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Selected morphological and agronomic descriptors for the characterization of cassava

W.M.G. Fukuda, C.L. Guevara, R. Kawuki, and M.E. Ferguson

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This cassava descriptor list was adapted and translated from W.M.G. Fukuda and C.L. Guevara. *Descritores morfológicos e agronômicos para a caracterização de mandioca* (*Manihot esculenta* Crantz). Documentos 78, EMBRAPA-CNPMF, 1998, 38 pp. ISSN 0101 – 5171

Who we are

Africa has complex problems that plague agriculture and people's lives. We develop agricultural solutions with our partners to tackle hunger and poverty. Our award-winning research for development (R4D) is based on focused, authoritative thinking anchored on the development needs of sub-Saharan Africa. We work with partners in Africa and beyond to reduce producer and consumer risks, enhance crop quality and productivity, and generate wealth from agriculture. IITA is an international non-profit R4D organization established in 1967, governed by a Board of Trustees, and supported primarily by the Consultative Group on International Agricultural Research.

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Contents

Background

This cassava list has been prepared specifically for a project entitled *Tapping Crop Biodiversity for the Resource Poor in East and Central Africa*, funded by the Rockefeller Foundation, the Generation Challenge Program, and Biosciences eastern and central Africa, and implemented by the International Institute of Tropical Agriculture (IITA). The national agriculture research institutes of seven countries, namely DR Congo, Rwanda, Kenya, Uganda, Tanzania, Mozambique, and Madagascar participated in the project and have contributed to the adaptation of the descriptor list. The list was also compared with the IPGRI descriptor list[1]. The majority of IPGRI descriptors are encompassed here.

Our thanks go to W.M.G. Fukuda and C.L. Guevara, the authors of the original descriptor list (EMBRAPA – CNPMF Documentos 78) and EMBRAPA for allowing us to use the descriptor list in this way.

Major objectives of the project were to document and characterize, both genotypically and phenotypically, cassava germplasm that breeders use in the region. This includes improved varieties as well as locally adapted farmer varieties. To analyze data together and draw comparisons, it is important that data collection, storage, and analysis are standardized. This descriptor list aims at helping to standardize characterization data, although obviously a certain amount of subjective interpretation is inevitable. It is proposed that measurements are taken three, six, and nine months after planting, and then at harvest. The traits to be evaluated on all these sampling occasions were selected after a consultative meeting with cassava breeders in the region. The traits are both descriptive, as well as being of agronomic value in the region. The majority of characters are qualitative, a few being quantitative. Equipment that would be useful for full characterization includes calipers, a protractor, and a digital balance under which cassava roots can be suspended. Further, this manual has also provided in the Annexes, relevant background information on some traits. For the sake of consistency we have used the same scoring scale as Fukuda et al. (1998).

The recommended experimental design is a replicated trial, i.e., two sites with the same genotypes. In some countries this may not be possible due to quarantine restrictions. The two sites would serve two purposes: (1) enable estimation of environmental variance associated with some of the measurable traits, and (2) provide a back-up in case of unforeseen problems. At each site, each genotype should be represented by 10 plants in one row at a spacing of 1 m x 1 m between and within rows. To remove border effects, assessments should be done using the eight central plants only. A sample data sheet is provided in Annex VI.

It is our hope that this translated and adapted manual will help to standardize and record in a uniform format characterization data from national germplasm collections not only in the participating project countries but across the region. We hope you find it useful! If you have comments or queries, please contact either Morag Ferguson (m.ferguson@cgiar.org) or Robert Kawuki (kawukisezi@naro-ug.org).

Morag Ferguson, IITA
Robert Kawuki, National Crops Resources Research Institute (NACRRI),
National Agricultural Research Organisation (NARO)

[1]IPGRI, CIAT. 2003. Descriptors for Cassava (*Manihot esculenta*). International Plant Genetic Resources Institute, Rome, Italy, and Centro Internacional para la Agricultura Tropical, Cali, Colombia.

Descriptors to be scored at three months after planting

1. Color of apical leaves

Record the most frequent occurrence.
Damage by cassava green mite may obscure this trait, so it is better to score earlier rather than later.

3 Light green
5 Dark green
7 Purplish green
9 Purple

Light green

Dark green

Purplish green

Purple

2. Pubescence on apical leaves

Record the most frequent occurrence.

