Ilmu Pertanian (Agricultural Science)
http://journal.ugm.ac.id/jip
Vol. 8 No. 3 December, 2023: 142–152| DOI: doi.org/10.22146/ipas.80278

Drought tolerance selection of several tomato varieties by using polyethylene glycol

Sholeh Avivi*, Novrida Yanti Sitompul, Tri Agus Siswoyo, and Mohammad Ubaidillah

Department of Agrotechnology, Faculty of Agriculture, University of Jember
Jl. Kalimantan No.37, Krajan Timur, Sumbersari, Jember, Jawa Timur 68121, Indonesia
*Corresponding author: savivi.faperta@unej.ac.id

Article Info

Received : 16th December 2022
Revised : 16th November 2023
Accepted: 24th November 2023

Keywords:
Drought stress, screening, Palupi, Ratna

Abstract

A prolonged dry season can cause drought stress and have an unfavorable impact on the growth of tomato plants, resulting in crop failure. Therefore, research is needed on the resistance of tomato varieties to drought stress. The recommended technique for drought resistance screening in tomatoes is in vitro cultivation using Polyethylene Glycol (PEG). The research aimed to obtain new varieties that could be used as promising lines for varieties tolerant to drought stress. The research method used included using ingredients in the form of 5 varieties of tomatoes (Ratna, Intan, Chung, Palupi, and Amelia) and 5 concentrations of PEG chemicals (0%, 5%, 10%, 15%, and 20%). Each seed of each tomato variety that had been sterilized using hypochlorite was germinated on MS0 media, then the germinated seeds with a size of ± 0.3 cm were transferred to MS0 + PEG treatment medium with each treatment concentration. The seeds that had been planted on the PEG-treated medium were then observed for growth for ± 4 weeks. The research data were analyzed using analysis of variance (ANOVA) and followed with DMRT at the 5% significance level. Based on the results, Palupi variety is the most tolerant variety, and Ratna variety is the most intolerant variety to drought stress. The higher the concentration of PEG used, the more it inhibits plant height, root length, and fresh weight of the roots.

INTRODUCTION

The dry season in Indonesia generally lasts 6 to 7 months in one cycle (Estiningtyas et al., 2012). The prolonged dry season that occurs in Indonesia results in reduced water supply in the soil causing the soil to experience drought (Qarana et al., 2020). Drought that occurs causes impacts and problems for the world of agriculture, especially on the rate of productivity related to meeting the water needs of a plant (Sujinah and Jamil, 2016) (Venkatesh et al., 2018). Tomato (*Solanum lycopersicum*) is one of the horticultural crops whose productivity is threatened during the dry season (Esan et al., 2018). Tomato has various benefits and is in great demand by most people (Zhou et al., 2020), especially residents in Indonesia. This is supported by BPS data for 2019 explaining that in the 2015–2019 range, tomato plants experienced an increase in production of almost 14%. Thus, treatment that can balance the level of market demand for the fulfilment of tomato plants is necessary (Chandrasekaran et al., 2021). Drought causes tomato plants to be in a phase of drought stress that can negatively affect their growth and development (Alordzinu et al., 2021). Research by Ningrum et al. (2020) also stated that the inability of tomato plants to adapt to drought stress is a problem in tomato cultivation at this time. The external environment is one of the factors that greatly influences the productivity and quality of tomato growth. In addition, tomato varieties also affect their productivity under drought stress. The difference in such resistance can also be influenced

How to cite: Avivi, S., Sitompul, N.Y., Siswoyo, T.A., and Ubaidillah, M. (2023). Drought tolerance selection of several tomato varieties by using polyethylene glycol. *Ilmu Pertanian (Agricultural Science)*, 8(3), pp. 142–152.

ISSN 0126-4214 (print) ISSN 2527-7162 (online)

by genetic factors contained in a plant (Dwinanti and Damanhuri, 2021). Therefore, a study on the screening of the tolerance level of tomato plants to drought stress is needed (Lamin-Samu et al., 2021). The resistance of tomato varieties to drought stress can be determined through the PEG test (Ibrahim and Musbah, 2018). Polyethylene glycol (PEG) compounds can lead to a reduction in water potential. Such properties of PEG can be utilized for simulating water potential reduction, making it a common method for testing a plant's resistance to drought (Qi et al., 2023). Polyethylene glycol (PEG) is a compound that is commonly used to determine the level of resistance of a variety of plants to drought stress (Li et al., 2020), especially the type PEG 6000 (Wu et al., 2022). The use of PEG was carried out in *in vitro* tissue culture techniques. The *in vitro* technique is the best technique that can be used in manipulating the environment or conditions in the planting area so that the growth response of tomato seeds occurs according to the conditions created in a planned manner (Oktavia et al., 2020). Research on the tolerance of tomatoes to drought stress is actually still a matter that is quite complex to study due to genetic, environmental, and other factors. Thus, *in vitro* tissue culture can serve as a representation for these issues when we need to specify particular elements that don't affect the external environment. Experiments using *in vitro* techniques can provide more specific, more targeted drought stress conditions without any intervention from other stresses. The tomato varieties used in this study are superior national tomato varieties with seeds readily available in the market. Information regarding the drought tolerance of these tomato varieties is not known, except for the Ratna variety, which is claimed by its producer to be drought-susceptible. The novelty of this research lies in the use of several compared varieties that have not been previously studied by other research teams. The aim of the research was to obtain new varieties that could later be used as promising lines for varieties tolerant to drought stress.

