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Research Article

Viability And Vigor Of Rice Varieties (Oryza Sativa L.) in High Temperature

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Abstract

The growth and initial development of the plant greatly determines the survival of the plant at the next stage. This initial phase is also the most sensitive phase of abiotic stress. The level of viability and vigor to produce normal sprouts can explain the success of germination. The aim of this research is to study the temperature change to viability and vigor in four rice varieties. Research started from January to February 2018 at Seed Technology and Plant Physiology Laboratory Andalas University and Chemistry Laboratory University Of Padang. This research applies Factorial Experiment in Completely Random Design, where the first factor is four levels of rice varieties, Anak Daro, Batang Piaman, Cisokan and Inpari 30. The second factor is temperature level, 28 0C, 32 0C, 36 0C, 40 0C, 44 0C and 48 0C. Viability and vigor decrease when temperature increase. The optimum temperature for rice germination is 28-32 0 C for Anak Daro, 28-36 0 C for Cisokan, at 28 0 C for Batang Piaman and Inpari 30. Anak Daro and Inpari 30 can germinate until 40 0C. The highest vigor index value at 28 0 C in Cisokan and Inpari 30 (89,33 %). At 28-32 0C Cisokan, Batang Piaman and Inpari 30 has been able to germinate on the second day after planting, but Anak Daro can normal germinate on the third day after planting.

Keywords: Seeds, Germination, Growth, Temperature Stress, Tolerance

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Introduction

Rice includes food crops which are consumed most by the world population with needs that are increasing every year due to population growth. Based on data from Badan Pusat Statistik (2010) explain the population increase of Indonesia in 2010 is 205.1 million increased to 273.2 million in 2025, so expected in 2025 rice production should reach 73 million tons of milled dry grain with an increase of 0,85%/ year (Deptan, 2010). Abiotic factors such as climate change affect the increase in rice production.

One of the factors causing climate change is the burning of fossil fuels which increases the concentration of CO2 in the atmosphere. CO2 held in the atmosphere makes the temperatures increase. The other factor is ENSO (El Nino-Southern Oscillation) and IOD (Indian Ocean Dipole) as a result of the interaction between the sea and the atmosphere affects the rain and temperature variability in Indonesia (Rahman et al., 2011). El Nino and La Nina phenomena affect plant productivity, where El Nino can reduce food productivity such as rice, secondary crop and corn, while the La Nina increases the productivity of plant (Irawan, 2006).

Based on Intergovernmental Panel on Climate Change (2007) report the temperature increase as 0,76 0C from 1850-1899 until 2001-2005. According to BMKG the annual temperature increase in the Maluku and Papua is 0,3 0C, Kepulauan Riau 0,022 0C, Bangka Belitung 0,036 0C, Jambi 0,015 0C, North Sumatera 0,028 0C and West Sumatera is 0,213 0C (BMKG, 2017). The growth and initial development of a plant greatly determines the survival of plants at the next stage. If seed fails to germinate so there is no life. Morphologically, normal seedlings are produced from the growth of the radicles and plumula that are perfect due to divisioncells followed elongation and enlargement cell (Sutopo, 1993). Based on Soepandi's research (2014) temperature stress for a long time can cause cell damage so the cell cannot develop properly and seed not could germinate.

The percentage of seed vigor index depends on changes in seed metabolism at high temperature. According to Yoshida (1978), the critical temperature for germination of rice is 45 0C, while for growth and development of sprouts at 35 0C. Therefore this research needs to be carried out as basic science to study plant responses to temperature stress and obtain high temperature resistant varieties for further research.

Materials and Methods

Research started from January to February 2018 at Seed Technology and Plant Physiology Laboratory Andalas University and Chemistry Laboratory University Of Padang. This research applies Factorial Experiment in Completely Random Design, where the first factor is four levels of rice varieties, Anak Daro, Batang Piaman, Cisokan and Inpari 30. The second factor is temperature level, 28 ^{0}C, 32 ^{0}C, 36 ^{0}C, 40 ^{0}C, 44 ^{0}C and 48 ^{0}C. Each experimental unit consisted of 50 seeds using a rolled paper power test method. The data were analyzed by the F test in 5% and continued by Duncan's New Multiple Range Test in 5%.