0 Absent
1 Present

Present

Absent

Descriptors to be scored at six months after planting

3. Leaf retention

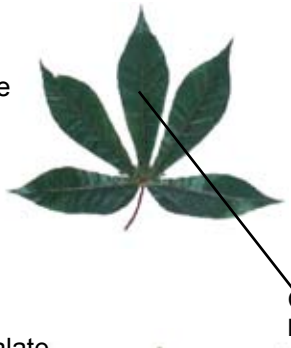
Measure 5–6 months after planting (See Annex 1). Visually score for leaf retention using a scale of 1–5. An average plant is one with leaves covering about half of the plant. Record the most frequent occurrence on all the eight central plants/clone/plot.

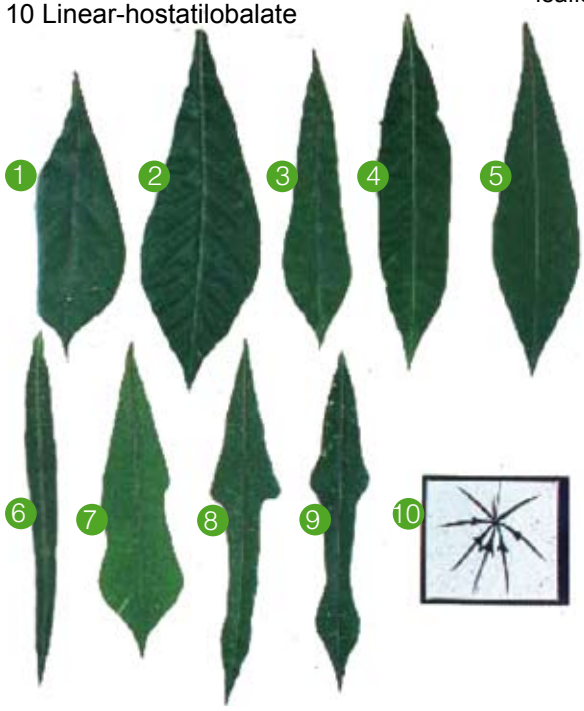
1 = Very poor retention
2 = Less than average retention
3 = Average leaf retention
4 = Better than average retention
5 = Outstanding leaf retention

4. Shape of central leaflet

Leaf taken from a mid-height position.
Record the most frequent occurrence.

1 Ovoid
2 Elliptic-lanceolate
3 Obovate-lanceolate
4 Oblong-lanceolate
5 Lanceolate
6 Straight or linear
7 Pandurate
8 Linear-piramidal
9 Linear-pandurate
10 Linear-hostatilobalate

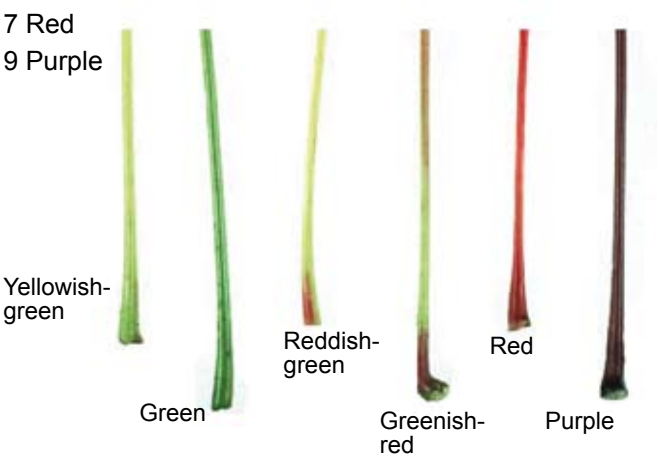




5. Petiole color

Leaf taken from a mid-height position.
Record the most frequent occurrence.
Intermediate descriptor states allowed.

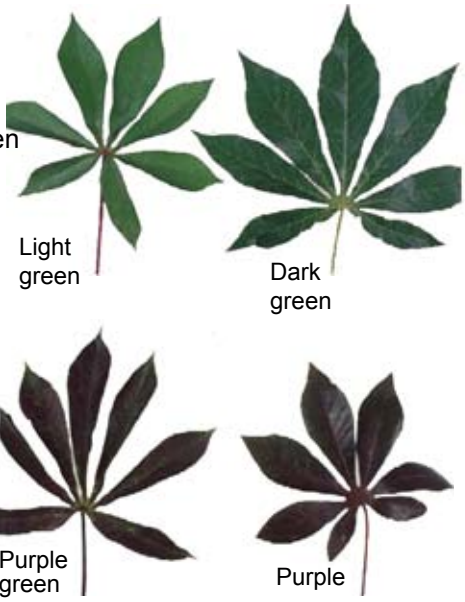
1 Yellowish-green
2 Green
3 Reddish-green
5 Greenish-red
7 Red
9 Purple



6. Leaf color

Observe a leaf from the middle of the plant.
Record the most frequent occurrence.
No intermediates allowed.