MATERIALS AND METHODS

Research design

The research was conducted in February 2022 at the Plant Tissue Culture Laboratory, Faculty of Agriculture, University of Jember. This research was conducted using a two-factor Completely Randomized Design. The first factor was five tomato varieties, and the second factor was five concentrations of PEG. The tomato varieties used were Ratna, Intan, Chung, Palupi, and Amelia. Ratna is a control variety that is not resistant to drought (Sakya et al., 2020). The PEG concentrations used were 0%, 5%, 10%, 15% and 20%. PEG 20% is the heavy stress limit for plants (Ghanbari and Sayyari, 2018). The materials used in this study included five varieties of tomato, PEG 6000, MS medium stock solution, phytagel, distilled water, spirits, detergent, 1% hypochlorite, 70% alcohol, 96% alcohol, 0.1 N NaOH/KOH, and 0.1 N HCL. Tools used include culture bottles, petri dishes, laminar Air Flow Cabinet, analytical balance, tweezers, autoclave, pH meter, spirit lamp, culture rack, hot plate, oven, and magnetic stirrer.

Research procedure

Sterilization was carried out using an autoclave for ±60 minutes at a temperature of 121°C and a pressure of 17.5 psi. Furthermore, the tools were further sterilized using ultraviolet light in the Laminar Air Flow (LAF) room for 1 hour by first spraying the tool using 95% alcohol. Sterilization of the LAF chamber was carried out by spraying the chamber with 95% alcohol and then irradiating the LAF using ultraviolet light for 1 hour before being used in the study.

MS0 media were made using A-F stock solution, which was put into an Erlenmeyer using a pipette then added sugar and a maximum of 800 ml of distilled water (aquadest). Preparation of treatment media was carried out by adding PEG to the solution according to the treatment of each concentration (0%, 5%, 10%, 15%, and 20%). The pH of the solution was measured on a hot plate by stirring it on a magnetic stirrer. The media that was completely mixed was put into a Duran bottle and then sterilized using an autoclave (temperature 121°C, pressure 17.5 psi) for ± 60 minutes. The autoclaved solution was then poured into the culture bottle in the LAF sterile room. Culture bottles that already contained media were labelled and then neatly arranged on the culture rack for incubation for three days (Harahap et al., 2013). Tomato seed explants were sterilized in the LAF room by shaking the tomato seeds using 1% hypochlorite in an Erlenmeyer tube (shaking tube) for 3 minutes, then the seeds were rinsed using sterile distilled water for three repetitions so that the tomato seeds were ready to be used as explants in the study (Roy et al., 2017). Planting in this study was carried out in two stages, namely planting seeds (seedlings) of each variety on MS0 seedling media in Petri Dish, then sub-culture on new media according to the concentration of each PEG treatment in culture bottles when the sprouts grew to length about 0.3 cm. After that, the seeds in the treatment bottles were incubated in the culture room with a temperature of 25°C and 70% humidity (Harahap et al., 2013). Incubation was carried out for four weeks (1 month).

The research variables observed included root initiation time (days after planting/DAP), which was carried out every day since the seeds were planted, plant height (cm), root length (cm), number of roots, number of fresh and fallen leaves, fresh weight and dry weight of roots (mg), number of normal plantlets, and percentage of plantlet growth.

RESULTS AND DISCUSSION

Based on the data from the experimental selection of tolerance in five tomato varieties (Ratna, Intan, Chung, Palupi, and Amelia) to drought stress using PEG chemical, there was an interaction observed in eight observation variables. These variables include root initiation, number of roots, number of fresh leaves, number of fallen leaves, dry weight of roots, number of normal growing plantlets, and the percentage of plantlet growth, while on the other three variables, namely plant height, root length, and fresh weight of roots, as well as the number of dead seeds, there was no interaction in the combination of tomato varieties and PEG treatments but there was a significant effect individually. The summary of the F-test results for all observation variables regarding the types of treatment is presented in Table 1.

