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Research Application Summary

Advances in Breeding for Highland Cassava in Uganda

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Abstract

Cassava (*Manihot esculenta* Crantz), a hugely popular staple crop in Uganda, is mostly grown at altitudes of ≤1200 meters above sea levels (ma.s.l). With Uganda's rapid population growth i.e., increasing from 24 million in 2010, to 42 million in 2017, the desire for food sufficiency is paramount. On our part as the National Agricultural Research Organization (NARO) together with partners, we have initiated breeding efforts that aim at adapting cassava to highland areas. Herein, we highlight progress made during the past five years that largely has involved three systematic processes. Firstly, creation of genetic variation using cassava clones sourced from: a) International Centre of Tropical Agriculture (CIAT); b) International Institute of Tropical Agriculture (IITA) and c) from Tanzania breeding programme. Secondly, evaluation and selection of created genetic variation at seedling stage; of the 3,043 F1s evaluated only 570 were advanced. Thirdly, undertaking multi-advancement and selection trials; three consecutive trials undertaken in 2015, 2016 and 2017. Evidently, most of the evaluated clones were resistant to Cassava Mosaic Disease (CMD), a key cassava production constraint. Clone performances varied markedly as witnessed by number of roots per plant (ranging from 0-15 roots), root weight per plant (ranging from 0-5.3kg) and harvest index (ranging from 0 -1), all evident after 12 months of growth. Accordingly, we have identified nine best-bet clones (UGH150024, UGH150122, UGH150135, UGH150141, UGH150149, UGH150152, UGH150310, UGH150338, and UGH150577) which are currently being evaluated jointly with farmers using the innovative "Triadic Comparisons of Technologies (TRICOT), approach. The best-two farmer-preferred clones will be officially released.

Key words: Cassava; highlands; officially released; selection; Zombo

Résumé

Le manioc (*Manihot esculenta* Crantz), une culture de base extrêmement populaire en Ouganda, est principalement cultivé à des altitudes de ≤1200 mètres au-dessus du niveau de la mer (ma.s.l). Avec la croissance rapide de la population ougandaise, qui est passée de 24 millions d'habitants en 2010 à 42 millions en 2017, le désir d'assurer l'autosuffisance alimentaire est primordial. Pour notre part, en tant qu'Organisation nationale de recherche agricole (NARO) et avec nos partenaires, nous avons lancé des efforts de sélection visant à adapter le manioc aux zones montagneuses. Dans ce document, nous soulignons les progrès réalisés au cours des cinq dernières années qui ont principalement impliqué trois processus systématiques. Premièrement, la création d'une variation génétique en utilisant des clones de manioc provenant : a) du Centre International d'Agriculture Tropicale (CIAT) ; b) de l'Institut International d'Agriculture Tropicale (IITA) et c) du programme de sélection de Tanzanie. Deuxièmement, l'évaluation et la sélection de la variation génétique créée au stade des semis ; sur les 3043 F1 évaluées, seules 570 ont été avancées. Troisièmement, la réalisation d'essais de sélection et d'avancement multiples ; trois essais consécutifs ont été

entrepris en 2015, 2016 et 2017. De toute évidence, la plupart des clones évalués étaient résistants à la maladie de la mosaïque du manioc (CMD), une contrainte essentielle de la production de manioc. Les performances des clones ont varié sensiblement, comme en témoignent le nombre de racines par plante (allant de 0 à 15 racines), le poids des racines par plante (allant de 0 à 5,3 kg) et l'indice de récolte (allant de 0 à 1), tous évidents après 12 mois de croissance. Par conséquent, nous avons identifié neuf meilleurs clones (UGH150024, UGH150122, UGH150135, UGH150141, UGH150149, UGH150152, UGH150310, UGH150338, et UGH150577) qui sont actuellement évalués conjointement avec les agriculteurs en utilisant l'approche innovante "Triadic Comparisons of Technologies (TRICOT)". Les deux meilleurs clones, préférés par les agriculteurs, seront officiellement mis sur le marché.

Mots clés : Manioc ; hauts plateaux ; officiellement libéré ; sélection ; Zombo

Introduction

Men, women and youth in many parts of sub Saharan Africa including Uganda, rank cassava (*Manihot esculenta* Crantz) as a key staple crop. The crop's clonal nature, tolerance to marginal soils and limited rainfall, all combined with flexible harvesting schedules, largely explain cassava's popularity among smallholder farmers as compared to other crops (Howler *et al*., 2013). Cassava's primary product, the starchy roots, can be processed into a wide variety of products for food, feed and/or industrial use. Additionally, young cassava leaves contain up to 25% protein, and are a valuable source of iron, calcium and vitamins. These inherent nutrients in the leaves make them a critical constituent of many diets in several African countries. The above narration explains the significance of cassava and thus, justifies interventions aimed at increasing and/or optimizing its productivity and utilization (Ceballos *et al* 2016).

