

Performance and Improved Biofortified Varieties under Smallholder Conditions

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Abstract

(*Manihot esculenta* Crantz) cornerstone security, nutrition, rural livelihoods in, where it provides a major of dietary energy millions of smallholder households. Despite its strategic importance, cassava productivity remains constrained by persistent biotic stresses, notably (CBSD), declining limited access to quality planting material and effective extension services. In response to these challenges, , has disseminated improved and biofortified cassava varieties, including provitamin A-rich yellow-fleshed clones, aimed at enhancing productivity, disease tolerance, nutritional quality. This study evaluated the agronomic performance, phytosanitary response, and farmers' perceptions of selected improved and biofortified cassava varieties under smallholder farming conditions in villages surrounding the INERA Mvuazi Research Centre in western DRC. Agronomic measurements were conducted in farmers' fields to assess yield components and dry matter content, while disease severity for cassava mosaic disease and CBSD was evaluated using standardized visual scoring methods. In parallel, structured farmer surveys were administered to capture perceptions of varietal performance, management constraints, and adoption dynamics. Results showed that all evaluated varieties exhibited satisfactory agronomic performance under farmer-managed conditions. Dry matter content ranged from 25.6% to 34.3%, indicating good suitability for consumption and processing. No statistically for most yield-related parameters. However, significant varietal differences were recorded for CBSD severity, with Ilona, Obama (TME 419), and Zizila demonstrating comparatively better tolerance. Farmers' adoption levels varied markedly among villages, reflecting differences in access to planting material, extension support, and perceptions of production risks. The findings confirm the agronomic and nutritional potential of improved and biofortified cassava varieties in the DRC while underscoring the importance of farmer-centred dissemination strategies and strengthened agricultural extension systems to achieve sustained adoption and impact.

Keywords: *Cassava, Biofortification, Agronomic Performance, Disease, Adoption.*

I. INTRODUCTION

Among and constitutes the dietary backbone of millions of households (DRC) (Treche, 1989; Vernier et al., 2018). In the DRC, cassava contributes substantially to daily caloric intake and plays a critical role in household food security, income generation, and socio-cultural practices. Its ability reasonable, irregular rainfall, limited external inputs makes it particularly well suited to smallholder farming systems (Osiru, 1990).

Resilience and productivity the remains and highly variable. Average yields achieved by smallholder farmers are far below the crop's genetic potential, largely environmental, institutional. Among most significant biotic stresses are notably have expanded in geographical range and severity across Central and East Africa over the

past two decades. Molecular studies have highlighted the complexity of cassava viral pathogens and their rapid evolution, complicating disease diagnosis and management (Adams et al., 2009).

More recently, cassava root necrosis disorders have been reported in western DRC and neighbouring countries, further threatening the stability of cassava-based production systems (Bakelana et al., 2019b; Bakelana et al., 2019e). These emerging diseases pose serious challenges for farmers, as root damage often remains undetected until harvest, leading to significant yield losses and reduced root quality.

In addition to phytosanitary constraints, cassava production in the DRC is affected by declining soil fertility, limited availability of certified planting material,

and weak agricultural extension systems (Frangoie et al., 2012; Silvin Bidiaka et al., 2015). Smallholder farmers often rely on informal seed systems and traditional knowledge, which, while adaptive, may limit access to improved technologies and timely information. Studies on agricultural extension in sub-Saharan Africa have consistently shown that inadequate farmer support services constrain crop (Bedrani et al., 1993; Christoplos, 2011).

To address these challenges, in partnership, has developed and disseminated improved and biofortified cassava varieties with enhanced yield potential, tolerance to major diseases, and improved nutritional quality. In particular, provitamin A-rich yellow-fleshed cassava varieties have been promoted as a strategy to combat micronutrient deficiencies, especially vitamin A deficiency, which remains a public health concern in the DRC (Mukendi et al., 2018; ABAS, 2023).

However, the successful uptake of improved and biofortified cassava varieties depends not only on their agronomic and nutritional performance but also on farmers' perceptions, learning processes, and socio-economic conditions that shape adoption decisions. Empirical evidence suggests that farmers evaluate new varieties based on a combination of yield stability, disease resistance, root quality, processing attributes, labour requirements, and perceived risks (Shakanye et al., 2017; Adisa, 2015). Participatory approaches and farmer-centred extension methods are therefore critical for facilitating informed decision-making and sustainable adoption.

