Quality diversity of 35 tea clones (*Camellia sinensis* var. sinensis) processed for green tea

M. KHAIS PRAYOGA[1,♥], HERI SYAHRIAN[1], VITRIA P. RAHADI[1], M. IQBAL PRAWIRA ATMAJA[1], HILMAN MAULANA[1], ANAS[2]

[1]Research Institute for Tea and Cinchona. Jl. Mekasari, Pasirjambu, Bandung 40972, West Java, Indonesia. Tel. +62-22-5927186,
♥email: mkhaisprayoga@yahoo.com
[2]Department of Agronomy, Faculty of Agriculture, Universitas Padjadjaran. Jl. Raya Bandung Sumedang Km 21, Jatinangor, Sumedang 45363, West Java, Indonesia

Abstract. *Prayoga MK, Syahrian H, Rahadi VP, Atmaja MIP, Maulana H, Anas. 2022. Quality diversity of 35 tea clones (*Camellia sinensis *var. sinensis) processed for green tea. Biodiversitas 23: 810-816.* The development of sinensis clones in Indonesia is still focused on increasing productivity and until now there has been no study on the level of genetic similarity and diversity based on quality characters. Therefore, the purpose of this study was to examine the level of kinship and genetic diversity of 35 sinensis clones from the collection of the Indonesia Research Institute for Tea and Cinchona. The study consisted of two stages, testing the content of chemical compounds (polyphenols and caffeine) and organoleptic testing. The material used in both tests was fresh shoots consisting of peko + 3 young leaves (P+3). In organoleptic testing, shoots of 35 sinensis variety clones were first processed into green tea. Furthermore, the processed green tea was tested organoleptically by three credible panelists. The data from the test results of chemical and organoleptic compounds were then tested statistically to get the coefficient of variation (CV), which indicates data diversity. The level of genetic closeness between clones based on quality characters was analyzed using the JMP 16.0 program (trial version), then arranged into clusters. To see the contribution of each parameter to the quality diversity of 35 sinensis clones, a principal component analysis (PCA) was carried out. The results of this study indicate that there are four main clusters grouping the 35 sinensis clones tested. The first cluster excels in the character of taste and aroma, the second cluster excels in appearance, seductive colour, and infusion, the third cluster excels in the character of polyphenols, while the fourth cluster excels in the character of caffeine. The characters that contributed to the genetic diversity of the 35 clones tested were caffeine, appearance, and aroma.

Keywords: Cluster analysis, green tea, principal component analysis, quality character, sinenesis clone

INTRODUCTION

Steeping tea is the drink with the highest consumption rate globally after water. The per capita consumption of processed *Camellia sinensis* leaves reaches 0.8 kg/year. Along with the growth of the world's population, the consumption of brewed tea is predicted to continue to increase. One type of tea that is quite popular globally is green tea. Over the last five years, green tea production in the world has increased by 4.21% (Soni et al. 2015; Palanivel et al. 2018).

Indonesia ranks fourth as the most significant green tea producer globally by supplying 1.37% of the world's needs. China is the first country in the world's largest green tea producer, which can supply 87% of the world's green tea needs. Meanwhile, Vietnam and Japan are in second and third place, with a supply capability of 4.58% and 4.14% (Soni et al. 2015). However, as one of the largest green tea producing countries globally, it turns out that the quality of green tea from Indonesia is still not able to meet international quality standards (Sriyadi 2011).

Most tea plants cultivated in Indonesia are hybrids of natural crosses between *C. sinensis* var. assamica and *C. sinensis* var. sinensis with properties that tend to Assamica

(Sriyadi 2011). The shoots of the Asamica variety can be processed into green tea. However, the best raw material for green tea is the shoots of the sinensis variety (Grechana et al. 2020). This is thought to be the cause of the weak competitiveness of Indonesian green tea compared to green tea from China, Vietnam, and Japan.

Increasing the competitiveness of Indonesian green tea can be done by developing quality tea clones of the sinensis variety. There are many and varied varieties of sinensis in Indonesia. However, the cultivation of tea sinensis has not developed because the plant still comes from seeds with low productivity. Therefore, sinensis tea has not been used as a raw material for shoots to produce green tea with international quality standards (Sriyadi 2011). Indonesia Research Institute for Tea and Cinchona (IRITC) currently has 35 clones of sinensis varieties whose quality characters are unknown. As an initial stage in developing quality clones of sinensis varieties, it is necessary to test the level of quality diversity of the 35 sinensis clones owned by IRITC. Thus, the purpose of this study was to determine the level of quality diversity of 35 clones of sinensis varieties that were processed into green tea.

