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Identification of Drought-tolerant Local Cowpea Varieties of Southwest Maluku (Indonesia)

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Abstract

Cowpeas grown in Southwest Maluku have local potential due to their diversity and ability to adapt to drought stress conditions that otherwise cause low productivity. The purpose of this study was to identify of local cowpea varieties of Southwest Maluku that show tolerance to drought. The experimental samples were seven local varieties and three reference cultivars. The drought stress treatment was altered watering periods, i.e., every two (P0) and ten days (P1) from growth to harvest. The results of this research showed that a ten-day watering period significantly decreased plant height, number of leaves, number of root nodules, root and shoot dry weight, photosynthesis rate, stomatal conductance, transpiration rate, relative water content, media water content, chlorophyll content, and number and weight of seeds per plant. Drought stress treatment increased proline content and root length. Correlation analysis showed a significant correlation between plant height with all variables, except for root length, proline content, and weight of seeds per plant. The correlation and cluster analyses showed that the KM7 variety is a drought tolerant genotype among the local cowpea varieties from Southwest Maluku. Therefore, the KM7 variety can be used as plant material in future breeding programs.

Abstrak

Identifikasi Varietas Lokal Kacang Tunggak Maluku Barat Daya (Indonesia) Toleran Kekeringan. Kacang tunggak yang ditanam di Maluku Barat Daya memiliki potensi lokal yang disebabkan keragaman dan kemampuan adaptasi terhadap kekeringan namun mengakibatkan produktivitas rendah. Tujuan dari penelitian ini untuk mengidentifikasi varietas lokal kacang tunggak Maluku Barat Daya yang toleran terhadap kekeringan. Sampel penelitian berupa tujuh varietas lokal dan tiga kultivar pembanding. Perlakuan cekaman kekeringan dibuat periode pemberian air yaitu dua hari sekali (P0) dan 10 hari sekali (P1) dari pertumbuhan sampai panen. Hasil penelitian ini menunjukkan bahwa periode pemberian air 10-hari sekali menurunkan tinggi tanaman, jumlah daun, jumlah bintil akar, berat kering akar dan tajuk, laju fotosintesis, konduktansi stomata, laju transpirasi, kadar air relatif, kadar air tanah, kadar klorofil, dan jumlah dan bobot biji per tanaman secara signifikan. Perlakuan cekaman kekeringan meningkatkan kadar prolin dan panjang akar. Analisis korelasi menunjukan korelasi yang signifikan antara tinggi tanaman dengan semua variabel, kecuali panjang akar, kadar prolin, dan bobot biji per tanaman. Korelasi dan analisis kluster menunjukkan bahwa varietas KM7 merupakan genotipe toleran terhadap kekeringan di antara varietas lokal dari Maluku Barat Daya. Dengan demikian, varietas KM7 dapat digunakan sebagai bahan tanaman dalam program pemuliaan ke depan.

Keywords: drought tolerance, local cowpea variety

Introduction

Food is one of the primary needs that is steadily escalating with increases in the population in Indonesia. Therefore, it must be available at all times in sufficient, safe, and nutritious amounts [1]. The government of Indonesia is attempting to ensure this by conducting food diversification programs based on local resources, and one of the programs involves optimization of the potential of local legumes. The development and utilization of local legumes as alternative foods are still not effective and remain limited, largely because of the dependence on soybean as raw material to produce processed foodstuffs, such as tempeh, sauce, etc. Currently, domestic soybean production in Indonesia is unable to meet the soybean demand, and it supplies only 65.61% of domestic consumption while 35% is imported [2]. However, many of the minor local legumes varieties could potentially be used as alternative food materials.

One potential alternative is cowpea (*Vigna unguiculata* (L.) Walp.), another legume species. It could be expanded as a food because it has a similar protein content to soybean [3]. Cowpea is also being considered as an intercrop on agricultural land, as it can adapt to a broad range of environments, produce pods even with poor soil nutrients, and grow well in less favorable environments such as dry lands [4]. In Indonesia, dry land areas account for 33.7% or 63.4 million ha of the total land mass [5].