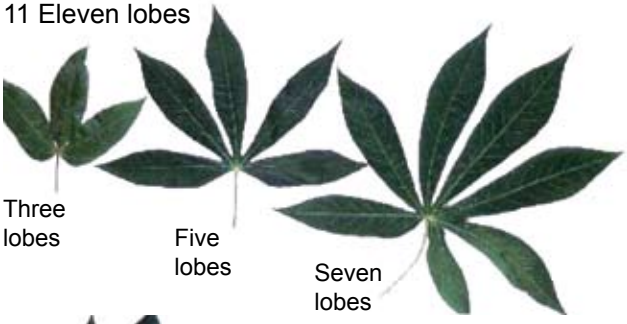
3 Light green
5 Dark green
7 Purple green
9 Purple

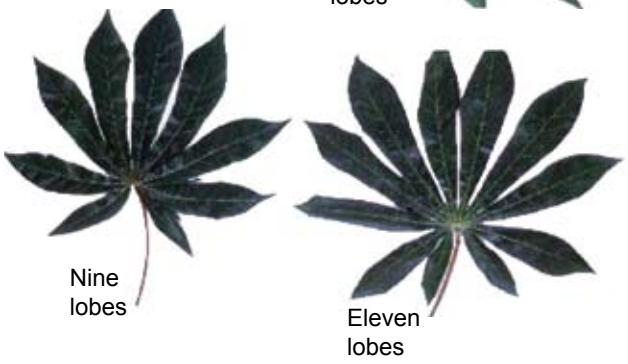


7. Number of leaf lobes

Observe a leaf from the middle of the plant.
Assess on five leaves and take the predominant number of lobes.
Record only one score.

3 Three lobes
5 Five lobes
7 Seven lobes
9 Nine lobes
11 Eleven lobes





8. Length of leaf lobe

Measure two leaves from the middle of the plant.
Measure from the intersection of all lobes to the end of the middle lobe.
Express in cm and record to one decimal place.

9. Width of leaf lobe

Measure two leaves from the middle of the plant.
Measure from the widest part of the middle lobe.
Express in cm, and record to one decimal place.

10. Ratio of lobe length to lobe width of central leaf lobe

11. Lobe margins

Observe from the middle third of the plant.
Record the most frequent occurrence.
No intermediates allowed.

3 Smooth
7 Winding

Smooth

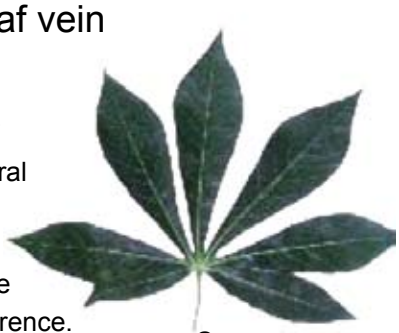
Winding

12. Petiole length

Observe from the middle third of the plant.
Measure two leaves/ plant.
Express in cm.

13. Color of leaf vein

Observe near the base of the lobes, on the upper side of the leaf, on the central lobe from a leaf from the middle of the plant. Record the most frequent occurrence. No intermediates allowed.



Green

3 Green
5 Reddish-green in less than half of the lobe
7 Reddish-green in more than half of the lobe
9 All red

Reddish-green in less than half of the lobe

Reddish-green in more than half of the lobe

All red

15. Flowering

At least one flower on each plant. Scoring should be repeated at regular intervals until harvest to determine whether flowering occurs. Record both presence of flowering and date of observation.

0 Absent
1 Present

16. Pollen

Scored at the same time as flowering.

0 Absent
1 Present

14. Orientation of petiole

Observe from the middle of the plant.
Take a general picture across the row.
No intermediates allowed.

1 Inclined upwards
3 Horizontal
5 Inclined downwards
7 Irregular

Inclined upwards

Horizontal

Inclined downwards

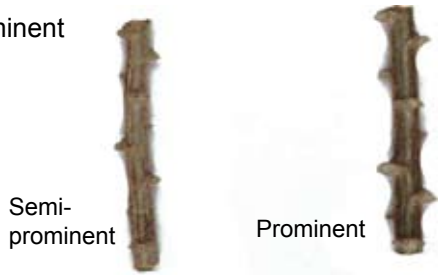
Irregular

Descriptors to be scored at nine months after planting

17. Prominence of foliar scars

Observe from the middle third of the plant.
Record the most frequent occurrence.

