Ilmu Pertanian (Agricultural Science)
*http://journal.ugm.ac.id/jip*
**Vol. 9 No. 3 December, 2024: 190–197 | DOI: doi.org/10.22146/ipas.100627**

# Exploration and characteristic of the local cassava accessions from Central Sulawesi

Mirawanty Amin[1], Syafruddin[1]*, Saidah[2], I Ketut Suwitra[3], Abdi Negara[1], Asni Ardjanhar[1], and Asnawi[3]

[1]Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency of the Republic of Indonesia, Cibinong Science Center, Jakarta
Bogor Street Km 46, Cibinong-Bogor, West Java 16915, Indonesia
[2]Research Center for Horticulture Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency of the Republic of Indonesia, Cibinong Science Center, Jakarta
Bogor Street Km 46, Cibinong-Bogor, West Java 16915, Indonesia
[3]Research Center for Estate Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency of the Republic of Indonesia, Cibinong Science Center, Jakarta
Bogor Street Km 46, Cibinong-Bogor, West Java 16915, Indonesia
*Corresponding author: syaf013@brin.go.id

## Article Info

**Received** : 11th October 2024
**Revised** : 23rd December 2024
**Accepted**: 23rd December 2024

**Keywords**:
Biodiversity, cassava, food security, local food, morphological, plant agronomic

## Abstract

Cassava serves as a local food that contributes to food variety, enhancing food security and family nutrition. This is feasible due to Indonesia's extensive biodiversity, which facilitates the availability of varied and high-quality food. Each location has cassava with distinct properties. This research aimed to identify the presence of native cassava and their specific properties in Central Sulawesi. The used methodology included a survey and observation of plant agronomic and morphological characteristics, according to the General Guide for the Preparation of Food Crop Variety Descriptions established by the Centre for Plant Protection and Agricultural Licensing of the Ministry of Agriculture of the Republic of Indonesia. The investigation discovered three indigenous cassava accessions in Palolo District, Sigi Regency, Central Sulawesi: Kahubi Bula, Kahubi Palolo 1, and Kahubi Palolo 2. The three accessions possess distinct morphological, agronomic, and nutritional properties. Kahubi Bula has a greater stem diameter, whereas Kahubi Palolo 2 exhibits the lowest tuber size. The cyanide levels in the three accessions exhibited the traits of cassava, characterized by a sweet flavour owing to their low concentrations: 0.07 for Kahubi Bula, 0.01 for Kahubi Palolo 1, and 0.08 for Kahubi Palolo 2.

## INTRODUCTION

Cassava serves as a crucial food supply for some segments of the global population, notably Indonesia (Sahri et al., 2022). Cassava is the fifth most significant food crop globally; however, it holds the second position among tuber crops, behind potatoes (Lestari and Apriyai, 2017). Indonesia is situated in the Central Indomalayan area, indicating its potential as a germplasm resource, particularly for cassava. Cassava is a natural plant of Indonesia with significant development potential. Indonesia has significant genetic variety of cassava throughout all provinces, characterized by considerable biological variation, which enhances its potential as a source for food, industry, and biofuel (Laila et al., 2015).

Central Sulawesi, particularly Sigi Regency, is renowned for its indigenous cassava from the Palolo District. The cassava from this area is highly sought after by locals due to its tender, non-bitter texture, and substantial tuber size. Palolo cassava is scarce because of the increasing intensity of agricultural

**How to cite**: Amin, M., Syafruddin, Saidah, Suwitra, I.K., Negara, A., Ardjanhar, A., and Asnawi. (2024). Exploration and characteristic of the local cassava accessions from Central Sulawesi. *Ilmu Pertanian (Agricultural Science)*, 9(3), pp. 190–197.

**ISSN 0126-4214 (print) ISSN 2527-7162 (online)**

activities. Indigenous varieties are being supplanted by better kinds that exhibit more uniform growth and accelerated maturation (Mishra et al., 2009). Additionally, climate change is a significant concern that may jeopardize the accessibility of plant genetic resources (SDG).

Global warming and natural calamities may induce genetic deterioration of current agricultural Sustainable Development Goals (SDGs). Consequently, it is imperative to implement conservation initiatives and prioritize the use of local varieties with high adaptability, considering both biotic and abiotic factors to ensure their sustainability in supporting food availability and security (FAO, 2015 and Kumar et al., 2022).