One area in Indonesia characterized by dry land is the Southwest Maluku district. This area has a very diverse local potential germplasm, including cowpea, but this germplasm has not been maximally developed. In dry lands, limited water availability is a consequence of low rainfall and long dry seasons that cause soil moisture levels to fall below field capacity. Water deficit can affect the quality and production of plants and can reduce the expansion rate of leaf area due to the lower growth rate and biomass production. Water deficit also decreases of the rates of photosynthesis and transpiration by diminishing the number of stomata [6]. The development of crops that can adapt to dry land requires a long selection process to obtain tolerant varieties both directly and indirectly [7].

Cowpeas are now cultivated in Southwest Maluku; however, no breeding programs have yet been established to develop cowpeas that are tolerant to drought. Therefore, further research is needed to identify a number of important characters that can be used for selection processes to generate drought-tolerant plant varieties in breeding programs. A previous study reported that watering periods of every ten days altered plant height, number of leaves, relative water content, and chlorophyll content [8]. Therefore, the aim of the present study was to identify local cowpea varieties grown in Southwest Maluku that show tolerance to water deficit based on variables associated with drought tolerance.

Materials and Methods

Plant materials. Seeds of seven local cowpea genotypes (KM1, KM3, KM4, KM6, KM7, KM8, and KM9) were obtained from farmers on Kisar Island, Southwest Maluku District and three cultivars (KT1, KT2, and KT7) were obtained from the Indonesian Legumes and Tuber Crops Research Institute (ILETRI) Malang for use in this study.

Experimental design. This split plot block design experiment was conducted at a greenhouse in the Department of Biology, IPB, from January to May 2018. The first factor was cowpea genotype (10 genotypes) and the second factor was drought stress. Drought stress treatment was applied in the form of watering period consisted of two levels: every two days (P0) and 10 days (P1), for 20 combinations of treatments with three replications and a total of 60 experimental units.

Procedures. Sandy soil was cleaned, sieved, and dried for one night. Next, 3 kg of the dried sandy soil was mixed with 80 g of manure, put into a plastic pot, and watered with 1500 mL of water to reach field capacity. Two seeds were planted in each pot at a planting depth of 3 cm. At 4 weeks after planting (WAP), a bamboo stick was installed in each pot to maintain the cowpea plant upright. Weeds were removed every 2 WAP. The drought stress treatment was applied from planting to harvest time with volume of water 300 mL [8]. The variables associated with drought tolerance was measured at 8 WAP and at harvest time when the pods had matured.

Measurement of variables associated with drought tolerance. The measured variables consisted of plant height, number of leaves, root length, number of root nodules, root and shoot dry weight, relative water content (RWC), media water content (MWC), proline content, chlorophyll content, photosynthesis parameters, yield component, and drought sensitivity index. The plant height was measured on the longest shoot from the surface of the soil, while number of leaves was calculated based on the trifoliate leaves that had fully bloomed. Root length was measured on the primary root, while the number of root nodules was calculated on all roots. The root and shoot dry weights were measured using a destructive method; i.e., the root and shoot of each plant were harvested separately, cleaned, and then dried in an oven at 70 °C for 48 hours and weighed to a constant weight.

RWC was determined by cutting the third leaf from the top, weighing 0.25 g of leaf as fresh weight (FW), soaking for 4 hours, and reweighing as turgid weight (TW) [9]. The leaf samples were then dried in an oven at 80°

C for 24 hours and weighed as dry weight (DW). The MWC was measured taking 50 g of soil composite from each pot and weighing it as wet weight (WW), followed by drying in an oven at 70° C for 48 hours, and weighing again as dry weight (DW).

Proline content was determined following the modification method [10]. A 0.25 g sample of leaves was weighed and mashed in mortar with 10 mL of 3% sulfosalicylic acid, and then centrifuged at 402 x g for 10 minutes. A 2 mL sample of the supernatant was put into a new tube and 2 mL of ninhydrin and 2 mL of glacial acetic acid were added. The mixture was heated in a water bath at 80° C for 1 hour, incubated on ice for 5 minutes, and then 4 mL toluene was added and vortexed for 10 seconds. The absorbance was read in a spectrometer at a wavelength of 520 nm.

Total chlorophyll content was measured using a previously described method [11]. A total of 0.1 g of leaves was mashed in mortar and mixed with 10 mL 80% acetone in a 15 mL tube. The mixture was centrifuged at 402 x g for 10 minutes. The absorbance of the supernatant was read at 646 nm (A_{646}) and 663 nm (A_{663}).

