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Research Paper

Drought Stress Tolerance of Indonesian Rice Varieties (*Oryza sativa* L.) and Its Kindship Relationship based on Morphological Characters

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Abstract. Morphological characters of ten Indonesia rice varieties under drought stress was analized under drought stress and normal condition to study their drought resistance mechanism and their kinship. All varieties showed changes in morphological characters in drought stress conditions. Drought stress has an impact on changes in the morphological characters of ten rice varieties. This results in changes in cluster groups under drought conditions. The objectves of this research were to study drought stress tolerancy of Indonesian rice varieties and its kinship relationship based on their morphological characters. Based on the results of the study, there was a change in morphological characters under drought stress conditions in all tested varieties, and ten lowland Indonesian rice varieties have different levels of tolerance to drought stress conditions. Inpari 31 and Salumpikit varieties have the ability to adapt better to drought stress conditions based on observations of the Standard Evaluation System for Rice (SES) scoring), and drought stress has an impact on changes in the morphological characters of ten rice varieties. These caused changes in cluster groups under drought stress conditions. The kinship relationship in optimum conditions with a distance of cluster combination (euclidean) on a scale of 10 is divided into 2 groups, namely the lowland rice group and upland rice group, while the kinship relationship in drought stress conditions with a cluster combination distance (euclidean) on a scale of 10 is divided into 3 groups, namely the rice varieties that are classified as sensitive, groups of lowland rice varieties, and upland rice groups that are classified as tolerant.

Keywords: Varieties, tolerance, drought stress, morphological characters.

INTRODUCTION

The main problem in lowland rice cultivation is the decreasing availability of groundwater and the existence of erratic climate change which causes prolonged drought. Climate change is one of the causes of drought which can reduce rice yields and quality (Tao *et al*., 2006). Drought has a serious impact on the growth of rice plants in both the vegetative and generative phases. Drought stress in generative phase decrease grain quality and rice yields (Akram *et al*., 2013; Sugiarto *et al*., 2018). Research on evaluating the resistance of ten rice varieties in drought stress conditions based on morphological characters is needed to determine the resistance and adaptation of rice varieties that are tolerant of drought stress.

Common symptoms of rice plants experiencing drought stress include; curled rice leaves, burnt leaves, reduced rice tillers, stunted plants, delayed flowering and empty seeds. Seeing these problems, an effort is needed to anticipate the impact of drought on rice production.

One of the efforts to anticipate the impact of drought can be done through the development of rice varieties that are tolerant to drought stress. Therefore, research on evaluating the resistance of ten rice varieties under

Table 1. Average plant height under optimum conditions and drought stress

Variety	Optimum (cm)			Drought (cm)		
Inpari 33	129,48	bc	x	98,87	e	Y
Inpari 32	123,28	cd	x	102,30	de	Y
Inpari 31	126,57	bcd	x	108,53	d	Y
Inpari 24	129,15	bc	x	115,48	c	Y
IR 32	120,93	d	x	102,68	de	Y
IR 36	130,95	b	x	119,05	c	Y
IR 64	132,92	b	x	120,87	c	Y
IR 68	161,13	a	x	137,57	b	Y
Salumpikit	161,70	a	x	144,60	a	Y
IR 20	133,65	b	x	107,50	d	Y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

drought stress conditions based on morphological characters is needed to determine the resistance and adaptation of rice varieties that are tolerant to drought stress.

METHODS

The research was conducted at the experimental farm of Agriculture Faculty, Jenderal Soedirman University, Central Java, Indonesia. The research carried out from March to September 2020. The tools used in this research are cultivation tools, laboratory and measurement equipments. The research materials consisted of 10 rice varieties (Inpari 24, Inpari 31, Inpari 32, Inpari 33, IR-20, IR-32, IR-36, IR-68, IR-64 (drought sensitive check varieties), and Salumpikit (drought tolerant check varieties)), inceptisol soil, urea fertilizer, fertilizers, polybags, labels and name boards. This study used a randomized block design (RBD) consisting of 2 factors. The first factor is 2 levels of drought stress treatment, namely the provision of optimum water and drought stressed water, while the second factor is ten rice varieties. The treatments given to each variety were the optimum conditions and drought-stressed conditions. The treatment started when the plants were 14 days after planting.

