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Tolerance of Five Upland Rice Cultivars at Various Levels of Drought Stress

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Abstract **Original Research Article**

The aim of this study was to determine the drought tolerance limit of five upland rice (*Paddy Gogo*) cultivars in the germination phase. This research was carried out at the Seed Science and Technology Laboratory, Faculty of Agriculture, University of Tadulako, Palu, Indonesia, from September to October 2020. This study was arranged using a completely randomized design (CRD) with a factorial design of 2 factors. The first factor was the cultivar consisting of five cultivars, i.e., Pau Tau Leru, Jahara, Uva Buya, Buncaili, and Kalendeng. The second factor was the Polyethylene Glycol (PEG) concentration which consisted of five levels, i.e., Without PEG, 10%, 20%, 30% and 40% PEG. There were 25 treatment combinations. Each treatment was repeated three times (75 experimental units). The results showed that Uva Buya and Jahara cultivars had a high tolerance for PEG which was characterized by the maximum growth potential, germination power above 85%, and germination time in less than 4 days with the treatment of 40% PEG concentration. Meanwhile, Pau Tau Leru, Buncaili, and Kalendeng cultivars were able to grow and germinate well up to 10% PEG concentration. Both Uva Buya and Jahara cultivars also had a longer and heavier plumule and radicle, and larger roots.

Keywords: Drought Stress, PEG, Upland Rice, Radicle, Tolerance.

Abbreviations (if any): All important abbreviations must be defined at their first mention there. Ensure consistency of abbreviations throughout the article.

INTRODUCTION

The need for national rice is a very important issue for the people of Indonesia, because the national rice production has decreased from year to year. National rice production has been focused on paddy fields, while paddy fields have shrunk due to population growth which continues to increase every year. One alternative way that can be applied to overcome this is to expand the area of rice cultivation on marginal lands because the development of rice plants in paddy fields is increasingly difficult to continue. The fertile land in Java is decreasing due to the activity of changing land functions from agricultural land to non-agricultural land. This condition causes the expansion of the area to be carried out outside Java. The condition of land outside Java is quite extensive but has obstacles, namely most of it is marginal land (Kamaludin *et al.*, 2021). Upland rice (Paddy Gogo) is a rice plant that can grow well on marginal land without having to use super luxurious technology. The biggest threat of upland rice is drought stress or the level of water availability for plants. Water plays an important role in plant growth, because water can affect plant metabolic processes (Wang *et al.*, 2021; Brendel 2021). Plants that are stressed by water will cause a decrease in water potential in the leaves and stomata closure which will further reduce the ability of photosynthesis and decrease the available CO2 so that the photosynthate produced will eventually decrease (Osakabe *et al.*, 2014; Sun *et al.*, 2020). Low water availability causes above-ground competition more than underground competition (Foxx & Fort, 2019).

The demand for national rice is a very important issue for the people of Indonesia, because the national rice production has decreased from year to year. National rice production has so far focused on lowland paddy fields, while paddy fields have been shrinking due to population growth which continues to increase every year. One alternative method that can be applied to overcome this issue is to expand the area of rice cultivation on marginal lands because the development of rice plants in paddy fields is increasingly difficult to continue. Upland rice (*Paddy Gogo*) is a rice plant that can grow well on marginal lands without having to use super luxurious technology. Plants that are tolerant and sensitive to drought stress will show different physiological responses (Ying *et al*., 2015; dos Santos *et al*., 2022). Drought-resistant plants can be seen from the nature of their roots or through root penetration tests and seed germination (Pandey & Shukla 2015; Taylor *et al*., 2021). Several researchers have conducted research on the resistance of rice plants to drought at the germination stage (Guimarães *et al*., 2016 ; Islam *et al*., 2018) have conducted research on the resistance of rice plants to drought using PEG as a selection agent. In addition, (Sunaryo *et al*., 2016) In conducting drought resistance screening, researchers generally use polyethylene glycol (PEG) as a selection method.