MATERIALS AND METHODS

Plants material

The plant materials used in this study were 35 tea clones of the sinensis type collected from the Indonesia Research Institute for Tea and Cinchona (IRITC) (Table 1). The tea plants used have been planted in the Gambung Experimental Garden of IRITC in West Java, Indonesia, since 1994, so that when the 35 clones were picked, they were approximately 27 years old. The material used was fresh shoots consisting of peko leaves + 3 young leaves (P+3). 100 g of shoots were used as a test material to determine the total polyphenol and caffeine content and 500 g of shoots were used as raw material for green tea so that the total shoots (P+3) were taken from each clone was 600 g.

Determination of total polyphenol and caffeine content

The sample used to determine of total polyphenol and caffeine content was 100 g of P+3 shoots from 35 clones tested. The tests were carried out at the IRITC laboratory. Total polyphenol determination was using spectrophotometry according to International standard ISO 14502-1:2005 (Prawira-Atmaja et al. 2018), while caffeine content was measured by the gravimetric method according to Indonesian national standard SNI 3945:2016 (Prawira-Atmaja et al 2018).

Green tea processing

Green tea processing is done by IRITC mini-processing using the panning method. The Panning method is a method of withering tea using a rotating hot cylinder so that the withered tea leaves are directly in contact with the hot cylinder, also known as the direct heating method (Sheibani 2014). A total of 500 g of tea shoots (P+3) withered using a rotary dryer (RD) for 7 minutes at a temperature of 150ºC, then manually rolled by hand for 20 minutes, then followed by drying at a temperature of 80ºC. for 15 minutes.

Sensory evaluation

Sensory evaluation was conducted by three expert panellists according to Indonesian National Standard SNI 3945:2016. A total of 2 g of green tea samples from 35 clones were brewed using 100 mL boiling water at 96-98ºC and then left for 10 minutes. After that, it is separated between the tea solution and the dregs. Parameters tested include appearance, seductive colour, taste, aroma, and infusion (Table 2).

Statistical analysis

The data from the test results of total polyphenol, caffeine content, and sensory evaluation were then tested statistically to get the coefficient of variation (CV), which indicates data diversity. The coefficient of variation (CV) is a measure of relative variability. It is the ratio of the standard deviation to the mean (average). Furthermore, the CV value is included in the criteria of <10%: very homogeneous, 10-20%: homogeneous, 20-30% heterogeneous, >30%: very heterogeneous (Matuszek et al. 2021).

The level of genetic closeness between clones based on quality characters was analyzed using the JMP 16.0 program (trial version). The JMP 16.0 program can be used to calculate genetic distance based on the similarity between the objects studied, then arranged in a single unit (cluster analysis) (Khan et al. 2021). The end of this analysis will form a dendrogram that describes the extent of the relationship between clones of diversity. To see how far the contribution of each parameter to the quality diversity of 35 clones of the sinensis variety, Principal Component Analysis (PCA) was carried out after first standardizing the data (ordinal scale) (Abdel-Hameed 2018).

Table 1. List of tested clones

Clone	Clone
R3	II.4.32
I.1.100	I.2.34
I.2.188	II.1.32
II.3.38	II.2.108
Yabukita	II.4.149
I.1.101	I.2.85
I.1.70	S2
II.3.16	II.2.43
I.2.45	II.1.3
II.1.60	II.3.109
I.2.167	I.4.113
I.1.93	II.1.98
II.2.157	II.1.1
II.1.46	R1
SGMBA	S1
S3	II.2.146
II.4.178	II.1.38
II.1.76	

Table 2. Parameters of sensory evaluation based on Indonesian National Standard

Parameters	Score and criteria
Appearance	1: bad
	2: unsatisfactory
	3: fair
	4: good
	5: very good
Seductive color	1: red/bad
	2: yellowish red/unsatisfactory
	3: reddish yellow/fairly bright
	4: bright greenish yellow/bright
	5: very bright yellowish green/very bright
Taste	41-49: Good–very good
	31-39: Fairly good–good
	21-29: Bad–unsatisfactory
Aroma	1: no smell
	2: not smell good
	3: ordinary
	4: fragrant
	5: very fragrant
Infusion	1: dull
	2: greenish
	3: fairly bright
	4: bright and coppery
	5: very bright and coppery

RESULTS AND DISCUSSION

Total polyphenol and caffeine content

Polyphenols are a group of chemical substances found in plants. This substance has a distinctive sign that it has many phenol groups in its molecule (Mukkun et al. 2021). Polyphenols are often found in polar glycosides and are readily soluble in polar solvents (Alara et al. 2021). Several necessary polymeric materials in plants such as lignin, melanin, and tannins are polyphenolic compounds. Sometimes, phenolic units are found in proteins, alkaloids, and terpenoids (Lattanzio 2013). Polyphenol compounds have a variety of health benefits. The health benefits of polyphenols can come from their properties as antioxidant molecules. As an antioxidant, this compound can control excess free radicals. In addition to having an antioxidant effect, polyphenols can also reduce inflammation in the body (Hussain et al. 2016).

