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Capsicum annum L. Storability Vigor and Estimation of Its Genetic Parameters

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Abstract. One of the problems of horticultural seeds is the lack of quality of seeds. This experiment aims to evaluate the methods of rapidly pouring hybrid, non-hybrid, local, introduced cayenne pepper seeds and large quantities produced in 2014 and 2016. Non-hybrid seeds were 4 production genotypes in 2014 and 4 in 2016. The hybrid seeds used were 10 production genotypes in 2014 and 8 in 2016. The data analysis used is an analysis of the regression line's angle of inclination, which is the angle resulting from the comparison of the ordinate and abscissa. Based on the results of rapid pouring tests using 20% methanol for 0, 2-, 4-, 6- and 8-hour information, the storability of seeds produced in 2014 was better and higher than in 2016 Therefore, hybrid chili seeds and non-hybrid chili seeds have the same seed storability vigor, as well as between local vs introduced chili seed also large chili seed vs cayenne pepper.

Keywords: hybrid; natural deterioration; non-hybrid; rapid aging method; raw cayenne

INTRODUCTION

One of the problems with horticultural seeds is the lack of quality seeds. The availability of quality horticultural seeds, including chili (*Capsicum annuum* L.), in 2014 was 0.800 million tons. Compared to 2013, there was an increase in production of 86.98 thousand tons (12.19 percent). This phenomenon was due to an enhancement in productivity of 0.23 tons per hectare (4.04 percent) and in the harvested area of 9.76 thousand hectares (7.80 percent) compared to 2013. However, this increase was still unable to meet national needs. Moreover, the decline in seed quality during the seed trade system reached 25% per year.

The decline in seed quality during the commercial system is due to the seeds that were stored during the storage period often facing sub-optimum conditions, especially relative humidity (RH) even at room temperature (Barsha et al., 2021). Seed vigor is the ability of seeds to germinate normally under sub-optimum conditions. The vigor of the seeds determines their shelf life of the seeds (Siyum et al., 2022).

Information about testing the storability of seeds, especially for chili seeds which are fast, precise, and the best, is a source of reference in perfecting this research. The seed vigor testing method validated by ISTA (2007) (International Seed Testing Association) is the AA (accelerated aging) fast aging method and the conductivity test (electrical conductivity).

Amorim (2021), investigated the relationship between seed shelf life vigor and seed deterioration and found that rapid shrinkage techniques were compatible with reduced seed quality in high-temperature storage. Based on research by McLeod et al., (2023) on seed deterioration and rapid depreciation methods in chickpea seeds (Arabian Bean) showed that the seeds that faced the seed damage positively correlated with the seed that faced the rapid damage.

The vigor of seed storability is influenced by genetic factors and may be controlled by several genes (McKenzie et al., 2021). Seed storability vigor is a quantitative trait that has been affected by environmental factors during seed formation, harvest and storage (Madigal et al., 2020). The impact of genetics related to seed storability has been investigated in Arabidopsis sp. (Pessoa et al., 2015).

The methods of rapid aging of soybean seeds consist of several steps, i.e first soaking soybean seeds in 20% ethanol solution for 2 hours, second soaking seeds in 20% methanol

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liquid solution for 2 hours, and third soaking seeds in 75°C hot water for 70 seconds. These methods will be adopted as the method of this study for testing the vigor of chili seed storability.

Chili seeds' ability to maintain quality in storage is crucial for seed vigor and shelf life (Ahmed et al., 2022). However, testing chili seed vigor lacks a widely accepted method. Genetic factors heavily influence seed vigor, affected by environmental conditions. Despite the importance, genetic information on chili seed vigor remains insufficient. Estimating genetic parameters like additive variants and heritability is essential for understanding chili seed shelf life (Zhang et al., 2020). Developing a rapid aging test method holds promise for predicting chili seed vigor during storage, benefiting chili breeding programs seeking high storage capacity. Numerous prior studies have delved into vigor analysis in different crops, such as black soybeans examined by Purwanti (2014), maize (Zea mays L) studied by Taini (2019), and cabbage (*Brassica oleracea* L. var. capitata) investigated by Rosida et al. (2015). Consequently, this research holds potential to contribute significantly to chili breeding programs aiming for enhanced storage capacity. The primary aim of this study is to develop a rapid aging test method capable of predicting the vigor of chili seeds during storage, which would be invaluable for improving chili seed storage capacity (Thakur et al., 2022). Therefore, the purpose of this study was to analyze the vigor of chili seeds and the estimation of their genetic parameters because the need for quality chili seeds is still lacking, the quality of the seeds decreases during storage so that the chili seeds that have the spirit high storage capacity is needed.

