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## DROUGHT TOLERANCE OF INDONESIAN TARO (*COLOCASIA ESCULENTA* [L.] SCHOTT.): COMPARISON BETWEEN DIPLOIDS AND POLYPLOIDS

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### SUMMARY

Food security based upon the improvement in crop productivity and adaptation to drought conditions have developed due to climate change. Taro (*Colocasia esculenta* [L.] Schott.) is a widely recognized local food source with the potential to support food security in Indonesia. Exploring polyploidization has shown to enhance productivity and adaptability to existing environmental conditions. The presented study aimed to evaluate the effects of ploidy levels and their variations on the drought tolerance of Indonesian taro under greenhouse conditions. An investigation of five taro clones (Bentul diploid, Bentul tetraploid, Kaliurang diploid, Kaliurang tetraploid, and Bolang triploid) for drought tolerance used different watering intervals. The different clones revealed a significant effect on the growth and physiological characters. Results indicated tetraploid clones exhibited the lowest growth percentage, chlorophyll content, and relative water content; however, they showed increased proline, total phenolic, flavonoid content, and antioxidant activity. This suggests tetraploid clones have a higher tolerance level than the other clones. The drought sensitivity index categorized diploid clones as sensitive, while tetraploid and triploid clones received the moderate category group. Moreover, results indicated polyploidization can potentially enhance taro's drought tolerance, thereby, improving food security in the context of climate change and global warming.

**Keywords:** Taro (*C. esculenta* [L.] Schott.), polyploidization, triploid, tetraploid, abiotic stress, drought sensitivity index, screening

**Key findings:** A comparison among the diploid, triploid, and tetraploid taro (*C. esculenta* [L.] Schott.) clones revealed an increase in ploidy correlates with an enhanced adaptability to drought-stress conditions.

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## INTRODUCTION

Taro (*Colocasia esculenta* [L.] Schott) is a widely recognized local food source with the potential as an alternative carbohydrate source. Most parts of taro plant are edible, except for the corm skin and true anatomical roots. The corms have the highest carbohydrate content, while the leaves are rich in protein. Additionally, the corm contains considerable minerals, vitamins, and essential amino acids, such as, phenylalanine and leucine. Taro has smaller starch grains than other food crops. Therefore, it is beneficial for diabetic patients, the elderly, and children with allergies and intestinal disorders (Fufa *et al.*, 2023).

With climate change and global warming, it is necessary to generate the taro cultivars of high adaptability and productivity in dry lands to support the food security program. Improving taro production through in vitro polyploidization might be one of the best approaches, which involves individuals with more ploidy levels than the normal two sets of chromosomes (Wen *et al.*, 2022). Polyploidy occurs either naturally or induced artificially. The induced of polyploidization involves antimitotic chemicals, such as, oryzalin, trifluralin, propox-methyl, and colchicine (Gantait and Mukherjee, 2021). This can also proceed through in vitro for higher efficiency and accuracy (Venial *et al.*, 2020).

The robustness of polyploid plants is an indication of improved adaptability to biotic and abiotic stress conditions. The increase in a plant's ploidy level has been evident, and significant improvement has progressed in its ability to adapt to various environmental conditions. Polyploidy influences the plant habit, xylem structure, and its function in response to water stress conditions (Misiukevicius *et al.*, 2024). The physiological responses of diploid and polyploid plants to water deficits considerably vary among the different crops. Therefore, it is crucial to consider ploidy as an essential element in assessing and understanding the effects of drought stress on plant growth, development, and physiological variables.

Therefore, a study is necessary to examine and compare the response and tolerance of diploid and polyploid plants to drought stress. Such types of studies would better assist in understanding the tolerance mechanism, given that polyploid plants have shown to exhibit better adaptation levels than their diploid counterparts, as evidenced in sugar beet (Wu *et al.*, 2019), barley (Chen *et al.*, 2021), and jewel orchid (Huang *et al.*, 2022). However, to date, no such comparative study has materialized with diploid and polyploid taro. Polyploidy induction experiments have also been progressive in taro clones Bentul (Wulansari *et al.*, 2016) and Kaliurang (Ermayanti *et al.*, 2018). Based on the foregoing discussion, the latest study aimed to evaluate the response of Indonesian diploid, triploid, and tetraploid taro to drought-stress conditions under the greenhouse condition.

## MATERIALS AND METHODS

In the presented study, all the diploid, triploid, and tetraploid taro clones originated from the Research Center for Applied Botany, BRIN, Indonesia. The Bentul (BTL-2x) and Kaliurang (KU-2x) were the naturally diploid clones, and the Bolang (BLG-3x) clone was a naturally triploid. The B544 clone was an in vitro-induced tetraploid of the Bentul diploid, and the KK1 was the in vitro-induced tetraploid clone of the diploid Kaliurang. This research transpired from January 2022 to February 2023 at the greenhouse facility of KST Ir. Soekarno BRIN, Cibinong, Indonesia.

The experiment layout had a completely randomized factorial design with two factors, i.e., taro clones and the watering interval. The taro clones encompassed five clones, as previously stated. The watering intervals comprised two levels, viz., daily and weekly watering. Establishing 60 experimental units continued by replicating each treatment combination six times. The 12-week-old taro plants, following acclimatization, originated from in vitro propagation and were utilized samples. The planting media comprised soil,

husk, and fertilizer in a 1:1:1 ratio, contained within 45 cm × 45 cm polybags. The polybags positioning was at intervals of 30 cm × 50 cm. Insecticide spraying also ensured pest control, while controlling weeds occurred manually. The treatments' application commenced after four weeks of planting.