In tea plants, polyphenols are one of the chemical compounds that play an important role in flavor formation (Tounekti et al. 2013). The contents of amino acids, polyphenols, as well as the ratio of polyphenol to amino acids, are important to the quality of green tea (Peng et al. 2020). The laboratory tests showed that the average polyphenol content in 35 clones of sinensis varieties was 17.75%. The coefficient of variation (CV) of the polyphenol content of the 35 sinensis clones was 14.51% (Table 3). According to Matuszek et al. (2021), if the CV value ranges from 10-20%, the data is homogeneous. Thus, the polyphenol content of the 35 sinensis clones tested was generally uniform or homogeneous.

According to (Dilksha et al. 2020), green tea generally contains 15-30% polyphenols. Of the 35 sinensis clones tested, three clones with polyphenol content below 15%, namely clone R3, Yabukita, and clone II.4.32. In terms of quality, the three clones did not meet the standards as raw materials for green tea. Yabukita was the clone with the lowest polyphenol content, namely 11.40%. In comparison, the clone with the highest polyphenol content was clone II.1.60 with a polyphenol content of 22.90%.

In contrast to the polyphenol content, the caffeine content in 35 sinensis clones had a CV value of 9.96% (Table 3). When referring to Matuszek et al. (2021) explicitly, this value means less than 10%, which means that the caffeine content in 35 sinensis clones is very homogeneous. However, if the CV value of the caffeine content were rounded off without a decimal, the value would be 10%, which means that the caffeine content of the 35 sinensis clones was homogeneous. Based on the Indonesian National Standard (SNI) 01-4453-1998, green tea quality requirements must have a caffeine content between 1.30-2.60% (Prawira-Atmaja et al. 2018). The average caffeine content of the 35 sinensis clones was 3.50% higher than the tea quality requirements based on SNI, where clone S3 had the lowest caffeine, which was 3.00%, and clone I.1.93 had the highest caffeine content, which was 4.53% (Table 3).

Tabel 3. Content of polyphenols and caffeine 35 clones variety sinensis

Clone	Total polyphenols (%)	Caffeine content (%)
R3	13.10	4.18
I.1.100	15.70	3.41
I.2.188	22.40	3.93
II.3.38	20.00	3.12
Yabukita	11.40	3.05
I.1.101	17.10	3.64
I.1.70	15.30	3.02
II.3.16	15.90	3.89
I.2.45	16.40	3.50
II.1.60	22.90	3.51
I.2.167	17.60	3.25
I.1.93	15.90	4.53
II.2.157	18.60	3.68
II.1.46	18.30	3.61
SGMBA	17.40	3.21
S3	16.70	3.00
II.4.178	17.50	3.51
II.1.76	20.20	3.54
II.4.32	14.20	3.56
I.2.34	18.80	3.50
II.1.32	18.40	3.53
II.2.108	19.70	3.28
II.4.149	19.00	3.32
I.2.85	20.40	3.09
S2	15.70	3.13
II.2.43	17.70	3.43
II.1.3	21.10	3.50
II.3.109	21.10	4.10
I.4.113	18.60	3.62
II.1.98	17.90	3.64
II.1.1	13.00	3.43
R1	20.20	3.74
S1	17.90	3.79
II.2.146	18.10	3.01
II.1.38	17.20	3.28
Average	17.75	3.50
Standard deviation	2.58	0.35
CV (%)	14.51	9.96

The caffeine content in tea is thought to be influenced by the environment (Mutuku et al. 2016). An environmental factor that affects caffeine content is altitude. The research results by Owuor et al. (1990) showed differences in the caffeine content of tea grown at different heights. Caffeine levels grown at an altitude of 1,860, 1,940, 2,120, and 2,180 meters above the sea level (m ASL) varied, which were 3.10%, respectively; 3.27%; 3.41%, and 3.57%. The shoot samples of 35 tea clones tested in this study came from the same plantation area, so the diversity of caffeine levels was homogeneous. Caffeine is one of the essential components that determine the quality of tea. The vital role of caffeine is to determine tea taste, especially the bitter taste (Ong et al. 2018; Tfouni et al. 2018). Therefore, information on caffeine content in 35 sinensis clones is very useful in supporting tea plant breeding activities. In its development, breeders can determine the desired breeding direction, whether low-caffeine tea or high-caffeinated tea.

Basically, there are many other chemical compounds contained in green tea such as polysaccharides, amino acids, minerals, and vitamins, however, in this study, only the total polyphenol and caffeine content were tested. This is one of the weaknesses of this study. Therefore, further research needs to be enriched by testing other chemical compounds such as compounds in terpenoid pathways, or in flavonoid pathways and amino acids.

Sensory evaluation

Sensory evaluation is based on the Indonesian National Standard (SNI) on tea quality by brewing 2 g of dry green tea dissolved in 100 mL of boiling water at a temperature of 96-98°C. Parameters tested include appearance, seductive colour, taste, aroma, and infusion. Appearance is a combination of the elements of colour, shape, texture, size uniformity, and foreign matter in dry green tea. The higher the value, the better the appearance quality. The test results from the three panelists obtained an average appearance of 4.17 (Table 3) and were classified as good. In general, the CV value on the appearance parameter is shallow, namely 3.24%. Thus the quality diversity on the appearance parameter is very heterogeneous because it is below 10%.