The tolerance scoring was evaluated based on the character of rolling and leaf drying which is carried out when the seeds are no longer watered after 14 days of planting until the sensitive variety (IR-64) dies or is fully rolled (score 9). Scoring for recovery / regrowth (recovery ability) is carried out when the plants have been maintained and watered again for 10 days after scoring for rolling and drying the leaves against drought. Scoring for leaf rolling, leaf dryness, and recovery was based on the Rice Standard Evaluation System (SES) from IRRI (2013). The variables observed were number of tillers per hill, number of productive tillers per hill, number of panicles per hill, plant height, panicle length, number of grains per panicle, flowering age, harvest age, grain weight per panicle, weight of 1000 seeds, percentage of filled grain per panicle, and rice Standard Evaluation System (SES) scoring.

The data from the observation of the morphological character performance were analyzed using the F test (analysis of variance) and if it was significantly different, it was carried out by the 5% Duncan Multiple Range Test (DMRT) level. Meanwhile, to determine the relationship between rice varieties, cluster analysis was carried out using the average linkage method using the SPSS 15 software tool, which will then be presented in the form of a dendogram.

RESULTS

DISCUSSION

Diversity of morphological characters of rice varieties in drought stress

The results of the responsiveness of ten rice varieties to two levels of treatment (optimum and drought stress) on morphological characters (growth and yield characters) shows differencess. The significance of the results of the two treatment levels (optimum and drought stress) on all the observed variables was very different. The root length was not different, while the other observed variables were very different. The significance of the interaction between treatment (optimum and drought stress) and varieties on observations of plant height (Table 1), number of productive tillers per clump (Table 6), number of panicles per clump (Table 7), weight of 1000 seeds (Table 5), number of grains per panicle (Table 3), and percentage of filled grains per panicle (Table 4) were very different.

The interaction between treatment (optimum and drought stress) with varieties on panicle length, flowering age, and harvest age was very different, while other observation variables were significantly different. The plant heights of ten rice varieties differed in appearance (Table 1).

Table 2. Average panicle length under optimum conditions and drought stress

Variety	Optimum (cm)			Drought (cm)		
Inpari 33	28,36	ab	x	20,58	def	y
Inpari 32	24,04	C	x	19,38	ef	y
Inpari 31	26,85	ab	x	23,68	bc	y
Inpari 24	27,43	ab	x	21,83	cd	y
IR 32	26,09	bc	x	21,46	cde	y
IR 36	27,47	ab	x	24,22	b	y
IR 64	28,71	A	x	26,49	a	y
IR 68	27,46	ab	x	23,28	bc	y
Salumpikit	21,19	D	x	18,64	f	y
IR 20	27,32	ab	x	22,48	bcd	y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

Table 3. Average number of grain per panicle at optimum and drought-stressed conditions

Variety	Optimum (grains)			Drought (grains)		
Inpari 33	161,78	d	x	82,61	d	y
Inpari 32	155,28	d	x	104,61	cd	y
Inpari 31	194,39	c	x	132,61	ab	y
Inpari 24	159,56	d	x	95,67	cd	y
IR 32	159,11	d	x	98,94	cd	y
IR 36	231,56	b	x	154,28	a	y
IR 64	189,44	c	x	138,67	a	y
IR 68	154,83	d	x	111,56	bc	y
Salumpikit	104,33	e	x	76,11	d	y
IR 20	257,61	a	x	147,50	a	y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

The average plant height at the interaction between optimum treatment and varieties ranged from 120.93 to 161.7cm. The average plant height in the interaction between drought stress treatments and varieties ranged from 98.87 to 144.6 cm. The difference in the appearance of plant height is caused by inhibition of the rate of division and extension of plant cells. Novitasari *et al*. (2019) confirmed reports of Fischer and Maurer (1978) that drought stress causes cell extension and division to be inhibited, so that plant height decreases.