The biggest threat of upland rice is drought stress or the water availability level for the plants. Water plays an important role in plant growth, because water can affect plant metabolic processes (Li *et al.*, 2020). Simulation of drought stress in the germination phase can be performed using Polyethylene glycol (PEG) because PEG can bind water, so that water is not available for seeds to germinate (Wang *et al.*, 2018; Tang *et al*., 2019). Plants that experience drought will respond through an osmotic mechanism that begins with osmotic changes in sugar, especially in xylose sugar, then followed by proteins that have small molecular weights. Takahashi *et al*., (2020) stated that in conditions where plants are experiencing drought stress, plants will respond by accumulating sugar. The decrease in osmotic potential would be accompanied by the accumulation of proline and an increase in betaine in roots and buds (Hosseinifard *et al.*, 2022). Plant cells will maintain turgor if the osmotic pressure decreases which results in normal physiological and biochemical processes in a dry state.

Local upland rice of various types with different properties spread throughout Indonesia, especially in Central Sulawesi Province. To date, several cultivars that are tolerant to drought stress during the germination phase have been identified, including Pulut ko, Roda, and Siang, capable of normal growth up to a stress of -1 bar PEG 6000 (Maemunah *et al.*, 2021). Cultivars of Raki, Kenari, Tagolu, and Tokalang were able to grow normally up to a concentration of -3 bar PEG 6000 (Irsam *et al*., 2016). The Tagolu cultivar was able to grow well up to 75% field capacity and Logi of 50% field capacity (Nurahmadi *et al*., 2019). Tagolu, Habo, and Dongan cultivars were able to grow well up to 50% soil moisture. Therefore, this study was conducted on the tolerance of five upland rice cultivars at various levels of drought stress which aimed to determine the drought tolerance limit of each cultivar in the germination phase.

MATERIALS AND METHODS

Study area

This research was conducted at the Seed Science and Technology Laboratory, Faculty of Agriculture, University of Tadulako, Palu, Indonesia from September to October 2020. The materials used were distilled water, PEG 6000, straw paper, transparent plastic, seeds consisting of 5 cultivars, i.e., Pau Tau Leru, Jahara, Uva Buya, Buncaili, and Kalendeng. The equipment used were an analytical balance, plastic spoon, 1000 mL measuring cup, stirring rod, label papers, scissors, plastic containers, tweezers, a paper press (IPB 72-1), germination racks, an oven, envelopes, a camera, and stationery.

Procedures

Ressearch Design

This study used a completely randomized design (CRD) as the environmental design and 2 factors of factorial design as the treatment design. The first factor consisted of five rice cultivars, i.e., Pau Tau Leru (K_1), Jahara (K2), Uva Buya (K_3), Buncaili (K_4), and Kalendeng (K_5). The second factor was the PEG concentration consisted of five levels, i.e., Without PEG (P_0), 10% PEG (P_1), 20% PEG (P_2), 30% PEG (P_3), and 40% PEG (P_4). There were 25 treatment combinations, and each treatment combination was repeated three times to obtain 75 experimental units. The experiment used the germination test of rolled paper set up in a plastic method. Each experimental unit used 50 seeds, so that 3,750 seeds were used.

The observed variables include

1. Maximum growth potential (MGP) was obtained by counting the number of sprouts that grow normally or abnormally. The maximum growth potential was calculated by the formula:

$$\text{MGP (\%)} = \frac{\sum \text{growing seeds}}{\sum planted\ seeds}\ x\ 100\%$$

2. Germination time

Germination was observed on the first, second day, and until the 14th day after the seeds were sown, germination time was calculated by the formula:

$$\text{GT} = \sum_{i=1}^{n} \frac{\text{N1.T1} + \text{N1.T2} + \ldots + \text{Ni.Ti}}{\text{Number of germinated seeds}}$$

Note: GT = Germination time

N_i = Number of germinated seeds (i)

T_i = Germination time (i)

3. Germination power was observed at the end of the germination observation by counting seeds that germinated normally. Germination power was calculated by the formula:

$$GP = \frac{\text{Number of Normal Sprouts}}{\text{Number of germinated seeds}} \, x \, 100\%$$

Plumule Length, Radicle Length, Root volume, Plumule Dry Weight, Radicle Dry Weight

Data analysis

To determine the effects of the treatments, Analysis of Variance (ANOVA) or F test was performed at the 5% level. If the ANOVA showed a significant effect, then it was continued with the median test. Furthermore, Honest Significant Difference (HSD) test at the 5% level was performed to determine which treatment gave better results on each factor and its interactions.