Based on the values in Table 1, there was interaction effects in the observed variables, such as root initiation, number of roots, number of fresh leaves, number of fallen leaves, dry weight of roots, percentage of normal growing plantlets, and the percentage of plantlet growth. Therefore, further testing was performed using the Duncan Multiple Range Test (DMRT) at a 5% significance level to determine the effects of each treatment combination on the tolerance of tomato seeds to drought. The non-significant (ns) results for the variables of plant height, root length, fresh weight of roots, and the number of dead seeds concerning treatment combinations indicate responses that are consistent with each treatment.

Plant height (cm)

This observation was carried out to determine the treatment that produced a tolerant response to drought stress, indicated by the height of the tomato plant that was greater than or equal to 8.83 cm as a control (Ningrum et al., 2020).

Based on Figures 1 and 2, the highest growth of tomato plants was produced in the P0 treatment (PEG 0%) with an average height of 10.85 cm. Treatment P1 (PEG 5%) produced plants with the second highest average of 9.76 cm, followed by treatment P2 (PEG 10%) with an average height of 7.75 cm then treatment P3 (PEG 15%) with an average height of 5.71 cm. Meanwhile, the lowest growth of tomato plants was produced in the P4 treatment (20% PEG) with an average height of 4.00 cm. These results prove that the use of Polyethylene Glycol can have a negative

Table 1. The results of the ANOVA F-test for all observation parameters

Observation Variables	F-Value		
	Varieties (V)	PEG (P)	V×P
Plant height (cm)	8.36**	39.88**	1.52^{ns}
Root initiation (dap)	245744.68**	2953404.26**	129734.04**
Root length (cm)	1.99^{ns}	7.02**	1.82^{ns}
Number of roots	7.20**	14.67**	5.94**
Number of fresh leaves	2.45*	4.57**	2.17*
Number of fallen leaves	5.54*	19.86**	2.96**
Fresh weight of roots (mg)	3.58*	6.12**	1.58^{ns}
Dry weight of roots (mg)	5.16*	6.83**	2.12*
Normal growing plantlets (%)	3.95**	6.53**	3.49**
Plantlet growth (%)	3.95**	6.53**	3.49**

Remarks: **= statistically significantly different; *= statistically different; ns= not statistically different.

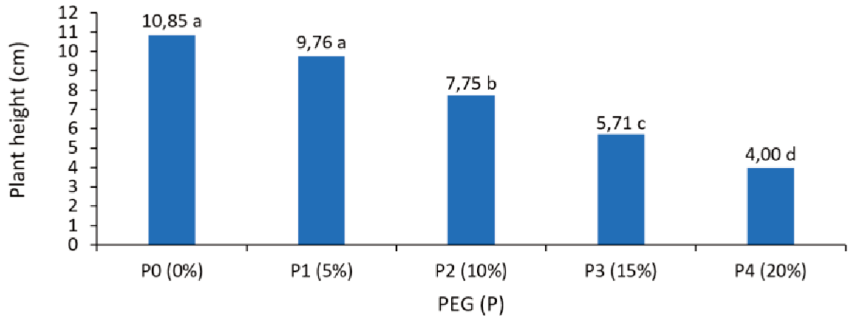

Figure 1. The average height of tomato plants (cm) treated with PEG

PEG 0% PEG 5% PEG 10% PEG 15% PEG 20%

Figure 2. Documentation of the average height of tomato plants (cm) treated with PEG

Table 2. The average root emergence (DAP) of the V×P treatment

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	3 d	3 d	6 b	5 c	8 a
V1 (Intan)	3 d	3 d	4 c	6 b	8 a
V2 (Chung)	5 b	4 c	4 c	5 b	8 a
V3 (Palupi)	5 c	4 d	6 b	5 c	9 a
V4 (Amelia)	5 b	5 b	4 c	5 b	10 a

Remarks: Values followed by different letters show significantly different results at 5% DMRT.

impact on plant growth (Cui et al., 2019), especially on tomato plant height (Yang et al., 2022), where plant height will decrease if the PEG concentration is increased.

Root initiation time (DAP)

This observation was carried out to determine which treatments produced a tolerant response to drought stress, which was characterized by root emergence at an average time of 4–5 DAP in the 0% PEG treatment and root emergence at an average time of 4–5 DAP in the PEG 20% treatment (Harahap et al., 2013). Based on Table 2, tomato plants showing the earliest root initiation time was Chung variety in the V2P3 treatment combination with the ability to produce roots at 5 DAP under drought stress with a PEG concentration of 15%, while the tomato variety experiencing the most drought stress was Ratna variety because at a PEG concentration of 10%, it took 6 DAP for root emergence. This is supported by the research of Harahap et al. (2013), stating that in non-PEG or 0% PEG conditions, tomato plants were able to produce roots at 4–5 DAP and were able to produce roots at 7 DAP on the treated with of 20% PEG. The higher the concentration of PEG, the more it inhibits the osmosis process within the cells, making it difficult for water to enter the cells. This condition mimics drought stress, hindering the growth of plant roots (Mehmandar et al., 2023).