Viability and vigor testing is carried out to determine the initial physiological quality of the seed. Rice seeds are soaked in water for 24 hours and left for 2 hours (Novriandi, 2013). Seeds are arranged on moistened paper (3 replications). After that, the paper is rolled horizontally and all test units are included in the germinator to maintain optimal germination conditions. Then observing the strength of rice sprouts was carried out on days 5 and 14 (ISTA, 2004). Seed rice that grows normally, abnormally and dead seeds are observed by studying morphology.

a. Germination Test (GT)

Germination Test was calculated from the first observation on day 5 and the second observation on day 14 (ISTA, 2004), calculated the percentage of normal germination with the following formula :

$$GT = \frac{\sum Seeds\ that\ germinate\ normally\ \ I+II}{\sum All\ seeds\ germinated} \times 100\%$$

b. Sprout Water Content (SWC)

Normal sprouts aged 14 days after planting were cleaned from the remaining seeds/cotyledons which were then dried in an oven at 80 ^{0}C for 24 hours, then put in a desiccator for ± 30 minutes and weighed (ISTA, 2004), calculating the moisture content of the sprouts with the following formula :

$$SWC = \frac{K1-KO}{KO} \times 100\ \%$$

K_1 = initial weight of sprouts before oven (fresh weight sprouts)
K_0 = the final weight of sprouts after oven (sprouts weight dry)

c. Maximum Grow Potential (MGP)

The maximum growth potential is calculated based on the percentage of seeds that are able to become normal or abnormal sprouts at the last observation (day 14) per number of seeds planted (ISTA, 2004), calculated the percentage of MGP with the following formula :

$$MGP = \frac{\sum Seed\ that\ germinate\ normally}{\sum All\ seeds\ germinated} \times 100\ \%$$

d. Growth Rate (GR)

Tests are carried out by observing the number of normal sprouts that appear every day from the first day to the 14th day of observation. The growing rate is calculated by the following formula:

$$GR = \sum_{i=1}^{14} d$$

Information:
GR : The seed growth rate (%/etmal)
d : Additional percentage of normal sprouts per etmal (1 etmal = 24 hours)

e. Vigor Index (VI)

The vigor index is calculated based on the percentage of normal sprouts on the first count (5 days after planting) (ISTA, 2004), calculated as the percentage of vigor index with the following formula :

$$VI = \frac{\sum Seed\ germinate\ normally\ count\ I}{\sum All\ seed\ germinated} \times 100\%$$

Results and Discussion

Based on variance on the 5% level, the germinate under high temperature and variety gave a real interaction, germination test, Water Content of Sprouts, Maximum Growth Potential, Growth rate and Vigor Index shown in Table.

a. Germination Test

Germination test needs to know the viability of seed in optimum condition. The viability of seed can be seen in Table 1.

Table 1. Germination Test of Four Varieties in Temperature Stresses

Temperature (^{0}C)	Varieties			
	Anak Daro	Batang Piaman	Cisokan	Inpari 30
	------ (%) ------			
28	80,09 ABb	87,67 Aa	87,66 Aa	85,61 Aa
32	84,33 Aa	77,33 Bb	80,67 Bab	78,00 ABb
36	77,33 ABab	74,00 Bb	80,34 Ba	72,00 ABb
40	44,33 Ba	0,00 Cc	0,00 Cc	33,34 Bb
44	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca
48	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca

Information : The numbers followed by lowercase letters in the same row and uppercase letters in the same column are not significantly different according to the DNMRT test at the level of 5%.

Based on Table 1 it is explained that at 28 ^{0}C the Batang Piaman variety has the highest germination (87.67%). At 32 ^{0}C Anak Daro has the highest germination strength of 84.33% and at 36 ^{0}C Cisokan has the highest germination (80,34%). At 40 ^{0}C the highest germination was Anak Daro 44.33%, while at 44 ^{0}C and 48 ^{0}C there were no seeds that could germinate normally.