Photosynthesis parameters, including photosynthesis rate, stomatal conductance, and transpiration rate, were measured at 09.00 a.m. using a LI-COR LI-6400 XT Portable System with 1000 PAR. The drought sensitivity index (S) was calculated from each variable using the following formula [12]:

$$S = 1-(Yp/Y)/1-(Xp/X) \quad (1)$$

where Yp = mean variable of a stress genotype, Y = mean variable of normal genotype, Xp = mean variable of all stress genotypes, and X = mean variable of all normal genotypes. The following criterion was used to determine the level of tolerance to drought stress: a plant with S <0.5 was classified as a tolerant genotype, 0.5 <S <1.0 as a medium tolerance genotype, and S> 1.0 as a sensitive genotype. The measured yield components were numbers of seeds per plant (NSP) and weights of seeds per plant (WSP) after harvest.

Statistical analysis. The data obtained were analyzed by ANOVA and continued with a Duncan test at a significant level of 5%, while correlation analysis was calculated using the Pearson correlation in SPSS 16.0. Principal component analysis (PCA) was conducted using PAST version 3.0.

Results and Discussion

The drought stress treatment had a highly significant effect (p <0.05) on the variables associated with drought tolerance from each genotype. In general, the P1 treatment caused a decrease in plant height, number of leaves, shoot dry weight, number of root nodules, and root dry weight, but it increased the root length. In addition, if compared with the cultivars from ILETRI, the local cowpea genotypes showed better growth. Significant differences were evident among the genotypes for all variables in the P1 treatment (p<0.05) (Table 1). The KM8 variety attained the highest plant height and greatest number of leaves, while the lowest values were obtained for the KM7 variety. The KM3 variety had the largest shoot dry weight and the KM7 variety has the smallest. The longest root length, greatest number of root nodules, and largest dry weight were obtained for the KM3 variety.

The local cowpea varieties show significant genetic variation in the variables associated with drought. The difference for each variable for each variety is a consequence of the duration of stress and the growth habit of the variety [13]. The reduction in the number of leaves observed in this study is in line with the results of previously reported studies [14,15,16], in which the decrease in leaf number was explained by a decrease in the leaf initiation rate and a resultant decline in photosynthetic activity, which in turn would reduce the shoot dry weight. The increased root length under drought stress confirmed that plant varieties are able to adapt and survive in this condition. An increase in root length can increase the root area to reach deep soil for water absorption may be present [15]. On the contrary, the decreased root dry weight caused the roots to be thinner in shape and smaller in volume. The decrease in the number of root nodules would be associated with a reduced presence of nitrogen fixing bacteria.

The KM6 variety had the highest average photosynthesis rate at 26.20 mol CO_2 m^{-2} s^{-1} with the lowest reduction percentage of 29.13 %, whereas the KM7 variety had the lowest rate of 16.01 mol CO_2 m^{-2} s^{-1} (Table 2). The stomatal conductance and transpiration rate was highest for the KM8 variety, while stomatal conductance was lowest for the KM4 variety and transpiration rate was lowest for the KM1 variety. These values are similar to previously reported research [17] showing that cowpeas under stress conditions had a low photosynthesis rate ranging from 13.17 to 18.80 mol CO_2 m^{-2} s^{-1}, while stomatal conductance and transpiration rate ranged from 0.07 to 0.15 and 2.29 to 4.26 mol H_2O m^{-2} s^{-1}, respectively. The first response to drought stress condition was stomatal closure, as evident by the decrease in stomatal conductance. The reduced turgor pressure and limited gas exchange between the atmosphere and leaf surface causes a decreased rate of transpiration, increased tissue dehydration, and slow growth of plant organs. These findings were also in line with previous research [18] that described drought stress-induced decreases in photosynthesis rate, stomatal conductance, assimilate production, and yield components.

The physiological variables of RWC, MWC, proline content, and chlorophyll content were also affected by drought stress (Figure 2). The P1 treatment gave the highest RWC for the KM7 variety and the highest MWC for the KM1 variety. Similar to MWC, the highest proline content was obtained for the KM1 variety. The KM3 variety had the highest total chlorophyll content and the KM9 variety had the lowest. The graph shown in Figure 1 indicates that the P1 treatment decreased RWC and MWC, but it could increase proline content. In general, the KM7 and KM1 varieties had lower shoot and root growth when compared to the other varieties. However, these two varieties show higher resistance to water stress.

