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Genetic Variation Based on RAPD Profiling and Production Loss of Cayenne Pepper due to Periodic Flooding

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***Abstract*— Cayenne pepper is known as a sensitive plant to water stress, either drought or flooding. However, not many studies on the plant's response to the naturally occurring periodic flooding have been reported to date. This study aimed to determine the agronomic and genetic response of cayenne pepper against periodic flooding and find whether RAPD profile reflects periodic flooding endurance. Three cultivars of cayenne pepper: Cakra Hijau (CH); Mhanu XR (M); and Sret (S) were used. Plants were treated with periodic flooding P0 (one day of flooding followed by two days of drainage), P1 (2 x P0), and P2 (3 x P0), and C as control. A completely randomized design was used for the experiment, and the data obtained were analyzed statistically. Plant height and the number of fruits between the control and every flooding treated plant were significantly different, indicating that periodic flooding caused the delay of stem growth and decreased fruit number of all cultivars. The number of branches was influenced significantly by periodic flooding. In contrast, the plant survival rate showed no significant difference among all treatments. The higher the periodic flooding, the higher the risk of plant death and increased risk of production loss. Jaccard's clustering on RAPD profiling indicated that the group was developed based on cultivar more than periodic flooding. It was concluded that CH differed from others and had better endurance against periodic flooding, made it a right candidate for a breeding program.**

***Keywords*— Cayenne pepper cultivars; climate change; periodic flooding; production loss; RAPD.**

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I. INTRODUCTION

Cayenne pepper or chili pepper, or *cabai rawit* in Indonesia [1], is one of the horticulture crops reported as being susceptible to water stress [2], not only to lack of water [3], but also excessive water stress [4]. There are two cayenne pepper species known in Indonesia, i.e., *Capsicum annuum* L. and *Capsicum frutescens* L. [5]. Cayenne pepper could be distinguished morphologically by their corolla's color, another color, the form of their fruit stalks, and their leaves' shape [1].

The increase of duration and frequency of heavy rainfalls due to climate change results in flooding stress [6], with climate change, therefore, having been reported to cause the decrease of the production of cayenne pepper [7]. Flooding stress affects crop production, and it becomes a global problem [8], with partial and complete flooding bringing negative effects to plants due to growth inhibition and crop production losses [9]. Besides, the flooding causes wilting and leads to the cayenne pepper plant's death [4].

Flooding causes limitations of gas exchange in roots makes the energy and carbohydrate deficits [6]. It leads to the oxygen-deficient conditions of both hypoxia and anoxia in roots. It increases the hydrogen peroxide (H_2O_2) levels. The hydrogen peroxide is one of the less-radical ROS (Reactive Oxygen Species) groups. The main radical ROS groups include superoxide anion or superoxide radical and hydroxyl radical [10]. Hydrogen peroxide is the source of a more active ROS, namely hydroxyl radical (• OH) through the Fenton and Haber-Weiss reaction [11]. Non-photosynthetic tissue becomes the primary source of H_2O_2 due to the activation of NAD(P)H oxidation and disruption in the electron transfer chain. In hypoxic conditions, interference with the electron transfer chain in the mitochondria increases H_2O_2, causing cells to undergo oxidative stress [12], [13]. Hydrogen peroxide is known to cause large changes in gene expression levels in plants [14], [15]. Oxidative stress due to high ROS concentrations damages macromolecules such as lipid, protein, and DNA. ROS oxidizes deoxyribose, damages strands, and eliminates nucleotides and base modification in DNA [16]. There are several techniques for investigating the genetic diversity that one can use, one of which is the Random Amplified Polymorphic DNA, and the above events are possible causes of genetic diversity.

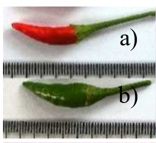
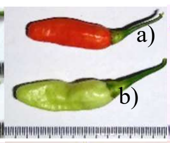
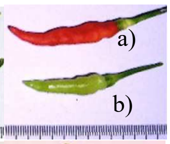
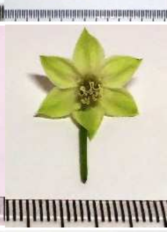
With the Random Amplified Polymorphic DNA (RAPD) as a molecular marker was used for several studies, such as hybrid identification in chili [17], genetic diversity of *Capsicum* [18]–[20], hybrid purity test of *C. annuum* [21], [22], a variety of *Durio zibethinus* Murr. [23], and genetic changes in *C. annuum* mutants [24]. RAPD application is easy and inexpensive. This is owing to it not using radioactive probes and does not require prior knowledge of gene sequences [17]. There were few studies of cayenne pepper in previous literature against periodic flooding but no information related to its genetic profile. This study aims to determine the agronomic response of cayenne pepper against periodic flooding due to climate change and confirm whether the RAPD-genetic profiling reflects the endurance of cayenne pepper against periodic flooding.