METHODS

Time and Place of Research

The research was conducted from January 2014 to January 2016 in the Seed Science and Technology Leuwikopo experimental garden and the experimental garden of the Tropical Fruit Study Center Tajur, as well as the Seed Science and Seed Science and Technology Education Bogor Agricultural Institute Dramaga and Leuwikopo.

Plants Materials

The seeds used in this research are the big chili seeds genotype IPB C9 collection of the Plant Genetics & Plant Breeding, Plant Seeds of the Institut Pertanian Bogor, which have just been harvested.

Research Procedures

The seeds are sown using a tray previously filled with seedling medium. The chili peppers are soaked in warm water for 24 hours. The aim is to accelerate seed germination and separate sinking seeds from floating seeds. At the time of the seedbed, soil moisture, and air humidity are taken care of by watering every morning. Fertilization is carried out once every four days by applying NPK Mutiara and Gandasil fertilizers. Fertilizers are dissolved in water and then moderately poured on the plant's roots. Pesticide spraying is arranged once a week. Seedlings are transferred to the field if 4–5 true leaf blades have already appeared and are 4–5 weeks old.

Land processing is carried out two weeks before planting by loosening the soil and applying manure. The manufacture of beds is 11 m long, 1.5 m wide, and 0.5 m high. The basic fertilizers consist of Urea, with successive doses of 200, 150, and 150 kg.ha^{-1} that are applied five days before planting. The installation of silver and black plastic mulch is carried out, followed by making planting holes with a distance of 50 cm x 50 cm. In the three days before planting, watering is carried out to reduce the damage to the roots compared to the installation of water after transplanting. Planting in the field was carried out in early June 2014 when the seedlings were four weeks old with 4-5 leaf blades. Planting seedlings is carried out in the

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afternoon to reduce stress from exposure to solar heat. Embroidery of dead plants is carried out one week after planting (MST). A total of 10 plants were covered to avoid contamination with other genotypes.

Plant maintenance includes watering, weeding, wiping, pest and disease control, and fertilizing. The weeding is done by removing weeds and other nuisance plants around the main crop using a hoe. Pruning is carried out when there are already water buds on the armpits of the leaves and the main stem. Pest and disease control have to be done if there are any symptoms of pest and disease attacks. The prevention was done by spraying plants with pesticides once a week at the time of the vegetative phase and twice a week at the time of the generative phase.

Pesticide application is following the recommended dosage. Harvesting occurs when the fruit reaches 75% maturity until full maturity and is carried out gradually for eight weeks. After harvesting, the seeds are extracted using tweezers and a cutting knife and then air-dried for 3-5 days. The moisture content of the final seeds is 8-10%. Next, the seeds are ready for use for testing. Seeds are placed in an airtight container and put in a storage room at a temperature of 5–10 °C

Chili Seed Vigor Testing Method

The method of natural deterioration at room temperature with high humidity (RH 90-95%) was controlled in this study and was confirmed as a comparison method for determining the method of testing the vigor of chili seeds. This is due to the absence of a standard method for testing the vigor of chili seeds. A rapid depreciation method close to the comparison method will be chosen as a vigor testing method for the shelf life of chili seeds. All methods are simulations of circumstances occurring in nature. For example, the comparator is a simulation of the condition of seed marketing, and the rapid pouring method is a simulation of natural sub-optimum conditions.

Pepper seeds were large produced in 2014 and 2016, the year of seed production is a factor that reflects the conditions observed or controlled in the experiment. The rapid pouring methods developed are (1) the rapid depreciation method with a hot water temperature of 60°C, (2) the rapid pouring method with 20% methanol, (3) the rapid depreciation method with 20% ethanol, and (4) the rapid depreciation method in 40°C. Each treatment of the rapid depreciation and the comparison method was repeated three times with five time periods (TO, T1, T2, T3, and T4).