Anak Daro has the highest normal germination at 32 ^{0}C is 84.33%, but when the temperature increases the normal germination decreases. Batang Piaman, Cisokan and Inpari 30 show that germination decreases with increasing temperature. According to Sadjad (1993) seeds that have normal germination > 80% means they have a high level of seed viability. Varieties that have more than 80% germination are Anak Daro at 28 ^{0}C and 32 ^{0}C, Batang Piaman and Inpari 30 only at 28 ^{0}C, while Cisokan has a percentage of normal sprouts of more than 80% at 28 ^{0}C, 32 ^{0}C and 36 ^{0}C.

The difference in varieties also determines the level of tolerance to high temperature stress. Anak Daro has increased germination when the temperature increases from 28 ^{0}C to 32 ^{0}C, then when the temperature increases again the germination decreases. So the optimum temperature for growth and development of Anak Daro is 32 ^{0}C, when the temperature exceeds that the seed viability decreases as a result of disturbance of the morphological and physiological processes of the sprouts in high temperature stress. Similar to Yoshida's statement (1981) that the temperature of 25 ^{0}C is optimal for radicular cell division and 30 ^{0}C for a radicular extension.

Batang Piaman and Cisokan only grow normally to 36 ^{0}C, while Anak Daro and Inpari 30 can grow normally to a temperature of 40 ^{0}C, although with a low germination rate (40-60%). This result is the same with the report from Yoshida's (1978) that the optimum temperature for growth and development of rice sprouts is between 25-30 ^{0}C. According to Myers *et al.,* (2017) that the temperature around 3 0 ^{0}C (86 ^{0}F) is optimum for food crop growth. The same results were also expressed by Yin *et al.*, (1996) the optimum temperature for normal growth of rice plants ranged from 27-30 ^{0}C.

According to Soepandi (2014) the initial effect of high temperature stress is more fluid lipid bilayer on the plasma membrane. In a long time it will certainly cause damage to the plasma membrane and cell death, therefore at temperatures of 44-48 ^{0}C the rice of Anak Daro, Batang Piaman, Cisokan and Inpari 30 cannot germinate. Each variety certainly has a different arrangement of amino acids, this will also cause different responses to enzyme activity. Amino acid changes in several genes responsible for rice synthesis also influence the diversity of rice palatability (Lestari *et al.,* 2012). Differences in the ability of rice genotypes from the four tested varieties need further research at the molecular level so that resistance genes can be found in Anak Daro and Inpari 3 0 varieties which can still grow at 40 ^{0}C, because there are no reports that analyze gene resistance to pressure high temperature in this variety.

Sprouts that grow abnormally only around 11-18% and sprouts die as much as 4% at a temperature of 28 ^{0}C. At 44 and 48 ^{0}C, the fungi are attacked after the third day and the fifth day all tested seeds have been attacked by fungi. Rotten seeds and cannot germinate are considered dead seeds. Growth and development of sprouts must be supported by good anabolic and catabolic reactions. Disorders of metabolic processes and catabolism in seeds when germination will inhibit the development of morphology and physiology (Mugnisyah and Setiawan, 1995).

b. Sprout Water Content

Rice varieties tested with high temperature stress treatment gave a real interaction with the water content of the sprouts (Table 2).

At a temperature of 28 ^{0}C, Cisokan has the highest water content (17.4 0%) which is not significantly different from the Batang Piaman (17.22%). At 32 ^{0}C and 36 ^{0}C Anak Daro had the highest sprout water content of 14.35% and 12.51%. At 40 ^{0}C Anak Daro also have the highest sprout water content (10, 9 1%) which is not significantly different from Inpari 30 (10,63%). There is no seed can germinate in 44 ^{0}C and 48 ^{0}C.

Anak Daro, Batang Piaman, Cisokan and Inpari 30 has the highest water content at 28 ^{0}C, when the temperature increases, the water content of the sprouts decreases. High temperatures can reduce the availability of water for plants because of the increase of transpiration and the volume of plant water consumption.