The use of local varieties is sometimes not accompanied by good technological input, resulting in low productivity. The low productivity of local varieties can be optimized by managing genetic resources through plant breeding (Govinaraj et al., 2015 and Khoury et al., 2021). Increased yield potential is possible if genetic resources are available. However, cassava is a plant that can be propagated vegetatively and its flowering phase requires a certain location at an altitude above 800 meters above sea level. This is what causes cassava to have low genetic diversity, especially in Indonesia (Lestari and Apriyai, 2017).

The Palolo District, located inside the Sigi Regency, is recognized for its notable cassava germplasm; yet, its presence and precise attributes remain mostly unidentified. Consequently, it is essential to conduct an inquiry and characterisation from agronomic, morphological, proximate, starch, and cyanide content perspectives. This study aimed to identify the presence and examine the visual traits present in each accession to facilitate their differentiation.

## MATERIALS AND METHODS

The exploration was conducted in Bunga Village, Palolo District, Sigi Regency, Central Sulawesi. This location is at an altitude of ± 585 m above sea level. Activities were carried out in November 2023.

The materials used were seventh month old cassava plants, 70% gray cardboard as a background for the object to be photographed, label paper, plastic bags, and office stationery. Meanwhile, the tools used were Olympus digital camera E-PL 7, RHS color charts, Deli digital calipers, digital scales, and meters.

The activities were implemented using surveys. A survey was conducted to identify the existence of cassava genetic resources based on information from agricultural extension coordinators and local farmers. Furthermore, the accessions found were immediately characterized at the cassava growing location using the General Guide for the Preparation of Food Crop Variety Descriptions established by the Centre for Plant Protection and Agricultural Licensing of the Ministry of Agriculture of the Republic of Indonesia in 2021.

Observations and descriptive method were made on agronomic and morphological characteristics of cassava plants that is plant type, characteristics of stem, leaf, and tubers. In addition to these components, the tubers of each accession were analyzed for proximate, starch and cyanide content.

## RESULTS AND DISCUSSION

### Location characteristics

Palolo District is a sub-district under the administrative jurisdiction of Sigi Regency, Central Sulawesi, with an area of 626.09 km² and including 21 villages. According to BPS data from Sigi Regency in 2023, this region has heights ranging from 560 to 900 meters above sea level (masl). The population is 29,264, with over 60% engaged in agriculture.

Palolo Regency is administratively bordered by Parigi Moutong to the north, Nokilalaki to the south, Parigi Moutong to the east, and Sigi Biromaru, Tanambulaya, and Gumbasa to the west. The meteorological conditions in this area have air humidity levels ranging from 75% to 85%, accompanied by an average monthly precipitation of 66.41 mm.

### Agronomic and morphological characteristics of cassava plants

The exploration in Palolo District, Sigi Regency, discovered three cassava accessions: Kahubi Bula, Palolo 1, and Palolo 2. These three accessions possess distinct features, particularly in the stem, leaves, and tubers, as well as in their proximate composition, starch content, and cyanide levels. The observational data is shown in Table 1–5.

### Plant type

The characterisation findings of three cassava accessions from Palolo District, Sigi Regency, indicate that all exhibit branching plant types, as shown in

Table 1. Table 1 illustrates that the three varieties of cassava plants are of the branching type. Cassava is a monoecious species, with female flowers that emerge 10–14 days prior to male blooms on the same branch. Self-pollination transpires when male and female flowers on distinct branches or separate plants of the same genotype bloom concurrently (Perera et al., 2012 and Pineda et al., 2020). Branching transpires during the formation of a flower. Farmers often choose cassava varieties that have an upright and unbranched growth habit. Farmers favor plants in the first growth phases whose primary stem remains unbranched until it attains a height of one meter (Liu et al., 2014 and Ceballos et al., 2020). Consequently, it was found in the field that the three cassava varieties in Palolo were almost extinct due to the lack of cultivation by several farmers.

The main stem, after a designated growth time, finally generates branches that may be either reproductive (producing flowers) or vegetative (producing further branches). The branch responsible for reproduction is very stable for variety description. The branches also dictate the majority of the traits of each variety (Ceballos and de la Cruz, 2012).