The colour of the appearance dramatically affects the quality of green tea, so that the chlorophyll content in the leaves will affect the appearance of the appearance (Ošťádalová et al. 2015). The results of Prawira-Atmaja et al. (2018) explained that the chlorophyll content in the sinensis variety tea leaves ranged from 1.59-2.15 mg g^{-1}. The higher the chlorophyll content in tea leaves, the better the appearance of the colour. In addition, the level of leaf bone strength also affects appearance because if the leaf bone is strong, then the leaf is not quickly broken during processing. The more broken leaves, the lower the appearance value of green tea (Prasanth et al. 2019).

Another parameter related to appearance is the seductive colour. This parameter assesses the colour that appears after the dry tea is brewed. Colour is a physical parameter formed when light hits an object and is reflected in the sense of sight. The assessment results showed that the average value of the seductive colour was 4,13. In general, the steeping colour of the 35 sinensis clones tested was bright greenish-yellow/bright and was classified as good. The highest seductive colour value was 4.57 in clone II.1.60, while the lowest value was 3.30 in clone I.1.93 (Table 3). Like the appearance parameter, the CV value in the seductive colour parameter is also low (<10%) at 6.37%. The chlorophyll content of the leaves influenced the seductive colour. The higher the chlorophyll content in the leaves, the better the seductive colour (Roshanak et al. 2016).

The third parameter in organoleptic testing is taste. The taste assessment includes briskness, strength, and foreign taste in green tea steeping water. Assessment of taste is different from other parameters. Value for taste ranges from 20-49. The higher the value, the better the taste of the tea. The assessment results showed that the average taste of the 35 sinensis clones was 41.29. Thus, the taste of the 35 clones is quite good. There were six clones with moderate-good taste, namely clone I.1.100, I.2.188, II.3.38, II.4.178, II.2.108, and clone II.1.98, then the rest were classified as good–very good. The clone with the highest taste was clone I.2.85, with a value of 44.33 (Table 3). As explained in the previous subsection, tea taste is influenced by polyphenol content, and it is proven that clone I.2.85, which has a high polyphenol content (20.40%), has the best taste to other clones.

In enjoying green tea, besides taste, the parameter that determines the quality is the aroma. The CV value of the aroma parameter was 4.38%, meaning that the aroma of the 35 synthetic clones tested was classified as very homogeneous. The average value of the aroma parameter is 4.08 and is classified as fragrant. Aroma is related to the volatile compounds present in a material, where the more volatile components, the stronger and sharper the aroma will be. However, the unfortunate thing in this study was that the test for volatile compounds was not carried out on the 35 sinensis clones tested. The clone with the best aroma was I.1.101 with a value of 4.33 (Table 4).

Table 4. Sensory evaluation results 35 clones variety sinensis

Clone	Appearance	Seductive colour	Taste	Aroma	Infusion
R3	4.40	4.00	41.67	4.27	4.13
I.1.100	4.27	4.37	37.67	3.93	4.37
I.2.188	3.90	4.13	38.00	3.83	4.10
II.3.38	4.00	4.17	39.00	4.23	4.00
Yabukita	4.47	4.50	41.67	3.70	4.23
I.1.101	4.40	4.17	41.00	4.33	4.13
I.1.70	4.27	3.93	40.00	4.17	4.23
II.3.16	4.03	3.97	41.67	4.10	4.00
I.2.45	4.13	3.97	42.33	4.17	4.23
II.1.60	4.10	4.57	43.00	4.10	4.13
I.2.167	3.93	4.00	42.00	4.27	4.00
I.1.93	4.17	3.30	41.33	3.67	3.93
II.2.157	4.10	4.07	43.00	4.27	4.17
II.1.46	4.37	4.23	43.00	4.27	4.17
SGMBA	4.07	4.07	42.33	4.03	3.90
S3	4.23	3.40	41.33	3.57	4.23
II.4.178	4.07	4.07	38.67	3.83	3.97
II.1.76	4.17	4.20	42.33	4.13	4.00
II.4.32	4.17	4.20	41.00	4.00	4.07
I.2.34	4.33	4.23	42.00	4.13	4.17
II.1.32	4.23	4.00	41.00	4.07	4.00
II.2.108	4.07	4.33	39.33	4.07	3.83
II.4.149	4.03	4.37	40.00	4.07	3.87
I.2.85	4.20	4.03	44.33	4.13	4.33
S2	4.33	3.77	43.33	4.07	4.30
II.2.43	4.10	4.33	41.00	4.13	4.23
II.1.3	4.10	4.33	42.00	4.23	4.33
II.3.109	4.20	4.23	40.67	4.23	4.13
I.4.113	4.23	4.27	41.00	4.17	4.13
II.1.98	4.17	4.33	39.67	4.17	4.07
II.1.1	4.10	4.23	42.00	4.23	4.00
R1	4.13	4.07	42.33	4.10	4.37
S1	4.00	3.87	42.33	4.20	4.33
II.2.146	4.17	4.30	41.33	4.03	3.93
II.1.38	4.30	4.37	41.67	4.03	3.93
Average	4.17	4.13	41.29	4.08	4.11
SD	0.14	0.26	1.50	0.18	0.15
CV (%)	3.24	6.37	3.64	4.38	3.67