RESULTS AND DISCUSSION

Maximum Growth Potential

The ANOVA results showed that the cultivars, the PEG concentrations, and the interaction between the two treatments had an effect on the maximum growth potential. The average maximum growth potential is presented in Table 1.

Table 1: Maximum Growth Potential (%) of Five Upland Rice Cultivars at Various PEG Concentrations

Cultivar	PEG concentration					HSD 5%
	Without PEG	10%	20%	30%	40%	
Pau Tau Leru	^{p}83.50 ^{d}	^{p}81.00 ^{cd}	^{q}76.00 ^{bc}	^{q}71.00 ^{b}	^{q}61.50 ^{a}	
Jahara	^{r}99.00 ^{d}	^{r}97.50 ^{cd}	^{r}93.00 ^{bc}	^{r}87.50 ^{ab}	^{r}85.00 ^{a}	
Uva Buya	^{r}100.00 ^{b}	^{r}98.00 ^{b}	^{r}98.00 ^{b}	^{r}89.00 ^{a}	^{r}86.50 ^{a}	5.75
Buncaili	^{p}82.50 ^{c}	^{pq}82.50 ^{c}	^{q}65.50 ^{b}	^{p}63.00 ^{b}	^{p}53.50 ^{a}	
Kalendeng	^{q}91.50 ^{c}	^{q}88.00 ^{c}	^{p}79.00 ^{b}	^{q}71.00 ^{a}	^{q}66.50 ^{a}	
HSD 5%	5.75					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r) are not significantly different in the HSD test (level = 0.05)

The HSD test results (Table 1) showed that the effect of the cultivars was different at each concentration of PEG. The Uva Buya cultivar had a higher maximum growth potential at each concentration of PEG, which was different from other cultivars, except the Jahara cultivar. Table 1 also shows that the effect of PEG concentration was different in each cultivar. Uva Bunya and Jahara cultivars had the potential to grow well up to 40% PEG concentration, while the Pau Tau leru, Buncaili and Kalendeng cultivars were only able to grow well at 10% PEG concentration.

Germination Power

The ANOVA results showed that the cultivars, PEG concentration, and the interaction between the two treatments had an effect on the germination power. The average germination power is presented in Table 2.

Table 2: Average Germination Power (%) of Five Upland Rice Cultivars at Various PEG concentrations

Cultivar	PEG concentration					HSD 5%
	Without PEG	10%	20%	30%	40%	
Pulu Tau Leru	^{p}83.00 ^{d}	^{p}81.00 ^{cd}	^{q}75.50 ^{bc}	^{q}70.50 ^{b}	^{q}59.50 ^{a}	
Jahara	^{r}99.00 ^{c}	^{q}96.00 ^{bc}	^{r}90.00 ^{ab}	^{r}87.50 ^{a}	^{s}84.00 ^{a}	
Uva Buya	^{r}100.00 ^{b}	^{q}97.50 ^{b}	^{r}97.00 ^{b}	^{r}90.50 ^{a}	^{s}85.00 ^{a}	6.12
Buncaili	^{q}94.50 ^{d}	^{q}81.50 ^{c}	^{p}64.00 ^{b}	^{p}62.50 ^{b}	^{p}53.00 ^{a}	
Calendar	^{q}91.50 ^{c}	^{p}86.50 ^{c}	^{q}78.50 ^{b}	^{q}71.00 ^{a}	^{r}66.00 ^{a}	
HSD 5%	6.12					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r) are not significantly different in the HSD test (level = 0.05)

The HSD test results (Table 2) showed that the effect of PEG concentration was different in each cultivar. Uva Buya and Jahara cultivars were able to germinate well up to 40% PEG concentration. Meanwhile, Pau Tau leru, Buncaili, and Kalendeng cultivars were able to germinate well up to 10% PEG concentration. Table 2 also shows that the effect of cultivars was different for each PEG concentration. At each concentration of PEG, Uva Buya cultivar had higher germination power compared to other cultivars, except Jahara cultivar.