## Stem characteristics

Observations on stem characteristics revealed that the branching angles of the three cassava accessions averaged over 65 degrees, with a uniform main stem type classified as monochotomous. Plant height varies from 3.0 to 3.4 m, stem diameter from 26.27 to 33.44 mm, and internode length from 13 to 14.5 mm. Stem coloration include mature stems, juvenile stems, and parenchyma. Two identical accessions are seen in the old stem: Kahubi Bula and Palolo 2, both exhibiting yellowish gray (156A), whilst Palolo 1 displays moderate brown (200D) (Figure 1). The three accessions exhibit distinct hues in young stems and parenchyma. The

**Table 1.** Plant types of three local cassava accessions from Palolo District, Sigi Regency

| No. | Accessions | Expression |
|---|---|---|
| 1 | Kahubi Bula | Branching |
| 2 | Palolo 1 | Branching |
| 3 | Palolo 2 | Branching |


**Figure 1.** Stem color of the three accessions Kahubi Bula, Kahubi Palolo 1, and Kahubi Palolo 2

**Table 2.** Stem characteristics of three accessions of local cassava plants from Palolo District, Sigi Regency

| Stem characteristics | Accessions | | |
|---|---|---|---|
| | Kahubi Bula | Palolo 1 | Palolo 2 |
| Angle of brancing | >65° | >65° | >65° |
| Type of main stem | Monochomomus | Monochomomus | Monochomomus |
| Plant height (m) | 3.0 | 3.4 | 3.1 |
| Stalk diameter (mm) | 33.44 | 26.27 | 28.26 |
| Internode length (mm) | 13 | 14.5 | 14 |
| Color of mature stem | Yellowish grey (156A) | Moderate brown (200D) | Yellowish grey (156A) |
| Color of young stem | Greyish olive green (N137B) | Dark greenish yellow (152D) | Strong yellow green (143B) |
| Parenchyma color | Moderate olive green (137B) | Brilliant yellow green (142B) | Greyish olive green NN 137B) |

observational data is shown in Table 2.

The height of the cassava plant typically ranges from 1.5 to 2.5 meters, while some specimens may reach heights of up to 3.5 meters (Wei et al., 2018). The stem is a crucial component of cassava since it facilitates vegetative or asexual reproduction. The lignified portion of the stem is often referred to as a stake or cutting, serving as a propagative element for plant development. Mature stems are cylindrical, with a diameter ranging from 20 to 60 mm, exhibiting silvery gray, purple, and/or yellow colors. With the development in stem diameter, substantial quantities of xylem accumulate, giving mature stems a lignin-like consistency and forming plugs that supplant the epidermis (Ceballos and de la Cruz, 2012; Mulualem, 2012; Nadjiam et al., 2016).

**Leaf characteristics**

The leaf morphology of the three accessions differed, with the exception of the characteristics of pubescence on immature leaves and the angle of the petiole to the stem. The lobe shapes from three accessions are lanceolate for Kahubi Bula, elliptical for Kahubi Paololo 1, and lanceolate for Kahubi Palolo 2. The immature leaves of Kahubi Bula and Palolo 1 have the same light olive color, whereas Palolo 2 has a moderate yellow-green coloration. The coloration of the top segment of the petiole at the apex of the stem for the three distinct accessions is as followes: red and silver-green for Kahubi Bula, strong red for Palolo 1, and strong purplish red for Palolo 2 (Figure 2, Table 3). Despite their variations, the accessions have


**Figure 2.** Appearance of leaf characteristics of the three cassava accessions

**Table 3.** Leaf characteristics of three accessions of local cassava plants from Palolo District, Sigi Regency

| Leaf characteristics | Accessions | | |
|---|---|---|---|
| | Kahubi Bula | Palolo 1 | Palolo 2 |
| Pubescence on young leaf | Absent | Absent | Absent |
| Shape of lobe | Lanset | Elip | Lanset |
| Number of lobe | 3–5 | 5 | 7 |
| Color of young leaf | Light Olive (152A) | Light Olive (152A) | Moderate Yellow Green (148A) |
| Mature leaf color | Light Green | Strong Yellow Green (144C) | Light Green |
| Leaf veins color on upper part | Dark Red | Brilliant Yellow Green (150A) | Greyish Olive Green (NN 137A) |
| Teethlets on mature leaf | Absent | Absent | Present |
| Color of upper part of petiole at the base of stem | Strong Yellow Green (144C) | Deep Red (53A) | Deep Red (60A) |
| Color of upper part of petiole on the tip of stem | Red and Silver Green | Strong Red (53B) | Strong Purplish Red (60B) |
| Color of under part of petiole on the central of stem | Strong Yellow Green (145A) | Moderate Yellow Green (147B) | Strong Yellow Green (143A) |
| Length of petiole (cm) | 52.8 | 35.5 | 52 |
| Angle of petiole to stem | Wide | Wide | Wide |
| Size of lobes of mature leaf | Length 15 cm<br>Wide 4.5 cm | Lenght 12 cm<br>Wide 5 cm | Lenght 14 cm<br>Wide 4.2 cm |

commonalities in character. The relevant characters are shown in Table 3.

