8	7.3
	Plastic sack	$y = - 112.539 / (1 + \exp^{((x + 14.4792) / 6.05907)})$	9.6	9.0
Tasikmalaya	Alfoil	$y = - 66.4152 / (1 + \exp^{((x + 18.1409) / 9.21187)})$	6.9	6.4
	PP	$y = - 100.285 / (1 + \exp^{((x + 21.7885) / 10.2971)})$	7.3	6.9
	Plastic sack	$y = 0.622291 / (1 + \exp^{((x - 4.09364) / 1.80522)})$	10.0	10.2

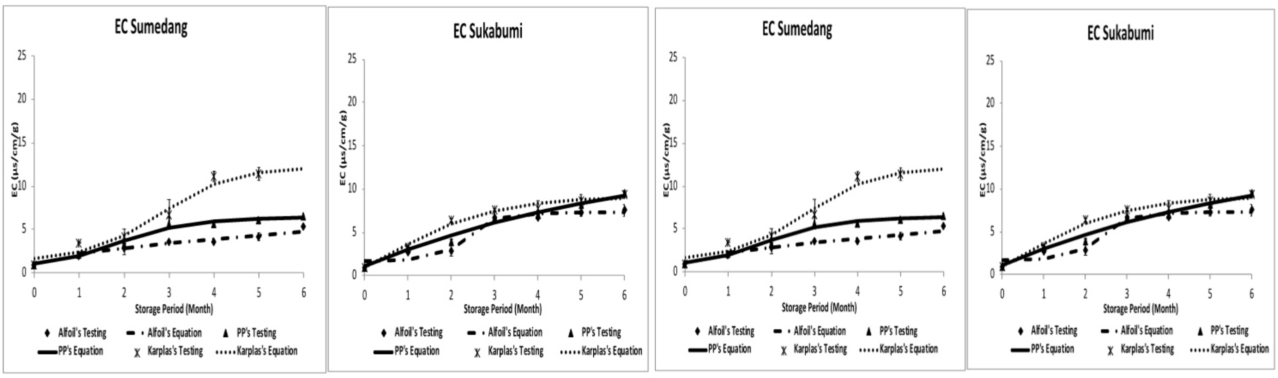

Figure 3. Fitting of the equation pattern of seed deterioration and outcomes of testing on EC variable

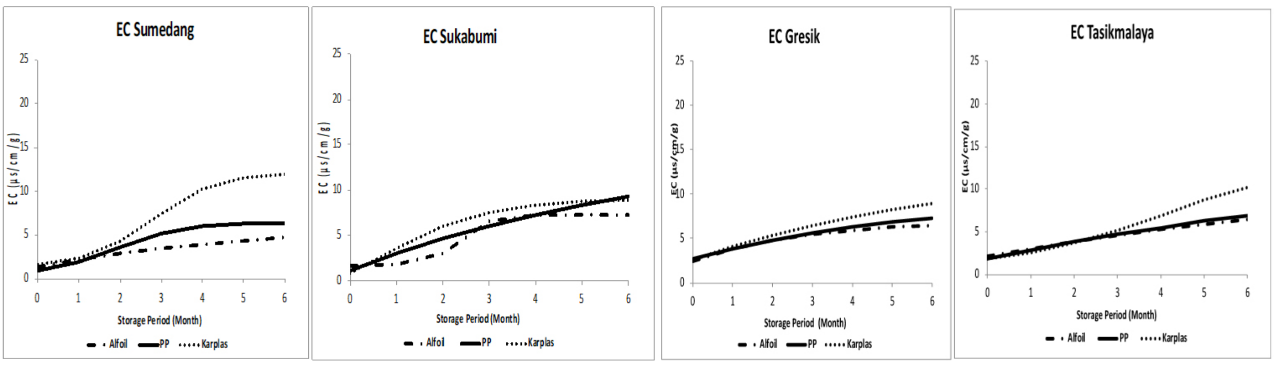

Figure 4. Seed deterioration patterns by EC variable

and it was presumed that it related to different chemical composition among landraces (Wahyuni, 2014). The higher increase of EC was on plastic sack, which has the highest permeability value for each landrace. The effects of plastic PP and aluminum foil permeability were not significantly different against the change of EC values, except on Sumedang landrace.

EC behavioral pattern of Sumedang landrace with plastic sack showed the fastest increase and followed by plastic PP and aluminum foil. EC behavioral patterns were inversely proportionate to deterioration rate, so that Sumedang landrace with plastic sack showed the fastest deterioration rate. The increase value of EC was seen after the second month, while during the previous storage period, it tended to increase sloping. Different shapes of line from EC behavioral pattern on Sumedang landrace were seen within 2 months-storage period. It also occurred on variable pattern of the SG during the same period of storage. EC is the preliminary indication of seed deterioration physiologically, which is marked by damages on cell membrane that finally affects on normal growth performance of the germinate.

EC behavioral patterns on Gresik and Tasikmalaya landraces have the similar patterns. Seeds, which were stored in plastic PP and aluminum foil, showed almost similar increase of EC, as described with line patterns that were very close together. EC behavioral pattern of Gresik landrace with plastic sack was above behavioral patterns of other packaging. EC behavioral pattern of Tasikmalaya landrace, which was kept in plastic sack, showed the same pattern with other packaging up to the period of 2.5 months, and then increase sharply. The anomaly point on behavioral pattern of Sukabumi landrace was on 3 month-storage period. It was shown by different lines, which tended to be sloping after the period. Seeds, which were stored in plastic sack and plastic PP, showed almost similar values of EC at the beginning and by the end of storage period that was shown by lines that were very close together at the point.

Size and testa color are factors that affect the increase of electrical conductivity. According to Wain-Tassi *et al.* (2012) small seeds of soybean may cause leakage of ions K^+, Ca^{2+}, and Mg^{2+}, which is lower than the big ones. Correlation between moisture content, organization on cell membrane of the seeds and amount of leakage in soaking agent solution of the seeds is basic theory of electrical conductivity test (Wain-Tassi *et al*. 2012). Low electrolyte leakage, which was released into the soaking agent solution of the seeds, indicates that seeds have high vigor (Carvalho *et al.* 2009).

CONCLUSIONS

General pattern of seed deterioration on bambara groundnut of Sukabumi, Sumedang, Gresik, and Tasikmalaya landraces is sigmoid by equation model of: y = a / (1 +exp $^{((x + b)/c)}$) in which a, b, and c are different constants on each landrace and type of packaging.

Seed deterioration pattern based on SG and EC variables on Sumedang landrace, which was kept in plastic sack, showed faster of deterioration rate pattern that indicated that Sumedang landrace has shorter storability.

Seed deterioration pattern based on SG and EC variables on Gresik landrace, which was kept in aluminum foil, showed slower of deterioration rate pattern that indicated that Gresik landrace has longer storability.

Research on such deterioration pattern can be utilized to determine seed storability an destablish vigor estimation model of seed storability of four bambara groundnut landraces.

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