

Cassava (*Manihot esculenta* Crantz) Selection under Medium Altitude Tropics in Preliminary Yield Trial

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Abstract. Cassava had many advantages, in addition to as food, it is also used for animal feed, and as an industrial material for various products. Cassava more tolerant to global climate change, so that cassava will be the food base of the future. With the conversion of land, land for cassava cultivation will shift to marginal land in the middle and highlands because it is unable to compete with high-value food commodities. Based on this, cassava is needed that is adaptive to land with medium to high altitudes (at least 700 m asl). The results showed that among of the 44 clones tested and two control varieties, the highest tuber yield was achieved by clone 344 (55.07 t.ha⁻¹) increased 2.11 times higher than average of control varieties. Clones 344 had a harvest index of 0.6, a dry matter content of 44.18%, a starch content of 22.08% and had the highest starch yield of 12.17 t.ha⁻¹. Other clones with tuber yield > 40 t.ha⁻¹ with relatively high branching were clone 368 (41.8 t.ha⁻¹), clone 584 (47.09 t.ha⁻¹), clone 222 (40.01 t.ha⁻¹), clone 712 (42.46 t.ha⁻¹), and clone 183 (42.90 t.ha⁻¹). Two control varieties had tuber yield average about 17.76 t.ha⁻¹.

Keywords : altitude, cassava, selection

1. Introduction

The major staples of rice, wheat, maize and soybean are now recognized as not being the complete solution to world food security. Diversification of farming of agricultural crops and food production has been recognized as a need, extending towards coarse grains, roots and tubers, pulses and oilseeds. In this aspect, cassava has been recognized as a crop that is able to address the global food security needs around the world. It has been biotechnologically manipulated for better growth and higher crop production for this purpose [1]. This root is a valuable source of food, employment and income for many developing communities. Cultivated mainly in Latin America, Asia and Oceania, it is estimated to be an important part of the diet of 500 million people in the world, being the fifth largest crop overall [2], even [3] state that cassava is considered a staple root crop for more than 800 million people living in developing tropical countries. About 70% of world cassava root production is used for human consumption either directly after cooking or in processed forms. The remaining 30% is used for animal feed and other industrial products, such as starch, glucose and alcohol [4]. And cassava (manioc, yuca, or mandioca; *Manihot esculenta* Crantz, Euphorbiaceae) is an important cash crop and food crop of resource-limited farmers in Africa, Asia, and Latin America and the Caribbean [5].

Cassava is widely grown in tropical and sub-tropical Africa, Asia, and Latin America, between latitudes 30°N and 30°S, from sea level to above 2,000 m a.s.l on marginal and highly-eroded low-fertility acidic soils, virtually without the application of agrochemicals [5][6][7]. Cassava's ability to produce in marginal environments makes it the ideal food security crop in sub-Saharan Africa where it is a staple. It can be grown with minimal inputs, but gives considerably higher yields with fertilizers and good management. The crop is flexible as to the time of harvest and can be stored naturally for long periods by keeping the plants in the field with the roots in the soil. It has a

remarkable ability to tolerate and recover from biotic and abiotic stresses. Cassava offers many different alternative uses as processed food, animal feed, starch, alcohol biofuel for vehicles etc. As countries develop, their demand for all these products increases dramatically. Although pruning the aerial parts of the plant 3 weeks before harvest can reduce deterioration of the roots [8], their generally short shelf-life means that they have to be used immediately or processed into dry products.

Cassava is principally grown in the lowland tropics, but extends into the northern and southern subtropics and into the highland tropics up to 2,200 m a.s.l. In the subtropics, low winter temperatures and long summer days may cause high stress for unadapted clones. CIAT studies [9] suggest that long days can drastically reduce yields but that varietal differences in photoperiod sensitivity apparently exist. Likewise, [10] have clearly shown that distinct genotypes are required for high altitude (mean temperature less than 22°C) compared to the lowland tropics [11]. Instead, the drafting of a climate change policy should be expedited so that the growing of drought-tolerant crops such as cassava could become a major thrust. Adaptation is influenced to a certain extent by governmental actions [12]. [13] reported that one variety namely Malang 4 and one clone namely CMM 03037-8 were identified more suitable in high altitude (around 800 m asl). In 2019 clone CMM 03038-7 have been released as new variety but it can not be categorize as variety that adaptive in high altitude because of not tested in multilocations trial in some high altitude site, so the yield stability in that location not yet known.

The harvested area and production of cassava in Indonesia in 2018 (forecast number) has increased. In 2018 the harvested area of cassava was 792,952 ha, while in 2017 was 772,975. Cassava production in 2018 reached 19,341,233 tons and in 2017 19,053,748 tons. While the cassava productivity was 243.91 quintal and in 2017 was 246.5 quintal [14]. According to data from [15], cassava harvested area has increased at a rate of 2.58% and production has increased at a rate of 1.51%, while productivity has decreased at a rate of -1.05% per year (growth rate in 2018 to 2017).