Based on the observations, several differences were noted in color and characteristics of the leaf stalks, such as the color of the young leaf, the color of the leaf veins on the upper part, the color of the upper part of the petiole at the base of stem, and the color of the underside of the petiole at the center of the stem. Varying differences in the color of leaf petiole can be used as a differentiator between genotypes (Laila et al.. 2015). Asare et al. (2011) stated that the color of the leaf petiole is an important characteristic for distinguishing cassava accessions in germplasm collections and can serve as a specific trait to differentiate cassava genotypes (Sudarmonowati et al., 2008). Cassava leaves, apart from containing chlorophyll, also contain various polyphenolic components that have the potential to be used as a functional food source (Laya and Koubala, 2020).

**Tuber characteristics**

The tubers exhibit variations in characteristics such as shape, cortex thickness, outer skin color, flesh color, ease of peeling, and scaly surface texture, despite several similarities among the three accessions. The Kahubi Bula tuber has a conical-cylindrical form, but both Palolo 1 and Palolo share an identical shape characterized by curls or galendongs. The cortex exhibits variability in thickness, with Palolo 1 measuring the most at 3.23 mm and Kahubi Bula the least at 2.10 mm. The tuber coloration is yellowish white (NN 155A) for Kahubi Bula, yellowish white (158D) for Kahubi Palolo 1, and pale yellow green (155A) for Kahubi Palolo 2 (Table 4).

**Skin color**

The external skin coloration of the three accessions varies significantly: Kahubi Bula has a light yellowish color (159A), Palolo 1 displays a moderate brown shade (165A), and Palolo 2 presents a brownish orange tint (165B). The tubers exhibit a color spectrum from yellowish white to light yellow, with all three accessions being easily peelable (Figure 3). The yellow hue of cassava tubers indicates the presence of carotene, a precursor of vitamin A. Ayetigbo et al. (2018) asserted that cassavas with yellow tuber coloration have the potential to serve as a source of β-carotene and a food coloring agent. The external epidermis is distinct in Kahubi Bula, which is smooth and non-scaly, while Palolo 1 and Palolo 2 have a scaly and rough texture (Table 4).

**Proximate, starch and cyanide content**

The results of the analysis of proximate content in the form of water, ash, protein, fat, and carbohydrate content showed varying values (Table 5). For water and ash content, Palolo 2 had the highest values, namely 57.67% and 1.33%. Meanwhile, Kahubi Bula had the lowest water content (55.03%) and Palolo 1 for ash content (1.01%). For protein, fat, and starch levels, Kahubi Bula had the highest values, namely 3.01%, 0.71%, and 73.33%, but this was not followed by the values for carbohydrate and cyanide levels. The highest carbohydrate content was obtained by the Palolo 1 and Palolo 2 accessions for cyanide levels.

Water content is closely related to harvest age. The longer the harvest, the lower the water content. This is in line with the results of research by Susilawati et al. (2008) who reported that the water content of fresh cassava is influenced by the age of harvest. The longer the cassava harvest, the lower the water content (Fernandez et al., 2019 and Enesi et al., 2022). The harvest time for cassava in Palolo District ranges from 6–8 months. Apart from that, according to Nugraha et al (2015), water content is also determined by the variety which is caused by plant genetics in

**Table 4.** Tuber characters of three accessions of local cassava plants from Palolo District, Sigi Regency

| Tuber characteristics | Accessions | | |
|---|---|---|---|
| | Kahubi Bula | Palolo 1 | Palolo 2 |
| Shape | Cylindrical-conical | Fusiform | Fusiform |
| Cortex thickness (mm) | 2.10 | 3.23 | 2.30 |
| The color of periderm | Lightwish Yellowish (159A) | Moderate Brown (165A) | Brownish Orange (165B) |
| The color of tuber | Yellowish White (NN 155A) | Yellowish White (158D) | Pale Yellow Green (155A) |
| Cortex removment | Easy | Easy | Easy |
| Surface of periderm of strorage root | No scaly and smooth | Scaly and rough | Scaly and rough |