II. MATERIALS AND METHODS

A. Materials

Three cultivars of cayenne pepper with different characteristics, Cakra Hijau (CH), Mhanu XR (M), and Sret (S) were used (Table I). All cultivar's seedlings were grown in a greenhouse using plant media with a composition comprising soil, compost, manure from goat dung, and husk charcoal (2:1:1:1)[4].

TABLE I
MORPHOLOGICAL CHARACTERISTICS OF CAYENNE PEPPER BASED ON TYPE OF FRUIT ORIENTATION AND COLOR OF THE FRUIT, FLOWER, AND SEEDS

Morphological Characteristic	Cultivars of cayenne pepper: Cakra Hijau	Mhanu XR	Sret
Type of fruit orientation	Erect	Pendant	Pendant
Fruits color mature (a) and immature (b)			
Flower			
Seeds			

B. Experimental Design

The experiment used a completely randomized design. Plants are grown in an organic-conversed management system and bioorganic pesticides for pest and disease management. All 30 DAS (days after sowing) seedlings from three cultivars were transplanted with one plant in one pot (approximately 35 cm of diameter) as 0 DAP (days after planted). Thirty DAP plants were treated with four levels of periodic flooding treatment such as control, which was non-flooding plants, P0 (plants treated with one day of flooding and followed with two days of drainage), P1 (plants treated with P0 treatment, with two times repetition), and P2 (plants treated with P0, with three times repetition). Each was executed with eight replications/treatment (Fig. 1) using a completely randomized design, as described on Pahlevi et al. [4]. Flooding treatment was carried out using tap water with a depth around 13 cm from the water surface or partial flooding Pahlevi et al. [4]. During the experiment, the range of temperature and relative humidity (RH) inside the greenhouse was 20.9°C–40.3°C and 30.7%–99.0%, respectively.

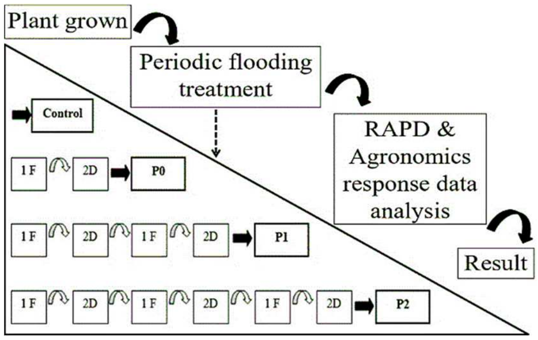


Fig. 1 Experiment flowchart and periodic flooding treatments scheme Control = non-flooded treatment, P0 = periodic flooding P0 (flooding treatment, treated with 1 day of flooding followed by 2 days of drainage), P1 = periodic flooding P1 (2 times P0), P2 = periodic flooding P2 (3 times P0), 1F = 1 day flooded-plants, 2D = 2 days drained-plants after flooding.

C. Agronomy Parameters

The effects of periodic flooding treatments were observed on agronomic response and RAPD profiling. Agronomic parameters related to production loss were plant height, the number of branches, the number of fruits, and the ratio of death and survived plants. Plants in serious conditions suffering from the disease were excluded from data recording. Plant height was observed by measuring the plant's height from the stem base until the highest apex, referring to Sujitno and Dianawati [25], started after treatment periods, and plant height was observed periodically were collected at 51 DAP. The number of plants branches was counted manually at 51 DAP. Death plants were counted, referring to Susilawati et al. [26] from the first treatment periods until the first harvesting periods. The number of fruits per plant was counted each harvesting time from the first harvesting time until the end harvesting time in one cycle harvesting periods.

D. DNA Isolation

Young leaf tissue collected after each flooding treatment was used for DNA isolation. DNA isolation was performed using cetyltrimethylammonium bromide (CTAB) methods referring to Sundari et al. [23], with modification. A total of 0.1 g of young leaf tissue was ground with pestle and mortar within liquid nitrogen. As much as 700 µl pre-heated CTAB buffer extract was added to ground leaves' tissue. Leaves' extract was transferred into microtubes, vortexed, and incubated at 65°C for 30 min. Homogenate was centrifuged at 13,000 rpm for 10 min at 4°C. The supernatant was added with PCI v/v, vortexed and centrifuged for 5 min 4°C at 13,000 rpm. The supernatant was added CI (v/v), vortexed and centrifuged 13,000 rpm at 4°C for 5 min. The ammonium acetate 7.5 M and ethanol absolute was added 0.1 (v/v) to supernatant followed by incubation at −20°C overnight for DNA precipitation. The supernatant was centrifuged at 13,000 rpm 4°C for 15 min. Pellet was washed using ethanol 70% by inverting and then centrifuged at 13,000 rpm for 10 min at 4°C. Pellet was air-dried and then re-suspended with 20 µl TE. DNA was then stored at −20°C for DNA analysis.