Germination Time

The ANOVA results showed that the cultivars, the PEG concentration, and the interaction between the two treatments had an effect on the germination time. The average germination time is presented in Table 3.

The results of the HSD test (Table 3) showed that the effect of the cultivar was different for each PEG concentration. The Uva Buya cultivar germinated faster at each concentration of PEG, which was different from the other cultivars, except the Jahara cultivar. Table 3 also shows that the effect of PEG concentration was different in each cultivar. Uva Buya and Jahara cultivars germinated in less than 4 days at a PGE concentration of 40%. Meanwhile, Pau Tau Leru, Buncaili, and Kalendeng cultivars germinated in less than 5 days at 10% PEG concentration.

Table 3: Germination Time (days) of Five Upland Rice Cultivars at Various PEG Concentrations

Treatment	**PEG concentration**					**HSD 5%**
	Without PEG	**10%**	**20%**	**30%**	**40%**	
Pulu Tau Leru	^{q}4. 1 1 ^{a}	^{q}4.95 ^{b}_	^{r}5.95 ^{b}	^{r}5. 9 5 ^{b}	^{q}6.89 ^{c}	0.59
Jahara	^{p}3.12 ^{a}	^{p}3.44 $^{a b}$	^{p}3.63 ^{ab}	^{p}3. 7 7 ^{b}	^{p}3.87 ^{b}	
Uva Buya	^{p}2.5 5 ^{a}	^{p}3.09 ^{a}	^{p}3.09 ^{ab}	^{p}3.35 ^{b}	^{p}3.3 7 ^{b}	
Buncaili	^{q}4.16 ^{a}_	^{q}4 . 5 6 ^{a}	^{q}5 . 0 6 ^{a}	^{q}5.33 ^{a}	^{q}6.98 ^{b}	
calendar	^{q}4 . 29 ^{a}	^{q}4 . 61 ^{a}	^{r}6. 01 $^{a b}$	^{r}6. 42 ^{b}	^{q}6. 52 ^{b}	
HSD 5%	0.59					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r,s,t) are not significantly different in the HSD test (level = 0.05)

Plumule Length

The ANOVA results showed that the cultivars and the PEG concentration had an effect, while the interaction between the two treatments did not affect the plumule length. The average length of the plumule is presented in Table 4.

Table 4: Plumule Length (cm) of Several Upland Rice Cultivars at Various PEG Concentrations

Cultivar	**PEG concentration**					**Average**	**HSD 5%**
	Without PEG	**10%**	**20%**	**30%**	**40%**		
Pulu Tau Leru	6.10	5.85	5.20	4.73	4.30	5.24 $^{\mathbf{a}}$	1.48
Jahara	6.47	6.09	5.79	5.42	5.63	5.88 $^{\mathbf{ab}}$	
Uva Buya	8.15	7.56	7.23	6.84	6.17	7.19 $^{\mathbf{b}}$	
Buncaili	5.61	4.92	4.53	3.90	3.42	4.47 $^{\mathbf{a}}$	
calendar	6.68	6.08	5.85	4.90	3.55	5.41 $^{\mathbf{a}}$	
Average	6.60 $^{\mathbf{b}}$	6.10 $^{\mathbf{b}}$	5.72 $^{\mathbf{ab}}$	5.15 $^{\mathbf{ab}}$	4.61 $^{\mathbf{a}}$		
HSD 5%	1.48						

Note: The mean values followed by the same letter in the same row (a,b) or column (p,q) are not significantly different in the HSD test (level = 0.05)

The HSD test results (Table 4) showed that the Uva Buya cultivar had a longer plumule, which was different from the other cultivars, except the Jahara cultivar. Table 4 shows that the treatment without PEG administration resulted in longer plumula length, which was different from that with 40% PEG concentration, but not different from that with 10%, 20%, and 30% concentrations.