3 Semi-prominent
5 Prominent



18. Color of stem cortex

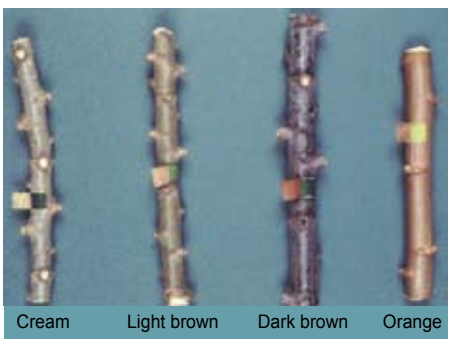
Observe from the middle third of the plant.
Make a small shallow cut and peel back the epidermis as in picture below.

1 Orange
2 Light green
3 Dark green

19. Color of stem epidermis

Peel epidermis back and look at underside of epidermis (skin).

1 Cream
2 Light brown
3 Dark brown
4 Orange



20. Color of stem exterior

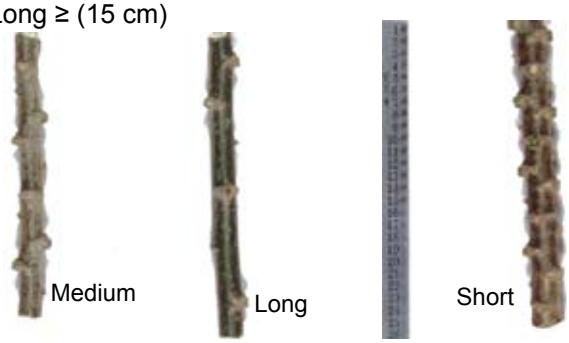
Observe on the middle third of the plant.

3 Orange
4 Greeny-yellowish
5 Golden
6 Light brown
7 Silver
8 Gray
9 Dark brown

21. Distance between leaf scars

Measure from the middle of stem on the middle third of the plant, where the scars are not flat. Make a measurement along the stem then divide the distance by the number of nodes in the measured part. Avoid taking measurements on mealy bug infected plants.
For conversion to qualitative data:

3 Short ≤ (8 cm)
5 Medium (8–15 cm)
7 Long ≥ (15 cm)



22. Growth habit of stem

1 Straight
2 Zig-zag

Zig-zag Straight

23. Color of end branches of adult plant

Observation to be taken on top 20 cm of plant.
Intermediates allowed.
Record the most frequent occurrence.

3 Green
5 Green-purple
7 Purple

Green-purple

Green

Purple

24. Length of stipules

Observation from upper third of plant.
Record the most frequent occurrence.
No intermediates allowed.

3 Short
5 Long

Short

Long

25. Stipule margin

Observation from upper third of plant.
Record the most frequent occurrence.
No intermediates allowed.

1 Entire
2 Split or forked

Entire

Split or forked

Descriptors to be scored at harvest

26. Fruit

0 Absent
1 Present

27. Seed

0 Absent
1 Present

28. Plant height

Measure vertical height from the ground to the top of the canopy.
Express in cm.
Record measurements from three plants.

29. Height to first branching

Measure vertical height from ground to first primary branch.
Zero = no branching.
Ignore side branching.
Express in cm.
Record measurements from three plants.

30. Levels of branching

Record number of divisions of branching.
Zero (0) for no branching
Ignore if side branching
Record the most frequent occurrence.

31. Branching habit

Observed at the lowest or first branching.
Record the most frequent occurrence on the plot.

1 Erect
2 Dichotomous
3 Trichotomous
4 Tetrachotomous

Erect

Dichotomous

Trichotomous

Tetrachotomous

32. Angle of branching

Measure at first primary branching (not side branches).
Record the angle measured, later divide the angle by two.
Record measurements from three plants.

33. Shape of plant

Record the most frequent occurrence on the plot.

1 Compact
2 Open
3 Umbrella
4 Cylindrical


Compact


Open


Umbrella


Cylindrical

34. Number of storage roots/plant

Record from each of three plants.

35. Number of commercial roots per plant

Record the number of roots from three plants with length greater than 20 cm.

36. Extent of root peduncle

Main roots only.
Record the most frequent occurrence.

0 Sessile
3 Pedunculate
5 Mixed


Sessile


Pedunculate


Mixed

37. Root constrictions

Measure on a mature root. This can be affected by nematodes and/or cassava brown streak diseases.
Record the most frequent occurrence.