E. RAPD Analysis

Program settings and primers used for RAPD refer to Sikora and Nowaczyk program [17]. Seven screened-polymorphic primers were used, such as OPA4, OPA7, OPA8, OPA11, OPA12, OPA14, OPA15. Program settings for RAPD were as follow: Pre-denaturation 91°C for 1 min, continued with 38 cycles consisting of denaturation 91°C for 15 s, annealing 42°C for 15 s, extension 72°C for 1 min 10 s, and final extension 72°C for 5 min. A 10 µl of RAPD cocktail was used with composition of 3 µl ddH2O, 5 µl PCR master mix (Intron), primer OPA 1.5 µl with concentration 10 pmol/µl, and DNA template 0.5 µl with DNA concentration around 500 ng/µl–1,000 ng/µl.

III. RESULT AND DISCUSSION

A. Plant Height

The plant height was significantly influenced by the interaction between cultivars and periodic flooding treatments ($p < 0.05$) (Fig. 2A). The averages of plant height of the control, P0, P1, and P2 of CH were 67.69 cm, 56.50 cm, 56.17 cm, and 51.10 cm, respectively; Mhanu XR (M) were control, P0, P1, and P2, 61.13 cm, 48.20 cm, 43.00 cm, and 42.50 cm, respectively; and Sret were 69.38 cm, 52.50 cm, 54.67 cm, and 50.50 cm, respectively. Control of all cultivars was significantly different from all periodic flooding treatments (P0, P1, and P2). The plant height among cultivars was significantly influenced ($p < 0.05$), with average CH at 58.92 cm, M at 50.33 cm, and S at 58.48 cm (Fig. 2B). Cultivar M was significantly different from CH and S. It showed the diversity of plant height responses among cayenne peppers when facing periodic flooding.

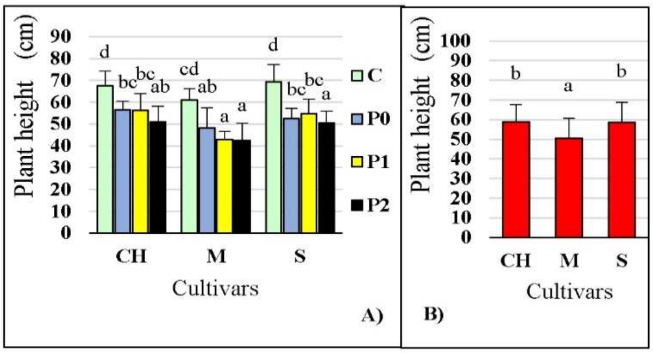


Fig. 2 Plant height response of cayenne pepper cultivated varieties (cultivars) in several types of periodic flooding stress (A) and among cultivars (B). CH = Cakra Hijau, M = Mhanu XR, S = Sret. P0 = P0 periodic flooding, P1 = periodic flooding P1, and P2 = periodic flooding P2. Different letters showed significant difference based on statistical test ($p < 0.05$).

Periodic flooding P0, P1, and P2 provided the same effect on the height of all cultivars of cayenne pepper (Fig 2). Plants experiencing periodic flooding P0 to periodic flooding P2 showed the same height, indicating that the first flooding still affected (P0) plants on periodic P2, and repeated flooding within a short period did not significantly affect the plants. However, waterlogging stress during the generative stage of red chili pepper varieties was reported to significantly decrease plant height in line with the increased waterlogging stress duration [27]. Although the plant height within the cultivar was similar among periodic flooding (P0, P1, and P2), when the plants were flooded for the first time and followed by quick drainage, it caused physiological disturbance within the plant; hence the plant suffered from multiple stress.

Flooding followed by drainage generated stress for the plants. Plants submerged in water will be deprived of oxygen and suffer from multiple stresses such as slow gas diffusion, accumulation of toxic end product, high risk for diseases infection. Then, when followed by drainage, plants were immediately exposed to high oxygen concentrations and plants suffered from dehydration, high risk of pests, diseases, etc. In this condition, the plants suffered from a post-flood injury due to oxidative stress [13], [28]–[30]. To survive these conditions, the plant tries to deal with oxidative stress by the limited energy and finally results in a delay in plant height growth.