Radicle Length

The ANOVA results showed that the cultivars, the PEG concentrations, and the interaction between the two treatments had an effect on the radicle length. The average radicle length is presented in Table 5. The HSD test results (Table 5) showed that the effect of PEG concentrations was different in each cultivar. The treatment without PEG resulted in longer radicle length in each cultivar, which was different from that with 20%, 30% and 40% PEG concentrations, but not different from that with 10% PGE concentration. The higher the PEG concentration, the shorter the radicle obtained. Table 5 also shows that the effect of the cultivars was different for each PEG concentration. At each PEG concentration, the Uva Buya cultivar had a longer radicle, which was different from the Pau Tau Leru, Buncaili, and Kalendeng cultivars, but not different from the Jahara cultivar.

Table 5: Average Radicle Length (cm) of Five Upland Rice Cultivars at Various PEG Concentrations

Cultivar	**PEG Concentration**					**HSD 5%**
	Without PEG	**10%**	**20%**	**30%**	**40%**	
Pulu Tau Leru	^{p}13.46 ^{c}	^{pq}12.8 $^{b c}$	$^{q r}$11.97 $^{a bc}$	$^{q r}$11.22 $^{a b}$	$^{p q}$10.48 ^{a}	1.69
Jahara	^{q}15.27 ^{c}	^{q}13.79$^{b c}$	^{rs}13.05^{ab}	^{r}12.18 ^{ab}	^{q}11.95 ^{a}	
Uva Buya	^{q}16.46 ^{d}	^{q}15.04 ^{cd}	^{s}13.98 ^{bc}	^{r}12.46 $^{a b}$	^{q}11.90 ^{a}	
Buncaili	^{p}11.81 ^{b}	^{p}11.13 ^{b}	^{p}10.14 ^{ab}	^{p}9.41 ^{a}	^{p}8.93 ^{a}	
calendar	^{p}12.18 ^{c}	^{p}11.38 $^{b c}$	$^{p q}$10.58 $^{a bc}$	^{pq}10.18 ^{ab}	^{p}9.68 ^{a}	
HSD 5%	1.69					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r) are not significantly different in the HSD test (level = 0.05)

Root Volume

The ANOVA results showed that the cultivars, the PEG concentrations, and the interaction between the two treatments had an effect on the root volume. The average root volume is presented in Table 6.

Table 6: Root Volume (mL) of Five Upland Rice Cultivars at Various PEG Concentrations

Cultivar	PEG concentration					HSD 5%
	Without PEG	10%	20%	30%	40%	
Pulu Tau Leru	^{p}0.45^{b}	^{p}0.39^{ab}	^{p}0.37^{ab}	^{p}0.34^{ab}	^{p}0.25^{a}	0.17
Jahara	^{q}1.44^{b}	^{q}1.39^{b}	^{q1}. 1.1 9^{a}	^{q}0. 9 2^{a}	^{r}0.76^{a}	
Uva Buya	^{q}1.59^{c}	^{q}1.45^{bc}	^{q}1. 3 1^{b}	^{q}1.06^{a}	^{r}0.92^{a}	
Buncaili	^{p}0.54^{a}	^{p}0.48^{a}	^{p}0.47^{a}	^{p}0.45^{a}	^{pq}0.37^{a}	
calendar	^{p}0.61^{a}	^{p}0.51^{a}	^{p}0.46^{a}	^{p}0.45^{a}	^{q}0.44^{a}	
HSD 5%	0.17					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r) are not significantly different in the HSD test (level = 0.05)

The HSD test results (Table 6) showed that the effect of PEG concentrations was different in Pau Tau Leru, Jahara, and Uva Buya cultivars, but not different in Buncaili and Kalendeng cultivars. In Pulu Tau Leru cultivar, the treatment without PEG resulted in larger roots, which was different from that with 40% PEG concentration, but not different from that with 10%, 20%, and 30% PEG concentrations. Meanwhile, in Jahara and Uva Buya cultivars, the treatment without PEG produced larger roots, which was different from that with 20%, 30% and 40% PEG concentrations, but not different from that with 10% PEG concentration. Table 6 also shows that the effect of cultivars was different at each concentration of PEG. The Uva Buya cultivar produced larger roots at each concentration of PEG, which was different from the other treatments; except for the PEG concentration of 40%, the Uva Buya cultivar did not differ from the Jahara cultivar.