Observations on growth parameters, including the number of leaves, petiole length, petiole base diameter, and number of tillers, continued every two weeks until harvest at 36 weeks. The measurement of relative water content of the leaves utilized the method of Barrs and Weatherley (1962), and the membrane stability injury's evaluation employed the technique of Arvin and Donnelly (2008). Measuring the membrane stability injury helped determine the electrolyte leakage. Chlorophyll content analysis ensued after 16 weeks of planting (Arnon, 1949). At harvest after 36 weeks of planting, the fresh and dry weight of plants, shoots, roots, and tubers, as well as, the number and length of roots, underwent further scrutiny.

Additionally, the physiological features, such as, proline content (Bates *et al.*, 1973), total phenolic content (TPC) (Malik *et al.*, 2014), total flavonoid content (TFC) (Nisa *et al.*, 2017), antioxidant activity based on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Maesaroh *et al.*, 2018), and ferric reducing antioxidant power (FRAP) (Sekhon-Loodu and Rupasinghe, 2019) were measured. These compounds' measurements used an Enzyme-Linked Immunosorbent Assay (ELISA) reader at wavelengths of 520 nm (proline), 750 nm (TPC), 415 nm (TFC), 517 nm (DPPH), and 595 nm (FRAP).

### Statistical analysis

All various recorded parameters underwent the analysis of variance (ANOVA). The characters with significantly different mean square interaction values reached selection. Pearson's correlation analysis proceeded to examine the relationship among the traits. Applying the R-Studio v.4.3.1 program determined means, correlation, and principal component analyses. The computation of drought sensitivity index

(DSI) of the taro clones applied the formula proposed by Fischer and Maurer (1978):

$$DSI = \frac{1 - \left(\frac{Y}{Y_p}\right)}{1 - \left(\frac{X}{X_p}\right)}$$

Where, DSI: Drought sensitivity index,

Y: Average observation of one genotype under drought condition,

Y<sub>p</sub>: Average observation of one genotype under optimum condition,

X: Average observation of all genotypes under drought condition, and

X<sub>p</sub>: Average observation of all genotypes under optimum condition.

The criteria for determining the drought sensitivity were, as follows, i.e., DSI value < 0.5 indicates the clone is tolerant, DSI value between 0.5 < DSI < 1.0 indicates the clone is moderately tolerant, and DSI value > 1.0 indicates the clone is sensitive to drought stress.

## RESULTS AND DISCUSSION

### Drought effect on taro growth

The analysis of variance revealed the taro clone treatments, watering treatments, and their interaction had a significant effect on growth characters, except for petiole length and root fresh weight (Table 1). The noteworthy interaction also suggested the taro clones responded differently under optimal (daily watering) and drought (weekly watering) conditions. The weekly watering interval treatment resulted in a decreased growth compared with the control group, which received water daily.

Overall, the drought treatment resulted in a decline in all the growth characters of the taro diploid, triploid, and tetraploid clones. Although the tetraploids exhibited a decrease in values, their superiority over the diploids and triploids remained evident. In growth parameters, the average values of relative decline ranged from 48.3% to 55.2% (Table 2). The relative decline in growth traits was

**Table 1.** Analysis of variance of taro clones with different watering intervals for growth traits.

Growth characters	Taro clones	Watering intervals	Interaction	CV (%)
Number of leaves	**	**	**	18.73
Petiole length (cm)	*	**	NS	19.27
Number of tillers	**	**	**	57.52
Diameter of petiole base (cm)	**	**	*	10.56
Number of roots	**	**	**	10.93
Root length (cm)	**	**	**	12.42
Plants fresh weight (g)	**	**	**	12.25
Plants dry weight (g)	**	**	**	12.06
Shoots fresh weight (g)	**	**	**	17.13
Shoots dry weight (g)	**	**	**	16.66
Roots fresh weight (g)	**	**	NS	31.68
Roots dry weight (g)	**	**	*	17.32
Tubers fresh weight (g)	**	**	**	18.56
Tubers dry weight (g)	**	**	**	16.44

CV: Coefficient of Variance; \*\*significant at  $p < 0.01$ ; \*significant at  $p < 0.05$ ; NS: Nonsignificant.

**Table 2.** Percent relative decline of growth characters in taro clones with different watering intervals.

Growth characters	Percentage of Relative Decline					
	BTL-2x	KU-2x	BLG-3x	B544-4x	KK1-4x	Average
Number of leaves	55.0	61.7	46.7	61.0	26.7	50.2
Petiole length (cm)	51.4	55.8	63.6	46.0	42.0	51.8
Number of tillers	15.0	100.0	64.0	60.0	20.0	51.8
Diameter of petiole base (cm)	56.9	63.8	65.9	42.3	47.3	55.2
Number of roots	57.2	52.7	52.1	48.0	52.0	52.4
Root length (cm)	54.1	52.6	52.7	46.8	50.8	51.4
Plants fresh weight (g)	59.7	55.0	51.1	48.7	51.8	53.3
Plants dry weight (g)	53.3	54.4	51.0	48.8	51.7	51.8
Shoots fresh weight (g)	54.2	45.0	51.0	47.0	44.4	48.3
Shoots dry weight (g)	56.3	49.8	52.5	45.3	44.3	49.7
Roots fresh weight (g)	52.2	56.8	57.7	52.1	51.2	54.0
Roots dry weight (g)	54.6	63.1	56.5	74.6	47.9	59.3
Tubers fresh weight (g)	53.7	53.6	53.6	49.4	53.5	52.8
Tubers dry weight (g)	51.0	56.7	53.9	47.6	53.4	52.5

due to cellular injury, disruption of the balance of protein content, and damage to cell membranes under stress conditions. These conditions also disrupt the osmotic balance, resulting in cell dehydration and affecting the growth response in roots and leaves (Dlamini, 2021).