In Thomas Robert Malthu's book "An Essay on the Principle of Population" published almost 220 years ago, he predicted, with key assumptions that human population increase would surpass food supply and thus, result into recurring famines! Taking the case of cassava in Uganda, we observed that Uganda's population increased from 24 million in 2010, to 42 million in 2017 (http://worldpopulationreview.com), while cassava production decreased from 3 MT in 2010 to 2.4MT in 2019 (http://www.fao.org/faostat). It's these disturbing trends that cause acute development challenges for the country. Thus, on our part as the National Agricultural Research Organization (NARO), we desire to address this challenge, by adapting cassava to non-traditional areas, an initiative that will complement on-going efforts to increase and deploy genetic gains in farmer's fields and thus increase cassava productivity. Accordingly, herein, we report on the progress made towards introducing, evaluating and selecting of cassava clones adapted to Zombo highlands of Uganda.

Approach

Creation of genetic variation. A total of 308 clones used as progenitors were sourced from a) International Centre of Tropical Agriculture (CIAT); b) International Institute of Tropical Agriculture (IITA) and c) from Tanzania breeding programme. These progenitors segregated for key agronomic, plant health and culinary end-user traits. The IITA clones were selected owing to their resistance to cassava mosaic disease (CMD); CIAT clones selected owing to their high starch and fresh root yield; and Tanzanian clones selected owing to their high tolerance to cassava brown streak disease (CBSD). These clones were established in field plots at National Crops Resources Research Institute (NaCRRI), Namulonge during the period 2012-2013. The resultant half sib seeds generated were harvested to constitute the diverse highland population upon which selection was

imposed. Namulonge, located in central Uganda at 1,160 ma.s.l provides optimal environment for flowering, fruit and seed set.

Seedling evaluation and selection. Approximately, 5,251 seedlings that resulted from 308 clones progenitors were planted in batches at two highland locations. The first batch comprising of 3,043 F1 seedlings were planted at Zombo, west Nile region at 1,600 masl. The second batch comprising of 2,208 F1 seedlings was planted at Bugiyanya, eastern Uganda at ~1700 ma.s.l. All plantings were done in 2013 at a spacing of 1m x 1m with 10 plants per row. At three months after planting (3MAP), data were collected on vigour and CMD, while at 6 MAP, data were only collected on CMD. At 12 MAP, individual seedlings were harvested and data on harvest index (HI) computed as a ratio of fresh root weight to total fresh biomass weight. The base selection index was used to select the top18% (i.e., 570 clones) to establish the clonal trial.

Multi-advancement and selection trials. These trials were only done on the first batch of seedlings i.e., Zombo seedlings; the second batch of seedlings from Bugiyanya were exclusively used for other studies. Accordingly, for the Zombo seedlings, three subsequent clonal evaluation trials were established at Zombo in 2014 and 2015. In September 2014, the selected 570 clones were planted in Zombo (trial referred to as CET-2014). Again, in the following year, (September 2015), the top-most performing 180 clones were selected from the CET-2014 trial, and established in Zombo, Bundibugyo and Namulonge (trials referred to as CET-2015). All trials were established using the augmented design with 5 checks (local varieties grown in Zombo highlands) namely Nyacharitas, Nyapamitu, Nyaronega, Nyarudota, and Nyapalei. Planting was done at a spacing of 1m x 1m with 10 plants per row.

A third clonal trial comprising of best performing clones selected from CET-2015 trials was established in 2016 at two locations; Zombo (41 clones) and Namulonge (28 clones). These trials are referred to as CET-2016. Trials were established in randomized complete block design with two replicates. Data were collected on CMD and CBSD severity at 6 MAP, and at harvest, data were collected on root number, root weight, HI and root dry matter content (DMC). Datasets generated from CET-2016 were used to make selection to advance clones for participatory variety selection (PVS) trials.

Research Application

Agronomic performance of F_1 cassava seedlings derived from progenitors sourced from IITA, CIAT and Tanzania, is presented in Table 1. Evidently, most of the evaluated seedlings were resistant to CMD, a key cassava production constraint; most individuals had severity scores ≤ 2 that is characteristic of CMD resistance (Table 1). Adaptation of cassava to Ugandan highlands as witnessed by number of roots per plant (ranging from 0-15 roots per plant), root weight per plant (ranging from 0-5.3kg) and harvest index (0-1) illustrate the possibility of identifying clones locally adapted to highlands that can mature within 12 months.

Cassava food culture (practices, attitudes, and beliefs) vary markedly among communities. Thus, some communities process cassava roots into flour with or without fermentation, while other communities boil cassava roots. Accordingly, root dry matter content (DMC) and fresh root yield (estimated indirectly as harvest index), become some of the critical basic traits that consumers desire. It was evident that at both highland locations (Zombo and Bundibugyo) clones with DMC $\geq$35% and HI $\geq$0.5 were observed (Figure 1). It is these clones that are of value for deployment in the Zombo highlands.