Superior varieties are needed to increase national cassava production. Currently, 15 superior varieties of cassava have been produced. Compared to other commodities, this figure is still very small and most of it is destined for industrial raw materials. Therefore, efforts to form new superior varieties of cassava with good taste for food are still needed and harmonized with the wishes of users. Until now the largest use of cassava for food. However, the use of cassava for consumption is limited because of the presence of HCN in tubers and also because of the low protein content of cassava. As mentioned by [16] that a major limitation to cassava use is the toxicity from the cyanide compounds found in the fresh root. For this reason, efforts need to be made to select suitable cassava for direct consumption by selecting clones with low HCN levels. Several studies have attempted to increase the protein content of cassava (biofortification) but have not been significant, so to increase the protein content is done by adding protein to the resulting product.

2. Materials and Methods

The research was carried out in Begawan Village, Jabung sub-district, Malang district, East Java Province, Indonesia, in the 2021 planting season. The design used was a randomized block design with two replications using 44 promising clones and two control varieties (Malang 1 and Adira 1). Cassava cuttings 25 cm long, planted at plot measuring 3 m x 5 m with a spacing of 1 m x 1 m. Before planting, the land is cleared from weeds and previous crop residues. Then, tillage was done manually and mounds were made with a distance between the mounds of 1 m, with a mound height about of 40 cm. Before planting, the planting hole was given 0.5 kg of manure (dose of 5 t.ha⁻¹). After the clones were embedded, the clone number was immediately assigned to each plot.

Plant cultivation is done by giving fertilizer a dose of 136 kg N + 67 kg P₂O₅ + 67 kg K₂O / hectare. Fertilizer is given 2 times, at the age of 1 month and 3 months, each half dose of fertilizer. The removal of shoots by leaving the best 2 shoots per plant was carried out at the age of 6 weeks after planting. Weed control was carried out twice, namely before fertilization was carried out, while at the same time improving the mounds. Control of plant-disturbing organisms is not carried out with the consideration that the level of attack is still within reasonable limits. Plants during the experiment relied on rainfall for their growth.

Harvesting is done at the age of 10 months after planting. Parameters observed at 6 months after planting (map) and 10 map included: plant height, branch height, red mite score, score of

leaf spot disease, length of small and big tuber, diameter of small and big tuber, number of small and big tuber in the plants sample, tuber yield, harvest index, dry matter content of tuber, starch content (gravity method), starch yield. Observations were also made on the parameter tuber flesh color and fresh tuber taste. The numeric data were analyzed with analysis of variance, if there was a significant difference, proceed with the LSD test (5%) to see differences between clones.

3. Results and Discussions

The results of the analysis of variance (ANOVA) on the observed parameters, the clone factor showed significant to very significant differences in the parameters of plant height (6 map and 10 map), branch height (6 map and 10 map), red mite attack score (10 map), big tuber diameter, number of big tubers, tuber yield per hectare, starch content, and starch yield per hectare, while other parameters were not significantly different (Table 1). The value of the coefficient of variation on the red mite attack score, brown leaf spot disease attack score, and the number of small tubers was very large, respectively 34.48%, 34.87%, and 50.53% (Table 1). In the attack of mites and spot disease, the high coefficient of variation was caused by the striking difference in scores on the same clone in different replicates, where in one replication the score was high, while in another replication the score was low. Similarly, in the parameter of the number of small tubers, the high value of the coefficient of variation was caused, among other things, because in one replication a clone had small tubers, while in other replication it did not have small tuber.

Table 1. Results of analysis of various growth parameters, yield components, and yields of cassava clones. Jabung, Malang district, East Java, 2020/2021.

Parameters	Replication	Clone	MSE	CV (%)
Plant height at 6 map (cm)	**	**	1405.75	13.75
Plant height at 10 map (cm)	**	**	1588.35	12.57
Branch height at 6 map (cm)	**	**	1284.52	23.79
Branch height at 10 map (cm)	**	**	1175.88	22.29
Red mite score at 10 map	**	*	0.401	34.48
Leaf spot disease score at 10 map	ns	ns	0.470	34.87
Length of big tuber (cm)	ns	ns	53.19	17.41
Length of small tuber (cm)	**	ns	11.58	20.47
Diameter of big tuber (cm)	ns	*	0.47	10.84
Diameter of small tuber (cm)	**	ns	0.36	20.15
Number of big tuber	**	*	3.39	20.83
Number of small tuber	ns	ns	1.61	50.53
Tuber yield (t.ha ⁻¹)	**	**	54.28	21.17
Harvest index	ns	ns	0.009	17.31
Tuber dry matter (%)	ns	ns	14.26	8,40
Starch content (%)	**	*	1.99	6.55
Starch yield (%)	**	**	4.350	22.43

Note: * = significant different at 5% ** = significant different at 1% ns=not significant

Plant height at the age of 6 map ranged from 178.34 cm - 369.17 cm with an average of 275.81 cm. There were 23 clones with a plant height of 6 months which was higher than the average. The plant height of the comparison varieties Adira 1 and Malang 1 was below the average, even the height of the Malang 1 variety was the lowest among all the clones tested. At the age of 10 months, the plant height ranged from 190.84 cm to 416.69 cm with an average of 319.88 cm. There were 27 clones with plant height above the average at the age of 10 months. As was the case at the age of 6 bst, the plant height of the comparison varieties was also below average.