In this research, all chili seeds used in the rapid shrinkage method are first raised in moisture content from 8–10% to 22%. This was done based on pre-experiments (pre-basic research) that had been done The number of chili seeds per test is 750 seeds, so for three tests, it requires 2250 seeds. The experimental design used in this experiment was a randomized complete block design (RCBD). The formula for adding moisture content to seeds (Wang et al., 2004) is written in formula 1).

$$V = [(100\text{-}MCo/100\text{-}MCr) \times W]\text{-}W \quad \ldots\ldots (1)$$

Remarks:
V = (added water) (mL), MC = (initial ir moisture content) (%)
MCr = (Required KA) (%), W = (Seed weight) (g).

The implementation of the experiment is as follows:

1. A natural deterioration method at room temperature (27-30°C) with controlled RH (90-95%) (comparison method). Chili seeds are available in packs of up to 15 seeds. The Strimin plastic containing 150 seeds was put into a plastic container using saturated KNO salt (RH 90-95%) which was arranged in a storage room at room temperature 27–30°C (Pamungkas et al., 2018). Room temperature storage was carried out five times, which are T1 = 0 months, T2 = 3 months, T3 = 6 months, T4 = 9 months, and T5 = 12 months.

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2. Fast depreciation method with 60°C hot water. 15 Strimin plastic packs containing 150 seeds are put into a hot water solution at 60°C using an EYELA Type NTS-1300 seed water bath. The immersion times are: T1 = 0 seconds, T2 = 6 seconds, T3 = 120 seconds, T4 = 180 seconds, and T5 = 240 seconds.
3. A rapid method of depreciation with methanol. Chili seeds as many as 15 Strimin plastic packets containing 150 seeds soaked in 20% methanol solution at room temperature at 27-30°C five times, i.e., T1 = 0 hours, T2 = 2 hours, T3 = 4 hours, T4 = 6 hours, T5 = 8 hours.
4. A method of rapid depreciation with ethanol. Chili seeds, as many as 15 Strimin plastic bags containing 150 chili seeds soaked in 20% ethanol solution at room temperature 27-30 °C 5 times, i.e. T1= 0 hours, T2= 2 hours, T3= 4 hours, T4= 6 hours, T5= 8 hours.
5. A rapid depreciation method with a temperature of 40°C. The 15 Strimin packets of plastic containing 150 chillies were stored at high temperatures (40±0.1°C) using a physical rapid pouring tool temperature of 40°C RH > 90% five times, i.e. T1= 0 hours, T2= 24 hours, T3= 48 hours, T4= 72 hours, T5= 96 hours.

After the rapid removal of chili seeds, the viability and vigor of the seeds were tested by the test method on paper using Whatman paper (UDK) and a Petri dish measuring 8 cm in diameter, 25 seeds per Petri dish. Then, six pieces of Petri dish are put in a standard germinator alternating at a temperature of 25–30°C, seed buro type 1-800-284-5779 for 14 days.

Observations were made on the benchmarks of (a) seed germination power (DB), (b) radicular length (PR), (c) hypocotyledonous length (PH), (d) sprouting speed (KCt), (f) electrical conductivity (DHL) dan (g) index vigor (vigor index) (IV). The benchmark calculation is as follows:

1. The length of the radicula (PR) is measured from the base of the root to the tip of the root, using a calipers (cm) at 14 days after planting.
2. The length of the hypocotyledonous (PH) is measured from the base to the highest stem before the first leaf (epicotyl) at 14 days after planting.
3. Germination Power (DB) (06) is calculated by observing the percentage of the number of normal sprouts in the first and second calculations compared with the total number of seeds planted multiplied by 100 using formula 2 (Pamungkas, Supriyon, & Purwanto (2018):

$$DB(\%) = \frac{KN \rightleftarrows I \quad day-7+KN \quad II \quad hit \quad day-14}{\text{Total Planted Seeds}} x100\% \quad \ldots. (2)$$

Remarks:
KN I = Number of normal sprouts at the first count on the 7th day
KN II = Number of normal sprouts on the second count on the 14th day

4. Seed Growing Spee, was observed every day until the 14th day, for the number of normal sprouts and the difference in hours of each observation. KCT is calculated by the formula 3 (Sachs et al., 2022).

$$K_{CT} = \sum_0^{14} d \quad \ldots. (3)$$

Remarks: d = Percentage of normal sprouts that grow on planting day per etmal (24 hours)

5. Vigor Index (%), calculated on the basis of the percentage of normal sprouts on the first count with the formula 4.

$$IV\ (\%) = \frac{KN\ I}{Total\ planted\ seeds}\ x\ 100\% \quad \ldots. (4)$$

Remarks: KN1 = Normal number of sprouts on the first count on the 7th day

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6. Electric Conductivity is measured in the following way, after a quick depreciation treatment, the seeds are weighed, then put into a cup containing 25 aquadest noodles and covered with aluminum foil, after being left for 6 hours at a temperature of around 10°C (Agustiansyah et al., 2021). The seeds are filtered and the aguabides from soaking the seeds are measured DHL. Each of the treatments is repeated three times.