The last parameter in organoleptic testing is infusion. The assessment of these parameters includes the evenness of colour in the green tea brewed dregs. The test results showed that the clone with the best infusion was clone I.1.101 with a value of 4.37, while the clone with the lowest infusion value was clone II.2.108 with a value of 3.83. As with other parameters, the CV value in the infusion parameter was below 10%, which means that the infusion value of the 35 sinensis clones tested was classified as very homogeneous.

In general, based on the results of CV analysis, 35 sinensis clones were tested classified as very homogeneous based on organoleptic tests. However, the clones with the highest values for each parameter were different. Thus, it is assumed that each clone has its advantages. The level of similarity in quality to the 35 clones was then analyzed based on the genetic distance of the tested parameters. Then, to determine the parameters that contributed to the differences in the quality of 35 sinensis clones, Principal Component Analysis (PCA) was conducted.

Cluster analysis and principal component analysis

The cluster analysis results based on the level of similarity on the quality characters of 35 sinensis clones obtained four main clusters. The first cluster consisted of 25 clones (R3, I.1.101, II.1.46, I.2.34, 1.4.113, II.2.43, II.1.98, II.3.1109, II.1.60, II.1.76, II.1.32, II.2.146, II.1.38, II.3.16, II.4.32, II.1.1, I.2.167, SGMBA, I.2.45, II.2.157, S1, II.1.3, R1, I.2.85, and S2), the second cluster consisted of 3 clones (I.1.100, I.1.70, and Yabukita), the third cluster consisted of 5 clones (I.2.188, II.4.178, II.3.38, II.2.108, and II.4.149), and the fourth cluster consisted of 2 clones (I.1.93 and S3). In general, clones with a reasonably high dissimilarity distance compared to other clones were clone I.1.93 and clone S3, which were in the fourth cluster (Figure 1). In tea plant breeding, information on the level of genetic kinship is needed to support clone development activities (Chaeikar et al. 2020). The farther the kinship of a crossed clone, the higher the chance of forming a superior clone (Govindaraj et al. 2015). Thus, kinship information on 35 sinensis clones is beneficial in tea plant breeding activities to engineer new clones that are superior in quality characters. Based on the analysis results using the JMP 16.0 program (trial version), it turns out that each character is interconnected with one another. For example, in Figure 1, it can be seen that the closely related characters are the seductive colour characters with aroma and appearance and infusion characters. In addition, based on the analysis results, it was also found that each cluster has advantages in certain characters.

The first cluster excels in the character of taste and aroma. The average value of taste in the first cluster was 41.92 (good), while the average aroma value reached 4.15 (fragrant). Meanwhile, the second cluster excels in appearance, seductive colour, and infusion characters, with the average values of each character respectively being 4.34 (good), 4.27 (bright greenish-yellow/bright), and 4.28. (bright and coppery). In the third cluster, the unique character compared to other clusters is the polyphenols

character, where the average polyphenols content in the third cluster is 19.72%. Then in the fourth cluster, the unique character compared to other clusters is the caffeine content with an average of 3.77% (Table 5). Each individual has their strengths and weaknesses (Simarmata et al. 2021). Information about the superiority of each character in each character is helpful in selection activities to select superior clones based on specific quality characters. In addition, this information is also valuable for determining cross-cluster combinations to engineer new clones that excel in quality characters.