Because the experimental location was in the medium-altitude plains with an altitude of about 700 m above sea level, all clones had productive branches. Where from this productive branching, flowers will be produced which will later become seeds (but in this research, seed yields are not a concern). The branch height at the age of 6 months old ranged from 75.00 cm to 271.67 cm with an

average branch height of 152.17 cm. A total of 20 clones had above average branch height. At the age of 10 mapt, the range of branch height was between 84.17 cm to 307.50 cm with an average branch height of 155.60 cm (Table 2). At the age of 10 map, there were 19 clones with above average branch height. In the cultivation of cassava, the branching character is very unfavorable. Farmers want cassava plants that do not produce branches or have high branches. However, this branching character is very needed in the program for the formation of new superior varieties through crosses, because with the occurrence of this branching will produce flowers at the branching point which will then produce seeds. Clones that branch in the highlands, but the branching point is high, if it is planted in the lowlands, it is most likely unbranched.

The main pests of cassava are red mites and leaf spot disease is also the main disease of cassava. Red mite pests usually attack cassava in the dry season, where in hot and dry weather conditions with low air humidity will trigger the development of mite pests and increase attacks. At the age of 10 bst, the attack of mites ranged from 1 to 3 with an average attack score of 1.84., this attack score was relatively low and was suspected not to affect yield loss. While leaf spot disease usually attacks in the rainy season, where with humid conditions it will trigger the growth of the fungus *Cercospora* sp which is the cause of brown leaf spot disease in cassava. The attack score of leaf spot disease ranges from 1 to 3.5 with an average attack score of 1.97.

Based on the correlation analysis, it was found that the score of mite attack and leaf spot was negatively correlated with plant height and branching height. This means that the lower the plant the attack score increases. The correlation value of mite attack score with planting height was -0.43** and -0.57** (6 months and 10 months old, respectively), with branching height of -0.39** (6 months old) and -0.45** (age 10 months). Meanwhile, the correlation value between leaf spot disease score and plant height was -0.22* (age 6 months) and -0.33** (age 10 months), and with branching height was -0.26* (6 months old) and -0.33** (age 6 months). 10 months) It is known that the attack of mites and leaf spot initially attack on the lower leaves, it is suspected that shorter plants get a higher attack because they are exposed to more attacks from nearby plants.

Table 2. Growth parameters (6 and 10 map), red mite attack score (10 map), brown leaf spot disease score (10 map) of 44 cassava clones and two control varieties. Jabung, Malang district, East Java, 2020/2021.

No	Clones	Plant height 6 map (cm)	Clones	Plant height 10 map (cm)	Clones	Branch height 6 map (cm)	Clones	Branch height 10 map (cm)	Clones	Mite attack score	Clones	Leaf spot score
1	584	369.17 a	64	416.67 a	64	271.67 a	64	307.50 a	674	3.0 a	147	3.5 a
2	64	328.34 ab	584	381.67 ab	368	224.17 ab	368	249.17 ab	78	3.0 a	459	3.0 ab
3	222	326.67 ab	368	369.17 abc	584	220.83 abc	748	235.00 bc	359	3.0 a	368	3.0 ab
4	560	318.34 abc	222	366.67 abc	222	217.50 a - d	6	220.84 bcd	392	3.0 a	725	2.5 abc
5	192	314.17 a - d	192	365.83 abc	753	201.67 a - e	737	208.34 b - e	147	3.0 a	674	2.5 abc
6	725	312.50 a - d	560	360.00 abc	706	200.00 a - f	560	206.67 b - f	1047	2.5 ab	78	2.5 abc
7	194	305.84 a - e	748	356.67 a - d	560	197.50 b - f	753	204.17 b - g	734	2.5 ab	32	2.5 abc
8	641	302.50 a - f	6	354.17 a - d	712	196.67 b - f	584	196.67 b - h	9	2.5 ab	194	2.5 abc
9	9	301.67 a - f	344	350.00 a - d	6	194.17 b - g	222	192.50 b - i	725	2.5 ab	409	2.5 abc
10	662	298.34 a - f	774	341.67 a - e	901	183.34 b - h	641	188.34 b - j	194	2.5 ab	770	2.5 abc
11	706	292.50 b - f	753	341.67 a - e	183	180.00 b - i	712	180.00 c - k	641	2.0 abc	359	2.5 abc
12	712	290.84 b - g	280	340.00 a - e	192	171.67 b - j	183	177.67 c - k	409	2.0 abc	145	2.0 bcd
13	748	290.83 b - g	725	338.34 a - e	280	170.84 b - k	280	171.67 c - l	1	2.0 abc	344	2.0 bcd
14	368	290.00 b - g	770	337.50 a - e	10	168.75 b - k	600	168.34 c - l	706	2.0 abc	14	2.0 bcd
15	774	288.34 b - h	737	336.67 a - e	737	166.67 b - l	10	168.33 c - l	735	2.0 abc	121	2.0 bcd
16	459	286.67 b - h	183	335.00 b - e	774	165.84 b - l	346	160.84 d - m	459	2.0 abc	392	2.0 bcd
17	392	285.84 b - h	346	333.33 b - e	641	164.17 b - l	901	159.17 d - n	145	2.0 abc	222	2.0 bcd
18	976	285.00 b - h	712	331.67 b - e	662	157.50 b - m	192	159.17 d - n	367	2.0 abc	1047	2.0 bcd
19	753	285.00 b - h	459	330.00 b - f	459	154.17 b - m	706	156.67 d - n	41	2.0 abc	560	2.0 bcd
20	344	284.17 b - h	121	328.34 b - f	392	153.34 b - m	14	154.17 d - n	600	2.0 abc	346	2.0 bcd
21	570	283.34 b - h	14	327.50 b - f	9	150.83 c - m	770	149.17 e - o	570	2.0 abc	734	2.0 bcd
22	346	280.84 b - h	641	327.50 b - f	346	150.83 c - m	459	148.34 e - o	748	2.0 abc	367	2.0 bcd
23	14	280.00 b - h	706	325.83 b - f	344	146.67 d - n	392	145.83 e - o	346	2.0 abc	192	2.0 bcd
24	735	275.00 b - i	976	324.84 b - f	194	145.00 e - n	344	142.50 e - o	6	1.5 bc	662	2.0 bcd
25	901	275.00 b - i	662	322.50 b - f	674	143.33 e - n	734	140.84 e - o	121	1.5 bc	753	2.0 bcd
26	10	272.50 b - i	9	322.50 b - f	14	139.17 e - n	9	140.84 e - o	32	1.5 bc	570	2.0 bcd
27	737	271.67 b - i	392	322.50 b - f	734	136.67 e - n	194	139.17 f - o	344	1.5 bc	584	2.0 bcd
28	1047	270.00 b - i	1047	318.34 b - g	121	133.33 e - n	976	137.50 g - o	368	1.5 bc	9	2.0 bcd
29	409	269.17 b - i	901	315.00 b - g	2	132.50 e - n	662	133.34 h - o	753	1.5 bc	1	2.0 bcd