Against this background, the present study aimed to (i) evaluate the agronomic performance and disease response of selected improved and biofortified cassava varieties under smallholder conditions and (ii) analyse farmers' perceptions and adoption dynamics in villages surrounding the INERA Mvuazi Research Centre in western DRC. By integrating agronomic assessments with socio-economic insights, the study seeks to contribute to evidence-based strategies for strengthening cassava varietal dissemination and the DRC.

In vicinity the INERA Mvuazi Research Centre, situated in Kongo Central Province in this region is part of the Lower Congo agroecological zone and is characterized by a pattern, which supports year-round cassava cultivation. Mean annual rainfall generally ranges between 1,200 and 1,500 mm, while average temperatures fluctuate between 24°C and 28°C, creating favourable conditions for root and tuber crops.

Farming systems in the area are predominantly smallholder-based and rely on manual labour, with cassava cultivated both as a subsistence crop and as a source of household income. Cassava fields are commonly intercropped with maize, groundnut, or legumes, and crop management practices vary widely among farmers. Since 2019, the study villages have benefited from research-for-development initiatives led by INERA in collaboration with IITA and development partners, focusing on the dissemination of improved and biofortified cassava

planting material (Frangoie et al., 2012; Mahungu et al., 2022).

II. PLANT MATERIAL

Eight improved and biofortified cassava (*Manihot esculenta* Crantz) varieties were evaluated in this study: Ilona, Kindisa, Kansakako, Mayombe, Butamu, Pululu, Obama (TME 419), and Zizila. These varieties were selected based on their availability in farmers' fields, their relevance within ongoing dissemination programmes, and prior agronomic characterization under Congolese agroecological conditions (Frangoie Ngoie, 2015; Cissé Bofétigué, 2015).

The selected varieties include both white- and yellow-fleshed clones, the latter having been developed for enhanced provitamin A content. Several of the varieties have been reported to exhibit tolerance to major making them suitable candidates for evaluation under farmer-managed conditions.

Evaluation directly in farmers' fields using an on-farm observational approach, reflecting real smallholder management conditions. Farmers managed their cassava plots according to their usual practices, including land preparation, planting density, weeding frequency, and harvesting time. This approach was adopted to capture varietal performance under realistic production environments rather than under controlled experimental station conditions.

Each selected variety was assessed in multiple farmer fields across different villages. Fields were geo-referenced to ensure spatial coverage and to reduce bias associated with localised environmental conditions. No external inputs such as mineral fertilisers or pesticides were applied beyond farmers' customary practices.

III. AGRONOMIC DATA COLLECTION

Agronomic data were collected at harvest, following standard principles of field experimentation and crop evaluation (Dagnelie, 2003). The main parameters measured included number of harvested plants per plot, and fresh root yield. Harvested roots were weighed using calibrated field scales.

A subsample of fresh roots collected from each variety. Root samples were peeled, chopped, and oven-dried. This parameter was used as an indicator of processing quality and consumer preference, consistent with previous cassava studies in the region (Mukendi et al., 2018; Raffailac, 1992).

➤ Disease Assessment

Phytopathological evaluations focused on disease were assessed using visual scoring scales adapted from established regional protocols. Foliar symptoms were recorded during crop growth, while root symptoms associated with CBSD and root necrosis were assessed at harvest.

Severity scores were assigned based on symptom intensity, allowing comparison among varieties. The presence of given recent reports of cassava root necrosis disease in western DRC and neighbouring countries (Bakelana et al., 2019e; Bakelana, 2022).

➤ *Farmer Surveys and Perception Analysis*

To complement agronomic assessments, structured and semi-structured surveys were administered to participating farmers. The surveys aimed to capture farmers' perceptions of varietal performance, preferred traits, management constraints, and factors influencing adoption decisions. Questions addressed yield stability, disease tolerance, root quality, labour requirements, access to planting material, and extension support.

The survey design was informed by participatory research and adult learning approaches commonly applied in agricultural extension and innovation studies (Bedrani et al., 1993; Ngalamulume, 2010; Jean Claude Mboka, 2017). Languages support trained enumerators to ensure clarity and accuracy of responses.

Agronomic disease software. Analysis of variance (ANOVA) was performed to compare agronomic performance and disease severity among cassava varieties.

Adoption rates and survey responses while synthesised thematically to identify recurring patterns in farmers' perceptions and learning processes (Bédard, 1981; Christian, 2014). The combined quantitative–qualitative approach allowed for an integrated interpretation of varietal performance and adoption dynamics.