The average number of tillers per clump in optimum conditions ranged from 15,83-42-83 stems and in drought stress ranged from 7.44 – 21.67 stems (Table 7). Number of productive tillers per clump of all varieties under optimum conditions 15.67 to 22.67 stems (Table 6). The number of productive tillers and tillers decreased in drought stress, ranged 7.33 – 17.33 stems from 15.67 – 22.67 stems in optimum conditions. The difference in the appearance of the number of productive tillers per clump was influenced by the drought stress treatment period given when the plant was in the vegetative phase. Sulistyono *et al.* (2018) stated that the drought stress treatment during the tillering period (20-35 days after planting) resulted in fewer productive tillers being formed.

The panicle lengths of ten rice varieties differed in appearance (Table 2). The average panicle length at the interaction between the optimum treatment and varieties ranged from 24.04 - 28.71 cm. The average panicle length in the interaction between drought stress treatments and varieties ranged from 18.64 to 26.49 cm. The difference in panicle length appearance is influenced by drought stress in the panicle initiation phase. Panicle initiation is very vulnerable to water requirements. This is in accordance with the research of Sujinah and Jamil (2016), that drought stress in the panicle initiation phase can reduce panicle length, panicle dry weight, and the number of grains per panicle.

Six varieties experienced delayed flowering in drought stress conditions, including Inpari 33, Inpari 31, Inpari 24, IR 32, IR 64, IR 68 (Table 8). Meanwhile, the other four varieties, namely Inpari 32, IR 36, IR 20 and Salumpikit, did not experience a significant change in flowering time. It impacts to their harvesting age (Table 9).

Drought stress can affect flowering time, so that harvest time is delayed. This is in accordance with the opinion of Borromeu *et al*. (2018) and Susanti *et al.* (2011) that lack of water in the vegetative phase can prolong flowering life and delay harvest age.

Table 4. Average percentage of filled grain per panicle at optimum and drought-stressed conditions

Variety	Optimum (%)			Drought (%)		
Inpari 33	85,94	ab	x	63,99	d	y
Inpari 32	87,34	ab	x	62,42	d	y
Inpari 31	91,75	a	x	89,04	a	x
Inpari 24	91,46	a	x	84,09	abc	x
IR 32	83,73	ab	x	77,26	bc	x
IR 36	86,34	ab	x	78,06	bc	y
IR 64	82,12	b	x	82,62	abc	x
IR 68	86,96	ab	x	85,61	ab	x
Salumpikit	61,17	c	x	42,36	e	y
IR 20	85,82	ab	x	76,74	c	y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

Table 5. Average weight of 1000 seeds under optimum conditions and drought stress

Variety	Optimum (gram)			Drought (gram)		
Inpari 33	27,41	a	x	22,87	bc	y
Inpari 32	26,24	ab	x	22,71	bc	y
Inpari 31	23,49	de	x	21,69	c	y
Inpari 24	25,65	bc	x	22,78	bc	y
IR 32	23,02	e	x	19,95	d	y
IR 36	24,77	bcd	x	22,29	c	y
IR 64	26,19	ab	x	25,16	a	x
IR 68	24,19	cde	x	24,13	ab	x
Salumpikit	24,74	bcd	x	23,06	bc	y
IR 20	17,92	f	x	15,67	e	y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

Table 6. Average number of productive tillers per clump under optimum and drought-stressed conditions