30	770	267.50 b - i	734	312.50 b - g	770	131.67 e - n	674	131.67 h - o	560	1.5 bc	901	2.0 bcd
31	183	267.50 b - i	10	309.17 b - g	145	130.00 e - n	145	131.67 h - o	976	1.5 bc	976	2.0 bcd
32	359	266.67 b - i	194	297.50 c - g	570	129.17 f - n	774	130.84 h - o	192	1.5 bc	2	1.5 cd
33	121	259.17 b - i	41	297.50 c - g	725	129.17 f - n	121	130.42 h - o	222	1.5 bc	6	1.5 cd
34	734	258.34 b - i	735	295.84 c - g	976	124.17 g - n	725	126.67 i - o	280	1.5 bc	600	1.5 cd
35	280	255.00 b - j	359	292.50 c - g	41	123.33 g - n	1	125.84 i - o	774	1.5 bc	641	1.5 cd
36	6	254.17 b - j	570	292.50 c - g	600	121.67 h - n	570	121.67 j - o	2	1.5 bc	280	1.5 cd
37	41	246.67 c - k	600	289.17 c - g	1047	111.67 h - n	359	121.67 j - o	10	1.5 bc	712	1.5 cd
38	145	239.17 d - k	145	279.17 d - g	367	110.00 i - n	1047	119.17 k - o	770	1.5 bc	735	1.5 cd
39	32	236.67 e - k	674	276.67 d - g	359	109.17 i - n	735	117.50 k - o	901	1.5 bc	774	1.5 cd
40	674	235.84 e - k	409	265.84 e - g	735	107.50 j - n	367	106.67 l - o	737	1.0 c	41	1.5 cd
41	2	227.50 f - k	1	264.17 e - g	32	106.67 j - n	32	105.84 l - o	64	1.0 c	10	1.5 cd
42	147	216.67 g - k	147	261.67 e - g	1	100.83 j - n	2	103.33 l - o	14	1.0 c	706	1.5 cd
43	367	213.34 h - k	32	250.83 fgh	409	99.17 k - n	409	92.50 mno	712	1.0 c	748	1.5 cd
44	600	203.33 ijk	367	241.67 gh	147	95.00 lmn	147	92.50 mno	662	1.0 c	737	1.0 d
45	78	181.67 jk	2	239.17 gh	748	85.84 mn	41	90.84 no	584	1.0 c	64	1.0 d
46	1	178.34 k	78	190.84 h	78	75.00 n	78	84.17 o	183	1.0 c	183	1.0 d
	averag e	275.81		319.88		152.17		155.60		1.84		1.97
	LSD (5%)	75.52		80.27		72.18		69.07		1.27		1.38

Table 3. Leght of large tuber (LLT), length of small tuber (LST), diameter of large tuber (DLT), diameter of small tuber (DST), number of large tuber (NLT), number of small tuber (NST) of 44 cassava clones and two control varieties. Jabung, Malang district, East Java, 2020/2021.