IV. AGRONOMIC

All eight improved biofortified cassava varieties evaluated under farmer-managed conditions exhibited satisfactory agronomic performance across the study villages. Survival rates at harvest were generally high, indicating good establishment and adaptation to local agroecological conditions. among varieties for number harvested plants or storage suggesting comparable vegetative growth and root initiation capacity across genotypes.

Fresh root yield did not differ significantly among the evaluated varieties. This absence of significant yield variation reflects the broad adaptability of the improved and biofortified varieties under smallholder conditions, where environmental heterogeneity and management variability often mask genetic yield differences. Similar observations have been reported in on-farm cassava evaluations conducted in other parts of Central and West Africa.

Dry matter content varied among varieties, with values ranging from 25.6% to 34.3% and an overall mean of approximately 30%. Varieties with higher dry matter content were generally preferred by farmers for processing and consumption, particularly for traditional products such

as fufu and chikwangu. These values are consistent with those reported for improved cassava varieties evaluated (Mukendi et al., 2018; Raffaillac, 1992), confirming the suitability of the evaluated varieties for local food systems.

➤ *Disease*

Incidence low across all evaluated fields, and no Symptoms were generally mild and did not result in noticeable yield losses during the study period, reflecting either low disease pressure or effective tolerance of the improved varieties.

In contrast, cassava brown streak disease (CBSD) severity differed significantly among varieties. Visual scoring revealed clear varietal differences in symptom expression, particularly at harvest when root symptoms were assessed. Ilona, Obama (TME 419), and Zizila consistently showed lower CBSD severity scores compared with the other varieties, indicating comparatively better tolerance.

Although foliar CBSD symptoms were observed in some fields, root necrosis symptoms were limited in both incidence and severity. No severe root rot or extensive necrosis was recorded, which contrasts with reports from other regions of western and central Africa where cassava root necrosis has caused substantial yield and quality losses (Bakelana et al., 2019e; Bakelana, 2022). This suggests that disease expression in the study area may be influenced by local epidemiological conditions, varietal tolerance, or both.

➤ *Farmers' Perceptions of Varietal Performance*

Farmers' perceptions of improved and biofortified cassava varieties varied across villages but were generally positive. Yield stability, root size, and dry matter content were frequently cited as desirable traits. Farmers also expressed appreciation for varieties perceived as less susceptible to disease, particularly in areas where CBSD symptoms had previously been observed.

Yellow-fleshed, biofortified varieties were recognised for their nutritional value, although some farmers indicated that consumer preferences and market demand influenced their willingness to expand cultivation. In several villages, farmers reported that taste, cooking quality, and suitability for processing remained critical determinants of varietal preference alongside agronomic performance.

➤ *Adoption Levels and Constraints*

Adoption rates of improved and biofortified cassava varieties differed markedly among villages. In communities with sustained access to planting material and regular extension support, adoption levels exceeded 80%. In contrast, adoption remained limited in villages where planting material was scarce or where farmer support services were weak.

Key constraints to adoption identified by farmers included limited access to quality planting material, labour shortages, and insufficient technical guidance on

recommended crop management practices. Some farmers expressed concerns related to production risks, particularly uncertainty about disease pressure and market acceptance of new varieties. These constraints contributed to partial adoption, where farmers cultivated improved varieties on small plots while maintaining traditional varieties as a risk management strategy.

V. DISCUSSION

The results of this study demonstrate that improved and biofortified cassava varieties disseminated by INERA and IITA are well adapted to smallholder farming conditions in western Democratic Republic of the Congo. The satisfactory agronomic performance observed across all evaluated varieties, particularly the absence of significant differences in yield components, suggests that these genotypes possess broad environmental adaptability. Similar findings have been reported in varietal evaluations conducted under farmer-managed conditions in other parts of Central and West Africa, where environmental variability and heterogeneous management practices often reduce the expression of genetic yield differences (Osiru, 1990; Vernier et al., 2018).

Dry matter content values ranging from 25.6% to 34.3% confirm the suitability of the evaluated varieties for local consumption and processing. High dry matter content is a critical trait for both household food security and market-oriented cassava production, as it directly influences processing efficiency and consumer acceptability (Raffaillac, 1992; Mukendi et al., 2018). The values reported in this study are consistent with those obtained in previous evaluations of improved cassava clones in the reinforcing relevance of dry matter content as a key adoption criterion.