Table 1. Agronomic performance of F_1 cassava seedlings in Zombo Highlands Uganda

Pedigree	Flowering Ability	Vigour	CMDs	Av. Root number	Harvest index	Root weight
CIAT Clones	0.98	3.46	1.31	3.96	0.46	0.41
IITA Clones	1.93	3.56	1.49	4.53	0.51	0.64
Tanzanian Clone	2.45	3.63	1.41	4.25	0.46	0.62
Unknown	3.84	3.50	1.53	4.97	0.54	0.82

Flowering ability measured as number of branches with inflorescence at 6 MAP; Vigour assessed at 3MAP using the 3, 5 and 7 scale; CMDs = cassava mosaic disease severity assessed at 6MAP; Av. Root Number = average number of roots harvested per seedling; Root weight = root weigh per seedling.

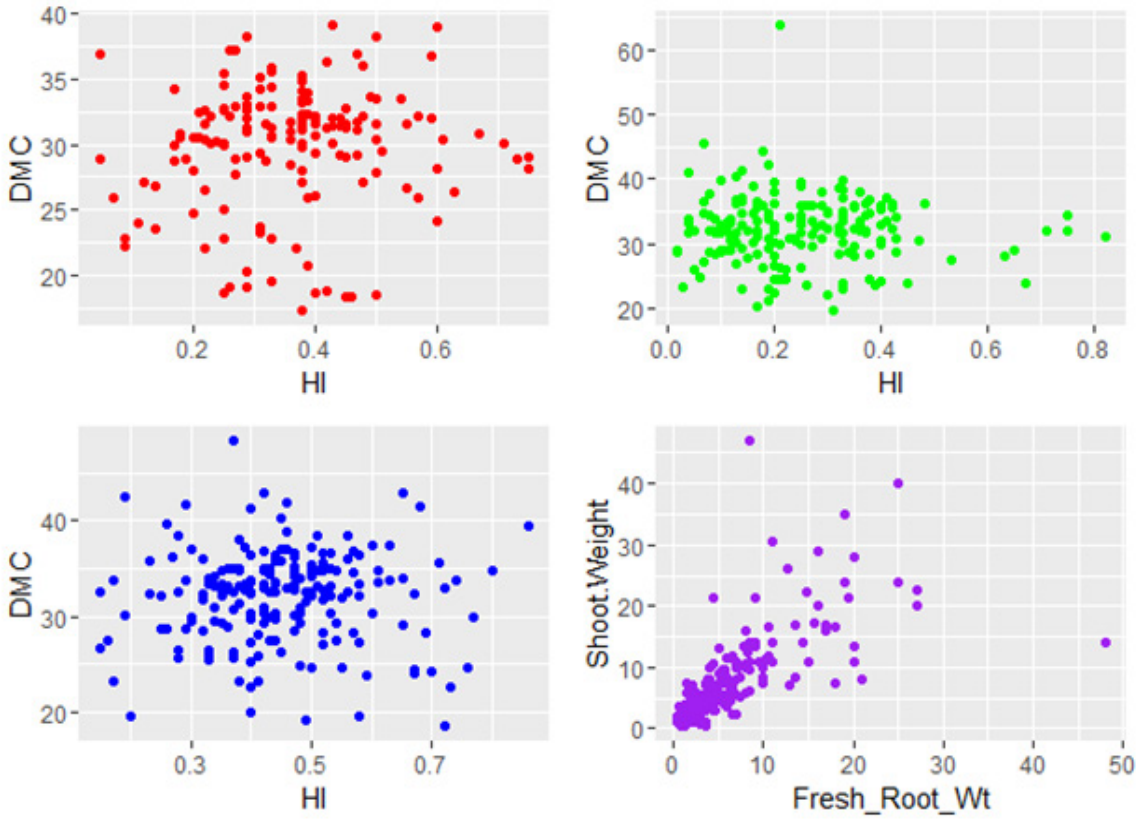

Figure 1: Agronomic performance of cassava clones at varied highland sites in Uganda

Red biplot = Variation in root dry matter content (DMC) and harvest index (HI) of 153 clones evaluated at Bundibugyo, a highland site. Green biplot = Variation in root dry matter content (DMC) and harvest index (HI) of 179 clones evaluated at Namulonge, a low land site. Blue biplot = Variation in root dry matter content (DMC) and harvest index (HI) of 172 clones evaluated at Zombo, a highland site. Purple biplot = relationship between shoot and root weight of clones evaluated at Zombo.

Conclusion

We have for the first time undertaken evaluation and selection of cassava for highland regions in Uganda. Our motivation for this action was to increase cassava productivity in Zombo highlands, an area predominated by cultivation of low yielding varieties notably Nyacharitas, Nyapamitu, Nyaronega, Nyarudota, and Nyapalei. Following five years of evaluation and selection, we have identified nine best-bet clones (UGH150024, UGH150122, UGH150135, UGH150141, UGH150149, UGH150152, UGH150310, UGH150338, and UGH150577) and one popular local

variety Nyarunega. As of this writing, these clones are being evaluating using the innovative "Triadic Comparisons of Technologies (TRICOT), participatory varietal selection approach with farmers. In the end, the best-two farmer-preferred variety, will be officially released as pioneer highland cassava varieties.

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