The determination of the best method is carried out by the following analysis (Harti et al., 2020). Selection of the best method determination:

1. based on the results of the diversity analysis of the viability and vigor data of chili seeds, all methods whose F test analysis results are real and have a (diversity coefficient) (KK) < 10% value of < 10% are selected and analyzed in the second stage.
2. Based on the results of Duncan's further test (DMRT) the viability and vigor of chili seeds in all methods to see how much effect the length of time of removal was on the decrease in vigor and viability of chili seeds.
3. The vigor data and viability of selected chili seeds in the second stage were analyzed through regression. The regression analysis results were selected with an R-Square value > 80%. The three analyses are controls to determine the best vigor testing method for the shelf life of chili seeds.
4. The t-test was carried out to see the rate of decrease in the vigor of chili seeds between the comparison method and the rapid depreciation method based on the angle of inclination of the vigor reduction rate line.
5. the simulated t-test results were selected as the best Rapid depreciation method close to the comparison method. The last stage is carried out recapitulation of the results and scoring of the results of the analysis, the method whose highest score was selected as a method of testing the shelf life of chili seeds.

RESULTS AND DISCUSSION

Natural Deterioration Method at Room Temperature with controlled RH (90-95%) (Comparison Method)

This study's natural deterioration method was at room temperature (comparison method) with controlled RH. This method carries environmental conditions similar to the extreme storage temperature conditions at the time of seed marketing, namely 27-30 °C, RH 90-95%. (Israel García-López et al., 2018) stated that the method of natural deterioration at room temperature can be used a comparison method in deterioration of seed. The comparison method was carried out for a year (12 months), but it turned out that the viability of seeds was only able to last six months, so viability and vigor data were produced at 3 points, namely 0, 3, and 6 months. Seed deterioration at RH 90-95% causes chili seeds faster physiological damage. According to (Amorim et al., 2021), Humidity and hot temperatures can encourage growth of fungi. It can damage the components of the seed and can affect the quality of the seed.

Whipping on the high room temperature and long curing time have an important role to reduce the seed viability thereby spurring seed metabolic processes which will result in depleting seed coat permeability. According to Elsima (2019), seeds are living things that, when stored under sub-optimum conditions (high temperature and RH), there is a process of catabolism, namely lipid peroxidation, which results in membrane damage to produce toxic by-products that cause the seeds to experience vigor decrease. Oxidative damage to DNA and proteins in cells results in a decrease in seed vigor during the shelf life (Chin et al., 2022). Pepper seeds and large produced in 2014 and 2016, the year of seed production was a factor that reflects the conditions observed or controlled in the experiment. Seed production years (2014 and 2016) were included as control factors, which

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are variables that are observed or controlled so as not to influence the experimental results, so that observed differences can be appropriately attributed to the treatment factors being evaluated.

Selection of a Quick Depreciation Method

This study is expected to produce at least one rapid depreciation testing method to suspect the vigor of chili seeds. The analysis of seed vigor requires several physiological, mathematical, biochemical or statistical approaches (Kusumawardana et al., 2018).

The resulting viability and vigor data were tested using the F test (variance analysis) in the first analysis. Real viability and vigor data with a diversity coefficient (KK) of < 10% are considered to pass the selection at the first stage of the analysis (Table 1). The comparison method, the method of rapid depreciation with hot water (60°C), methanol, ethanol, and temperature (40°C) had a noticeable effect (F test) on the viability and vigor of chili seeds on almost all observed benchmarks, except radicular length in the comparison method, rapid depreciation with hot water and temperature of 40°C. At this stage, the selection of KK < 10% after the selection of real F test results (Table 1).

The selection results showed that rapid depreciation using methanol was the best method. Another fairly good method is rapid pouring in 60°C hot water with the same benchmark as the method of rapid pouring using methanol, except on the PR.