This study shows that the principal component analysis (PCA) has reduced the number of characters tested into three main components. However, the existing diversity still represents the total diversity. Principal component analysis (PCA) shows the components of the characters that contribute to the total diversity. The total diversity comes from all the involved characters and can be seen from the eigenvalues with more than one value (Al-Naggar et al. 2020). The accumulation of eigenvalues in the three main components has explained the diversity of the genetic material in question by 64.32%.
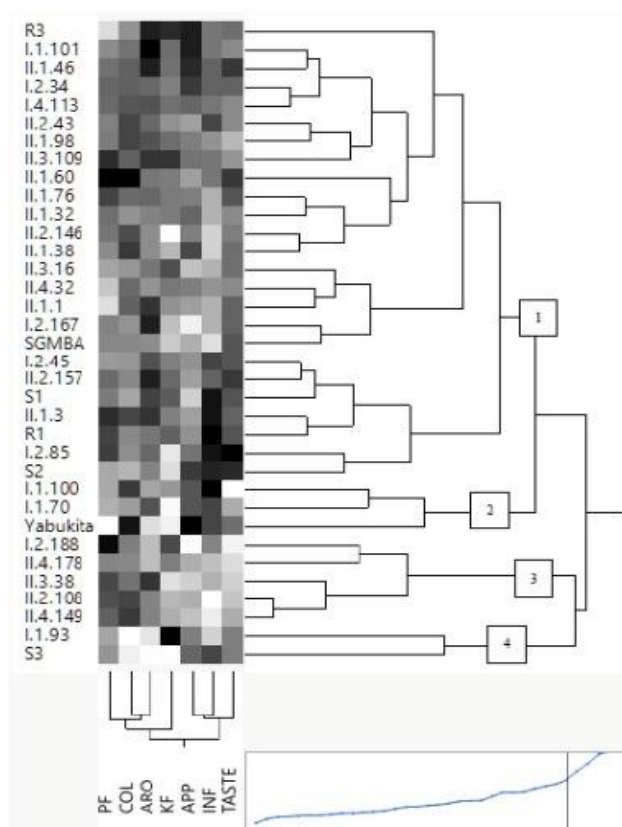
Figure 1. Cluster analysis of 35 sinensis clones based on quality characters. Note: PF: polyphenols, COL: seductive colour, ARO: aroma, KF: caffeine, APP: appearance, INF: infusion, TASTE: taste, and the darker the colour, the higher the content in the character

Table 5. Comparison of the average value of each character in each cluster

Character	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Polyphenols (%)	17.91	14.13	**19.72**	16.30
Caffeine (%)	3.53	3.16	3.43	**3.77**
Appearance	4.18	**4.34**	4.01	4.20
Seductive Colour	4.15	**4.27**	4.21	3.35
Taste	**41.92**	39.78	39.00	41.33
Aroma	**4.15**	3.93	4.01	3.62
Infusion	4.13	**4.28**	3.95	4.08

Table 6. Eigenvalue, variability, cumulative, and loading factor on quality character

Principal component	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	1.74	1.52	1.24	0.90	0.80	0.50	0.30
Variability (%)	24.79	21.77	17.76	12.84	11.42	7.10	4.31
Cumulative (%)	24.79	46.56	64.32	77.16	88.59	95.69	100.00
Polyphenols	-0.52	0.28	0.24	-0.35	0.26	0.50	-0.39
Caffeine	-0.09	-0.14	0.63	0.64	0.27	0.18	0.24
Appearance	0.59	0.11	-0.24	0.34	0.16	0.45	-0.48
Seductive Colour	-0.27	0.43	-0.56	0.27	0.20	0.23	0.52
Taste	0.35	0.42	0.35	-0.22	-0.53	0.35	0.36
Aroma	-0.14	0.64	0.13	0.36	-0.21	-0.49	-0.37
Infusion	0.39	0.32	0.19	-0.33	0.69	-0.31	0.18

The first principal component (PC1) with an eigenvalue of 1.74 has a diversity contribution of 24.79% of the appearance character. The second principal component (PC2) with an eigenvalue of 1.52 contributed to the total diversity of 21.77% from the aroma character. Meanwhile, PC3 has an eigenvalue of 1.24 and contributes to the total diversity of 17.76% from the caffeine character (Table 6). Characters contributing to diversity in each PC are identified if the character has a loading factor value >0.5 (Gour et al. 2017). In addition, according to Al-Naggar et al. (2020), characters with a high loading factor and a positive value contribute maximum to the diversity contained in the genetic material used.

The most contributing characters to the diversity of 35 sinensis clones based on quality characters were caffeine, appearance, and aroma. According to Rostini et al. (2020), the appearance of plants is the result of the interaction between genetics and the environment (G x E). Based on this, it is suspected that the environmental influence on the caffeine character, appearance, and aroma is relatively tiny. Therefore, the character is thought to be the genetic influence of each clone. Meanwhile, it is suspected that the environment exceptionally influences other characteristics such as polyphenols, seductive colour, taste, and infusion.

Research on the genetic diversity of tea in Indonesia focuses more on morphological characters, as has been done by Rahadi et al. (2016) and Martono and Syafaruddin (2018). Until now, there has been no testing of the genetic diversity of tea based on quality characters, so the information in this study is essential for the development of tea plant breeding that leads to quality. Furthermore, the results of this study can be an illustration for breeders in determining the parents of the cross to produce a more

targeted bastard population. Selection of parents should avoid the level of kinship that is too close because it increases the possibility of the accumulation of recessive genes and causes "deep cross depression" in the offspring, which is certainly not expected in the plant breeding process (Labroo et al. 2021). However, it would be better to strengthen the diversity and kinship information based on this quality by molecular analysis at the gene, chromosome, or DNA level.