No	Clones	LLT	Clones	LST	Clones	DLT	Clones	DST	Clones	NLT	Clones	NST
1	145	60.33 a	78	24.66 a	737	7.58 a	64	3.66 a	901	13.0 a	560	6.0 a
2	344	55.83 ab	41	23.33 ab	359	7.50 ab	1047	3.66 a	183	11.8 ab	976	5.2 ab
3	192	55.33 abc	1	23.00 abc	735	7.38 abc	41	3.66 a	725	11.8 ab	662	4.2 abc
4	706	51.66 a - d	32	21.33 a - d	1047	7.34 a - d	367	3.58 ab	584	11.0 abc	734	3.8 a - d
5	748	51.00 a - e	976	21.33 a - d	560	7.34 a - d	560	3.50 abc	560	11.0 abc	9	3.7 a - e
6	147	50.16 a - f	712	19.83 a - e	368	7.34 a - d	359	3.50 abc	280	11.0 abc	725	3.7 a - e
7	368	48.50 a - f	753	19.50 a - f	409	7.00 a - e	222	3.40 a - d	194	11.0 abc	674	3.2 b - e
8	1047	46.83 a - g	1047	19.17 a - f	662	6.95 a - f	706	3.34 a - d	409	10.8 a - d	459	3.2 b - e
9	560	46.16 a - h	9	18.83 a - g	344	6.95 a - f	368	3.34 a - d	41	10.5 a - e	10	3.2 b - e
10	32	45.83 a - h	725	18.33 a - g	584	6.86 a - f	570	3.28 a - d	570	10.3 a - e	735	3.0 b - f
11	367	45.66 a - h	560	18.00 a - g	706	6.84 a - f	901	3.22 a - d	641	10.3 a - e	641	3.0 b - f
12	600	45.33 b - h	359	18.00 a - g	64	6.84 a - f	584	3.18 a - e	774	10.0 a - e	78	3.0 b - f
13	674	45.16 b - h	368	17.83 a - g	145	6.84 a - f	147	3.16 a - e	192	10.0 a - e	64	2.8 b - f
14	392	45.00 b - h	662	17.50 b - g	367	6.75a - g	183	3.16 a - e	600	10.0 a - e	280	2.8 b - f
15	9	43.50 b - h	674	17.33 b - g	600	6.66 a - h	280	3.15 a - e	14	9.8 a - f	748	2.8 b - f
16	183	43.50 b - h	774	17.33 b - g	674	6.66 a - h	10	3.13 a - e	359	9.5 a - g	368	2.7 b - f
17	194	42.83 b - i	145	17.16 b - g	712	6.53 a - i	192	3.08 a - e	737	9.5 a - g	706	2.7 b - f
18	737	42.50 b - i	147	17.00 b - g	748	6.52 a - i	641	3.08 a - e	1047	9.5 a - g	121	2.7 b - f
19	774	42.17 b - i	346	16.67 b - g	570	6.42 a - i	145	3.08 a - e	662	9.3 a - g	222	2.7 b - f
20	409	42.16 b - i	584	16.67 b - g	222	6.42 a - i	748	3.07 a - e	344	9.3 a - g	194	2.7 b - f
21	2	41.83 b - i	748	16.50 b - g	41	6.33 a - j	662	3.06 a - e	674	9.2 b - h	600	2.7 b - f
22	976	41.67 b - i	2	16.41 c - g	770	6.30 a - j	976	3.05 a - e	753	9.2 b - h	6	2.5 c - f
23	78	41.66 b - i	222	16.33 c - g	32	6.27 a - j	674	3.00 a - e	10	9.2 b - h	192	2.5 c - f
24	121	41.16 b - i	600	16.16 c - g	725	6.25 a - j	392	3.00 a - e	9	9.2 b - h	145	2.5 c - f
25	41	41.00 c - i	706	16.16 c - g	6	6.18 b - j	753	3.00 a - e	712	9.2 b - h	712	2.5 c - f
26	753	40.66 c - i	194	16.16 c - g	194	6.18 b - j	14	2.98 a - e	6	8.8 b - i	570	2.3 c - f
27	280	40.66 c - i	344	16.16 c - g	774	6.16 b - j	737	2.91 a - e	145	8.7 b - i	147	2.3 c - f
28	734	40.00 d - i	901	15.83 d - g	183	6.66 b - j	344	2.90 a - e	222	8.5 b - i	770	2.2 c - f
29	584	39.66 d - i	392	15.50 d - g	192	6.08 c - j	32	2.88 a - e	735	8.2 b - i	409	2.0 c - f
30	641	39.50 d - i	770	15.33 d - g	78	6.00 d - j	600	2.84 a - e	368	8.2 b - i	183	2.0 c - f
31	346	38.16 d - i	121	15.16 d - g	753	6.00 d - j	121	2.83 a - e	32	8.0 c - i	1	2.0 c - f
32	770	37.67 d - i	737	15.00 d - h	14	5.96 d - j	774	2.81 a - e	121	8.0 c - i	392	2.0 c - f
33	725	37.66 d - i	734	15.00 d - h	9	5.95 e - j	735	2.80 a - e	64	7.8 c - i	359	2.0 c - f
34	662	37.66 d - i	14	15.00 d - h	901	5.95 e - j	346	2.76 a - e	770	7.7 c - i	1047	1.8 c - f
35	10	37.50 d - i	641	14.50 d - h	346	5.92 e - j	712	2.68 a - e	392	7.5 c - i	344	1.8 c - f
36	570	37.50 d - i	280	14.50 d - h	641	5.83 e - j	78	2.66 a - e	78	7.3 c - i	774	1.8 c - f
37	64	37.33 d - i	64	14.33 e - h	734	5.75 e - j	734	2.66 a - e	734	7.3 c - i	584	1.8 c - f
38	6	37.33 d - i	183	14.33 e - h	10	5.73 e - j	9	2.61 a - e	748	7.2 d - i	14	1.8 c - f
39	222	37.16 d - i	459	14.33 e - h	459	5.65 e - j	459	2.56 a - e	459	6.8 e - i	901	1.7 c - f
40	359	36.50 e - i	6	14.33 e - h	280	5.58 f - j	770	2.56 a - e	706	6.8 e - i	41	1.5 d - f
41	901	36.00 f - h	570	14.16 e - h	392	5.45 g - j	725	2.46 a - e	976	6.2 f - i	753	1.5 d - f