1 Few to none
2 Some
3 Many


Few to none (3 or less)

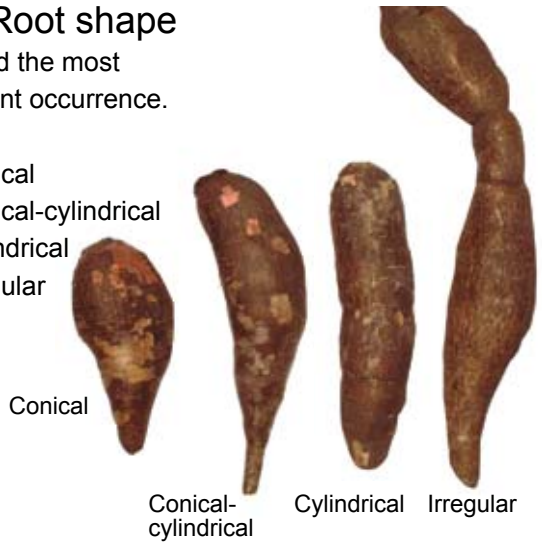

Some (4-6)


Many to none (more than 6)

38. Root shape

Record the most frequent occurrence.

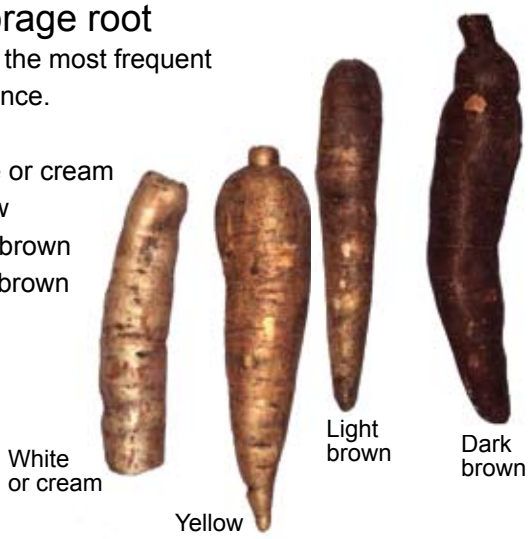
1 Conical
2 Conical-cylindrical
3 Cylindrical
4 Irregular



39. External color of storage root

Record the most frequent occurrence.

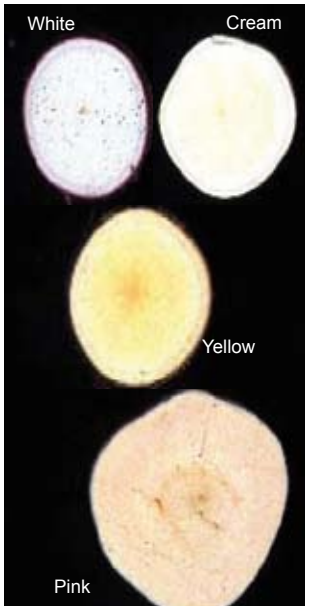
1 White or cream
2 Yellow
3 Light brown
4 Dark brown



40. Color of root pulp (parenchyma)

Record the most frequent occurrence.

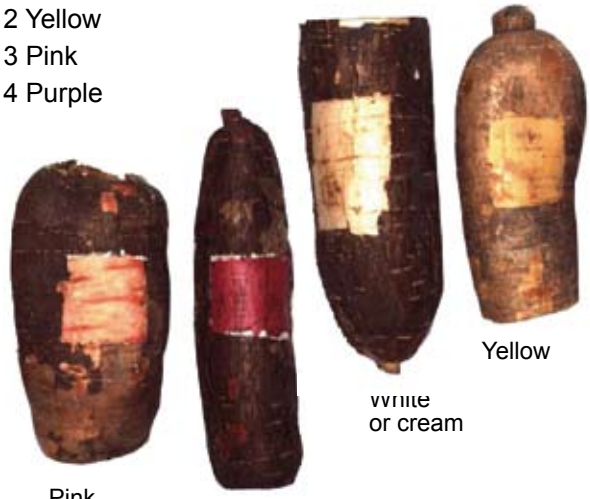
1 White
2 Cream
3 Yellow
4 Orange (no photo)
5 Pink



41. Color of root cortex

Record the most frequent occurrence.

1 White or cream
2 Yellow
3 Pink
4 Purple



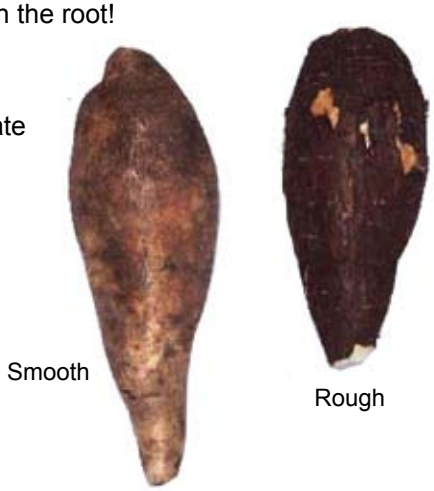
42. Cortex: ease of peeling

1 Easy
2 Difficult

43. Texture of root epidermis

Record the most common root type.
Please touch the root!