The lowest percentage of relative decline appeared for the number of tillers (20%) in the tetraploid clone Bentul and for the number of leaves (26.7%) in the tetraploid clone Kaliurang (Table 2). A low percentage of relative decline in growth characters enunciated the said clones have superior

performance even under water-limited conditions, suggesting the clones as more tolerant to drought conditions (Udpuay *et al.*, 2024). Genotypes exhibiting minimal relative decline under water stress conditions possess considerable potential for use as donor genotypes for the assembly of stress-tolerant crop plants (Kumar *et al.*, 2018). Genotypes that exhibit tolerance can also improve the efficiency of water and nutrient utilization for growth under water limited conditions (Ullah *et al.*, 2019). Taro tetraploid clones demonstrated the capacity to continue growing even under water-limited conditions. A hypothesis is the

response of the different taro clones for growth characters interconnect to different ploidy levels.

Tetraploid plants tend to exhibit greater size than their diploid counterparts. The higher drought tolerance exhibited by tetraploid plants seemed associated with their larger cell size, which enables them to retain more water in tissues through enhanced thickness of epidermal and palisade tissues (Tossi *et al.*, 2022). In plants, the larger cell size results in increased metabolic activity, leading to a wider root cortex. This limits the radial hydraulic conductivity of the roots, reducing water uptake, and increasing drought tolerance (Doyle and Coate, 2019).

### Drought effect on taro physiology

The analysis of variance revealed taro clone treatments significantly influenced almost all the physiological parameters, except membrane stability (Table 3). The watering interval factors notably affected all physiological characters. The interaction between taro clones and watering factors demonstrated a highly significant effect on most traits, except the membrane stability injury.

Drought stress induces variations in physiological traits, and the taro tetraploid clones exhibited higher proline content, TPC, and TFC than diploids and triploid clones (Figure 1). The analysis of antioxidant activity using the DPPH and FRAP methods also yielded varied results. In all types of clones, the water stress treatment decreased the antioxidant

activity value based on the DPPH method, however, showed an increase through the FRAP method. The drought treatments also reduced the chlorophyll content in all types of taro clones.

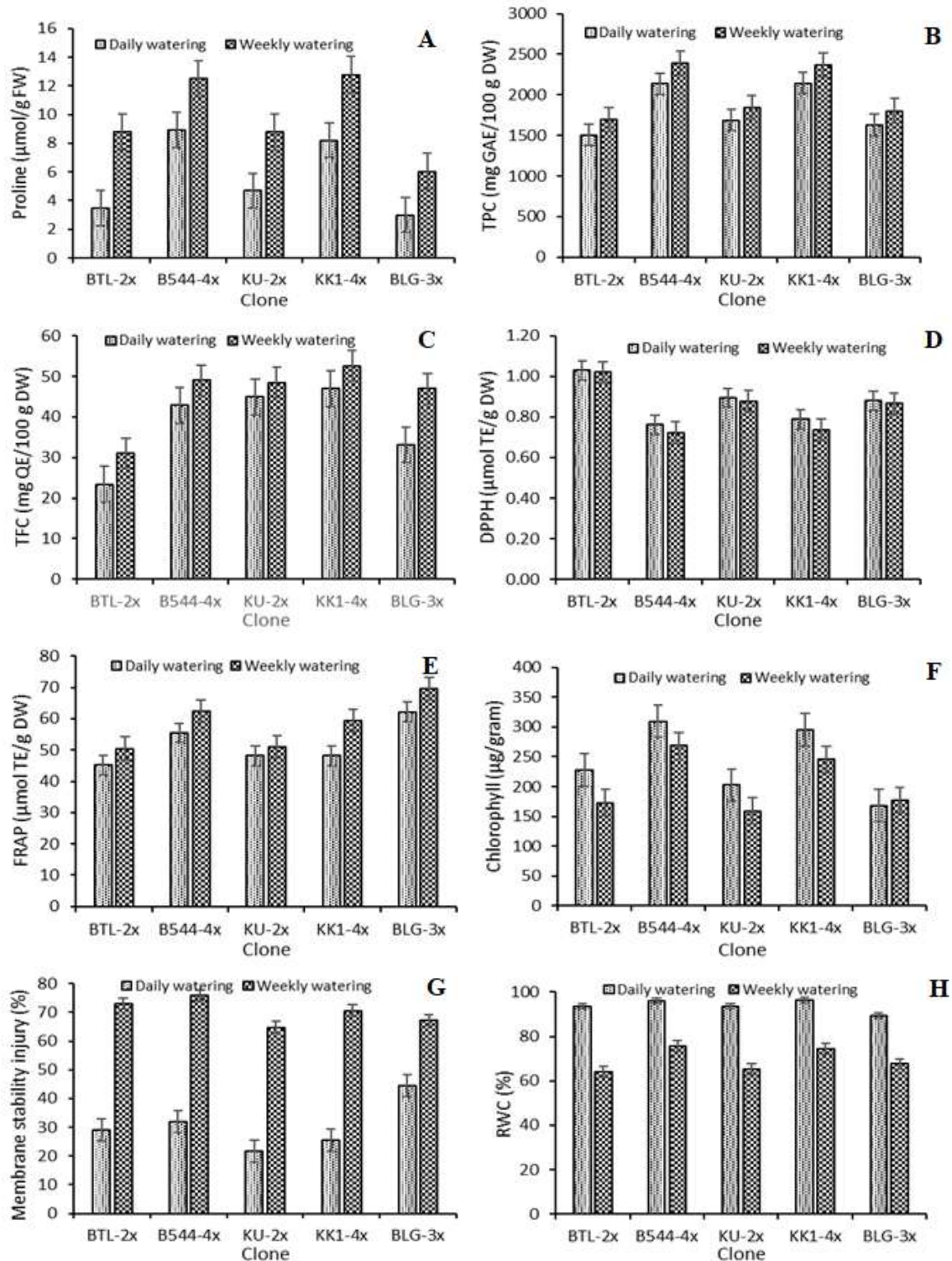
The presented results further indicated drought treatment raised the proline content in taro diploids, triploids, and tetraploids. An increase in proline under stress conditions resulting from a decline in relative water content was also evident in tea seedlings (Upadhyaya *et al.*, 2016), wheat (Altaf *et al.*, 2021), and tomatoes (Patane *et al.*, 2022). Proline is a known regulator of the osmotic adjustment and produces several osmo-protectants. Proline also revealed to reduce water loss in cells by regulating cytosolic acidity under water deficit conditions (Islam *et al.*, 2023).