42	14	33.00 ghi	192	14.00 e - h	976	5.44 g - j	194	2.45 b - e	346	6.1 ghi	367	1.3 d - f
43	712	33.00 ghi	10	13.66 e - h	147	5.33 hij	6	2.42 b - e	147	5.8 ghi	737	1.3 d - f
44	1	32.16 ghi	367	12.66 fgh	121	5.33 hij	1	2.33 cde	2	5.5 hi	2	1.2 ef
45	735	32.00 hi	735	12.00 gh	2	5.17 ij	2	2.25 de	367	5.5 hi	32	1.2 ef
46	459	28.66 i	409	8.16 h	1	5.00 j	409	2.00 e	1	5.3 i	346	0.5 f
	averag e	41.88		16.62		6.31		2.97		8.84		2.51
	LSD (5%)	14.69		6.85		1.38		1.21		3.71		2.56

Based on the observation of yield components, the length of large tubers ranged from 28.66 cm to 60.33 cm (average 41.88 cm). The length of small tubers has a range between 8.16 cm to 24.66 cm with an average of 16.62 cm. The diameters of large bulbs ranged from 5.00 cm to 7.58 cm with an average of 6.31 cm, while the diameters of small bulbs ranged from 2.00 cm to 3.66 cm (with an average of 2.97 cm). For the number of large tubers, from 44 clones tested and 2 comparison varieties the range was between 5.31 bulbs to 13 bulbs per plant with an average of 5.31 bulbs, while the number of small bulbs was between 0.5 bulbs and 6 bulbs per plant (average 2.51 bulbs/plant) (Table 3).

Table 4. Fresh tuber yield, harvest index, dry matter content, starch content, and starch yield of 44 cassava clones and two control varieties. Jabung, Malang district, East Java, 2020/2021.