Disease assessments revealed contrasting patterns between. The generally low cassava mosaic disease across all varieties may reflect the effectiveness of past breeding efforts and dissemination of tolerant planting material. In contrast, the significant varietal differences observed for CBSD severity highlight the continuing threat posed by this disease and the importance of varietal tolerance as a core management strategy. The comparatively better performance of Ilona, Obama (TME 419), and Zizila supports previous reports identifying these varieties as more tolerant to CBSD under field conditions (Bakelana et al., 2019e).

The limited expression of root necrosis symptoms observed in this study contrasts with findings from other regions of western and central Africa, where cassava root necrosis disease has been associated with severe yield and quality losses (Bakelana et al., 2019b; Bakelana, 2022). This discrepancy may be attributed to differences in local epidemiological conditions, varietal composition, or the stage of disease spread. Nevertheless, the presence of CBSD symptoms, even at low levels, underscores the need for continued surveillance and the integration of disease tolerance into cassava improvement programmes.

Beyond agronomic, technical performance, farmers' perceptions and adoption dynamics emerged as critical determinants of varietal uptake. Adoption rates varied widely among villages, reflecting differences in access to planting material, extension services, and information. These findings align with broader literature indicating that technological innovation in smallholder agriculture is strongly influenced by institutional and socio-economic factors rather than by agronomic performance alone (Bedrani et al., 1993; Christoplos, 2011).

Farmers' preferences were shaped by a combination of yield stability, root quality, disease tolerance, and processing characteristics, as well as by risk management considerations.

The tendency of farmers to maintain traditional varieties alongside improved ones reflects a rational strategy to hedge against uncertainty related to disease outbreaks, labour availability, and market acceptance. Similar behavioural patterns have been documented in studies on cassava varietal adoption in eastern and central Democratic Republic of the Congo (Shakanye et al., 2017).

The role of extension and learning processes was particularly evident in villages with high adoption rates. Communities benefiting from sustained extension support, farmer training, and access to quality planting material exhibited greater confidence in adopting improved and biofortified varieties. Participatory approaches such as farmer field schools and innovation platforms have been shown to enhance experiential learning, reduce perceived risks, and foster collective problem-solving among farmers (Ngalumulume, 2010; Fatunbi et al., 2015; Jean Claude Mboka, 2017). Strengthening such approaches could therefore accelerate the dissemination and sustained use of improved cassava technologies.

Overall, highlight the need for integrated strategies that combine genetic improvement with effective extension systems and farmer-centred dissemination pathways. While improved and biofortified cassava varieties offer clear agronomic and nutritional advantages, their long-term impact will depend on the alignment of technical innovations with farmers' knowledge systems, preferences, and socio-economic realities.

VI. CONCLUSION

Improved and biofortified cassava varieties evaluated under smallholder conditions in the Democratic Republic of the Congo demonstrate stable agronomic performance, high dry matter content, and tolerance to major, particularly. These traits confirm their potential to enhance productivity, food security, and nutritional quality, especially through provitamin A enrichment.

However, adoption is uneven and strongly influenced by access to quality planting material, extension support, and farmers' perceptions of risk and management requirements. Sustainable impact will require integrated

dissemination strategies that combine participatory extension approaches, strengthened farmer training, and attention to socio-economic and behavioural factors shaping varietal adoption.

- Maurice Kilumba Kabemba: Conceptualized
- Jose Bidiantondo: Survey design, analysis, review.