Plumule Dry Weight

The ANOVA results showed that the cultivars, the PEG concentrations, and the interaction between the two treatments had an effect on the plumule dry weight. The average dry weight of plumules is presented in Table 7.

Table 7: Dry Weight of Plumules (g) of Five Upland Rice Cultivars at Various PEG Concentrations

Cultivar	PEG concentration					HSD 5%
	Without PEG	10%	20%	30%	40%	
Pulu Tau Leru	^{p}0.07^{a}	^{p}0.07^{a}	^{p}0.06^{a}	^{p}0.05^{a}	^{p}0.0 5^{a}	0.02
Jahara	^{q}0.15^{d}	^{q}0.14^{cd}	^{q}0.12^{bc}	^{q}0.10^{ab}	^{qr}0.09^{a}	
Uva Buya	^{r}0.21^{c}	^{r}0.1 8^{b}	^{r}0.16^{b}	^{r}0.13^{a}	^{r}0.11^{a}	
Buncaili	^{p}0.08^{a}	^{p}0.0 8^{a}	^{p}0.07^{a}	^{p}0.07^{a}	^{p}0.06^{a}	
calendar	^{p}0.08^{a}	^{p}0.0 8^{a}	^{p}0.0 7^{a}	^{p}0.07^{a}	^{pq}0.07^{a}	
HSD 5%	0.02					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r) are not significantly different in the HSD test (level = 0.05)

The HSD test results (Table 7) showed that the effect of PEG concentrations was different in Uva Buya and Jahara cultivars, but not different in Pau Tau Leru, Buncaili, and Kalendeng cultivars. In Uva Buya and Jahara cultivars, the treatment without PEG resulted in heavier plumule dry weight, which was different from the other concentrations; except for the Jahara cultivar, the 10% PEG concentration was not different from that without PEG. Table 7 also shows that the effect of cultivars was different at each concentration of PEG. The Uva Buya cultivar produced heavier plumule dry weight at each concentration of PEG, which was different from the other treatments; except for the PEG concentration of 40%, the Uva Buya cultivar did not differ from the Jahara cultivar.

Radicle Dry Weight

The ANOVA results showed that the cultivars, the PEG concentrations, and the interaction between the two treatments had an effect on the radicle dry weight. The average dry weight of the radicles is presented in Table 8.

Table 8: Dry Weight of Radicles (g) of Five Upland Rice Cultivars at Various PEG Concentrations

Cultivar	PEG concentration					HSD 5%
	Without PEG	10%	20%	30%	40%	
Pulu Tau Leru	^{p}0.0 8 ^{b}	^{p}0.0 5 ^{a}	^{p}0.05 ^{a}	^{pq}0.05 ^{a}	^{p}0.0 4 ^{a}	0.02
Jahara	^{qr}0.09 ^{b}	^{q}0.09 ^{b}	^{q}0.0 8 ^{ab}	^{qr}0.07 ^{ab}	^{pq}0.06 ^{a}	
Uva Buya	^{r}0.11 ^{b}	^{q}0.10 ^{ab}	^{q}0.1 0 ^{ab}	^{r}0.09 $^{a\,b}$	^{q}0.08 ^{a}	
Buncaili	^{p}0.05 ^{a}	^{p}0.05 ^{a}	^{p}0.04 ^{a}	^{p}0.04 ^{a}	^{p}0.04 ^{a}	
Calendar	^{pq}0.07 ^{b}	^{p}0.05 ^{ab}	^{p}0.04 ^{a}	^{p}0.0 4 ^{a}	^{p}0.0 4 ^{a}	
HSD 5%	0.02					