It seems that cayenne pepper showed a quiescence strategy against flooding stress. Growth quiescence is a strategy in temporary flooding due to conserving energy [31]. However, there was no significant difference among periodic flooding treatments (P0, P1, and P2), but there was a tendency to decrease plant height. The same phenomenon was also reported in tomatoes, where there was a decrease in plant height due to waterlogging in different stress duration levels [32], [33]. In contrast, a decrease in plant height significantly occurred in tobacco varieties due to waterlogging [34]. These differences might be due to differences in flooding treatment, species, and also different environments. While in soybean (*Glycine max*), hampering in plant height due to repeated temporary flooding was higher than hampering due to saturated soil culture [35]. Flooding also hampered the plant height of *Solanum dulcamara* [36]. As mentioned by Barickman et al. [37], waterlogging decreased cucumber plant height significantly.

B. Number of Branches

The number of branches significantly decreased by periodic flooding ($p < 0.05$) (Fig. 3A). Average branches number of CH (Control, P0, P1, P2) were 21.50, 16.17, 9.33, 8.00, respectively; M 5.75, 4.40, 3.80, 4.00, respectively, and S 12.75, 4.80, 4.83, 3.00, respectively. Branches number of CH and S decreased significantly. Periodic flooding P1 did begin to influence branches number significantly in CH, but in S, it started in P0. In M, all treatments showed the same responses. Branches number of cultivars CH was significantly different from M and S, with the average value of CH, M, and S being 14.60, 4.65, and 7.08, respectively (Fig. 3B).

The more often flooding occurred, the more the plant suffered, which then affected branch development, and therefore frequent flooding, which happened in short intervals, gave rise to a bad effect on the number of branches of cayenne pepper. The decrease in branch number also took place in red chili under waterlogging stress conditions; the longer the stress suffered by red chili, the fewer branches it tended to have [26], [27]. Decreased branches per plant also occurred in the soybean variety, which was caused more by repeated temporary flooding compared with saturated soil culture [35].

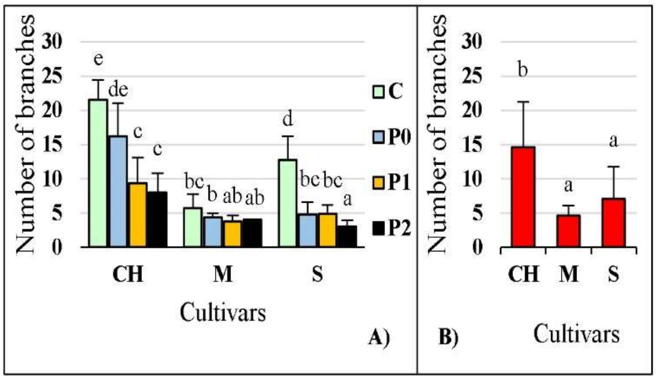


Fig. 3 Plants branches response of cayenne pepper cultivars based on periodic flooding (A) and based on cultivars (B). Cakra Hijau (CH) cultivar, Mhanu XR (M) cultivar, Sret (S) cultivar in several treatments of periodic floodings such as Control, P0, P1, and P2. The different letters show statistically significant differences ($p < 0.05$).

C. Ratio of Survive and Death Plants

The ratio of survived and death plants indicated the same responses by the interaction between cultivars and periodic flooding ($p > 0.05$), with the average of survived plants (%) (control, P0, P1, and P2) in CH for all treatments being 100%, but in M the averages were 100.00%, 75.00%, 75.00%, and 62.50%, respectively, and in S the averages were 100.00%, 87.50%, 75.00%, and 62.50%, respectively (Fig. 4A). Hence, there was a tendency to increase plant death, especially in M and S and therefore CH had relatively better endurance than two other cultivars. Among cultivars, CH had significantly better resistance to periodic flooding than M and S with a significance value of 0.025 ($p < 0.05$) (Fig. 4B) with the percentage average of surviving plants of CH, M, and S being 100.00%, 78.13%, and 81.25%, respectively. Thence the increasing level of periodic flooding increased the potential for plant mortality, especially in M and S. In periodic flooding, CH was more sustainable than M and S. The decrease in surviving plants also took place in red chili suffering from waterlogging stress (vegetative stage and generative stage). The longer the stress duration suffered by the red chili plants, the more deaths occurred [26], [27]. In tomato, the death occurrence varied among tomato genotypes, i.e., death plant occurred in flood-intolerant tomato in short time of flooding stress [32].