The weekly watering treatment resulted in an increase in total phenolic content in all types of taro clones. The increasing trend also aligned with an increase in the ploidy level of taro clones. Mei *et al.* (2020) demonstrated the same results in a comparative study between diploids and tetraploids of *Echinacea purpurea*. The accumulation of phenolic compounds under stress conditions functions as a plant defense system. Findings of Kiani *et al.* (2021) further indicated phenolic compounds function as non-enzymatic antioxidants and eliminate ROS in wheat. Phenolic compounds serve to protect biological systems by maintaining redox balance, thereby, enabling plants to adapt to abiotic stress conditions.

**Table 3.** Analysis of variance of taro clones with different watering intervals for physiological traits.

Physiological traits	Taro clones	Watering intervals	Interaction	CV (%)
Proline ( $\mu\text{mol}/\text{gram FW}$ )	**	**	**	4.45
TPC (mg GAE/100gram DW)	**	**	**	0.61
TFC (mg QE/100gram DW)	**	**	**	5.31
DPPH ( $\mu\text{mol TE}/\text{gram DW}$ )	**	**	**	0.62
FRAP ( $\mu\text{mol TE}/\text{gram DW}$ )	**	**	**	1.51
Chlorophyll ( $\mu\text{g}/\text{gram}$ )	**	**	**	4.08
Membrane stability injury (%)	NS	**	NS	21.12
RWC (%)	**	**	**	2.02

TPC: Total Phenolic Content; TFC: Total Flavonoid Content; DPPH: 2,2-Di-Phenyl-1-Picryl-Hydrazyl; FRAP: Ferric Reducing Antioxidant Power; RWC: Relative Water Content; CV: Coefficient of Variance; \*\*significant at  $p < 0.01$ ; NS: Nonsignificant.



**Figure 1.** Graphs of physiological features in taro clones with different watering intervals on proline content (A), total phenolic content/TPC (B), total flavonoid content (C), 2,2-di-phenyl-1-picryl-hydrazyl/DPPH (D), ferric reducing antioxidant power/FRAP (E), chlorophyll content (F), membrane stability (G), relative water content/WC (G).

Flavonoid compounds are pivotal in the plant's response to environmental stress. Flavonoids also prevent water loss by reducing transpiration through stomata and increasing the plant's tolerance to drought conditions by acting as ROS scavengers (Conti *et al.*, 2022). The presented results further revealed drought stress treatment resulted in an increase in flavonoid content in all types of taro clones. However, the pattern of increase varied among the clones with different ploidy levels. The latest results were in a greater analogy with findings demonstrated about the drought resistance in potatoes (Zaki and Radwan, 2022) and sweet potato (Abewoy, 2023).

ROS generation is one of the most critical consequences of drought stress, which can cause oxidative damage to cellular components, such as, lipids, proteins, and nucleic acids. In the pertinent study, the quantification of non-enzymatic free radical scavenging ability through antioxidant analysis used the DPPH and FRAP methods in taro clones. The discrepancy in responses observed through the DPPH and FRAP methods suggests a divergence in gene expression related to stress signaling, which, in turn, stimulates the synthesis of antioxidant compounds in cassava (Koundinya *et al.*, 2024).

The higher chlorophyll content of taro tetraploid clones than their diploids indicates a higher level of drought tolerance, as also observed in the apple tetraploid tree (Wójcik *et al.*, 2022). Research on macadamia demonstrated cultivars capable of maintaining high chlorophyll content under drought stress conditions can exhibit enhanced light energy utilization efficiency, thereby, exhibiting greater drought tolerance (Kang *et al.*, 2024).