3 Smooth
5 Intermediate
7 Rough



44. Root taste

Raw root only

1. Sweet
2. Intermediate
3. Bitter

45. Cortex thickness

Measure from three roots, at the proximal (closest to stem), mid- and distal (furthest from stem) ends. Use calipers if available; otherwise try to estimate.

1 Thin
2 Intermediate
3 Thick

46. Dry matter content (%)

See Annex II for details.
Measure on three plants.

47. Starch content (%)

See Annex II for details.
Measure on three plants.

48. Harvest index

See Annex III for details.
Measure on 4–6 plants/clone.

49. Cyanogenic potential (CNP)

See Annex IV for details.
Score 1–9 for four plants/clone and three roots/plant.

50. Postharvest deterioration

Optional descriptor.
See Annex V for details.

Annex I

Leaf retention

Background

Unlike in some other crops such as the cereals, cassava experiences simultaneous growth and development of the economic plant part (roots) and the photosynthetic sites, the leaves. This could imply that greater leaf longevity will result in higher yields. However, because of the simultaneous growth of the roots and the leaves, there is competition for assimilates for development of leaf area index (LAI) and roots. Thus, if longevity of leaves is increased to maintain high photosynthetic rates, it may be possible to maintain a given LAI with less distribution of assimilates to leaf development and more to root growth. Indeed clones with the leaf retention trait were observed to produce more total fresh biomass and higher root dry matter than plants without the trait (Lenis et al. 2006). Hence, this trait presents an additional opportunity to increase cassava yields. The heritability of HI has also been reported to be relatively high (0.55) (Lenis et al. 2006). It is against this background that we propose to include leaf retention in this study.

Methodology

1. Done between five and six months after planting; this period normally coincides with drought stress in most cassava-growing regions in eastern and southern Africa.
2. Visually score for leaf retention using a scale of 1–5. An average plant is one with leaves covering about ½ of the plant.
   1 = Very poor retention
   2 = Less than average retention
   3 = Average leaf retention
   4 = Better than average retention
   5 = Outstanding leaf retention
3. Record per clone should be made by observing all the eight central plants per clone.

Reference

Lenis, J.I., F. Calle, G. Jaramillo, J.C. Pérez, H. Ceballos, and J. Cock. 2006. Leaf retention and cassava productivity. Field Crops Research 95: 126–134.

Annex II

Assessment for dry matter (DM) and starch content

Background

Heritability for DM in cassava is relatively high; 0.87 broad sense heritability and 0.51 – 0.67 narrow sense heritability (Kawano et al. 1987). Estimation of DM and starch content in cassava is based on the principle of a linear relationship between specific gravity with DM and or starch content. Percentage DM = 158.3x – 142, while starch content = 112.1x – 106.4; where x = specific gravity. Specific gravity is measured according to the following methodology:

Methodology

1. Prepare root samples weighing 3–5 kg.
2. Weigh sample in air (Wa) using a suitable balance. Ensure that that the roots are generally free from soil and other debris
3. Weigh the sample in water (Ww).
4. Ensure that you use the same container to weigh both in air and in water. A sturdy wire basket works perfectly as it allows soil debris to fall through and also allows easy measurement in water.
5. Compute specific gravity at
   $$\frac{Ww}{Wa - Ww}$$
6. Compute DM and starch content using the formulas DM = 158.3x – 142, and starch content = 112.1x – 106.4.

Clone	Wa (g)	Ww (g)	Specific gravity (x)	DM (%)	Starch (%)
Variety 1					
Variety n					

Reference

Kawano K., W.M.G. Fukuda, and U. Cenpukdee. 1987. Genetic and environmental effects on dry matter content of cassava root. Crop Science 27:69–74.

Weighing sample in air (Wa) and Weighing sample in water (Ww). *Photos from CIAT*

Annex III

Harvest index

Background

Harvest index (HI), defined as the proportion of the fresh root weight in biomass, is a valuable trait in cassava breeding. As opposed to selections based solely on fresh root yield, HI-based selections are stable across evaluation stages and will truly represent genotype yield potential under monoculture. It is likely that true genetic progress in cassava will be achieved through utilization of HI (Kawano 1990). The assessment of HI is relatively simple and straightforward. It is against this background that we propose to incorporate this trait in the study.

Methodology

1. At harvest, uproot 4–6 plants per clone
2. Separately, weigh the roots and the aboveground biomass (stems, branches, and leaves).
3. Compute HI as

$$HI = \frac{\text{Weight of roots}}{\text{Weight of roots + weight of aboveground biomass}}$$

4. Repeat process 1 to 3 for all entries and record observations in the following format:

Clone	Plants (no.)	Root wt (kg)	Aboveground wt (kg)	Total wt	HI

Reference

Kawano, K. 1990. Harvest index and evolution of major food crops cultivars in the tropics. Euphytica 46:195-202.