Lack of oxygen disrupts energy supply, ion transport, and membrane integrity, giving rise to nutritional deficiencies in roots and in shoots [38], and plant death occurs due to this lack of oxygen, which results in an energy crisis in the root. Flooding causes increasing severity of diseases [39], and due to the inability of plants to handle the severity and duration of stress, it leads to plant death [6]. Furthermore, death response in periodic flooding causes multiple stress in plants, not only by submergence (flooding) followed by de-submergence (drainage) but also by the presence of more pest and disease infection in high humidity environments post-flooding [28]. In climate change challenges, flooding coupled with high temperature causes plants to undergo rapid wilting and death [40].

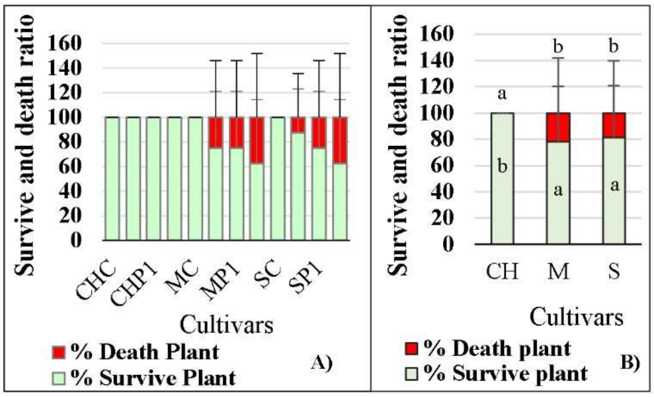


Fig. 4 Ratio of surviving and death plants of cayenne pepper among cultivars and periodic flooding interactions (A) and cultivars (B). Cakra Hijau (CH), Mhanu XR (M), and Sret (S) at periodic flooding treatments (control, periodic 0 [P0], periodic 1[P1], and periodic 2 [P2]). No different letter means no significant difference ($p > 0.05$) (A) and different letter shows significant difference based on statistical test ($p < 0.05$) (B).

D. Number of Fruits per Plant

The number of fruits per plant significantly decreased by periodic flooding ($p < 0.05$), especially M, between the control and other treatments (P0, P1, and P2). The average fruits number per plant in CH (control, P0, P1, and P2) was 166.25, 104.00, 111.00, and 101.75, respectively, in M was 178.00, 69.00, 72.00, and 53.75, respectively, and S was 168.00, 140.25, 86.00, and 66.67, respectively (Fig. 5A). Although, there was the same response among treatments in CH. There were significant different responses between control and P1 and P2 in S, although there were also the same responses among P0, P1, and P2. There were no significant differences in fruits among cultivars CH, M, and S, and the average was 120.75, 106.63, and 120.79, respectively (Fig. 5B).

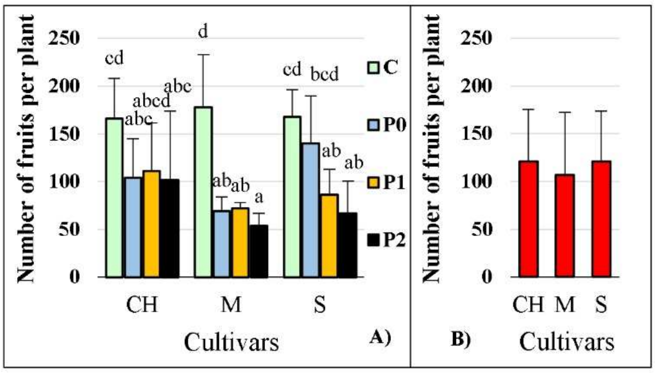


Fig. 5 Potential fruits number per plant of cayenne pepper cultivars (CH = Cakra Hijau, M = Mhanu XR, and S = Sret) due to periodic flooding with several levels (C = control, P0 = periodic flooding P0, P1 = periodic flooding P1, and P2 = periodic flooding P2). The different letter means significant difference based on statistical tests ($p < 0.05$).

This study indicated that periodic flooding had the potential to reduce the fruit number found in cayenne pepper. Although there was a tendency of decrease in fruits number, it seemed that periodic flooding had no significant effect in CH compared with S and M. With the most falling flowers and fruits caused by flooding treatment and other stress, i.e., disease infection, M was the cultivar most affected among the others by periodic flooding (Fig. 5A). According to [28], flooding and post flooding increase pathogen infection and insect attack.