Variety	Optimum (stem)			Drought (stem)		
Inpari 33	16,50	cd	x	11,83	cd	y
Inpari 32	18,00	bcd	x	7,33	e	y
Inpari 31	15,67	D	x	11,00	de	y
Inpari 24	21,50	ab	x	12,67	bcd	y
IR 32	22,00	A	x	14,00	abcd	y
IR 36	19,83	abc	x	14,00	abcd	y
IR 64	18,33	bcd	x	13,67	abcd	y
IR 68	16,67	cd	x	15,50	abc	x
Salumpikit	19,67	abc	x	17,33	a	x
IR 20	22,67	A	x	16,00	ab	y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

The number of grains per panicle of ten rice varieties had different appearances (Table 3). The average number of grains per panicle in the interaction between optimum treatment and varieties ranged from 104.33 to 257.61 grams. The average number of grains per panicle in the interaction between drought stress treatments and varieties ranged from 76.11 to 154.28 grams. The difference in the number of grains per panicle is influenced by the availability of water in the panicle initiation phase. Lack of water during the panicle initiation phase can cause

Table 7. Average number of tillers per clump under optimum and drought-stressed conditions

Variety	Optimum (panicles)			Drought (panicles)		
Inpari 33	17,33	De	x	12,00	cd	y
Inpari 32	18,50	cde	x	7,33	d	y
Inpari 31	15,83	E	x	11,50	cd	y
Inpari 24	21,50	bcd	x	12,67	bc	y
IR 32	24,50	B	x	14,00	bc	y
IR 36	20,17	bcde	x	14,00	bc	y
IR 64	19,33	cde	x	14,67	bc	y
IR 68	16,67	E	x	15,50	bc	x
Salumpikit	42,83	A	x	21,67	a	y
IR 20	22,67	bc	x	17,17	b	y

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

Table 8. Average age of flowering under optimum conditions and drought stress

Variety	Optimum (days after planting)			Drought (days after planting)		
Inpari 33	69,17	cd	y	76,33	ab	x
Inpari 32	68,50	D	x	71,33	c	x
Inpari 31	67,83	D	y	71,83	c	x
Inpari 24	70,00	cd	y	75,50	b	x
IR 32	68,50	D	y	72,00	c	x
IR 36	74,67	A	x	77,50	ab	x
IR 64	72,33	bc	y	79,17	a	x
IR 68	69,67	cd	y	76,33	ab	x
Salumpikit	57,67	E	x	59,17	d	x
IR 20	77,83	A	x	77,83	ab	x

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

Table 9. Average harvest age at optimum and drought-stressed conditions

Variety	Optimum (days after planting)			Drought (days after planting)		
Inpari 33	103,33	bc	y	108,00	bcd	x
Inpari 32	103,17	bc	y	112,17	ab	x
Inpari 31	100,83	c	x	100,83	e	x
Inpari 24	102,00	c	y	109,67	abcd	x
IR 32	104,67	bc	y	113,33	a	x
IR 36	105,00	bc	y	109,67	abcd	x
IR 64	103,33	bc	x	107,00	cd	x
IR 68	107,33	ab	x	109,83	abcd	x
Salumpikit	109,67	a	x	111,17	abc	x
IR 20	105,33	bc	x	106,33	d	x

- Numbers followed by the same letter in the same column (a-e notation) are not significantly different in DMRT 5%.
- Numbers followed by the same letter in the same line (x,y notation) were not significantly different in DMRT 5%.

the growth of panicles to be stunted. hat the amount of grain per panicle is determined by the availability of water.

The average percentage of filled grain per panicle in the interaction between drought stress treatment and varieties ranged from 42.36 to 89.04% (Table 4). The average percentage of filled grain per panicle in the interaction between the optimum treatment and the varieties ranged from 61.17 to 91.75%. The effect of drought stress on panicle formation and grain filling can cause grain shape and size to become smaller.The difference in the percentage of filled grain per panicle is due to the length of the dry period experienced by the plants. Drought stress causes plant growth and development to be less than optimal, so that the formation of empty unhulled rice