According to [19], drought stress can affect the water status of the plant. The water potential in the leaves and the relative water content can be used to determine the water status and to screen for plant tolerance to stress. The decrease in RWC and MWC are caused by differences in relative humidity. Conversely, the increase in proline content also is determined by plant age, leaf age, leaf position, and leaf size. Limited water supply can cause a reduction in the chlorophyll level that depends on the stress duration [18].

Table 1. Variables Associated with Drought Tolerance of 10 Cowpea Genotypes Under Drought Stress Treatments

Varieties	PH (cm)		NL (blade)		SDW (g)		RL (cm)		NN (nodule)		RDW (g)	
	P0	P1	P0	P1	P0	P1	P0	P1	P0	P1	P0	P1
KM1	226.93^{a}	165.07^{abc}	36^{a}	18.33^{bc}	3.2^{a}	1.43^{bcd}	12.8^{c}	42.6^{bc}	36.67^{a}	17.67^{b}	0.61^{a}	0.13^{c}
KM3	228^{a}	180.4^{a}	39.33^{a}	19.33^{ab}	3.87^{a}	1.85^{a}	24.87^{c}	58.43^{a}	75^{a}	59.33^{a}	0.56^{a}	0.21^{a}
KM4	195.17^{a}	158.47^{bc}	51^{a}	15^{cd}	4.05^{a}	1.71^{a}	20.53^{c}	53.87^{ab}	44.33^{a}	24.67^{b}	0.77^{a}	0.21^{a}
KM6	208.1^{a}	169.57^{abc}	30^{a}	16^{cd}	2.47^{a}	1.62^{bcd}	16.3^{c}	55.57^{ab}	37.33^{a}	29.67^{b}	0.49^{a}	0.17^{bc}
KM7	147.8^{c}	144.2^{d}	19.33^{ab}	12.33^{e}	1.67^{bcd}	0.96^{d}	11.27^{c}	31.4^{c}	29.33^{a}	19.67^{b}	0.35^{a}	0.13^{c}
KM8	219.57^{a}	188.07^{a}	33.67^{a}	20.33^{a}	3.1^{a}	1.62^{bcd}	13.77^{c}	32.07^{c}	35.33^{a}	17^{b}	0.5^{a}	0.14^{bc}
KM9	201.07^{a}	170.43^{abc}	21^{a}	16^{cd}	1.69^{bcd}	1.18^{cd}	11.5^{c}	33.13^{c}	34.67^{a}	24.67^{b}	0.48^{a}	0.16^{bc}
KT1	193.9^{a}	148.9^{bc}	21.67^{a}	13.33^{de}	2.44^{a}	1.69^{bcd}	15.13^{c}	31.73^{c}	30^{a}	20.67^{b}	0.46^{a}	0.19^{bc}
KT2	189.3^{a}	144.13^{d}	29^{a}	15^{cd}	3.09^{a}	1.33^{bcd}	12.17^{c}	34.2^{c}	51^{a}	26.33^{b}	0.36^{a}	0.14^{bc}
KT7	188.07^{a}	156.5^{bc}	26^{a}	13.33^{de}	1.95^{a}	1.36^{bcd}	12.8^{c}	31.8^{c}	33.67^{a}	23^{b}	0.38^{a}	0.14^{bc}

The numbers in the same column followed by different letters show significant differences (α=0.05). PH: plant height; NL: number of leaves; SDW: shoot dry weight; RL: root length; NN: number of root nodules; RDW: root dry weight; P0: watering period every two days; P1: watering period every ten days

Table 2. Photosynthesis Rates, Stomatal Conductances, and Transpiration Rates of 10 Cowpea Genotypes under Drought Stress Treatments