Decrease of fruits number due to flooding not only occurred in cayenne pepper but also in some red chili varieties under waterlogging stress [26], tomato intolerance to flooding was evidenced after the duration of continuous flooding [32], cape gooseberry (*Physalis peruviana* L.) in line with increased days of waterlogging [41]. The decrease in fruit number began to occur since the cayenne pepper flooded for the first time. The increasing frequency of periodic flooding can reduce the fruit's number of cayenne pepper, which is detrimental to farmers. In China, *C. annuum* L. farming has great C. annuum production and quality losses due to waterlogging [42].

Production losses in all cultivars of cayenne peppers varied. CH suffered lower production losses than other cultivars (M and S) after periodic flooding. CH has more endurance in periodic flooding than M and S. M and S had slightly different production losses, with S having a better response in the number of fruits per plant than M.

F. RAPD Profiling

RAPD bands' patterns were different between cultivars but similar among flooding treatments within cultivars (Figs. 6 A-G). There were several different treatments, but the band pattern within the cultivars was the same. Band pattern profiling showed some uniqueness, which was only possessed by specific particular cultivars (Table II). Several unique bands belonged only to CH but not others; for example, bands with the size around 220 bp, 300bp, 360 bp, 830 bp, and 1110 bp as the amplicon products OPA12. CH was also having other unique bands, which were amplified by other primers such as OPA15 (480 bp and 650 bp); OPA4 (530 bp, 570 bp, 620bp); OPA7 (450 bp, 600 bp, 870 bp); OPA8 (500 bp, 970 bp, 1270 bp); and OPA11 (250 bp, 330 bp, 630 bp, 840 bp). Other unique bands belonged to both cayenne pepper cultivars (M and S) but were absent in CH, such as; a band with the size around 860 bp of OPA14; band size around (260 bp, 310 bp, 400 bp, 430 bp, 700 bp, and 810 bp) of OPA12; band size around (500 bp and 630 bp) of OPA15; band size around (600 bp and 660 bp) of OPA4; band size around (750 bp, 800 bp, 900 bp) of OPA7; band size around (430 bp and 1000 bp) of OPA8; and band size around (1700 bp) in OPA11. These unique bands occurred almost in each flooding treatment (control, P0, P1, and P2) in both cultivars.

Jaccard's similarity test of interaction between periodic flooding treatment and cultivar (Fig. 7) showed that the group developed was more based on cultivars than periodic flooding treatments. Control and P2 treatments such as CC with CP2, MC with MP2, or SC with SP1 were grouped close together. Due to periodic flooding treatment, ROS activity was not at the level to alter or disrupt DNA although some plants were dead; control plants that showed no death responses had close position treatment plants (MP2 and SP1) that showed dead responses (Table III and Table IV). The death responses might occur because of plants' lack of adaptive capability in each cayenne pepper cultivar. A previous study using mutagenic treatment successfully produced polymorphic bands in Chili (*C. annuum*). Such band polymorphism was due to variation in a band, the disappearance of bands reducing or altering the binding sites of *Taq* polymerase and appearance of new bands due to DNA structural alteration [43].