Table 10. Tolerance of rice varieties under drought stress

No	Variety	LR		LD		R	
		Score	Criteria	Score	Criteria	Score	Criteria
1	Inpari 33	7	S	3	ST	1	T
2	Inpari 32	5	SS	3	ST	1	T
3	Inpari 31	5	SS	1	T	1	T
4	Inpari 24	3	ST	1	T	1	T
5	IR 32	3	ST	1	T	1	T
6	IR 36	7	S	3	ST	1	T
7	IR 64	9	VS	9	VS	3	ST
8	IR 68	9	VS	7	S	1	T
9	Salumpikit	5	SS	1	T	3	ST
10	IR 20	5	SS	5	SS	1	T

T (Tolerant), ST (Slightly Tolerant), SS (Slightly Sensitive), S (Sensitive), VS (Very Sensitive), LR (Leaf Rolling), LD (Leaf Drying), and R (Recovery).

increases. The longer the drought stress, the lower the grain weight per clump which increases the number of empty unhulled rice.

The weights of 1000 seeds of ten rice varieties have different appearances (Table 5). The average weight of 1000 seeds on the interaction between optimum treatment and varieties ranged from 17.92 to 27.41 grams. The average weight of 1000 seeds in the interaction between drought stress treatments and varieties ranged from 15.67 to 25.16 grams. The difference in the weight yield of 1000 seeds was influenced by the dryness stress treatment in the vegetative phase. Drought period from 3 to 6 weeks after the plant has an effect on reducing the weight of 1,000 grain (Tubur *et al*., 2012).

Tolerance of Ten Rice Varieties under Drought Stress Conditions

The resistance of ten rice varieties under drought stress conditions was determined based on 3 aspects of scoring based on Standard Evaluation. Observation of drought stress in the vegetative phase of rice was carried out by looking at the indicator of the sensitive check comparison variety (IR 64) experiencing long symptoms in most of the completely dry leaves (score 9). Observations were made by scoring based on the Standard Evaluation System (SES) (IRRI, 2013).There were four varieties suspected to be moderately tolerant (Inpari 24, IR 32, Inpari 31 and Salumpikit), one variety were suspected to be slightly tolerant (Inpari 32, Inpari 33, and IR 36), two varieties were suspected to be sensitive (IR 20).), and two varieties, IR 64 and IR 68 were suspected to be very sensitive (Table 10). The varieties that have the greatest impact on leaf curl under drought stress conditions are IR 68 and IR 64. It reflects their drought sensitivity. Akbar *et al*. (2018) also reported that drought-resistant plants have the lowest leaf curl scores.

Varieties with the lowest impact on leaf curl under drought stress conditions were Inpari 24 and IR 32. Inpari 24 and IR 32 were thought to have the ability to avoid drought (drought avoidance) by suppressing the rate of transpiration in the leaves. Leaf curling is a plant's effort to avoid drought by reducing the rate of transpiration, light exposure and leaf dehydration (Wening *et al*., 2019; Han *et al*., 2018).

Leaf drying scoring is one way to determine the resistance of rice plants under drought stress conditions. The results of the study on leaf drying variables showed that there were four varieties suspected to be tolerant (Inpari 31, Inpari 24, IR 32, and Salumpikit), three varieties were suspected to be moderately tolerant (Inpari 33, Inpari 32, and IR 36), one variety was suspected to be moderately sensitive (IR 20), one variety was suspected to be sensitive (IR 68), and one variety was suspected to be very sensitive (IR 64). The IR 64 variety had the greatest impact on leaf drying under drought stress conditions. It is suspected that the IR 64 variety cannot adapt well to drought stress conditions. Decrease in water potential due to continuous drought treatment causes the leaves of rice plants to wither and dry out (Palit *et al*., 2015).

Recovery is the ability of plants to grow again after a drought. Recovery scoring is important. It has a close relationship with the continuation of plant growth and development. Recovery scores showed that eight varieties, namely Inpari 33, Inpari 32, Inpari 31, Inpari 24, IR 32, IR 36, IR 68, and IR 20 were thought to be able to recover after drought stress. Two varieties, namely IR 64 and Salumpikit.were slightly recovery after drought stress. The results of the recovery scoring indicated that the ten varieties of rice used had recovery ability after drought stress. According to Afrianingsih *et al.* (2018), a genotype that is able to grow back after drought stress is included in the drought recovery mechanism.