No	Clones	Fresh tuber yield (t.ha ⁻¹)	Clones	Harvest index	Clones	Dry matter content (%)	Clones	Starch content (% wb)	Clones	Starch yield (t.ha ⁻¹)
1	344	55.07 a	280	0.63 a	748	50.20 a	706	23.97 a	344	12.17 a
2	584	47.90 ab	145	0.63 a	64	49.87 a	748	23.95 a	359	9.77 ab
3	725	47.73 ab	600	0.62 ab	192	49.06 ab	737	23.58 ab	368	9.71 ab
4	1047	44.02 abc	32	0.61 ab	14	48.88 ab	368	23.35 abc	584	9.53 abc
5	409	43.75 a - d	344	0.60 abc	737	48.74 ab	770	23.21 abc	409	9.42 abc
6	183	42.90 a - e	6	0.59 a - d	706	48.13 abc	359	23.20 abc	725	9.34 abc
7	712	42.46 a - e	194	0.59 a - e	222	47.89 abc	976	22.47 a - d	183	9.32 abc
8	145	42.36 a - e	570	0.58 a - e	147	47.59 abc	346	22.47 a - d	145	9.08 a - d
9	359	41.83 a - e	41	0.57 a - f	9	47.16 abc	662	22.47 a - d	901	9.07 a - d
10	368	41.80 a - e	725	0.57 a - g	770	47.07 abc	64	22.46 a - d	712	8.91 a - e
11	774	40.54 a - f	409	0.56 a - g	359	46.99 abc	901	22.46 a - d	1047	8.90 a - e
12	901	40.33 a - g	774	0.56 a - g	10	46.97 abc	280	22.18 a - d	706	8.89 a - e
13	222	40.01 b - g	367	0.56 a - g	183	46.85 abc	753	22.09 a - d	280	8.70 b - e
14	10	39.81 b - g	1047	0.56 a - g	662	46.71 a - d	735	22.09 a - d	662	8.68 b - e
15	280	39.63 b - g	641	0.56 a - g	368	46.70 a - d	570	22.09 a - d	10	8.64 b - f
16	662	38.86 b - g	392	0.55 a - h	41	46.27 a - d	344	22.08 a - d	737	8.55 b - f
17	192	38.09 b - g	9	0.55 a - h	194	46.15 a - d	147	22.08 a - d	774	8.35 b - f
18	706	36.84 b - g	584	0.55 a - h	976	45.98 a - e	459	22.08 a - d	192	8.29 b - f
19	41	36.81 b - g	346	0.55 a - h	392	45.95 a - e	9	22.08 a - d	222	8.07 b - f
20	641	36.58 b - g	674	0.53 a - h	78	45.83 a - e	192	21.72 a - d	41	7.85 b - g
21	737	36.20 b - g	10	0.53 a - h	674	45.46 a - e	674	21.72 a - d	748	7.84 b - g
22	32	35.92 b - g	147	0.52 a - h	725	45.50 a - e	409	21.72 a - d	570	7.81 b - g
23	600	35.74 b - g	368	0.52 a - h	145	45.44 a - e	183	21.72 a - d	9	7.77 b - g
24	570	35.66 b - g	359	0.51 a - h	735	45.36 a - e	14	21.72 a - d	600	7.76 b - g
25	9	35.20 b - h	901	0.51 a - h	901	45.36 a - e	145	21.72 a - d	32	7.61 b - g
26	14	34.44 b - h	753	0.50 a - i	346	45.22 a - e	10	21.71 a - d	14	7.57 b - h
27	753	33.88 b - h	121	0.50 a - i	570	45.13 a - e	600	21.71 a - d	64	7.49 b - h
28	64	33.58 b - i	662	0.50 a - i	121	45.12 a - e	194	21.38 a - e	753	7.47 b - h
29	194	33.48 b - i	737	0.48 a - j	1047	45.12 a - e	6	21.35 a - e	194	7.08 b - h
30	121	33.17 b - j	183	0.48 a - j	367	44.82 a - e	41	21.35 a - e	346	7.08 b - h
31	748	32.71 c - j	2	0.47 a - j	280	44.78 a - e	1047	21.05 b - e	121	6.96 b - i
32	346	31.91 c - k	560	0.47 a - j	753	44.53 a - e	121	20.99 b - e	641	6.91 b - j
33	560	31.67 c - k	78	0.47 a - j	344	44.18 a - e	560	20.99 b - e	770	6.81 b - j
34	6	31.110 c - k	748	0.46 a - j	584	44.07 a - e	712	20.99 b - e	560	6.65 b - j
35	734	29.335 c - k	770	0.45 a - j	600	44.05 a - e	774	20.68 cde	6	6.60 b - j
36	770	29.19 c - k	735	0.45 b - j	734	43.91 a - e	32	20.65 cde	674	6.28 c - k
37	674	29.03 d - k	222	0.43 c - j	409	43.56 a - e	222	20.64 cde	734	5.92 d - k
38	392	28.74 e - k	192	0.42 d - j	560	43.09 a - f	2	20.31 def	147	5.87 d - k
39	147	26.50 f - k	712	0.41 e - j	2	41.97 b - f	1	20.28 def	392	5.65 e - k
40	367	26.26 f - k	14	0.41 e - j	774	41.09 c - g	725	19.94 def	735	5.64 e - k

41	735	25.67 g - k	734	0.41 e - j	1	41.01 c - g	734	19.92 def	367	5.29 f - k
42	459	20.80 hijk	976	0.40 f - j	32	40.74 c - g	367	19.92 def	459	4.62 g - k
43	976	18.96 ijk	64	0.39 g - j	6	39.13 d - g	392	19.92 def	976	4.21 h - k
44	78	18.37 jk	706	0.38 hij	641	38.53 efg	584	19.92 def	2	3.66 ijk
45	2	17.68 k	459	0.32 ij	712	35.60 fg	641	18.86 ef	1	3.55 jk
46	1	17.66 k	1	0.31 j	459	33.85 g	78	17.48 e	78	3.20 k
	average	34.78		0.51		44.90		21.53		7.49
	LSD (5%)	14.84		0.18		7.60		2.84		3.38

Based on observations of fresh tuber yield, harvest index, dry matter content, starch content, and starch yield of 44 clones and two control varieties, the fresh tubers yield ranged from 17.66 t.ha⁻¹ to 55.57 t.ha⁻¹ (average 34.78 t.ha⁻¹). There were 25 clones that had tuber yields above the average and 13 clones of them had tuber yields > 40 t.ha⁻¹. [17] reported that tuber yield of 24 clones in 2018 ranged from 22.4 to 51.5 t.ha⁻¹ (average 34.6 t.ha⁻¹), and in the 2019 tuber yield ranged from 24.1 t.ha⁻¹ to 54.6 t.ha⁻¹ (average 38.6 t.ha⁻¹). While [18] reported that the fresh tuber yield of 15 genotypes in 10 months ranged 30.33–55.67 t/ha with mean 41.34 t/ha. It can be seen that the average tuber yield in this experiment was not significantly different from that of [17], but lower than that reported by [18] because this study has entered the multi-location test stage. Harvest index had a range between 0.32 to 0.63 with an average of 0.51 cm. The range of tuber dry matter content was between 33.85% to 50.2% with an average of 44.9%. For starch content, the 44 clones tested and two control varieties ranged from 17.48% to 23.97% with an average of 21.53%, while starch yield ranged from 3.2 t.ha⁻¹ to 12.17 t.ha⁻¹ (mean 7.49) (Table 4).