Measuring the membrane stability injury sought to determine electrolyte leakage levels due to drought stress treatment. The results indicated the stress treatment led to an increase in the percentage of membrane damage in all types of taro clones (Figure 1). Both diploid and tetraploid of genotype Kaliurang showed the lowest percentage of membrane injury. Both diploid and tetraploid clones of genotype Bentul gave the highest percentage of membrane damage. The percent difference between control and stress

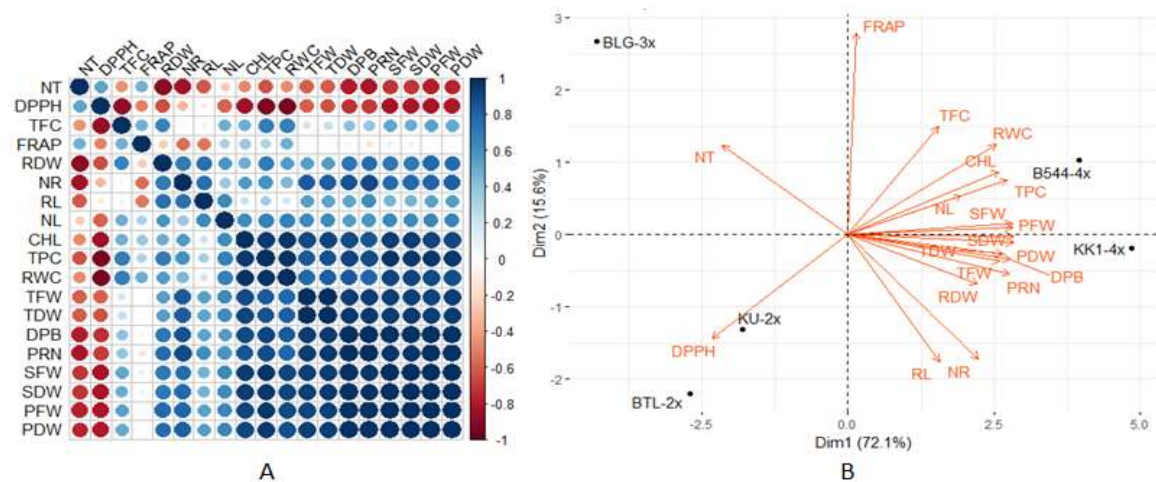
treatments in all the taro clones was significant. The outcomes further signified drought treatment resulted in an elevated percent value of membrane damage in all the clones. However, the tetraploid clones exhibited lower values than diploid and triploid counterparts. Khalvandi *et al.* (2021) reported the degree of electrolyte leakage in cell membranes can serve as an indicator to assess wheat plants' tolerance to drought stress conditions.

The stress treatment caused a decrease in leaf relative water content (Figure 1). However, in the leaves of taro diploids and tetraploids, the relative water content did not differ significantly from triploids under a stress environment. In the control treatment, the response pattern varied, and the taro tetraploid clones exhibited higher values than other types of clones. Drought stress appeared to correlate with a reduction in the relative water content of plants. The latest results also demonstrated a decline in relative water content in all types of clones following drought treatment. In the case of mild drought stress, plants were typically capable of maintaining their relative water content in a manner comparable to that observed in more severe stress levels in *Tagetes minuta* L. (Babaei *et al.*, 2021).

### Correlation analysis

In taro clones, the selected characters resulting from the analysis of variance and with the percent relative decline on drought screening underwent Pearson's correlation analysis. Pearson's correlation analysis indicated the taro traits, viz., the diameter of petiole base with a fresh and dry weight of plant (0.99), shoots (0.98), and tuber (0.96), as well as, proline content (0.99), chlorophyll content (0.89), TPC (0.97), and relative water content (0.98), exhibited a significant positive correlation (Figure 2.A). The number of roots positively correlated significantly with proline content (0.90). The TPC also emerged as significantly positively associated with proline content (0.89), chlorophyll (0.96), and relative water content (0.98); however, it has a considerable negative correlation with DPPH (-





**Figure 2.** Pearson's correlation analysis (A) and biplot of the first two principal component (B) of the growth and physiological characters of taro clones.

NL: number of leaves; DPB: diameter of petiole base; NR: number of roots; NT: number of tillers; SFW: shoots fresh weight; SDW: shoots dry weight; RDW: roots dry weight; PFW: plant fresh weight; PDW: plant dry weight; RL: root length; TFW: tuber fresh weight; TDW: tuber dry weight; TPC: total phenolic content; TFC: total flavonoid content; PRN: proline content; DPPH: 2,2-Di-Phenyl-1-Picryl-Hydrazyl; FRAP: ferric reducing antioxidant power; CHL: chlorophyll; RWC: relative water content.

0.93). Additionally, TFC demonstrated a significant negative correlation with DPPH (-0.88). The relative water content occurred to have a substantial negative relation with the DPPH (-0.94).

The correlation between chlorophyll content and relative water content in taro clones appeared as significantly positive (0.97). Based on those results, growth variables can be applicable to determine drought sensitivity, except for the petiole length and root fresh weight. Similarly, physiological traits can also be helpful to ascertain drought sensitivity, except membrane stability in taro genotypes. Correlation analysis revealed characters with a considerable positive correlation can be beneficial in the selection process to identify specific traits with a significant positive impact on the drought tolerance in Bambara groundnut (Rahmah *et al.*, 2020) and rice (Wibisono *et al.*, 2024).