The Kinship of Ten Rice Varieties Based on Morphological Characters

The results of the identification of ten varieties of rice

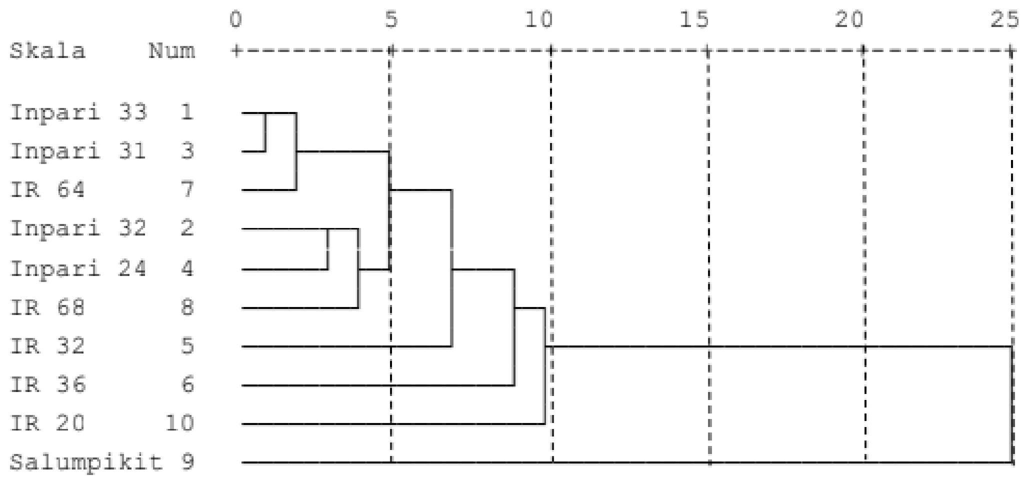

Figure 1. Dendrogram of optimum condition on ten rice varieties

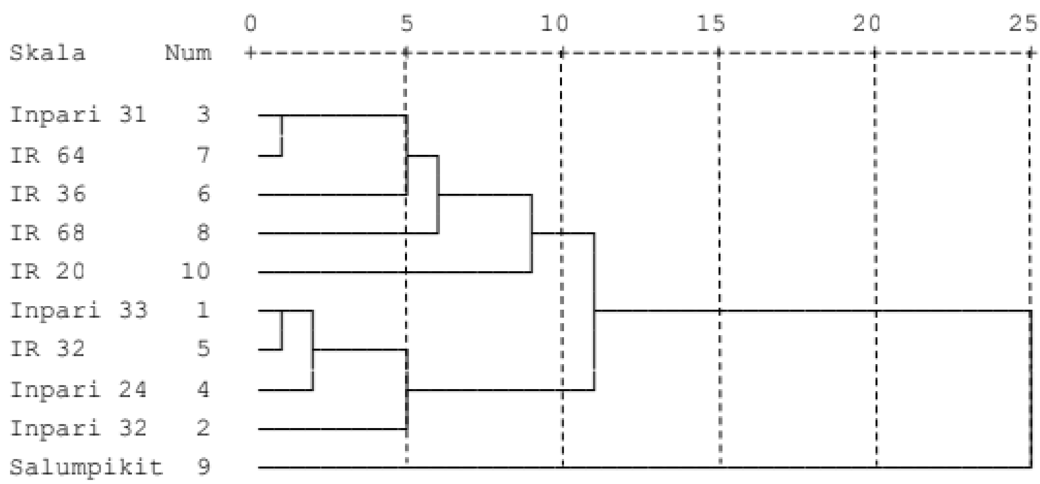

Figure 2. Dendrogram of drought stress condition on ten rice varieties

indicates there is a diversity of qualitative and quantitative properties. The tabulation of quantitative and qualitative character data for each variety is presented in Figure 1. Quantitative and qualitative identification aims to obtain information about the characteristics of a variety so that it can be used to distinguish one variety from another. Conventional identification uses morphological markers that refer to the Guide for System Characterization and Evaluation of Rice Plants, National Commision of Germplasm, Ministry of Agriculture (Silitonga *et al*., 2003) which has been modified.