The second analysis was carried out by further testing the Duncan Multiple Range Test (DMRT) (Table 2). The comparison method of rapid irradiation with hot water, methanol, ethanol, and at high temperatures showed a linear decrease in almost all observed benchmarks and caused physiological damage to the seeds of chili peppers. The selection results show that the method of rapid depreciation of methanol is correct.

Another fairly good method is the method of rapid pouring with 60°C hot water with the same benchmark as the method of pouring methanol, except for the radicular length benchmark.

The third is a regression analysis of all treatment methods at the selected benchmark to see the value of the coefficient of determination R-Sq/R2 > 80%. The value of the coefficient of determination is high, indicating a close quantitative relationship between the treatment and the observed benchmark. The method with a benchmark with an R-value of 2 > 80% is the rapid depreciation method with 60°C hot water, followed by the rapid depreciation method with methanol and at high temperatures (Table 3).

The results can be used as a reference for the selection of rapid depreciation methods known as the best in the study. Furthermore, in the fourth analysis, a t-test was carried out to see the difference between the comparison method and the rapid depreciation method (hot water, methanol, and ethanol, as well as at high temperatures).

The fourth analysis is a t-test between the rate of decrease in vigor shelf life of seeds compared method with four other methods. The t-test was carried out against the angle of inclination of the regression line to represent the rate of decrease in the vigor of the shelf life of chili seeds. The results showing the same unreal angular magnitude with the comparison method showed no difference between the comparison method and the rapid depreciation method. The hybrid seeds used were 10 production genotypes in 2014 and 8 in 2016, iIntroduced and local cayenne pepper seeds and largely produced in 2014 and 2016.

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Table 1. Analysis of viability and vigor of chili seed vigor testing methods

Treatment	Benchmark	F value	Pr>F	Influence	KK	Mean
Controlled RH deterioration method at room temperature (Moon comparison method)	PR (mm)	13.82	0.02	*	34.76	41.59
	PH (mm)	7.07	0.08	ns	34.93	15.52
	BK (g)	58.99	0.00	**	17.09	0.68
	DB (%)	52.30	0.00	**	6.44	56.66
	KCT (%/etmal)	775.87	0.00	**	6.68	0.28
	DHL (mmhos/cm/g)	340.85	0.00	**	8.29	329.57
						46.67
	IV (%)	555.26	0.00	**	7.63	
Quick mastery with hot water (minutes)	PR (mm)	18.75	0.18	ns	12.79	64.99
	PH (mm)	2.02	0.00	**	9.24	23.30
	BK (g)	448.59	0.00	**	2.35	0.78
	DB (%)	31.03	0.00	**	6.01	86.40
	KCT (%/etmal)	171.24	0.00	**	7.70	0.30
	DHL (mmhos/cm/g)	15691.00	0.00	**	7.55	33.92
	IV (%)	111.46	0.00	**	1044.00	1983.73
Fast aging with 20% methanol (hours)	PR (mm)	28.50	0.00	**	14.87	40.92
	PH (mm)	6.01	0.02	**	6.29	24.71
	BK (g)	61.25	0.00	**	9.78	0.60
	DB (%)	17.43	0.00	**	5.98	86.40
	KCT (%/etmal)	454.27	0.000	**	2.90	0.42
	DHL (mmhos/cm/g)	4.30	.04	**	7.81	33.92
	IV (%)	29.17	0.00	**	15.82	6.93
Controlled deterioration at high temperatures (hours)	PR (mm)	11.80	0.00	**	15.04	70.20
	PH (mm)	2.19	0.16	ns	8.76	22.57
	BK (g)	2705.47	0.00	**	2.34	4.03
	DB (%)	6.91	0.01	**	7.61	79.73
	KCT (%/etmal)	7.11	0.01	**	20.63	0.55
	DHL (mmhos/cm/g)	135.88	0.000	**	9.33	36.64
	IV (%)	33.38	.00	**	19.37	44.93
Rapid evaporation with ethanol (hours)	PR (mm)	45.85	0.00	**	11.47	41.67
	PH (mm)	8.02	0.01	**	8.17	26.21
	BK (g)	21.47	0.00	**	14.7	0.64
	DB (%)	7.85	0.01	**	7.02	86.13
	KCT (%/etmal)	10.97	0.000	**	42.97	0.26
	DHL (mmhos/cm/g)	719.24	.00	**	8.97	8.60
	IV (%)	41.73	0.00	**	15.13	55.60