### Principal component analysis

For drought tolerance evaluation in taro clones, based on the Eigenvalue >1, two main

components were notable together in explaining 87.7% of the total variation. The biplot demonstrated the taro clones' separation depended on their ploidy level in different quadrants (Figure 2.B). The antioxidant activity based on FRAP exhibited a high degree of diversity, with the longest vector line also authenticated. The number of leaves, fresh and dry weight of plants, shoots, tubers, and roots, as well as, proline, chlorophyll, and phenolic contents, exhibited a significant positive correlation. The taro tetraploid clones showed a high variability in the plants' fresh and dry weights, shoots, proline, chlorophyll, phenolic, and relative water content. The diploid clones presented high variability in the DPPH parameter, while the triploid clones demonstrated high variability for the number of tillers.

In ascertaining the main factors influencing the taro genotypes' tolerance to drought stress, employing principal component analysis (PCA) of the correlated characters also ensued. The PCA is one of the multivariate analyses that can condense data with various variable dimensions into fewer dimensions (Ilin



and Raiko, 2010). PCA also helps to determine the axis of differentiation contributing mostly to the total diversity (Khan *et al.*, 2024). The determination of principal components based on Eigenvalues (>1) ensures each retained component is more diverse than a single variable in the original data, thus, providing a considerable explanation and assisting in efficient dimensionality reduction (Mattjik and Sumertajaya, 2013). In this study, PCA revealed the most significant contributors to drought tolerance in taro are the number of leaves, the fresh, and dry weights of the plant, shoot, tuber, and root, as well as, proline, chlorophyll, and phenolic contents.

### Stress tolerance index

The average drought sensitivity index (DSI) in each taro character became a reference for determining the drought tolerance. The taro diploid clones were apparently in the sensitive category, with DSI values of 1.12 (Bentul) and 1.02 (Kaliurang). The tetraploid clones belonged to the moderate classification, with a DSI value of 0.99. The taro triploid clones also received a moderate classification, with a DSI value of 1.00.

Finding the stress tolerance index had the objective of determining the ability of taro genotypes to tolerate drought stress. The drought sensitivity index is one of the indices for use to assess the decline caused by a sub-optimum environment in comparison to an optimum environment. The low value of DSI indicates the genotypes tested under sub-optimum conditions did not exhibit a noteworthy decrease, thus, categorizing them as tolerant (Anshori *et al.*, 2019; Kisman *et al.*, 2021). The DSI value's calculation used the values of the selected characters from the correlation and principal component analyses, as also demonstrated in previous studies in potatoes (Zaki and Radwan (2022) and mung beans (Islam *et al.*, 2023).

### CONCLUSIONS

A comparison of the growth patterns and physiological responses of taro (*C. esculenta*

[L.] Schott.) diploid, triploid, and tetraploid clones revealed an increase in their adaptability to drought stress with an upsurge in their ploidy level. The drought sensitivity index indicated the taro diploid clones belonged to the sensitive category, while triploid and tetraploid clones in the moderate category. The data regarding the sensitivity of taro to drought can be applicable in the development of drought-tolerant taro varieties. Furthermore, farmers may utilize this information to select taro species with moderate tolerance during the extended dry season.

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### REFERENCES

- Abewoy D (2023). Response of sweet potato (*Ipomoea batatas*) to drought stress: Review. *Glob. Acad. J. Agric. Biosci.* 5(5): 107-112.
- Altaf A, Gull A, Zhu X, Zhu M, Rasool G, Ibrahim MEH, Aleem M, Uddin S, Saeed A, Shah AZ, Zada A, Quan M, Yonggang D, Xu D, Chen L (2021.) Study of the effect of PEG-6000 imposed drought stress on wheat (*Triticum aestivum* L.) cultivars using relative water content (RWC) and proline content analysis. *Pak. J. Agri. Sci.* 58(1): 357-367. doi:10.21162/PAKJAS/21.953.
- Anshori MF, Purwoko BS, Dewi IS, Ardie SW, Suwarno WB (2019). Selection index based on multivariate analysis for selecting doubled-haploid rice lines in lowland saline-prone area. *SABRAO J. Breed. Genet.* 51(2): 161-174.
- Arnon D (1949). Copper enzymes in isolated chloroplasts polyphenol oxidase in *Beta vulgaris*. *Plant Physiol.* 24(1): 1-15.
- Arvin MJ, Donnelly DJ (2008). Screening potato cultivars and wild species to abiotic stresses using an electrolyte leakage bioassay. *J. Agric. Sci. Technol.* 10: 33-42.
- Babaei K, Moghaddam M, Farhadi N, Ghasemi PA (2021). Morphological, physiological, and phytochemical responses of Mexican