Varieties	PR (mol CO_2 m^{-2} s^{-1})		SC (mol H_2O m^{-2} s^{-1})		TR (mol H_2O m^{-2} s^{-1})	
	P0	P1	P0	P1	P0	P1
KM1	36.39^{a}	20.35^{ab}	1.04^{a}	0.6^{b}	13.18^{a}	11.91^{b}
KM3	41.69^{a}	26.04^{ab}	1.32^{a}	0.75^{ab}	14.4^{a}	12.84^{ab}
KM4	37.03^{a}	21.13^{ab}	0.53^{b}	0.46^{b}	13.87^{a}	12.78^{ab}
KM6	37.13^{a}	26.2^{ab}	0.98^{a}	0.64^{b}	13.79^{a}	12.88^{ab}
KM7	37.32^{a}	16.01^{b}	1.01^{a}	0.52^{b}	13.4^{a}	12.99^{ab}
KM8	40.59^{a}	20.43^{ab}	1.84^{a}	1.05^{a}	14.09^{a}	13.05^{a}
KM9	34.37^{a}	23.23^{ab}	0.67^{b}	0.5^{b}	13.63^{a}	12.96^{ab}
KT1	37.8^{a}	26.7^{a}	0.63^{b}	0.52^{b}	13.39^{a}	12.01^{ab}
KT2	32.76^{a}	22.68^{ab}	0.7^{b}	0.53^{b}	14.21^{a}	12.22^{ab}
KT7	38.97^{a}	24.4^{ab}	1.08^{a}	0.83^{ab}	13.74^{a}	12.83^{ab}

The numbers in the same column followed by different letters show significant differences (α=0.05). PR: photosynthesis rate; SC: stomatal conductance; TR: transpiration rate; P0: watering period every two days; P1: watering period every ten days

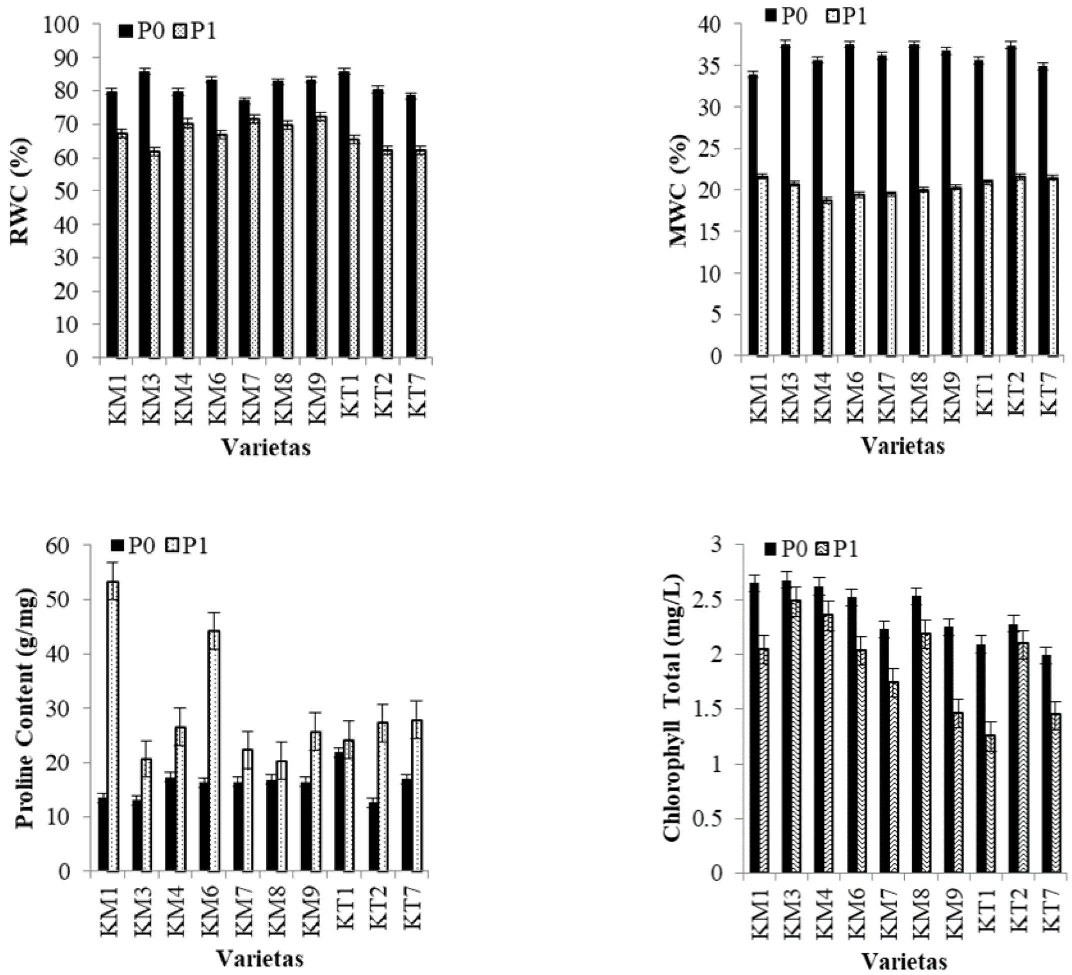

Figure 1. Physiological Variables of 10 Cowpea Genotypes under Drought Stress Treatments