Annex IV

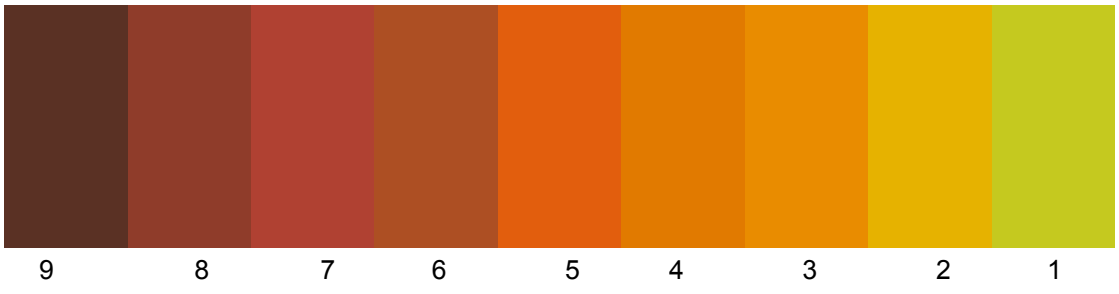
Cyanogenic potential (CNP)

Background

To date, no acyanogenic cassava has been reported; glucosides, linamarin, and lotaustralin are found within all cassava plants. On contact with the enzyme linamarase (released upon tissue damage, as in many forms of processing), acetone cyanohydrin and glucose are produced. The acetone cyanohydrin either spontaneously breaks down or it is acted upon by the enzyme hydroxynitrile lyase to produce acetone and hydrogen cyanide. In practice, low CNP varieties are desirable for both safe human and animal utilization. Elsewhere, studies have established a relationship between CNP levels in cassava and starch physical properties (viscosity, cooking time, gel instability, and gelification index). In some parts of Africa, bitter varieties (which usually happen to have high CNP level) are reported to have higher starch content, and make better quality products that even store better. It's against this background that we propose to examine this trait.

Methodology

1. There are large effects of environments on root cyanogens; nevertheless, both broad and narrow sense heritabilities for CNP are high, ranging between 0.87–1.07.
2. Because CNP varies considerably between plants, analysis will be done using 4 plants/clone, and on 3 roots per plant.
3. Materials required include knives, glass tubes (12 cm long with tightly fitted rubber stops) and the scoring scale.
4. Consumables required include filter papers (Whatman No. 1.6 cm x 1 cm) picric acid anhydrous sodium carbonate, and toluene.
   Please note that both picric acid and toluene (methylbenzene or phenyl methane) are hazardous chemicals, and NEED TO BE HANDLED WITH EXTREME CARE AND WITH APPROPRIATE PROTECTION.
5. For each root sample, make a cross-sectional cut at the mid-root position.
6. Pinpoint the mid position between the peel and the center of the parenchyma (root flesh) and make a 1 cm^3 cube cut.
7. Place the cut root cube into a glass tube and add 5 drops of toluene onto it; tightly seal the glass tube with the stopper.
8. Take a strip of Whatman filter paper and dip it into freshly prepared alkaline picrate mixture until saturated.
9. Suspend the picrate-saturated filter paper above the cut root cube in the glass tube; ensure that the tube is tightly fitted with the rubber stopper.
10. After 10–12 hours, score for color intensity using the 1–9 scale below.



The generated data should be recorded in the format shown below:

Clone	Plant number	Root sample	CNP score
	1	1	
	1	2	
	1	3	
	2	1	
	2	2	
	2	3	
	3	1	
	3	2	
	3	3	
	4	1	
	4	2	
	4	3	

Annex V

Postharvest deterioration

The rapid postharvest deterioration of cassava continues to be a huge challenge to the commercialization of the crop in eastern and central Africa. Clearly, the production chain of cassava from the field, storage, and transportation to processing centers would benefit from a longer shelf life than currently exists. This aspect has drawn limited research attention in the region. As a starting point, it is vital to examine variation of this trait in the regional germplasm collection with the objective of identifying parental lines with higher shelf life that can be used in hybridization schemes in the region. Moreover, narrow sense heritability for postharvest deterioration reflecting both physiological and microbial effects have been reported to range between 0.4 and 0.6 (Kawano and Rojanaridpiched 1983). It is against this background that we propose to examine this trait in cassava.