In conclusion, thirty-five sinensis clones were tested containing homogeneous polyphenols (CV: 14.51%) and very homogeneous caffeine content (CV: 9.96%) and based on the results of organoleptic tests also had appearance characteristics (CV: 3.24%), seductive color (CV: 6.37%), taste (CV: 3.64%), aroma (CV: 4.38%), and very homogeneous infusion (CV: 3.67%). However, the cluster analysis results showed four main clusters grouping the 35 sinensis clones tested. The first cluster consists of clones R3, I.1.101, II.1.46, I.2.34, 1.4.113, II.2.43, II.1.98, II.3.1109, II.1.60, II.1.76, II.1.32, II.2.146, II.1.38, II.3.16, II.4.32, II.1.1, I.2.167, SGMBA, I.2.45, II.2.157, S1, II.1.3, R1, I.2.85, and S2, the second cluster consists of clones I.1.100, I.1.70, and Yabukita, the third cluster consisted of clones I.2.188, II.4.178, II.3.38, II.2.108, and II.4.149, the fourth cluster consisted of clones I.1.93 and S3. Each cluster has advantages in certain characters. The first cluster excels in the character of taste and aroma, and the second cluster excels in appearance, seductive colour, and infusion. The third cluster excels in the character of polyphenols. In contrast, the fourth cluster excels in the character of caffeine. The characters that contributed to the genetic diversity of the 35 clones tested were caffeine, appearance, and aroma.

ACKNOWLEDGEMENTS

REFERENCES

Abdel-Hameed UK. 2018. Creating E-content using NTSYspc software for the students of plant taxonomy. Scholars Acad J Biosci 6 : 455-458. DOI: 10.21276/sajb.2018.6.6.3.

Alara OR, Abdurahman NH, Ukaegbu CI. 2021. Extraction of phenolic compounds: A review. Curr Res Food Sci 4: 200-214. DOI: 10.1016/j.crfs.2021.03.011.

Al-Naggar AM, Shafik MM, Musa RYM. 2020. Genetic diversity based on morphological traits of 19 maize genotypes using principal component analysis and GT biplot. Annu Res Rev Biol 35: 68-85. DOI: 10.9734/ARRB/2020/v35i230191.

Chaeikar SS, Falakro K, Rahimi M, Khiavi SJ, Ashourpour M. 2020. The investigation of genetic diversity based on SCoT markers, morphological, and chemical characters in tea (*Camellia sinensis* L.) clones. J Hortic Postharvest Res 3: 269-284. DOI: 10.22077/jhpr.2020.2848.1097.

Diksha K, Rohit C, Anshul. 2020. A review article on antioxidant profile of green tea polyphenols in the treatment of various diseases. World J Pharm Pharm Sci 9: 1646-1663. DOI: 10.20959/wjpps20206-16378.

Gour L, Maurya SB, Koutu GK, Singh SK, Shukla S S, Mishra DK. 2017. Characterization of rice (*Oryza sativa* L.) genotypes using principal component analysis including scree plot and rotated component matrix. Intl J Chem Stud 5 : 975-983.

Govindaraj M, Vetriventhan M, Srinivasan M. 2015. Importance of genetic diversity assessment in crop plants and its recent advances: An overview of its analytical perspectives. Genet Res Intl 2015: 431487. DOI: 10.1155/2015/431487.

Grechana OV, Serbin AG, Trshecinskiy SD, Panasenko OI, Klimenko LY, Oproshanska TV, Saliy OO. 2020. Some questions about teae folia (*Thea sinensis* L. seu *Camellia sinensis* L. Kuntze) as a medicinal raw material. Eur Asian J Bio Sci 14 : 2569-2575.

Hussain T, Tan B, Yin Y, Blachier F, Tossou MCB, Rahu N. 2016. Oxidative stress and inflammation: What polyphenols can do for us?. Oxid Med Cell Longev 2016: 7432797. DOI: 10.1155/2016/7432797.

Khan MMH, Rafii MY, Ramlee SI, Jusoh M, Al Mamun M, Halidu J. 2021. DNA fngerprinting, fxation-index (Fst), and admixture mapping of selected Bambara groundnut (*Vigna subterranea* [L.] Verdc.) accessions using ISSR markers system. Sci Rep 11: 14527. DOI: 10.1038/s41598-021-93867-5.

Labroo MR, Studer AJ, Rutkoski JE. 2021. Heterosis and hybrid crop breeding: A multidisciplinary review. Front Genet 12: 643761. DOI: 10.3389/fgene.2021.643761.

Lattanzio V. 2013. Phenolic Compounds: Introduction. In: Ramawat KG, Me´rillon JM (Eds.). Natural Products. Springer, Berlin.

Martono B, Syafaruddin. 2018. Genetic variability of 21 tea genotypes (*Camellia sinensis* (L.) O. Kuntze) based on rapd markers. J Indust Beverag Crops 5 : 77-86.

Matuszek DB, Bierczyński K, Jędrysiak A, Kraszewska A. 2021. Homogeneity of the selected food mixes. Czech J Food Sci 39: 197-207. DOI: 10.17221/225/2020-CJFS.