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REFERENCES

- [1]. Abaca, A., Kawuki, S. R., Tukamuhabwa, P., Baguma, Y., Pariyo, A., Orone, J., Alicai, T., Bua, A., & Omongo, C. A. (2012). Progression de la maladie des stries brunes du manioc (CBSD) dans les racines de manioc infectées en Ouganda. *Journal ougandais des sciences agricoles*, 13(1), 45–51.
- [2]. ABAS. (2023). Stratégie pragmatique pour le programme de transformation agricole en République Démocratique du Congo. IITA, AALI, ATA-RDC et CGIAR, Kinshasa.
- [3]. Adams, M. J., Antoniw, J. F., & Fauquet, C. M. (2009). Critères moléculaires pour la discrimination des genres et des espèces au sein de la famille des Potyviridae. *Virology*, 150, 459–479.
- [4]. Alicai, T., Omongo, C. A., Maruthi, M. N., Hillocks, R. J., Baguma, Y., Kawuki, R., Bua, A., Otim-Nape, G. W., & Colvin, J. (2007). Re-emergence of cassava brown streak disease in Uganda. *Plant Disease*, 91(1), 24–29.
- [5]. Bakelana, Z. (2022). La maladie des nécroses racinaires du manioc en République Démocratique du Congo et ses environs. Université de Kinshasa.
- [6]. Bakelana, Z., Boykin, L., Mahungu, N. M., et al. (2019b). Premier rapport et évaluation préliminaire de la nécrose des racines du manioc en Angola. *Revue internationale de l'agriculture, de l'environnement et de la biorecherche*, 4(3), 37.
- [7]. Bakelana, Z., Boykin, L., Monica, K., et al. (2019e). Cassava root necrosis disease: A new disease spreading in western DRC. *Journal of Agricultural Science*, 11(2), 31.
- [8]. Bedrani, J., et al. (1993). *Techniques de vulgarisation agricole et communication rurale*. Paris: INRA.
- [9]. Bédard, A. (1981). *Méthodes d'analyse qualitative en sciences sociales*. Montréal: Presses Université de Montréal.
- [10]. Boujemaa, A. (2021). Adoption of agricultural innovations in sub-Saharan Africa: socio-economic determinants. *African Journal of Agricultural Research*, 16(7), 1050–1062.
- [11]. Christoplos, I. (2011). Mobiliser les potentialités de vulgarisation rurale et agricole. Rome: FAO.
- [12]. Christian, K. (2014). Farmer learning processes and adoption of improved varieties in sub-Saharan Africa. *Agricultural Extension Review*, 5(2), 45–60.
- [13]. Cissé Bofétigué, M. (2015). Evaluation agronomique des clones améliorés de manioc en Afrique de l'Ouest. *Journal of Tropical Agriculture*, 53(1), 23–34.
- [14]. Dagnelie, P. (2003). *Théorie et méthodes statistiques appliquées à l'agronomie et à l'élevage*. Gembloux: Presses agronomiques.
- [15]. Eleweka, O. (1997). Cassava varietal evaluation in smallholder systems. *African Crop Science Journal*, 5(3), 115–123.
- [16]. Fatunbi, A. O., et al. (2015). Farmer field schools and participatory innovation platforms: Enhancing adoption of agricultural technologies. *Journal of Agricultural Extension*, 19(1), 1–12.
- [17]. Frangoie, et al. (2012). Cassava production systems in western DRC. *Journal of Tropical Crops*, 29(2), 123–136.
- [18]. Frangoie Ngoie, B. (2015). Caractérisation de clones améliorés de manioc au Congo. *Revue congolaise d'agronomie*, 12(1), 21–32.
- [19]. Jean Claude Mboka. (2017). Participatory approaches to farmer innovation adoption in Central Africa. *African Journal of Rural Development*, 3(1), 41–54.
- [20]. Mahungu, N. M., Ndonga, A., Kendenga, T., & Bidiaka, S. (2022). Le manioc en RD Congo. IITA–INERA–USAID.
- [21]. Mukendi, et al. (2018). Évaluation des clones de manioc à pulpe jaune pour leur teneur en β -carotène. Ngandajika, RDC.
- [22]. Ngalumulume, J. (2010). Adult learning and farmer field schools: Lessons from DRC. *International Journal of Agricultural Extension*, 1(2), 33–45.
- [23]. Osiru, M. (1990). Cassava: A strategic crop for food security in sub-Saharan Africa. *African Journal of Crop Science*, 2(1), 10–17.
- [24]. Raffailac, M. (1992). Physico-chemical properties of cassava roots in Central Africa. *Journal of Tropical Agriculture*, 37(2), 89–98.
- [25]. Shakanye, S., et al. (2017). Analyse des déterminants de l'adoption des variétés du manioc dans le Sud-Kivu. *Africa Science*, 18(4), 123–135.
- [26]. Silvin Bidiaka, et al. (2015). Adoption and dissemination of improved cassava varieties in DRC. *Journal of Development and Agricultural Economics*, 7(5), 196–204.
- [27]. Trèche, S., et al. (1989). Manioc et sécurité alimentaire en Afrique centrale. *Revue d'Agriculture Tropicale et de Botanique Appliquée*, 36(4), 345–356.
- [28]. Vernier, P., et al. (2018). Cassava as a staple crop in Central Africa: Status and perspectives. *African Journal of Food, Agriculture, Nutrition and Development*, 18(2), 13345–13363.