Methodology

1. Randomly select five commercially sized roots (minimum length 18 cm) to represent each clone.
2. Cut off a section about 1 cm from both the proximal and distal ends; cover the distal end with cling film.
3. Store the roots under ambient conditions.
4. After 7 days make seven 2-cm transversal slices starting from the proximal end.
5. Score each slice on a scale of 1–10, corresponding to the percentage of the cut surface showing discoloration (with 1 = 10% and 10 = 100%).
6. Take average of the seven slices to represent the deterioration of the root.

The generated data should be recorded in the format shown below:

Clone	Root no.	Deterioration score (1–10) on the 2-cm slices								
		1	2	3	4	5	6	7	Mean	Remark
	1									
	2									
	3									
	4									
	5									

Reference

Kawano, K. and C. Rojanaridpiched. 1983. Genetic study on postharvest root deterioration in cassava. Kasetsart Journal, Thailand. 17:14–26.

Annex VI

Data sheet

Characterization of cassava germplasm in eastern and southern africa

Country:
Site:
Date of planting:
Accession name:

Trait	Schedule	Score	Remark
1. Color of apical leaves	2-3 MAP		
2. Pubescence on apical leaves	2-3 MAP		
3. Leaf retention	5-6 MAP		
4. Shape of central leaflet	6 MAP		
5. Color of petiole	6 MAP		
6. Color of leaf	6 MAP		
7. Number of leaf lobes	6 MAP		
8. Length of leaf lobe	6 MAP		
1st leaf lobe	6 MAP		
2nd leaf lobe	6 MAP		
9. Width of leaf lobe	6 MAP		
1st leaf lobe	6 MAP		
2nd leaf lobe	6 MAP		
10. Ratio of leaf lobe	6 MAP		
1st leaf lobe	6 MAP		
2nd leaf lobe	6 MAP		
11. Lobe margins			
12. Petiole length	6 MAP		
1st leaf sample	6 MAP		
2nd leaf sample	6 MAP		
13. Color of leaf vein	6 MAP		
14. Orientation of petiole	6 MAP		
15. Flowering	6 MAP onwards		
Date of scoring			
16. Pollen	6 MAP onwards		
17. Prominence of foliar scars	9 MAP		
18. Color of stem cortex	9 MAP		
19. Color of stem epidermis	9 MAP		
20. Color of stem exterior			
21. Distance between leaf scars	9 MAP		
1st measurement			
2nd measurement			
22. Growth habit of stem	9 MAP		
23. Color of end branches	9 MAP		
24. Length of stipule	9 MAP		
25. Stipule margin	9 MAP		
26. Fruit	5-12 months		
27. Seed	8-12 months		
28. Height of plant	At harvest		
1st plant	At harvest		
2nd plant	At harvest		
3rd plant	At harvest		

Trait	Schedule	Score	Remark
29. Height of first branching	At harvest		
1st plant	At harvest		
2nd plant	At harvest		
3rd plant	At harvest		
30. Levels of branching	At harvest		
31. Branching habit	At harvest		
32. Angle of branching	At harvest		
1st plant	At harvest		
2nd plant	At harvest		
3rd plant	At harvest		
33. Shape of plant	At harvest		
34. Number of storage roots/plant	At harvest		
1st plant			
2nd plant			
3rd plant			
35. Number of commercial roots/ plant (minimum length 18 cm)	At harvest		
1st plant			
2nd plant			
3rd plant			
36. Extent of root peduncle	At harvest		
37. Root constriction	At harvest		
38. Root shape	At harvest		
39. External color of root	At harvest		
40. Color of the root pulp (parenchyma)	At harvest		
41. Color of root cortex	At harvest		
42. Cortex ease of peeling	At harvest		
43. Texture of root epidermis	At harvest		
44. Root taste	At harvest		

MAP = months after planting

45. Peel thickness assessment

Root no.	Proximal (mm)	Mid (mm)	Distal (mm)
1			
2			
3			
Mean			

46 & 47. Dry matter and starch content

Clone	Weight in air (g)	Weight in water (g)	Specific gravity (x)	DM (%)	Starch (%)

48. Harvest index (HI)

Clone	Plants (no.)	Root wt. (kg)	Aboveground wt. (kg)	Total wt.	HI

49. Cyanogenic potential (CNP)

Clone	Plant no.	Root sample	CNP score
	1	1	
	1	2	
	1	3	
	2	1	
	2	2	
	2	3	
	3	1	
	3	2	
	3	3	
	4	1	
	4	2	
	4	3	
	Mean		

50. Postharvest deterioration

Clone	Root no.	Deterioration score (1-10) on the 2-cm slices								
		1	2	3	4	5	6	7	Mean	Remark
	1									
	2									
	3									
	4									
	5									