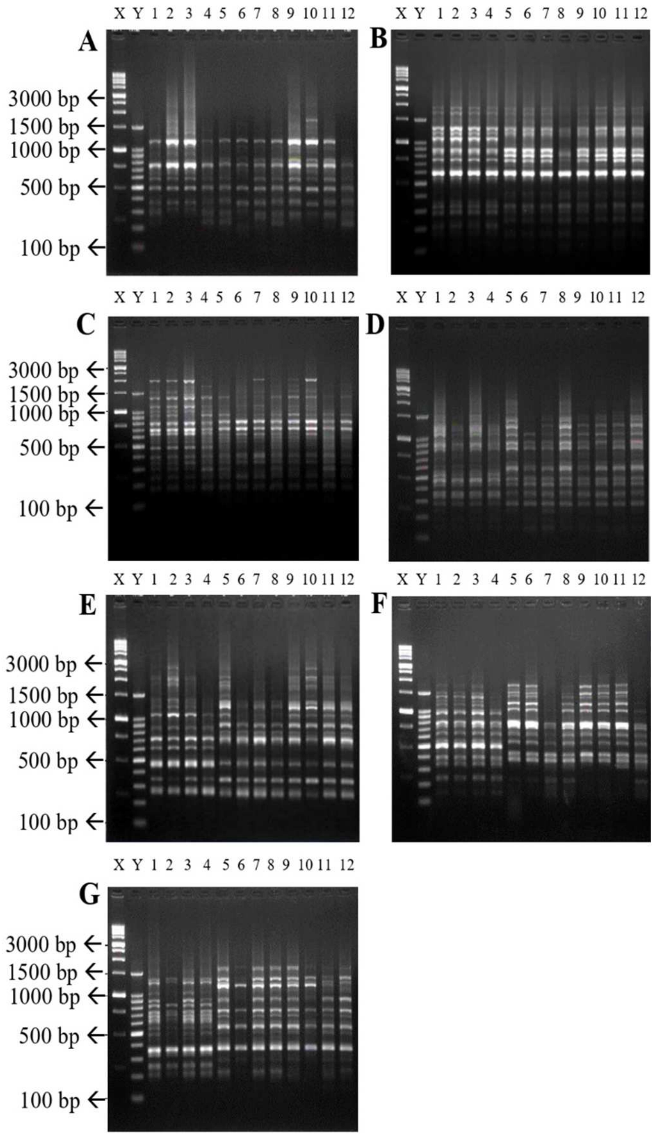


Fig. 6 RAPD profiling using OPA14 (A), OPA12 (B), OPA15 (C), OPA4 (D), OPA7 (E), OPA8 (F), OPA11 (G) of 3 cayenne pepper cultivars (Cakra Hijau, Mhanu XR, and Sret) in 1.5% agarose electrophoresis. X = DNA Marker 1Kb, Y = DNA Marker 100bp, and well 1–12: CHC (Cakra Hijau Control), CP0, CP1, CP2, MC (Mhanu XR Control), MP0, MP1, MP2, SC (Sret Control), SP0, SP1, and SP2 respectively.

The clustering analysis showed two groups, which appear to be based on cultivars and not by treatment, CH, and M-S group (Fig. 7). Based on morphological characteristics (Table I), CH group has different fruit orientation, mature and immature fruit color, flower color, and seed appearance, differences in response on branch number, surviving and death responses against periodic flooding treatment compared with M and S cultivars (Fig. 3 and Fig. 4). CH seemed more enduring against periodic flooding than M and S. Cultivars M and S have a close morphological appearance despite some different characteristics such as fruit appearance and slightly different response against periodic flooding treatment (Fig. 2; Fig. 3; Fig. 5).

It seems that RAPD methods are reliable in distinguishing among cayenne peppers. However, clustering based on RAPD band profiles is not directly related to the expression of plant response to the flooding treatment and may not be used to reference plant adaptation to specific periodic flooding stress. Although, more enduring cultivars against flooding stress had different genome profiling. Likewise, RAPD methods were reported reliable to distinguish genetic diversity among cultivars in the same species of chili in India [20], effective for identification of closely related pepper varieties [44], reliable in accessions of hot chili pepper (*C. frutescens*) characterization in Brazil and become a valuable tool in breeding programs [45].

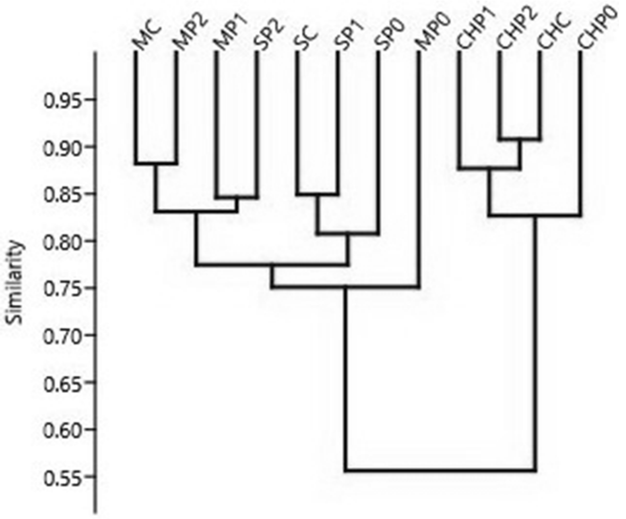


Fig. 7 UPGMA clustering based on RAPD band profile using Jaccard's similarities test

Individual variations in these cultivars might cause the band profile differences within cultivars both in the same and different flooding treatment. This research was recommended to conduct further studies to verify CH cultivars into an appropriate nomenclature system since CH cultivar had different band profiles with other *C. frutescens* L. cultivars (Fig. 7), although some said that it is a cultivar of *C. frutescens* [46].