Root length (cm)

This observation was carried out to determine the treatment that produced a tolerant response to drought stress, which was characterized by an average plant height greater than or equal to 7.3 cm as a control. Based on Figures 3 and 4, the longest roots were produced in the single factor treatment P0 with an average root length of 7.43 cm. Then P1 produced the second longest root with an average of 6.98 cm, followed by P2 with an average of 6.77 cm and P3 with an average of 5.94 cm. Meanwhile, the shortest roots were produced in the single factor P4 treatment with an average of 3.80 cm. This is in accordance with research Wu et al. (2019) and Goharrizi et al. (2019) which stated that the higher the concentration of PEG, the more significant the decrease in the length of plant roots.

Number of roots (strands)

The number of roots was counted at the end of the observation to determine the final response of root growth to each treatment. Root quantity observations were conducted on plants that had been removed from the media bottle.

According to Harahap et al.(2013), in the stress-free treatment, tomato plants were able to produce an average of 21 roots. Palupi variety was found to be able to produce the most roots, 15.33, even at a PEG concentration of 20%. In contrast, the plants treated with a PEG concentration of 0% (Table 3) had not yet

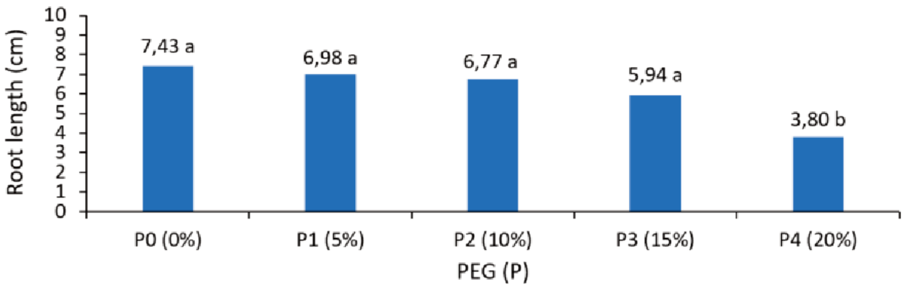

Figure 3. Average root length of tomato plants (cm) treated with PEG (P)

PEG 0% PEG 5% PEG 10% PEG 15% PEG 20%

Figure 4. Documentation of the average height of tomato plants (cm) treated with PEG

Table 3. The average number of roots (strands) resulting from the effect of the V×P treatment combination

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	12.07 bc	19.87 a	16.73 ab	6.07 d	7.93 cd
V1 (Intan)	14.93 ab	13.13 b	11.60 b	19.00 a	5.33 c
V2 (Chung)	17.13 a	14.80 ab	12.07 b	14.20 ab	10.67 b
V3 (Palupi)	10.87 c	17.20 ab	19.80 a	19.53 ab	15.33 bc
V4 (Amelia)	14.00 a	14.13 a	12.40 a	12.93 a	5.53 b

Remarks: Values followed by different letters show significantly different results at 5% DMRT.

reached an average of 21 roots. This is in accordance with research by Petrović et al. (2021), stating that drought stress inhibits of plant growth and development, especially in leaf growth. Thus, it can be said that the Palupi variety has the ability to survive drought stress up to 20% PEG concentration. Meanwhile, the tomato plant that has the most intolerant to drought stress in this research variable is the Ratna variety with a combined V0P3 treatment for 6.07 roots produced.

Number of fresh leaves

The total number of fresh leaves (leaves still attached to the plant) was counted at the end of the observation to determine the final response of the quantity of fresh leaves to each treatment. Observations of the number of fresh leaves were also conducted on plants that have been removed from the media bottle.

Based on Table 4, tomato plants showing the best level of tolerance to drought stress in producing fresh leaves in this study was Chung variety treated with 15% PEG (9.30 fresh leaves produced). This indicates that the Chung variety is able to withstand drought stress conditions up to a 15% PEG concentration in producing fresh leaves. Meanwhile, the tomato plant that is intolerant to drought stress in this research is Palupi variety which produced 4.13 fresh leaves after receiving a combination of V3P1 treatment since Palupi variety experienced a significant decrease in the number of fresh leaves compared to other varieties when treated with 5% PEG media. This can prove that tomato plants that are able to be under drought stress can produce more than 8 fresh leaves (Ningrum et al., 2020). However, at the highest PEG concentration (20% PEG), the largest number of fresh leaves was produced by the V2P4 treatment combination with an average of 7.20 fresh leaves.