Mukkun L, Lalel HJD, Kleden YL. 2021. The physical and chemical characteristics of severalaccessionsof sorghum cultivated on drylands in East Nusa Tenggara, Indonesia. Biodiversitas 22 : 2520-2531. DOI: 10.13057/biodiv/d220509.

Mutuku A, Wanyoko J, Wachira F, Kamunya S, Chalo R, Kimutai S, Moseti K, Karori S. 2016. Influence of geographical regions on catechin and caffeine levels in tea (*Camellia sinensis*). Am J Plant Sci 7: 562-571. DOI: 10.4236/ajps.2016.73049.

Ong JS, Hwang LD, Zhong VW, An J, Gharakhani P, Breslin PAS, Wright MJ, Lawlor DA, Whitfield J, MacGregor S, Martin NG, Corneli MC. 2018. Understanding the role of bitter taste perception in coffee, tea and alcohol consumption through Mendelian randomization. Sci Rep 8: 16414. DOI: 10.1038/s41598-018-34713-z.

Ošťádalová M, Tremlová B, Pokorná J, Král M. 2015. Chlorophyll as an indicator of green tea quality. Acta Veterinaria Brno 83: 103-109. DOI: 10.2754/avb201483S10S103.

Owuor PO, Obaga SO, Othieno CO. 1990. The effects of altitude on the chemical composition of black tea. J Sci Food Agric 50: 9-17.

Palanivel M, Gopal V, Thevar KS, Veilumuthu S. 2018. Impact of different steeping time and water temperature on tea liquor. Intl J Technical Res Sci 3: 15-18. DOI: 10.30780/IJTRS.V3.I1.2018.005.

Peng P, Wang L, Shu G, Li J, Chen L. 2020. Nutrition and aroma challenges of green tea product as affected by emerging superfine grinding and traditional extraction. Food Sci Nutr 8: 4565-4572. DOI: 10.1002/fsn3.1768.

Prasanth MI, Sivamaruthi BS, Chaiyasut C, Tencomnao T. 2019. A review of the role of green tea (*Camellia sinensis*) in antiphotoaging, stress resistance, neuroprotection, and autophagy. Nutrients 11: 1-24. DOI: 10.3390/nu11020474.

Prawira-Atmaja, MI, Shabri, Khomaini HS, Maulana H, Harianto S, Rohdiana D. 2018. Changes in chlorophyll and polyphenols content in *Camellia sinensis* var. sinensis at a different stage of leaf maturity. IOP Confer Series Earth Environ Sci 131: 012010. DOI: 10.1088/1755-1315/131/1/012010.

Rahadi VP, Khomaeni HS, Chaidir L. Martono B. 2016. Genetic diversity and relationships of tea germplasm collection based on leaf morphology character and yield components. J Industr Beverage Crops 3: 103-108. DOI: 10.21082/jtidp.v3n2.2016.p103-108.

Sahar R, Rahimmalek M, Goli SAH. 2016. Evaluation of seven different drying treatments in respect to total flavonoid, phenolic, vitamin C content, chlorophyll, antioxidant activity and color of green tea (*Camellia sinensis* or *C. Assamica*) leaves. J Food Sci Technol 53: 721-729. DOI: 10.1007/s13197-015-2030-x.

Simarmata T, Prayoga, MK, Setiawati, MR, Adinata K, Stöber S. 2021. Improving the climate resilience of rice farming in flood-prone areas through *Azolla* biofertilizer and saline-tolerant varieties. Sustainability 13: 12308. DOI: 10.3390/su132112308.

Sheibani E. 2014. Effects of water chemistry and panning on flavor volatiles and catechins in teas (*Camellia sinensis*). [Dissertation]. Virginia Polytechnic Institute and State University, Virginia. [United States of America]

Soni RP, Katoch M, Kumar A, Ladohiya R, Verma P. 2015. Tea: Production, composition, consumption and its potential an antioxidant and antimicrobial agent. Intl J Food Ferment Technol 5: 95-106. DOI: 10.5958/2277-9396.2016.00002.7.

Sriyadi B. 2011. Superior sinensis tea clones release of GMBS 1, GMBS 2, GMBS 3, GMBS 4, and GMBS 5. Tea Cinchona Res J 14 : 59-71. DOI: 10.22302/pptk.jur.jptk.v14i2.12.

Tfouni SAV, Camara MM, Kamikata K, Gomes FML, Furlani RPZ. 2018. Caffeine in teas: Levels, transference to infusion and estimated intake. J Food Sci Technol 38: 661-666. DOI: 10.1590/1678-457X.12217.

Tounekti T, Joubert E, Hern´andez I, Munn´e-Bosch S. 2013. Improving the polyphenol content of tea. Crit Rev Plant Sci 32: 192-215. DOI: 10.1080/07352689.2012.747384.