The response or adaptation ability of plants against periodic flooding is hard to determine from genome band profile, but it is encoded by several genes in QTL genes related to water stress, enormously flooding stress. A study of *C. annuum* using resistance mutant plants showed that under waterlogging conditions, the plants expressed some genes related to hormone synthesis (*Cap.ARATH, CapRAP2*), antioxidant enzymes (*Cap.POD*), and adversity regulation (*Cap.MYB1R1*) [42]. Whereas, in soybean, 20 QTL had been reported associated with flooding stress traits [47]. In barley with a different hour of waterlogging periods stress, there were different genes expressed, i.e., genes induced by waterlogging were closely related to carbon and energy metabolism, nitrogen and amino acid metabolism, ROS scavengers, hormones-related genes, and transcription factors [48].

TABLE III
RAPD PROFILING OF 3 CAYENNE PEPPER CULTIVARS

Primer	Sequence (5'→3')	Band				Unique band	
		∑	Mm	Pm	Size Range (bp)	Size (bp)	cv.
O	TCTGTG CTGG	18	5	13	240–2320	860	M, S
OPA 12	TCGGCG ATAG	25	10	15	120–2290	1110	CH
						830	CH
						810	M, S
						700	M, S
						430	M, S
						400	M, S
						360	CH
						310	M, S
						300	CH
						260	M, S
						220	CH
OPA 15	TTCCGA ACCC	24	12	12	190–2750	650	CH
						630	M, S
						500	M, S
						480	CH
OPA 4	AATCGG GCTG	29	15	14	150–3330	660	M, S
						620	CH
						600	M, S
						570	CH
						530	CH
OPA 7	GAAACG GGTG	24	8	16	270–3520	900	M, S
						870	CH
						800	M, S
						750	M, S
						600	CH
						450	CH
OPA 8	GTGACG TAGG	20	6	14	150–2210	1270	CH
						1000	M, S
						970	CH
						500	CH
						430	M, S
OPA 11	CAATCG CCGT	20	6	14	220–1700	1700	M, S
						840	CH
						630	CH
						330	CH
						250	CH

Note: ∑ = total band, Mm = monomorphic, Pm = Polymorphic, cv. = cultivars

.

TABLE III

GENETIC SIMILARITY MATRIX ON TREATMENT AND CULTIVAR INTERACTION BASED ON JACCARD'S SIMILARITY TEST

	CHC	CHP0	CHP1	CHP2	MC	MP0	MP1	MP2	SC	SP0	SP1	SP2
CHC	1.00											
CHP0	0.83	1.00										
CHP1	0.90	0.86	1.00									
CHP2	0.91	0.79	0.85	1.00								
MC	0.61	0.56	0.59	0.59	1.00							
MP0	0.51	0.51	0.50	0.50	0.74	1.00						
MP1	0.57	0.51	0.54	0.60	0.82	0.76	1.00					
MP2	0.60	0.53	0.61	0.59	0.88	0.77	0.85	1.00				
SC	0.57	0.57	0.57	0.54	0.85	0.76	0.80	0.82	1.00			
SP0	0.51	0.60	0.54	0.51	0.77	0.77	0.73	0.70	0.83	1.00		
SP1	0.54	0.57	0.54	0.54	0.84	0.78	0.77	0.80	0.85	0.79	1.00	
SP2	0.59	0.51	0.56	0.60	0.83	0.69	0.85	0.82	0.76	0.66	0.79	1.00

TABLE IIIV

REPRESENTATIVE OF DEATH AND SURVIVED TREATED PLANTS USED FOR RAPD PROFILING

Cultivars	Plant treatment	Status
Cakra Hijau	CHC	Survive
	CHP0	Survive
	CHP1	Survive
	CHP2	Survive
Mhanu XR	MC	Survive
	MP0	Survive
	MP1	Death
	MP2	Death
Sret	SC	Survive
	SP0	Survive
	SP1	Death
	SP2	Death

Genetic diversity among cayenne pepper cultivars can be a valuable germplasm candidate for breeding programs to develop cultivars with a good yield that are more adaptable to environmental stress, especially climate change. Knowledge of genetic diversity provides valuable information for germplasm resources management required in breeding programs [49], [50]. Crossbreed over species is needed to expand genetic diversity [1], [51] and to promote better production and improve resistance to biotic and abiotic stress [52].

IV. CONCLUSIONS

Periodic flooding inhibited plant height growth, branch number, led to plant death, and decreased the potential of fruit number in cayenne pepper plants. CH had better endurance against periodic flooding than M and S. RAPD techniques can be used to distinguish cayenne pepper cultivars with more endurance characteristics against flooding stress.

NOMENCLATURE

bp	base pair
cv	cultivars
Mm	monomorphic
OPA	operon A
Pm	polymorphic
QTL	a quantitative trait locus
rpm	revolutions per minute
UPGMA	unweighted pair group method with arithmetic mean

Greek letters

∑	total band
o	degree

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