Number of fallen leaves

The number of fallen leaves was counted at the end of the observation to determine the final response of leaf defense to each treatment. The calculation of the number of fallen leaves was conducted on plants that had been removed from the media bottle. This observation was carried out to identify treatments that resulted in a tolerant response to drought stress, as indicated by a lower average number of fallen leaves.

Based on Table 5, the tomato plant showing the highest tolerance to drought stress in producing the

Table 4. The average number of fresh leaves from the treatment of tomato varieties with PEG

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	5.60 ab	9.27 a	7.40 ab	5.67ab	2.87 b
V1 (Intan)	8.13 a	5.87 ab	4.53 ab	4.20 ab	1.80 b
V2 (Chung)	4.00 b	7.00 ab	7.80 ab	9.20 a	7.20 ab
V3 (Palupi)	3.33 a	4.13 a	4.67 a	4.87 a	5.13 a
V4 (Amelia)	2.80 c	9.53 a	9.27 ab	4.40 bc	1.60 c

Remarks: Values followed by different letters show significantly different results at 5% DMRT.

Table 5. Average number of fallen leaves as affected by tomato varieties treated with PEG

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	22.67 a	4.00 b	5.33 b	2.00 b	2.00 b
V1 (Intan)	4.33 a	0.67 a	0.00 a	2.00 a	0.00 a
V2 (Chung)	7.33 a	6.33 a	9.67 a	4.67 a	4.67 a
V3 (Palupi)	14.67 a	5.33 ab	1.33 b	0.00 b	3.33 b
V4 (Amelia)	18.67 a	12.33 a	3.67 b	2.67 b	0.00 b

Remarks: Values followed by different letters show significantly different results at 5% DMRT.

lowest number of fallen leaves was Palupi variety treated with a PEG concentration of 15% (0 fallen leaves). This indicates that Palupi variety is able to survive drought stress conditions up to a 15% PEG concentration in minimizing the number of fallen leaves. Meanwhile, the tomato plant intolerant to drought stress was Chung variety treated with a PEG concentration of 10% (9.67 fallen leaves). This indicates that at a PEG concentration of 10%, the Chung variety was already experiencing stress to drought stress as indicated by the increasing number of fallen leaves produced.

Root fresh weight (mg)

This observation was carried out to determine which treatment produced a tolerant response to drought stress, characterized by a larger average fresh weight.

Based on Figure 5, the highest root fresh weight was produced in the treatment of single factor V2 (Chung variety) with an average root fresh weight of 55.00 mg. Then V0 (Ratna variety) produced the second highest root fresh weight, with an average weight of 46.91 mg, followed by V3 (Palupi variety) with an average weight of 31.28 mg, then V1 (Intan variety) with an average weight of 22.71 mg. Meanwhile, the fresh root wight was the lowest in the treatment of single factor V4 (Amelia variety) with an average weight of 18.17 mg. Thus, it can be seen that V2 (Chung variety) produces the heaviest fresh roots when compared to V0 (Control) and V4 (Amelia variety) that produced the lightest fresh roots when compared to V0 (control).

Based on Figure 6, the highest root fresh weight

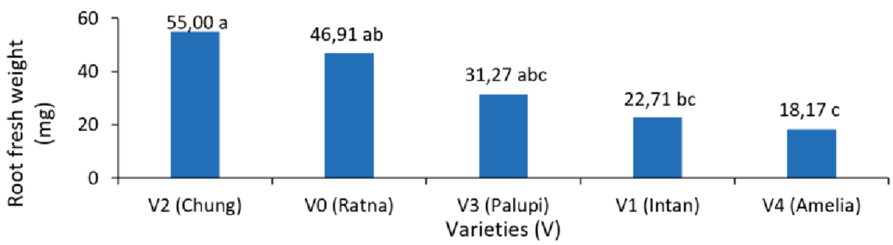

Figure 5. Average fresh weight of roots of the tested varieties

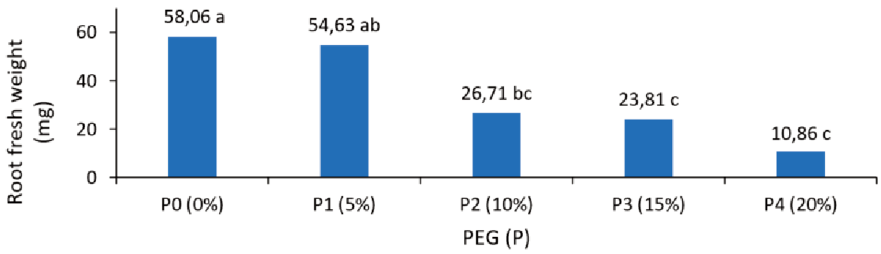

Figure 6. Average fresh weight of roots treated with PEG

Table 6. Average dry weight of roots of tomato varieties treated with PEG

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	14.32 a	7.54 b	8.55 b	5.47 b	6.04 b
V1 (Intan)	6.96 a	3.59 a	3.59 a	10.16 a	3.93 a
V2 (Chung)	9.64 b	15.88 a	38.25 b	9.61 b	4.12 b
V3 (Palupi)	7.06 b	14.19 a	9.38 ab	4.78 b	4.27 b
V4 (Amelia)	3.63 a	7.06 a	5.89 a	4.83 a	0.70 a