Table 2. Sprout Water Content Rice In High Temperature

Temperature (^{0}C)	Varieties			
	Anak Daro	Batang Piaman	Cisokan	Inpari 30
	------ (%) ------			
28	15,71 Aab	17,22 Aa	17,40 Aa	15,00 Ab
32	14,35 Aa	13,34 Ba	12,90 Ba	13,33 Ba
36	12,51 Ba	12,22 Ba	12,30 Ba	11,76 Ba
40	10,91 BCa	0,00 Cc	0,00 Cc	10,63 BCa
44	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca
48	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca

Information : The numbers followed by lowercase letters in the same row and uppercase letters in the same column are not significantly different according to the DNMRT test at the level of 5%.

Increased plant transpiration occurs to avoid the adverse effects of high temperature stress (Takahashi *et al.*,2008). Based on the research results Sances-Reinoso *et al.,* (2014) showed that the treatment of the temperature at 35 ^{0}C increase transpiration three varieties of rice compared to 25 ^{0}C temperature treatment.

c. Maximum Grow Potential

Maximum growth potential is a measure of total viability in seeds, where seeds have the ability to germinate and the metabolic processes.

Table 3. Maximum Grow Potential Four Varieties of Rice in Temperature Stresses

Temperature (^{0}C)	Varieties			
	Anak Daro	Batang Piaman	Cisokan	Inpari 30
	------ (%) ------			
28	86,47 ABa	92,00 Aa	90,00 Aa	90,33 Aa
32	93,67 Aa	91,00 Aa	92,66 Aa	93,66 Aa
36	82,00 ABb	88,33 Aab	92,67 Aa	87,67 Aab
40	64,00 Ba	0,00 Bb	0,00 Bb	58,00 Ba
44	0,00 Ca	0,00 Ba	0,00 Ba	0,00 Ca
48	0,00 Ca	0,00 Ba	0,00 Ba	0,00 Ca

Information : The numbers followed by lowercase letters in the same row and uppercase letters in the same column are not significantly different according to the DNMRT test at the level of 5%.

At 28 ^{0}C it can be seen that Batang Piaman has the highest percentage of maximum growth potential, which is 92% and not significantly different from the Cisokan and Inpari 30. At 32 ^{0}C shows the results of Anak Daro having the highest maximum potential growth percentage, which is 93.67%. At 36 ^{0}C Cisokan has the highest maximum growth potential (92.66%), while at 40 ^{0}C Anak Daro has the highest maximum growth potential (64%).

The seed of Anak Daro has the highest maximum growth potential at 32 ^{0}C (93.67%) which has increased from 28 ^{0}C (86.47%), but the percentage of PTM decreases at 36 ^{0}C and 40 ^{0}C. Sadjad (1993) states that seeds that have high growth potential can produce tough plants in the field even though the growth environment is not optimal. Batang Piaman showed that the decrease percentage of maximum growth potential when the temperature is increasing with the percentage of the highest maximum growth potential is 92% at 28 ^{0}C. This is different from the Cisokan, where the higher the temperature, the percentage of maximum growth potential also increases is 90% at 28 ^{0}C increasing to 92.66% at 32 ^{0}C and increasing again to 92.67 % at 36 ^{0}C. Inpari 30 has the highest percentage of maximum growth potential at 28 ^{0}C (90,33%) and decreases when the temperature treatment increases.

Batang Piaman and Cisokan can only germinate at temperatures of 28 to 36 ^{0}C, Anak Daro and Inpari 30 can germinate to temperatures of 40 ^{0}C, while at temperatures of 44 and 48 ^{0}C all varieties that can't germinate. According to Yoshida (1981), a critical temperature for growth and development of rice at 35 ^{0}C. Therefore at temperatures of 44 ^{0}C and 48 ^{0}C has disrupted the metabolic process of rice so that germination fails. This is same as the Sopandie statement (2014) that cell damage or cell death due to high temperatures can cause the germination process to fail.

d. Growth Rate

Growing rate is the level of ability of a seed to grow quickly with normal conditions.The interaction between varieties and temperature can be seen in Table 4.

At 28 ^{0}C the Cisokan had the highest growth rate (84.7% etmal). At 32 ^{0}C Cisokan also had the highest growth rate percentage of 80,71% etmal and not significantly different from the Anak Daro and Inpari 30. At 36 ^{0}C and 40 ^{0}C Anak Daro has the highest growth rate value of 70 % etmal and 43.33% etmal. At 44 ^{0}C when the initial germination of the Anak Daro, Batang Piaman and Cisokan can still grow with very low growth rates, while the temperature of 48 0 C there are no seeds that can germinate.