Note: The mean values followed by the same letter in the same row (a,b,c) or column (p,q,r) are not significantly different in the HSD test (level = 0.05)

The HSD test results (Table 8) showed that the effect of PEG concentrations was different in Pau Tau Leru, Jahara, Uva Buya, and Kalendeng cultivars, but not different in the Buncaili cultivar. In each cultivar, the treatment without PEG resulted in heavier radicle dry weight. Table 8 also shows that the effect of cultivars was different at each concentration of PEG. At each PEG concentration, the Uva Buya cultivar resulted in heavier plumule dry weight, which was different from the Pau Tau Leru, Buncaili, and Karendeng cultivars, but not different from the Jahara cultivar.

DISCUSSION

The use of PEG 6000 solution in the germination phase of the drought stress test was able to inhibit the availability of water absorbed by the seeds, so that it can simulate the drought conditions in the field. PEG 6000 has a heavier molecule so it is more proper in creating drought stress (Pasaribu *et al*., 2021). The germination percentage of a seed in the use of PEG 6000 is the same as in soil conditions with low water potential. The use of PEG can induce drought stress, so that it is the same as drought conditions as in the field because it can reduce water potential (Muscolo *et al*., 2014;Meher *et al*., 2018).

The ANOVA results showed that the interaction between the cultivars and the PEG concentrations affected the variables of maximum growth potential, germination power, germination time, root volume, plumule and radicle dry weight. The results showed that the administration of PEG with a concentration of 40% can give a significantly different effect from that without PEG. However, there were cultivars that were still able to germinate well even under stress conditions such as Uva Buya and Jahara cultivars with growth potential of 86.50% and 85.00%; germination power of 85.00% and 84.00%; and faster growing time of 3.33 days and 3.87 days, respectively, compared to the other cultivars.

The Uva Buya cultivar is the best cultivar because by the administration of PEG concentrations of up to 40%, it is able to produce maximum growth potential, higher germination power, and faster germination time, and this cultivar has genetic superior. Rice seeds that are able to germinate in a stressed state mean that the seeds are able to absorb water well and vice versa (Lechowska *et al*., 2019). If the seeds are not able to germinate, this is because the more difficult it is for water to enter the seeds resulting in inhibited metabolic activity in the seeds. The minimum standard of germination power for rice seeds for each seed class is ≥ 80% (Huong *et al.*, 2019).

Seeds that can grow normally under stress are criteria for drought tolerant rice plants (Fahad *et al*., 2017;Sabouri & Dadras 2022). The Jahara and Uva Buya cultivars have good germination power because their germination powers are above 80% and have good viability. Therefore, the Jahara and Uva Buya cultivars are tolerant to drought stress because they have met the criteria for being able to germinate and grow under stressed conditions.

The response of plant roots in stressed conditions is to have longer root growth. The administration of PEG 6000 can increase root length and root dry weight (Meher *et al*., 2018). The criteria for drought tolerant plants are to expand or deepen their roots (Comas *et al*., 2013). This study showed that the Uva Buya cultivar, at each concentration of PEG, had higher radicle length, root volume, and radicle dry weight than other cultivars. However, the higher the concentration of PEG given, the radicle length, root volume, and radicle dry weight decreased significantly. This can be seen from the results that the radicle length with treatment without PEG was 16.46 cm. With increasing PEG up to 40% concentration, the radicle length decreased significantly up to 11.90 cm.

Likewise for root volume, the treatment without PEG administration had a root volume of 1.65 cm^3, so that it experienced a significant decrease of 0.92 cm^3 in the PEG administration with a concentration of 40%. For the resulting dry weight, the treatment without PEG resulted in a dry weight of 0.11g and experienced a significant decrease of 0.08 g in the administration of 40% PEG concentration. According to the research by (Maemunah *et al*., 2021), the increase of PEG concentration up to 40% can reduce radicle growth and root volume. The similar results in the study of Hellal *et al*., (2018) stated that the administration of PEG 6000 showed a tendency to decrease in root length. This was thought to be caused by the presence of planting media (straw paper) which limited root growth, and a decrease occurred in the radicle dry weight caused by different PEG administration 6000, so that the metabolic processes of the seeds are disturbed. In addition, the conditions of water deficit, the percentage of plant roots, dry weight and wet weight of Alfalfa plants decreased.