Remarks: numbers followed by different letters show significantly different results at 5% DMRT.

was produced in the single factor treatment P0 with an average root fresh weight of 58.06 mg. Then P1 produced the second highest root fresh weight (54.63 mg), followed by P2 with an average root fresh weight of 26.71 mg, then P3 with an average root fresh weight of 23.81 mg. Meanwhile, the lowest root fresh weight was in the treatment of single factor P4 with an average weight of 10.86 mg. So, it can be seen that P0 as a control produces the heaviest fresh roots, and P4 produces the lightest fresh roots when compared to P0 (control).

Root dry weight (mg)

Root dry weight was measured on tomato plants that had been in the oven for 24 hours. This observation was carried out to determine which treatment produced a tolerant response to drought stress, which was characterized by a lower average root dry weight.

Lower root dry weight indicates that the plant contains higher water content and can be said to be more tolerant to drought stress conditions. Based on Table 6, tomato plants showing the lowest tolerance to drought stress in producing the lowest root dry weight in this study was Intan variety treated with 5% and 10% PEG (3.59 mg). This indicates that the Intan variety is able to withstand drought stress conditions up to a 10% PEG concentration in producing the lowest root dry weight. Meanwhile, the tomato plants intolerant to drought stress was Palupi variety treated with the 5% PEG, resulting in 14.19 mg dry weight of the roots produced. This indicates that at a PEG concentration of only 5%, Palupi variety had already experienced drought stress as indicated by the increasing value of the dry weight of the roots produced.

The number of normal plantlets

This observation was carried out to determine the treatment that produced a tolerant response to drought stress, which was characterized by a high number of normal plantlets. Based on Table 7, Ratna variety (V0) as a control, was resistant to drought stress up to a PEG concentration of 10% (P2) by producing 100% normal plantlets, and had already experiencing drought stress at 15% PEG concentration (P3) by producing 60% normal plantlets. Intan variety (V1) was resistant to drought stress up to 15% PEG concentration (P3) by producing 100% normal plantlets and had experienced drought stress at 20% PEG

Table 7. The average percentage of normal plantlets growing normally as a result of the interaction of V and P treatments

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	100% a	100% a	100% a	60% b	73% b
V1 (Intan)	100% a	100% a	100% a	100% a	93% a
V2 (Chung)	100% a	100% a	100% a	93% a	100% a
V3 (Palupi)	100% a	100% a	100% a	100% a	100% a
V4 (Amelia)	100% a	100% a	100% a	67% b	40% b

Remarks: Values followed by different letters show significantly different results at 5% DMRT.

Table 8. The average percentage of plantlet growth as a result of the V×P treatment interaction

Varieties (V)	PEG (P)				
	P0 (0%)	P1 (5%)	P2 (10%)	P3 (15%)	P4 (20%)
V0 (Ratna)	100.00 a	100.00 a	100.00 a	60.00 b	73.33 b
V1 (Intan)	100.00 a	100.00 a	100.00 a	100.00 a	93.33 a
V2 (Chung)	100.00 a	100.00 a	100.00 a	93.33 a	100.00 a
V3 (Palupi)	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a
V4 (Amelia)	100.00 a	100.00 a	100.00 a	100.00 a	40.00 b

Remarks: Values followed by different letters show significantly different results at 5% DMRT.

concentration (P4) by producing 93% normal plantlets. Chung variety (V3) was resistant to drought at 10% PEG concentration (P2) by producing 100% normal plantlets and had experienced drought stress at 15% PEG concentration (P3) by producing 93% normal plantlets. Palupi variety (V3) was resistant to drought stress up to 20% PEG concentration (P4) by producing 100% normal plantlets and had not experienced drought stress at the 20% PEG concentration. Amelia variety (V4) was resistant to drought stress up to 10% PEG concentration (P2) by producing 100% normal plantlets and had experienced drought stress at 15% PEG concentration (P3) by producing 67% normal plantlets. Thus, based on the number of normal plantlets produced, Palupi variety is the most tolerant variety to drought stress because it does not experience drought stress up to the highest concentration of 20% PEG, and the most intolerant variety to drought stress is Ratna variety since it has experienced drought stress at a PEG concentration of 15%.