Table 3 shows the mean numbers and weights of seeds per plant under drought stress treatment. Significant differences are evident for each variety under drought stress. The KM3 variety had the highest number of seeds per plant in the P1 treatment, while the largest seed weight was found in the KM4 variety. These results are in agreement with those obtained previously [20], where increasing water deficit caused a reduction in grain yield and number of pods per plant, regardless of the phenological stages at which the stress occurred. The reduction in the number and weight of seeds observed in this study agrees with previous research [17] and is due to a reduction in pollen fertility, an increased seed abortion, and a reduction in pod filling. In addition, calculation of the percentage decrease based on yield component between P0 and P1 showed that the KM7 variety had the lowest the percentage decrease of the yield component, thereby classifying this variety as a tolerant variety. This is according to a previous study [21], which mentioned that the tolerance to drought can be evaluated by two approaches. The first is a direct approach based on the percentage decrease in seed numbers in response to stress compared to the unstressed condition. The second is an indirect approach that monitors morphological and physiological variables associated with tolerance to drought. A genotype that shows the largest percentage decrease is classified as a sensitive genotype while the genotype with the lowest percentage decrease is classified as a tolerant genotype.

The drought sensitivity index on all variables showed the existence of a tolerance to a variance in the stress (Table 5). However, prediction of a tolerant variety based on the sensitivity index is difficult and must be comprehensive [22]. If compared with the cultivar from ILETRI, some of the local KM varieties (i.e., KM7 and KM8) had the lowest sensitivity indexes varieties. This might be caused by the background genetics of the genotypes or by the effects of environmental conditions on germination and vegetative and reproductive growth. Plant genotypes are classified as tolerant if the plant is able to produce seeds even under stress condition. In this study, the KM7 variety had the lowest growth but was able to produce seeds even under drought stress.

Correlation analysis and principal component analysis. Plant height, relative water content, proline accumulation, and number of seeds can be used as indicator characters to cluster a tolerant variety [23]. Correlated variables can be evaluated by principal component analysis for clustering of tolerance [24]. In this research, the results of correlation analysis revealed a significant positive correlation between plant height with all variables except root length, proline content, and weight of seeds per plant. Principal component analysis showed that the 12 correlated variables used for clustering the tolerant variety could be reduced to nine variables. The first main component had an eigen value of 4.02, the second eigen value was 2.99, the third was 1.97, and the fourth was 1.03. The results of cluster analysis based on correlated variables revealed two main clusters with 20% similarity. Cluster I was member cultivars from ILETRI and cluster II consisted of local varieties from Southwest Maluku (Figure 2). The KM7 variety had the highest genetic distance from other genotypes and showed the greatest differences in responses to drought stress. The KM7 variety was a more tolerant variety if compared to the other varieties. In general, the KM7 variety had the most reduced shoot and root characters if compared to the other varieties under stress conditions. It also had the highest relative water content and the longest times of flowering and pod production as a mechanisms of tolerance to drought stress. Therefore, KM7 can be categorized as a drought tolerant plant. However, it is not being cultivated by the community in Southwest Maluku because of its poor performance when processed as food material [25].

Table 3. Yield Component 10 Cowpea Genotypes under the Drought Stress Treatment

Varieties	NSP (seed)		PD NSP	WSP (g)		PD WSP
	P0	P1	(%)	P0	P1	(%)
KM1	6.33a	2.67c	58.09	0.31cd	0.11d	52.91
KM3	14.3a	7a	49.03	0.64a	0.36cd	42.68
KM4	34a	5.33ab	83.99	3.8a	0.59a	83.6
KM6	16.3a	5b	62.58	0.65a	0.42cd	36.78
KM7	3.67b	2.67c	28.89	0.12d	0.09d	30
KM8	10.3a	5.67ab	45.56	0.67a	0.49cd	50.69
KM9	8.33a	5b	37.63	0.58a	0.32cd	44.29
KT1	32.7a	10a	70.44	2.41a	0.69a	70.74
KT2	28.7a	8a	72.39	1.43a	0.55bc	61.74
KT7	18a	4b	73.85	1.03a	0.19d	74.22