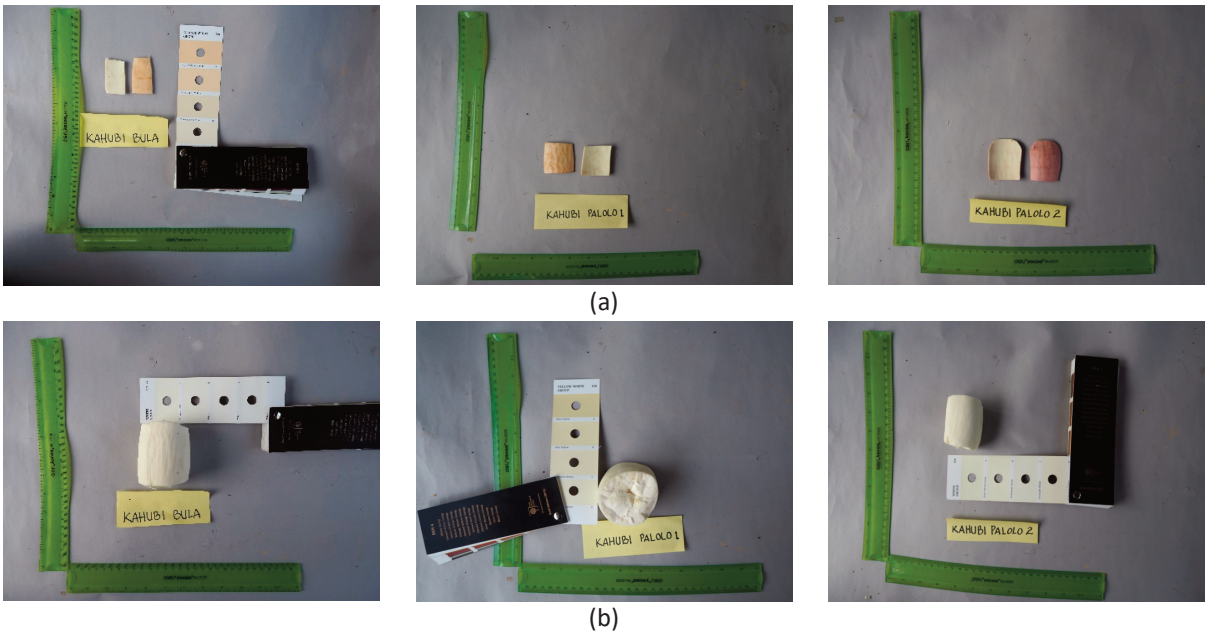


**Figure 3.** Appearance of skin color of the three accessions (a); and tuber color (b)

**Table 5.** Results of analysis of proximate, starch and cyanide content

| Parameter | Accessions | | |
|---|---|---|---|
| | Kahubi Bula | Palolo 1 | Palolo 2 |
| Water content (%) | 55.03 | 56.25 | 57.67 |
| Ash content (%) | 1.19 | 1.01 | 1.33 |
| Protein content (%) | 3.01 | 1.91 | 2.87 |
| Fat content (%) | 0.71 | 0.49 | 0.94 |
| Carbohydrate content (%) | 40.05 | 40.34 | 37.18 |
| Starch content (%) | 73.33 | 69.15 | 66.34 |
| Cyanide levels (mg/100 g) | 0.07 | 0.01 | 0.08 |

Remarks: Analyzed at the Mathematics and Natural Sciences Faculty Laboratory, Tadulako University, 2023.

absorbing water.

The average protein content of cassava from Palolo District is high, ranging from 1.91 to 3.01%. The protein content in plants is influenced by fertilization and N content in the soil. Root crops that are not fertilized with N produce tubers with low protein levels (Suminarti, 2010 and Chaiareekitwat et al., 2022). According to Crowder and Chedda (1982), protein levels will decrease according to increasing plant age and fiber content

The starch content of the three accessions was at high criteria. The high and low levels of starch are thought to be caused by the speed of starch synthesis in each cassava accession. Apart from that, Suhartina (2005) reported that starch content is also greatly influenced by harvest age, variety, planting location, and climate. Widaningrum and Purwani (2006) stated that the starch content of a food ingredient affects the properties of the amigraph. The higher the starch content, the thicker the material.