- marigold (*Tagetes minuta* L.) to drought stress. *Sci. Hortic.* 284. doi: 10.1016/j.scienta.2021.110116.
- Barrs H, Weatherley P (1962). A re-examination of the relative turgidity technique for estimating water deficit in leaves. *Biol. Sci.* 15: 413–428.
- Bates L, Waldren R, Teare I (1973). Rapid determination of free proline for water-stress studies. *Plant Soil.* 39: 205–207.
- Chen Y, Xu H, He T, Gao R, Guo G, Lu R, Chen Z, Liu C (2021). Comparative analysis of morphology, photosynthetic physiology, and transcriptome between diploid and tetraploid barley derived from microspore culture. *Front. Plant Sci.* 12: 626916. doi:10.3389/fpls.2021.626916.
- Conti V, Romi M, Guarnieri M, Cantini C, Cai G (2022). Italian tomato cultivars under drought stress show different content of bioactive in pulp and barrels of fruits. *Foods* 11(3). doi:10.3390/foods11030270.
- Dlamini PJ (2021). Drought stress tolerance mechanisms and breeding effort in sugarcane: A review of progress and constraints in South Africa. *Plant Stress* 2. doi:10.1016/j.stress.2021.100027.
- Doyle JJ, Coate JE (2019). Polyploidy, the nucleotype, and novelty: The impact of genome doubling on the biology of the cell. *Int. J. Plant Sci.* 180(1): 1–52. doi: 10.1086/700636.
- Ermayanti TM, Wijayanta A, Ratnadewi D (2018). Induksi poliploid pada tanaman talas (*Colocasia esculenta* (L.) Schott) kultivar Kaliurang dengan perlakuan kolkisin secara *in vitro*. *J. Biol. Indo.* 14(1): 91–102.
- Fischer R, Maurer R (1978). Drought resistance in spring wheat cultivars. I grain yield responses. *Aust. J. Agric. Res.* 29: 897–912. doi:10.1071/AR9780897.
- Fufa TW, Oselebe HO, Abteu WG, Amadi CO (2023). Physicochemical analysis of taro (*Colocasia esculenta* (L.) Schott) accessions. *Asian J. Res. Agric.For.* 9(4): 29–41. doi:10.9734/ajraf/2023/v9i4232.
- Gantait S, Mukherjee E (2021). Induced autopolyploidy—a promising approach for enhanced biosynthesis of plant secondary metabolites: An insight. *J. Genet. Eng. Biotechnol.* 19(1). doi:10.1186/s43141-020-00109-8.
- Huang X, Ouyang K, Lou Y, Xie G, Yang Y, Zhang J (2022). A comparative study of characteristics in diploid and tetraploid *Anoectochilus roxburghii*. *Front. Nutr.* 9.1034751. doi:10.3389/fnut.2022.1034751.
- Ilin A, Raiko T (2010). Practical approaches to principal component analysis in the presence of missing values. *J. Mach. Lear. Res.* 11: 1957–2000.
- Islam MR, Kamal MM, Hossain MF, Hossain J, Azam MG, Akhter MM, Hasan MK, Al-Ashkar I, Almutairi KF, El-Sabagh A, Rahman MA, Iqbal MA, Islam MS (2023). Drought tolerance in mung bean is associated with the genotypic divergence, regulation of proline, photosynthetic pigment and water relation. *Phyton-Int. J. Exp. Bot.* 92(3). doi:10.32604/phyton.2023.025138.
- Kang Z, Zhang W, Guo G, Pan X, Huang D, Wang R, Shen X (2024). Morphological and physiological responses of 14 macadamia rootstocks to drought stress and a comprehensive evaluation of drought resistance. *Environ. Exp. Bot.* 219. 105630. doi:10.1016/j.envexpbot.2023.105630.
- Khalvandi M, Siosemardeh A, Roohi E, Keramati S (2021). Salicylic acid alleviated the effect of drought stress on photosynthetic characteristics and leaf protein patterns in winter wheat. *Heliyon* 7(1). doi:10.1016/j.heliyon. 2021.e05908.
- Khan MM, Rahman MM, Hasan MM, Amin MF, Matin MQI, Faruq G, Alkeridis LA, Gaber A, Hossain A (2024). Assessment of the salt tolerance of diverse bread wheat (*Triticum aestivum* L.) genotypes during the early growth stage under hydroponic culture conditions. *Heliyon* 10(7). doi:10.1016/j.heliyon.2024.e29042.
- Kiani R, Arzani A, Mirmohammady MSAM (2021). Polyphenols, flavonoids, and antioxidant activity involved in salt tolerance in wheat, *Aegilops cylindrica* and their amphidiploids. *Fron. Plant Sci.* 12. doi:10.3389/fpls. 2021.646221.
- Kisman, Hemon AF, Listiana BE, Ismayanti FD, Asrul L (2021). Drought susceptibility index and correlation of soybean based on yield and yield component. *IOP Conf. Series: Earth Env. Sci.* 681. 012020. doi: 10.1088/1755-1315/681/1/012020.
- Koundinya AVV, Nisha A, Ajeesh BR (2024). Early vigour: A key to drought tolerance in cassava based on physiological and biochemical traits including inherent non-enzymatic antioxidant activity. *Sci. Hortic.* 331. doi: 10.1016/j.scienta.2024.113110.
- Kumar S, Sachdeva S, Bhat K, Vats S (2018). Plant responses to drought stress: Physiological, biochemical, and molecular basis. *Biot. Abio. Stress Tol. Plants* doi:10.1007/978-981-10-9029-5\_1.