The numbers in the same column followed by different letters show significant differences (α=0.05). NSP: number of seeds plant^{-1}; WSP: weight of seeds plant^{-1}; PD: percentage decreases; P0: watering period every two days; P1: watering period every ten days

Table 5. Drought Sensitivity Index

Varieties	PH	NL	SDW	RL	NN	RDW	PR	SC	TR	RWC	MWC	PC	CT	NSP	WSP
KM1	1.46	1.02	1.2	1.39	1.46	1.07	1.12	1.22	1.18	0.88	0.83	3.63	1.14	0.83	0.96
KM3	1.12	1.05	1.13	0.8	0.59	1.08	0.96	1.25	1.32	1.56	1.02	0.72	0.38	0.74	0.65
KM4	1.01	1.46	1.25	0.97	1.25	1.06	1.09	0.39	0.97	0.65	1.09	0.66	0.5	1.22	1.27
KM6	0.99	0.97	0.74	1.44	0.58	0.97	0.75	1.01	0.81	1.11	1.1	2.1	0.98	1.21	0.54
KM7	0.13	0.75	0.91	1.06	0.93	0.88	1.45	1.39	0.37	0.39	1.05	0.45	1.09	0.11	0.33
KM8	0.77	0.82	1.03	0.79	1.46	1.01	1.26	1.23	0.9	0.87	1.07	0.25	0.69	0.49	0.39
KM9	0.81	0.49	0.65	1.12	0.81	0.95	0.83	0.76	0.6	0.73	1.02	0.7	1.75	0.79	0.67
KT1	1.24	0.79	0.66	0.65	0.88	0.97	0.75	0.52	1.27	1.33	0.94	0.13	2	1	1.08
KT2	1.28	1	1.23	1.08	1.36	0.9	0.78	0.67	1.72	1.26	0.97	1.43	0.42	1.04	0.93
KT7	0.9	1.01	0.65	0.88	0.89	0.91	0.95	0.67	0.81	1.15	0.88	0.79	1.39	1.13	1.22

PH: plant height; NL: number of leaves; SDW: shoot dry weight; RL: root length; NN: number of root nodules; RDW: root dry weight; PR: photosynthesis rate; SC: stomatal conductance; TR: transpiration rate; RWC: relative water content; MWC: media water content; PC: proline content; CT: chlorophyll total; NSP: number of seeds plant^{-1}; WSP: weight of seeds plant^{-1}

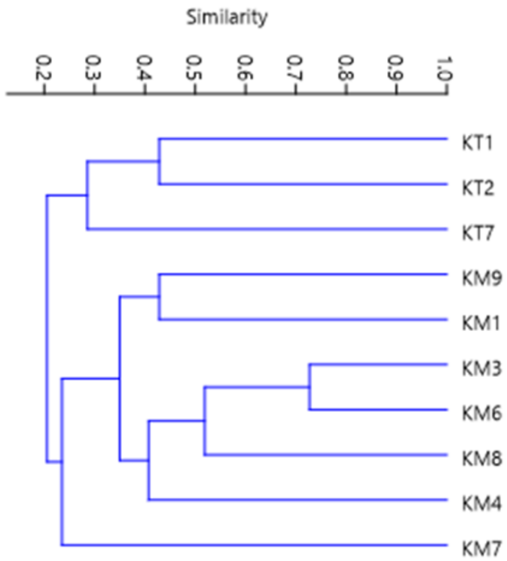

Figure 2. Cluster Analysis based Correlated Variables

Conclusion

A watering regime of providing water every ten days significantly reduced all the measured variables i.e., plant height, number of leaves, number of root nodules, root and shoot dry weight, photosynthesis rate, stomatal conductance, transpiration rate, relative water content, media water content, chlorophyll content, and number and weight of seeds per plant except for root length and proline content. These variables can be used as parameters for screening drought tolerance traits in local cowpea varieties from Southwest Maluku (Indonesia). The KM7 variety can be considered a tolerant variety based on its parameters associated with drought tolerance, and this variety can be used as plant material in breeding programs aimed at developing superior cowpea varieties.

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