Cyanide acid (HCN), recognized as a blue toxin, is naturally created by cassava via physiological processes. The cyanide concentrations in the three cassava accessions from the Palolo District were minimal, making them safe for consumption and free from any bitter flavor. The three varieties of local cassava are non-bitter cassava. According to McKey et al. (2010), sweet cassava has fewer than 100 mg $kg^{-1}$ of cyanogenic chemicals per fresh tuber, but 'bitter' cassava contains more than 100 mg of cyanogenic compounds. A bitter flavor indicates elevated HCN concentrations. Hydrogen cyanide (HCN) in cassava is a phenotypic characteristic influenced by both genetic and environmental variables (Ifeabunika,

et al., 2017 and Mbah et al., 2019). Crowder and Chedda (1982) asserted that the HCN concentration in a plant is affected by genetic determinants, climatic conditions, soil fertility, and plant age.

## CONCLUSIONS

Results of cassava exploration in the Palolo District. Three accessions were identified in Sigi: Kahubi Bula, Kahubi Palolo 1, and Kahubi Palolo 2. The three local cassava accessions exhibited distinct agronomic and morphological variability, including variations in plant types, leaves, stems, tubers, as well as proximate composition, starch content, and cyanide levels. The disparity among the three accessions is evident in the stem diameter, with Kahubi Bula exhibiting a greater size. Kahubi Palolo 2 has the lowest tuber size. Research on biodiversity is crucial since it enhances resistance to climate change by ensuring the availability of nutritious local food sources.

## REFERENCES


Asare, P.A., Galyuon, I.K.A., Sarfo, J.K., and Tetteh, J.P. (2011). Morphological and molecular based diversity studies of some cassava (*Manihot esculenta* Crantz.) germplasm in Ghana. *Afr J Biotechnol*, 10, pp. 13900–13908.

Ceballos, H., Rojanaridpiched, C., Phumichai, C., Becerra, L.A., Kittipadakul, P., Iglesias, C., and Gracen, V.E. (2020). Excellence in cassava breeding: perspectives for the future. *Crop Breed Genet Genom,* 2(2), 200008.

Chaiareekitwat, S., Latif, S., Mahayothee, B., Khuwijitjaru, P., Nagle, M., Amawan, S., and Muller, J. (2022). Protein composition, chlorophyll, carotenoids, and cyanide content of cassava leaves (*Manihot esculenta* Crantz) as influenced by cultivar, plant age, and leaf position. *Food Chemistry,* 372, 131173.

Ceballos,H., and de la Cruz, G.A. (2012). Cassava Taxonomy and Morphology. In: Ospina Patiño, Bernardo; Ceballos, Hernán, eds., *Cassava in the third millennium: Modern production, processing, use, and marketing systems*. Latin American: Centro Internacional de Agricultura Tropical (CIAT); and Cali, CO: Caribbean Consortium to support Cassava Research and Development (CLAYUCA), Technical Centre for Agricultural and Rural Cooperation (CTA), pp. 15–28.

Enesi, R.O., Hauser, S., Pypers, P., Kreye, C., Tariku, M., and Six, J. (2022). Understanding changes in cassava root dry matter yield by different planting dates, crop ages at harvest, fertilizer application and varieties. *European Journal of Agronomy,* 133, 126448.

FAO. (2015). *Climate change and food security: risks and responses*. [pdf] United Nations. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/a4fd8ac5-4582-4a66-91b0-55abf642a400/content [Accessed 12 October 2024]

Fernandes, D. de S., dos Santos, T.P.R., Fernandes, A.M., and Leonel, M. (2019). Harvest time optimization leads to the production of native cassava starches with different properties. *International Journal of Biological Marcromolecules,* 132, pp. 710–721.

Govindaraj, M., Vetriventhan, M., and Srinivasan, M. (2015). Importance of genetic diversity assessment in crop plants and its recent advances: an overview of its analytical perspectives. *Genetics Research International,* (1), 431487.

Ifeabunike, O.B., Nwaedozie, J.M., and Aghanwa, C.I. (2017). Proximate Analysis, Hydrogen Cyanide and Some Essential Mineral Content of Sweet Cassava Variety (Manihot utilisima) and Bitter Cassava Variety (Manihot palmata) Cultivated in Kachia Local Government Area of Kaduna State, Nigeria. *International Journal of Biochemistry Research & Review,* 19 (1), pp. 1–12.