Anak Daro has the highest growth rate at 28 ^{0}C (81.13% etmal), then decreases when the temperature increases. Same with Batang Piaman that the highest growth rate was found at 28 ^{0}C which was 83.21% etmal and when the temperature increased, the rate of seed growth was reduced. Cisokan and Inpari 30 also have the highest growth rate values at 28 ^{0}C is 84.7% etmal and 82.5% etmal, when the temperature increases the growth rate of seed decrease.

Batang Piaman, Cisokan and Inpari 30 have been able to germinate on the second day after planting, while the Anak Daro was able to germinate normally on the third day after planting at 28 ^{0}C and 32 ^{0}C. At 36 ^{0}C and 40 ^{0}C germination occurred on the fourth day after planting, but at 40 ^{0}C has slow and abnormal growth and development of sprout.

Table 4. Growth Rate of Four Rice Varieties in High Temperature

Suhu (^{0}C)	Varietas			
	Anak Daro	Batang Piaman	Cisokan	Inpari 30
	------ (% etmal) ------			
28	81,13 Aa	83,21 Aa	84,70 Aa	82,50 Aa
32	80,16 Aa	77,74 ABa	80,71 Aa	78,60 Aa
36	70,00ABa	69,28 Ba	66,25 Ba	64,72 ABa
40	43,33 Ba	1,18 Cb	3,60 Cb	39,26 Ba
44	0,07 Ca	0,03 Ca	0,03 Ca	0,00 Ca
48	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca

Information : The numbers followed by lowercase letters in the same row and uppercase letters in the same column are not significantly different according to the DNMRT test at the level of 5%.

Observations on the first day after germination, at 44 and 48 ^{0}C have appeared a little radicle, but starting on the fifth day the sprouts die and the fungi grows in the area around the sprouts. The osmotic potential increase due to high temperatures causes the imbibition not to be maintained so that the seeds germinate slowly and normal sprouts decrease.

e. Vigor Index

Based on variance on the 5% level, the germinate under high temperature and variety gave a real interaction to Vigor Index shown in Table 5.

At 28 ^{0}C Cisokan has the highest percentage of vigor index (89.33%) which was not significantly different from Batang Piaman (88%). At 32 ^{0}C Anak Daro has the highest vigor index is 84% and at 36 ^{0}C Batang Piaman has the highest vigor index is 82.6%. Anak Daro has the highest percentage of vigor index is 48% at 40 ^{0}C

Anak Daro has the highest vigor index at 28 ^{0}C (80,6%) then the percentage of vigor index decreases when the temperature increases. The same results in Batang Piaman that the highest percentage of vigor index at 28 ^{0}C was 88% and decreased when the temperature was higher. Cisokan and Inpari 30 also showed the same results that the highest seed vigor index was at 28 ^{0}C (89.33%) and (85.31%) and also decreased in the next temperature treatment.

Table 5. Vigor Index of Rice Germination Under Temperature Stresses

Temperature (^{0}C)	Varieties			
	Anak Daro	Batang Piaman	Cisokan	Inpari 30
		------ (%) ------		
28	80,60 Ab	88,00 Aa	89,33 Aa	85,31 Aab
32	84,00 Aa	76,6 Bb	82,00 Bab	80,00 Abab
36	79,33 Aab	75,32 Bb	82,60 Ba	76,00 ABb
40	48,00 Ba	0,00 Cb	0,00 Cb	37,3 Ba
44	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca
48	0,00 Ca	0,00 Ca	0,00 Ca	0,00 Ca

Information : The numbers followed by lowercase letters in the same row and uppercase letters in the same column are not significantly different according to the DNMRT test at the level of 5%..

Conclusions

High temperature makes viability and vigor of seed rice decrease. The optimum temperature for germination of rice at 28-32 ^{0}C for Anak Daro, at 28-36 ^{0}C for Cisokan and 28 ^{0}C for Batang Piaman and Inpari 30.

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