Percentage of plantlet growth rate

Tomato plants tolerant to drought are characterized by a higher plantlet growth % value. The average % of plantlet growth rate as affected by the treatments is presented in Table 8 below. Based on Table 8, the tomato plants showing the highest tolerance to drought stress in producing the highest percentage of plantlet growth rate in this study was Palupi variety treated with 20% PEG, resulting in 100% plantlet growth rate. This indicates that Palupi variety is able to withstand drought stress conditions up to a 20% PEG concentration in producing the percentage of plantlet growth rate. Meanwhile, the tomato plants intolerant to drought stress in terms of plantlet growth rate was Ratna variety treated with 15% PEG, resulting 60% plantlet growth rate. This indicates that at a PEG concentration of 15%, Ratna variety was already experiencing drought stress as indicated by the decrease in the percentage value of the plantlet growth rate.

CONCLUSIONS

There was an effect of a single treatment of tomato varieties on drought stress, in which Chung variety produced the highest plants and the heaviest fresh roots. Palupi variety was the most tolerant variety, while Ratna variety was the most intolerant variety to drought stress. The research results obtained in the treatment turned out to be due to the varieties that played the main role, and indeed there were varieties of tomatoes that were tolerant, less tolerant, and intolerant to drought stress. Suggestions for the future are to increase tolerance to drought stress, so as to provide more benefits. The higher the concentration of PEG used, the more it inhibits plant height, root length, and fresh weight of the roots.

ACKNOWLEDGEMENTS

The authors would like to express many thanks to Fundamental Research Project Program from The Directorate General of Higher Education, Research, and Technology (DGHERT) of the Ministry of Education, Culture, Research, and Technology (MOECRT) of the Republic of Indonesia, contract number: 2624 /UN25.3.1/LT/2022, which support the research.

REFERENCES

Alordzinu, K.E., Li, J., Lan, Y., Appiah, S.A., Aasmi, A., and Wang, H. (2021). Rapid estimation of crop water stress index on tomato growth. *Sensors*, 21(15), 5142.

Chandrasekaran, M., Boopathi, T., and Manivannan, P. (2021). Comprehensive assessment of ameliorative effects of amf in alleviating abiotic stress in tomato plants. *Journal of Fungi*, 7(4), 303.

Cui, Q., Li, Y., He, X., Li, S., Zhong, X., Liu, B., Zhang, D., and Li, Q. (2019). Physiological and iTRAQ based proteomics analyses reveal the mechanism of elevated CO_2 concentration alleviating drought stress in cucumber (*Cucumis sativus* L.) seedlings. *Plant Physiology and Biochemistry*, 143(July), pp. 142–153.

Dwinanti, A. W. and Damanhuri. (2021). Uji Daya Hasil Calon Varietas Hibrida Tomat (*Lycopersicum esculentum* Mill.) pada Musim Hujan. *PLANTROPICA: Journal of Agricultural Science*, 6(1), pp. 38–48.

Esan, V. I., Ayanbamiji, T. A., Adeyemo, J. O., and Oluwafemi, S. (2018). Effect of Drought on Seed Germination and Early Seedling of Tomato Genotypes using Polyethylene Glycol 6000. *International Journal of Sciences*, 4(02), pp. 36–43.

Estiningtyas, W., Boer. R., Las, I., and Buono, A. (2012). Identification and Delineation of Drought Area for Climate Risk. *Jurnal Meteorologi dan Geofisika*, 13(1), pp. 9–20.

Ghanbari, F. and Sayyari, M. (2018). Controlled drought stress affects the chilling-hardening capacity of tomato seedlings as indicated by changes in phenol metabolisms, antioxidant enzymes activity, osmolytes concentration and abscisic acid accumulation. *Scientia Horticulturae*, 229, pp. 167–174.

Goharrizi, K. J., Moosavi, S. S., Amirmahani, F., Salehi, F., and Nazari, M. (2019). Assessment of changes in growth traits, oxidative stress parameters, and enzymatic and non-enzymatic antioxidant defense mechanisms in Lepidium draba plant under osmotic stress induced by polyethylene glycol. *Protoplasma*, 257(2), pp. 459–473.

Harahap, E. R., Siregar, L. A. M., and Bayu, E. S. (2013). Pertumbuhan Akar pada Perkecambahan Beberapa Varietas Tomat dengan Pemberian Polyethylene Glikol (PEG) secara In Vitro. *Pendidikan Kimia PPs UNM*, 1(1), pp. 91–99.

Ibrahim, K. M. and Musbah, H. M. (2018). Increasing poly phenols in coleus blumei at the cellular and intact plant levels using PEG stress. *Research Journal of Pharmacy and Technology*, 11(1), pp. 321–327.