Karri, V.R., and Nalluri N. (2016). Cassava: meeting the global protein need. *Plant Science Today,* 3(3), pp. 304–311.

Khppury, C.K., Brush, S., Costich, D.E., Curry, H.A., de Haan, S., Engels, J.M.M., Guarino, L., Hoban, S., Mercer, K.L., Miller, A.J., Nabhan, G.P., Perales, H.R., Richards, C., Reggins, C., and Thormann, I. (2021). Crop genetic erosion: understanding and responding to loss of crop diversity. *New Phytologist,* 233(1), pp. 84–118.

Kumar, L., Chhogyel, N., Gopalakrishnan, T., Hasan, M.K., Jayasinghe, S.L., Kariyawasam, C.S., Kogo, B.K., and Ratnayake, S. (2022). Chapter 4 - Climate change and future of agri-food production. *Global Tends Opportunities, and Sustainability Challenges,* 2022, pp. 49–79.

Laila, F., Zanetta, C.U., Waluyo, B., Amien, S., and Karuniawan, A. (2015). Early Identification

of Genetic Diversity and Distance from Indonesia Cassava Potential as Food, Industrial and Biofuel Based on Morphological Characters. *Energy Procedia,* 65, pp. 100–106.

Laila, F., Zanetta, C.U., Waluyo, B., Amien, S., and Kurniawan, A. (2015). Early identification of genetic diversity and distance from Indonesia cassava potential as food, industrial and biofuelbased on morphological characters. *Energy Procedia,* 65, pp. 100–106.

Liu, Q., Liu, J., Zhang, P., and He, S. (2014). Root and Tuber Crops. *Encyclopedia of agriculture and food systems,* 2014, pp. 46–61.

Lestari, T., and Apriyadi, R. (2017). Genetic potential of cassava biodiversity in Bangka Island, Indonesia. *Cell Biology & Development,* 1(2), pp. 41–45.

Mbah, E.U., Nwankoo, B.C., Njoku, D.N., and Gore, M.A. (2019). Genotypic evaluation of twenty-eight high-and low cyanide cassava in low land tropics, southeast Nigeria. *Heliyon,* 5(6), E01855.

McKey, D., Cavagnaro, T.R., Cliff, J., and Gleadow, R. (2010). Ekologi kimia dalam sistem manusia dan alam yang saling terkait: manusia, singkong, interaksi multitrofik dan perubahan global. *Chemoecology,* 20, pp. 109–133.

Mulualem, T. (2012). Cassava (*Mannihot esculenta* Cranz) Varieties and Harvesting Stages Influenced Yield and Yield Related Components. *Journal of Natural Sciences Research,* 2(10), pp. 122–128.

Nadjiam, D., Sarr, P.S., Naitormbaide, M., Mbaiguinam, J.M.M., and Guisse, A. (2016). Agro-morphological characterization of cassava (manihot esculenta crantz) cultivars from chad. *Agricultural Science,* 7, pp. 479–492.

Perera, P.I.P., Quintero, M., Dedicova, B., Kularatne, J.D.J.S., and Ceballos, H. (2012). Comparative morphology, biology and histology of reproductive development in three lines of Manihot esculenta Crantz (Euphorbiaceae: Crotonoideae). *AoB Plants,* 5, pls046.

Pineda, M., Morante, N., Salazar, S., Cuasquer, J., Hyde, P.T., Setter TL, and Ceballos H. (2020). Induction of earlier flowering in cassava through extended photoperiod. *Agronomy,* 10(9), 1273.

Sahro, R.H., Hidayah, N., Fadhillah, N., Fuadi, A., Abidin, I., Hannifa, W., and Wulandari, S. (2022). Tanaman pangan sebagai sumber pendapatan petani di kabupaten Karo. *Jurnal Inovasi Penelitian,* 2(10), pp. 3223–3230.

Sudarmonowati, E., Hartati, N.S., Sugiharti, S., Rahman, N., Fitriani, H., and Hartati, W. (2008). Seleksi tanaman unggul menggunakan marka RAPD. Laporan Teknik, Pusat Penelitian Biologi–LIPI.

Wei, M., Andersson, R., Xie, G., Salehi, S., Boström, D., and Xiong, S. (2018). Properties of Cassava Stem Starch Being a New Starch Resource. *Starch - Stärke*, 70(5-6), 1700125.