Table 5. Root flesh colour and fresh root taste of 44 cassava clones and two control varieties. Jabung, Malang district, East Java, 2020/2021.

No	Clones	Root flesh colour	Fresh root taste
1	1047	White	Sweet
2	10	White	Sweet
3	32	White	Sweet
4	735	White	Sweet
5	194	White	Sweet
6	346	White	Sweet
7	712	White	Sweet
8	662	Light yellow	Sweet
9	570	White	Bitter
10	222	White	Bitter
11	121	White	Bitter
12	774	White	Bitter
13	901	White	Sweet
14	770	White	Sweet
15	14	White	Sweet
16	584	White	Sweet
17	392	Light yellow	Sweet
18	459	White	Sweet
19	748	White	Bitter
20	9	White	Sweet
21	280	White	Sweet
22	976	White	Sweet
23	725	White	Sweet
24	6	White	Sweet
25	367	White	Sweet
26	145	Light yellow	Sweet
27	734	White	Sweet

28	344	White	Sweet
29	706	Light yellow	Sweet
30	641	White	Sweet
31	192	Light yellow	Sweet
32	737	White	Sweet
33	753	White	Bitter
34	368	White	Sweet
35	600	White	Bitter
36	147	White	Sweet
37	78	White	Sweet
38	409	White	Sweet
39	359	White	Sweet
40	64	White	Sweet
41	674	White	Bitter
42	41	White	Sweet
43	183	White	Sweet
44	560	White	Sweet
45	M1	Light yellow	Sweet
46	A1	Yellow	Sweet

Of the 44 promising clones observed, most had white tuber flesh color (39 clones or 86.63%), five clones had a light yellow color (11.36%). While the control variety Malang 1 had light yellow tubers and Adira 1 had yellow tubers. For tuber taste, 36 clones (81.81%) had sweet taste, eight clones (18.18%) had bitter taste, and the two control varieties had sweet taste (Table 5). Cassava which has a bitter tuber taste and high starch content is used as raw material for tapioca, while sweet cassava for consumption. Cassava is classified as bitter and sweet which is determined by its HCN content. Bitter cassava contains high content of HCN (above 100 mg of HCN per kilogram of fresh weight of roots) while sweet cassava with low cyanide content (below 100 mg of HCN per kilogram of fresh weight of roots) [19].

Based on the cluster analysis, two clusters were formed. Cluster 1 consisted of six clones and the second cluster consisted of 40 clones (Figure 1). The two comparison varieties, namely Adira 1 and Malang 1 and clones 367, clone 78, clone 976, and clone 459 were in the same cluster and had low average yields.

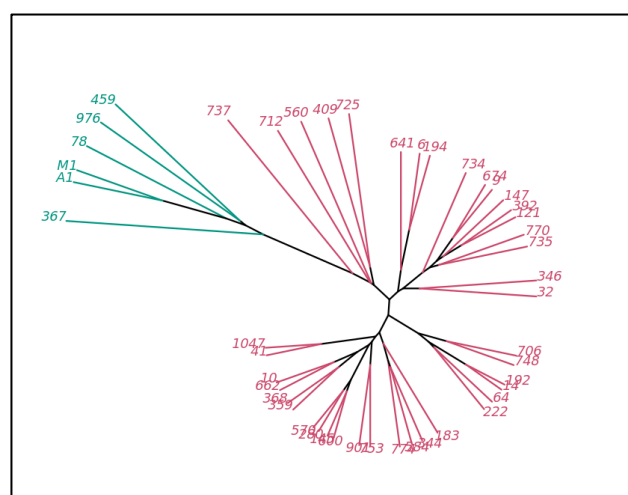


Figure 1. Cluster analysis based on the average linkage method ([PBSTAT-CL 2.1.1](#))

4. Conclusions

- The results of the research at the preliminary yield test stage showed that of the 44 clones tested the highest tuber yield was achieved by clone 344 (55.07 t.ha⁻¹), increased 2.11 times higher than average of control varieties.

- b. Clones 344 had a harvest index of 0.6, a dry matter content of 44.18%, a starch content of 22.08% and had the highest starch yield of 12.17 t.ha⁻¹.
- c. Other clones with tuber yield > 40 t.ha⁻¹ with relatively high branching were clone 368 (41.8 t.ha⁻¹), clone 584 (47.09 t.ha⁻¹), clone 222 (40.01 t.ha⁻¹), clone 712 (42.46 t.ha⁻¹), and clone 183 (42.90 t.ha⁻¹).

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