Remarks: DHL = Electrical conductivity; PR = Radicular length; PH = Length of hypocotyl; IV = Vigor index; BK = Sprout weight; KK = Coefficient of diversity; DB = Germination power; * = different at the test level of 5%; TU = Benchmark; Kct = Growing speed; ** = different at the test level of 1%; ns = non-significant

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Table 2. The average middle value of all chili seed vigor testing methods

Treatment	Time	PR (mm)	PH (mm)	DB (%)	KCT (%/etmal)	DHL (mmhos/cm/g)	IV (%)
Natural deterioration (months)	0	54.95a	22.50a	98.67a	0.59a	3.44a	96.67a
	3	50.13a	17.72ab	67.33b	0.24b	422.27b	67.33b
	6	48.08a	6.31abc	0.00c	0.00c	563.00c	0.00c
Quick mastery with hot water (minutes)	0	102.60a	22.51a	98.67a	0.59a	3.44a	96.67a
	1	54.95b	22.47a	94.67ab	0.43b	18.11b	60.00b
	2	48.82b	21.79a	93.33ab	0.28c	36.04c	4.67bc
	3	48.50b	23.43a	88.00b	0.27c	49.28d	29.33c
	4	49.47b	23.28a	57.33c	0.08d	62.73c	14.67d
Rapid evaporation with methanol (hours)	0	74.63b	22.50b	98.67a	0.59a	3.44a	96.67a
	2	30.11a	22.52b	84.00b	0.57b	7.63ab	96.00ab
	4	23.49b	25.04b	78.67b	0.35b	7.80b	86.67b
	6	25.28b	27.56a25	77.33b	0.31b	10.90b	53.33c
	8	29.66a	.90b	66.67c	0.28c	9.27b	16.00d
Fast aging at high temperature (hours)	0	60.54a	22.50b	98.67a	0.59a	3.44a	96.67a
	24	55.96a	23.49ab	86.67b	0.79a	32.60b	24.00cd
	48	54.95a	28.63a	86.67b	0.77a	42.76c	25.33c
	72	53.60a	28.16a	80.00c	0.44a	54.36d	58.67b
	96	51.12a	23.67a	74.67d	0.31a	77.57c	25.33c
Rapid evaporation with ethanol (hours)	0	60.54a	22.50b	98.67a	0.59a	3.44a	96.67a
	2	55.96a	30.11a	90.67ab	0.31b	3.52a	66.67b
	4	54.95a	23.49b	85.33b	0.03d	3.06a	64.00ab
	6	46.19ab	25.28b	84.00b	0.11c	3.02a	36.00c
	8	38.16b	29.66a	72.00c	0.26ab	29.63b	14.67d

Remarks: the numbers followed by the same letter in the same column show no real difference; DHL = (Electrical conductivity); PR = (Radicular length); PH = (Length of hypocotyl); IV = (Vigor index); BK = (Sprout weight); DB = (Germination power); Kct = (Growing speed).

The result means that the rapid depreciation method shows the exact value of the rate of decrease in vigor as the comparison method. The result of the most unrealized test was the rapid depreciation method with methanol, followed by the rapid depreciation method with 60°C hot water (Table 4).

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Table 3. Recapitulation of the results of the benchmark regression analysis of all chili seed vigor testing methods

Treatment	benchmark	Regression equation	R-Sq (%)
Comparison method (month)	DB (%)	DB = 106 – 50.00 time	96.33
	KCT (%/etmal)	KCT = 0.583 – 0.30 time	98.60
	DHL (mmhos/cm/g)	DHL = 32.40 + 289 time	91.90
Fast drying with hot water 60°C (minutes)	IV (%)	IV = 93.30 – 48.0 time	99.30
	BK (g)	BK = 1.05 – 0.14 time	96.53
	DB (%)	DB = 102 - 6.00 time	56.17
Rapid evaporation with methanol (hours)	KCT (%/etmal)	KCT = 0.56 – 0.12 time	94.83
	DHL (mmhos/cm/g)	DHL = 2.21 + 15.30 time	99.00
	PH (mm)	PH = 21.70 + 0.75 time	61.50
	BK (g)	BK = 0.88 – 0.68 time	58.90
Controlled deterioration at 40°C (hours)	DB (%)	DB = 96.00 – 3.80 time	82.93
Rapid evaporation with ethanol (hours)	KCT (%/etmal)	KCT = 0.59 – 0.05 time	81.47
	DHL (mmhos/cm/g)	DHL = 4.52 + 0.64 time	62.90
	BK (g)	BK = 0.81 + 0.67 time	74.37
	DB (%)	DB = 96.80 + 0.23 time	96.33
	DHL (mmhos/cm/g)	DHL = 8.12 + 0.71 time	91.90
	PH (mm)	PH = 24.20 – 10.60 time	14.67
	DB (%)	DB = 106 – 50.00 time	80.87
	DHL (mmhos/cm/g)	DHL = -1.49 + 2.48 time	47.60