Lamin-Samu, A. T., Farghal, M., Ali, M., and Lu, G. (2021). Morpho-Physiological and Transcriptome Changes in Tomato Drought Stress. *MDPI*, 10(1809), pp. 1–24.

Li, S., Zhou, L., Addo-Danso, S. D., Ding, G., Sun, M., Wu, S., and Lin, S. (2020). Nitrogen supply enhances the physiological resistance of Chinese fir plantlets under polyethylene glycol (PEG)-induced drought stress. *Scientific Reports*, 10(1), pp. 1–8.

Mehmandar, M. N., Rasouli, F., Giglou, M. T., Zahedi, S. M., Hassanpouraghdam, M. B., Aazami, M. A., Tajaragh, R. P., Ryant, P., and Mlcek, J. (2023). Polyethylene Glycol and Sorbitol-Mediated In Vitro Screening for Drought Stress as an Efficient and Rapid Tool to Reach the Tolerant *Cucumis melo* L. Genotypes. *Plants*, 12(870), pp. 1–17.

Ningrum, A. R., Nuraini, A., Suminar, E., and Mubarok, S. (2020). Respons dua mutan tomat terhadap cekaman kekeringan. *Jurnal Kultivasi*, 19(2), pp.1156–1161.

Oktavia, F., Stevanus, C. T., and Dessailly, F. (2020). Optimasi Kondisi Suhu dan Kelembaban Serta Pengaruh Media Tanam terhadap Keberhasilan Aklimatisasi Tanaman Karet Asal Embriogenesis Somatik. *Jurnal Penelitian Karet*, 38(1), pp. 1–16.

Petrović, I., Savic, S., Gricourt, J., Causse, M., Jovanovic, Z., and Stikic, R. (2021). Effect of long-term drought on tomato leaves: the impact on metabolic and antioxidative response. *Physiology and Molecular Biology of Plants*, 27(12), pp. 2805–2817.

Qarana, A., Basri, H., and Sugianto (2020). Identifikasi Potensi Kekeringan Agro-Hidrologi di Lahan Pertanian dan Non-Pertanian Kabupaten Pidie. *Jurnal Ilmiah Mahasiswa Pertanian*, 2(3), pp. 30–37.

Roy, M. R., Rashed, M. R. U., and Mitu, A. S. (2017). Screening and Diversity Analysis of Drought Tolerant Genotypes in Vitro Tomato. *Agricultural Research & Technology: Open Access Journal*, 4(2), pp. 34–39.

Sakya, A. T., Sulistyaningsih, E., Purwanto, B. H., and Indradewa, D. (2020). Drought Tolerant Indices of Lowland Tomato Cultivars. *Indonesian Journal of Agricultural Science*, 21(2), pp. 59.

Sujinah and Jamil, A. (2016). Mekanisme Respon Tanaman Padi terhadap Cekaman Kekeringan dan Varietas Toleran. *Iptek Tanaman Pangan*, 11(1), pp. 1–8.

Venkatesh, P., Thirumalaikumar, Devkar, V., Mehterov, N., Ali, S., Ozgur, R., Turkan, I., Mueller-Roeber, B., and Balazadeh, S. (2018). NAC transcription factor JUNGBRUNNEN1 enhances drought tolerance in tomato. P*lant Biotechnology Journal*, 16(2), pp. 354–366.

Wu, K. C., Huang, C. M., Verma, K. K., Deng, Z. N., Huang, H. R., Pang, T., Cao, H. Q., Luo, H. B., Jiang, S.L., and Xu, L. (2022). Transcriptomic responses of Saccharum spontaneum roots in response to polyethylene glycol–6000 stimulated drought stress. *Frontiers in Plant Science*, 13(October), pp. 1–26.

Wu, L., Yang, H., Li, Z., Wang, L., and Peng, Q. (2019). Effects of Salinity-Stress on Seed Germination and Growth Physiology of Quinclorac-Resistant *Echinochloa crus-galli* (L.) Beauv. *Agronomy*, 12(5), pp. 1–11.

Yang, L., Bu, S., Zhao, S., Wang, N., Xiao, J., He, F., and Gao, X. (2022). Transcriptome and physiological analysis of increase in drought stress tolerance by melatonin in tomato. *PLoS ONE*, 17(5), pp. 1–23.

Zhou, R., Yu, X., Wen, J., Jensen, N. B., dos Santos, T. M., Wu, Z., Rosenqvist, E., and Ottosen, C. O. (2020). Interactive effects of elevated CO_2 concentration and combined heat and drought stress on tomato photosynthesis. *BMC Plant Biology*, 20(1), pp. 1–12.