Although the percentage at each given concentration of PEG tends to decrease, the Uva Buya cultivar achieved a higher length, volume and dry weight of the radicle than other cultivars. Therefore, the Uva Buya cultivar is identified as tolerant to drought stress because it can maintain root growth even under stress. A good germination response is by maximizing roots even in a state of stress. Upland rice plants are able to adapt to drought stress, so that it does not show symptoms of drought stress by elongating the roots to seek water availability. Larger volume of plant roots will facilitate the absorption of more water, so that plants are able to grow in stressed conditions. Kim *et al*., (2020) also stated that roots play a role in absorbing water and minerals, and distributing it to all plant organs to meet growth needs because roots are the main vegetative organs in plant growth and development.

The higher the concentration of PEG given, the response of plumule growth will decrease, so that it is directly proportional to the plumule dry weight. This is in contrast to the research of Maemunah *et al*., (2021) that an increase in PEG concentration up to 40% did not have a decreasing effect on plumule dry weight. This study revealed that the Jahara cultivar, at each concentration of PEG, showed the dry weight of the plumules tended to decrease with every increase in the concentration of PEG given from 0.15 g to 0.09 g. However, the percentage value of the plumule dry weight in the treatment without PEG was not different from that of 10% PEG. The percentage value of the plumule dry weight of 10% PEG was not different from that of 20% PEG, but it was different from that of PEG concentration of 30% and 40%. PEG administration can affect the decrease in leaf area due to the plant crown weight in stressed conditions. In the Uva Buya cultivar, treatment without PEG administration resulted in the heaviest plumule dry weight of 0.21g, which was different from all treatments of PEG concentrations; but with the PEG concentrations of 20%, 30% and 40%, the results were not significantly different. According to (Hellal *et al*., 2018) if the plumule length grows shorter, it will affect and decrease the dry weight of the plumule which is different from that without PEG (Control), and this can indicate that the rice is drought tolerant.

Zhang *et al*., (2020) stated that stressed plants try to maintain growth by conserving water use by minimizing all plant surfaces. Therefore, Uva Buya was indicated as tolerant to drought stress. The results of the analysis showed that the cultivar treatments had a very significant effect on the plumule length. The response of each cultivar was different in response to drought stress. This was indicated from the results of the average plumule length. The Uva buya cultivar had a longer plumule of 7.19 cm and was not different from the Jahara cultivar of 5.88cm. Even under stressed conditions, these two cultivars had a good germination response in maximizing plumule growth. This is in line with the research of Maemunah *et al*., (2021) that the Uva Buya cultivar is the best cultivar because it has a longer plumule length than other cultivars.

The shorter plumule growth character indicates that the rice plant is drought tolerant, which is different from the growth under normal conditions. Therefore, it can be stated that the Uva buya and Jahara cultivars are tolerant to drought stress because they are able to grow well under stressed conditions. The results also showed that the PEG concentration treatments had a very significant effect on the plumule length. The availability of minimal ground water can affect the plant growth and development. The increased concentration of PEG can affect the growth of plumules with a significant difference. The effect of PEG with a concentration of 40% on the plumule growth was different from that without PEG (Control), where increasing the concentration of PEG up to 40% caused a decrease in plumule growth of 30.13%.

In accordance with the research of Maemunah *et al*., (2021), increasing the PEG concentration up to 40% can reduce the growth of plumules. Shortening the length of the plumule is a form of response to drought tolerant rice varieties.The Uva Buya and Jahara cultivars had a high tolerance to PEG which was characterized by the maximum growth potential, germination power above 85%, and germination time in less than 4 days with the treatment of 40% PEG concentration. Meanwhile, Pau Tau Leru, Buncaili, and Kalendeng cultivars were able to grow and germinate well up to 10% PEG concentration. Both Uva Buya and Jahara cultivars also had longer and heavier plumules and radicles, and larger roots.

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