Kinship relationship of ten rice varieties under optimum conditions is divided into 5 categories, namely distances of 5, 10, 15, 20 and 25 (Figure 1). Cluster combination distance (Euclidean) on a scale of 5 was divided into 5 groups that had the closest kinship. Group 1 consists of varieties Inpari 33, Inpari 32, Inpari 31, Inpari 24, and IR 64. Group 2 consists of varieties IR 32. Group 3 consists of varieties IR 36, group 4 consists of varieties IR 20, and group 5 consists of Salumpikit variety. Cluster combination distance (euclidean) on a scale of 10, 15, 20, and 25 was divided into 2 groups with the closest kinship. Group 1 consists of varieties Inpari 33, Inpari 32, Inpari 31, Inpari 24, IR-32, IR-36, IR-64, IR-68, and IR-20, while group 2 consists of varieties Salumpikit.

Dendogram of drought stress conditions showed that ten rice varieties were divided into five categories, namely 5, 10, 15, 20, and 25 distances of cluster combinations (Figure 2). Cluster combination distance (Euclidean) on a scale of 5 was divided into 5 groups that had the closest kinship. Group 1 consists of varieties Inpari 31, IR 64, and IR 36. Group 2 consists of varieties IR 68. Group 3 consists of varieties IR 20. Group 4 consists of varieties Inpari 33, IR 32, Inpari 24, and Inpari 32. group 5 consists of the Salumpikit variety. The cluster combination distance (Euclidean) on a scale of 10 was divided into 3 groups that had the closest kinship relationship. Group 1 consists of varieties Inpari 31, IR 64, IR 68, and IR 20. Group 2 consists of varieties Inpari 33, IR 32, Inpari 24, and Inpari 32. Group 3 consists of varieties Salumpikit. Cluster combination distance (Euclidean) on a scale of 15, 20, and 25 was divided into 2 groups with the closest kinship. Group 1 consisted of Inpari 33, Inpari 32, Inpari 31, Inpari 24, IR 32, IR 36, IR 64, IR 68, and IR 20, while group 2 consisted of the Salumpikit variety. Cluster combination distance (euclidean) on a scale of 10 under drought stress conditions was divided into 3 groups. Group 1 is a rice variety classified as sensitive, consisting of Inpari 33, Inpari 32, Inpari 24, and IR-32. Group 2 is a lowland rice variety that is relatively tolerant, consisting of Inpari 31, IR-64, IR-36, IR-20, and IR-68. Group 3 is an upland rice variety that is classified as somewhat tolerant, namely Salumpikit.

CONCLUSIONS

Based on the results of the study, it can be concluded that there was a change in morphological characters under drought stress conditions in all tested varieties. Ten varieties have different levels of resistance to drought stress conditions. Inpari 31 and Salumpikit varieties have the ability to adapt better to drought stress conditions based on observations of the Standard Evaluation System for Rice (SES) scoring. Drought stress has an impact on changes in the morphological characters of ten Indonesia rice varieties. This causes changes in cluster groups under drought stress conditions. The kinship relationship in optimum conditions with a distance of cluster combination (euclidean) on a scale of 10 is divided into 2 groups, namely the lowland rice group and upland rice group, while the kinship relationship in drought stress conditions with a cluster combination distance (euclidean) on a scale of 10 is divided into 3 groups, namely the rice varieties that are classified as sensitive, groups of lowland rice varieties that are classified as tolerant, and upland rice groups that are classified as tolerant.

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