Remarks: PH = (Hypocotyl length) ; BK = (Sprout weight); DB = (Germination) KCT = (Growing speed); IV = (Vigor Index), DHL = (Electrical conductivity); RSq = R (R regression line)

The following analysis is a recapitulation of the results of the one to four analyzes, which are based on the real F test, the KK value < 10%, R-Sq > 80%, and the t test of the regression line angle compared to the regression line angle of the comparison method (Table 5). The results show that the most common measuring angles with the comparison method are the methanol rapid aging method (total score selected 12) followed by the rapid aging method with hot water (total score selected 11).

This is caused by the decrease in seed vigor due to the seed degradation of the membrane. Membrane degradation causes (1) indicated by increasing the value of electrical conductivity (DHL), (2) loss of energy needed in the biosynthesis process and increased respiration speed, (3) the food reserves in the embryo are depleted, (4) viability and vigor of seeds decrease, (5) loss of resistance in environmental stress conditions, and (6) accelerate the process of deterioration (Ernawati, Rahardjo, & Suroso (2017); Pathak, et al. (2010) dan Soltani et al. (2010).

This is supported by the research of Faso (1985) on soybean seeds soaked in 20% ethanol solution or 20% methanol solution and 75°C hot water for 70 seconds. So, in conclusion, immersion in methanol solution is the best method to predict seed deterioration of soybean varieties compared to other soybean seeds.

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Table 4. T test results between standard methods and 4 chili seed vigor testing methods Benchmark Angle (°)

Treatment	Corner BK	Corner DB	Corner KCT	Corner DHL	Corner IV
Comparison method (month)Fast drying with hot water (minutes)	28.61	28.45	29.80	28.20	27.24
	19.98 *	22.24 ns	28.58 ns	27.17 ns	30.58 ns
Rapid evaporation with methanol (hours)	21.31 ns	27.24 ns	28.78 ns	24.47 ns	27.64 ns
Controlled deterioration at high temperature (hours)Rapid evaporation with ethanol (hours)	11.02 *	27.93 ns	17.46 *	27.57 ns	23.36 ns
	6.11 **	27.6 ns	13.16 *	16.43 *	27.72 ns

Remarks: BK = (Sprout weight); DB = (Germination); Kct = (Growing speed); (Vigor Index), DHL = (Electrical conductivity); ns = non-significant; * = significant (α= 5%) and ** = very significant (α= 1%)

Table 5. Summary of test analysis results on the development of chili seed vigor testing methods for KK(%), R-Sq(%) and t-test (°) values

Treatment	PH			BK			DB			KCT			DHL			IV			TOTAL
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Rapid depreciation with methanol	V	X	X	V	X	V	V	V	V	V	V	V	V	X	V	X	X	V	12
Rapid depreciation with hot water	X	X	X	V	V	X	V	V	V	V	V	V	V	V	V	X	X	V	11
Rapid depreciation with high temperatures	X	X	X	V	X	X	V	V	V	X	X	X	V	X	X	X	X	V	6
Rapid depreciation with ethanol	V	X	X	X	X	X	V	V	V	X	X	X	V	X	X	X	X	V	6

Remarks: BK = (Sprout weight); DB = (Germination); Kct = (Growing speed); IV = (Vigor Index); DHL = (Electrical conductivity); (1) = KK < 10%; (2) R-Sq > 80%; (3) = Angle (°); X = Ineligible to be selected; V = Eligible to be selected; TOT = Number of qualified to be selected; Sdt = (angle of inclination of the varying regression line); R-Sq = (Regression line correlation value); KK = (Coefficient of diversity of analysis).

CONCLUSION

Based on the results of rapid pouring tests using 20% methanol for 0, 2-, 4-, 6- and 8-hour information. Therefore, hybrid chili seeds and non-hybrid chili seeds have the same seed storability vigor, as well as between local vs introduced chili seed also large chili seed vs cayenne pepper.

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