- Maesaroh K, Kurnia D, Al Anshori J (2018). Perbandingan metode uji aktivitas antioksidan DPPH, FRAP dan FIC terhadap asam askorbat, asam galat dan kuersetin. *Chim. et Nat. Acta.* 6(2): 93. doi:10.24198/cna.v6.n2.19049.
- Malik A, Ahmad AR, Ahmad R (2014). Determination of phenolic and flavonoid contents of ethanolic extract of Kanunang leaves (*Cordia myxa* L.). *Int. J. Pharm. Res.* 7(2): 243–246.
- Mattjik A, Sumertajaya IM (2013). Perancangan Percobaan dengan Aplikasi SAS dan Minitab Jilid 1. IPB Press.
- Mei B, Xie H, Xing H, Kong D, Pan X, Li Y (2020). Changes of phenolic acids and antioxidant activities in diploid and tetraploid *Echinacea purpurea* at different growth stages. *Rev. Bras. Farmacogn.* 30: 510–518. <http://doi.org/10.1007/s43450-020-00069-7>.
- Misiukevicius E, Mazeikiene I, Stany V (2024). Poidy's role in daylily plant resilience to drought stress challenges. *Biology* 13. 289. doi: 10.3390/biology13050289.
- Nisa K, Nurhayati S, Apriyana W, Indriarningsih AW (2017). Investigation of total phenolic and flavonoid contents, and evaluation of antimicrobial and antioxidant activities from *Baeckea frutescens* extracts. *IOP Conf. Series: Earth Env. Sci.* 101(1). doi:10.1088/1755-1315/101/1/012002.
- Patane C, Cosentino SL, Romano D, Toscano S (2022). Relative water content, proline, and antioxidant enzymes in leaves of long shelf-life tomatoes under drought stress and rewatering. *Plants* 11.3045. doi:10.3390/plants11223045.
- Rahmah NI, Ilyas S, Setiawan A (2020). Evaluation of Bambara groundnut (*Vigna subterranea* L.Verdc.) genotypes for drought tolerance at germination stage. *SABRAO J. Breed. Genet.* 52(1): 45–63.
- Sekhon-Loodu S, Rupasinghe HPV (2019). Evaluation of antioxidant, antidiabetic and antiobesity potential of selected traditional medicinal plants. *Front. Nutri.* 6. doi:10.3389/fnut.2019.00053.
- Tossi VE, Martínez TLJ, Laino LE, Iannicelli J, Regalado JJ, Escandón AS, Baroli I, Causin HF, Pitta-Álvarez SI (2022). Impact of polyploidy on plant tolerance to abiotic and biotic stresses. *Front. Plant Sci.* doi:10.3389/fpls.2022.869423.
- Udpuay S, Ullah H, Himanshu SK, Tisarum R, Cha-um S, Datta A (2024). Drought tolerance screening of okra genotypes in relation to growth and physio-biochemical traits at the vegetative stage. *Genet. Res. Crop Evol.* 71(3):1271–1290. doi:10.1007/s10722-023-01689-3.
- Ullah H, Santiago-Arenas R, Ferdous Z, Attia A, Datta A (2019). Improving water use efficiency, nitrogen use efficiency, and radiation use efficiency in field crops under drought stress: A review. *Adv. Agron.* 156: 109–157. doi:10.1016/bs.agron.2019.02.002.
- Upadhyaya H, Dutta BK, Panda SK (2016). Drought induced physiological and biochemical changes in leaves of developing seedlings of tea *Camellia sinensis* (L.) O Kuntze cultivars. *J. Tea Sci. Res.* 6(4): 1–11.
- Venial LR, Mendonça MAC, Amaral-Silva PM, Canal GB, Passos ABR de J, Ferreira A, Soares TCB, Clarindo WR (2020). Autotetraploid *Coffea canephora* and auto-alloctaploid *Coffea arabica* from *in vitro* chromosome set doubling: New germplasms for coffea. *Front. Plant Sci.* 11. doi:10.3389/fpls.2020.00154.
- Wen Y, Liu H, Meng H, Qiao L, Zhang G, Cheng Z (2022). *In vitro* induction and phenotypic variations of autotetraploid garlic (*Allium sativum* L.) with dwarfism. *Front. Plant Sci.* 13. doi:10.3389/fpls.2022.917910.
- Wibisono K, Dama H, Dewi AK (2024). Multivariate analysis and preference selection index to selecting rice genotype adaptive on drought stress environment during generative stage. *AIP Conf. Proc.* 2957. 080007. doi:10.1063/5.0183906.
- Wójcik D, Marat M, Marasek-Ciolakowska A, Klamkowski K, Buler Z, Podwyszynska M, Tomczyk PP, Wójcik K, Treder W, Filipczak J (2022). Apple autotetraploid-phenotypic characterization and response to drought stress. *Agronomy* 12. 161. doi: 10.3390/agronomy12010161.
- Wu GQ, Lin LY, Jiao Q, Li SJ (2019). Tetraploid exhibits more tolerant to salinity than diploid in sugar beet (*Beta vulgaris* L.). *Acta Physiol Plant.* 41: 52. doi:10.1007/s11738-019-2844-7.
- Wulansari A, Martin AF, Ermayanti TM (2016). Induksi tanaman poliploid talas (*Colocasia esculenta* (L.) Schott.) dengan perlakuan orizalin secara *in vitro*. *J. Biol. Indon.* 12(2): 297–305.
- Zaki HEM, Radwan KSA (2022). Response of potato (*Solanum tuberosum* L.) cultivars to drought stress under *in vitro* and field conditions. *Chem. Biol. Tech. Agric.* 9(1). doi: 10.1186/s40538-021-00266-z.