Minimum Requirements for the Registration and Release of Biofortified Provitamin A and Non-provitamin A Maize Varieties in Nigeria

MINIMUM REQUIREMENTS FOR THE REGISTRATION AND RELEASE OF BIOFORTIFIED PROVITAMIN A AND NON-PROVITAMIN A MAIZE VARIETIES IN NIGERIA

In order to match with technological development and to keep continuous progress in industries, standards are subject to periodic review. Users shall ascertain that they are in possession of the latest edition.

The Registrar,
National Committee on Registration and Release of Crop Varieties,
Livestock Breeds and Fisheries,
NACGRAB, Moor Plantation,
P.M.B 5382
Dugbe Ibadan,
Oyo State
Tel. +2348036042204;
+2348034221101

E-mail:
varietyreleasenigeria@gmail.com;
nacgrab@gmail.com

Website:
www.nacgrab.gov.ng

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Foreword

Maize is a popular staple crop in Nigeria but most of the conventional maize varieties in the country are deficient in Vitamin A. To address this nutritional gap, it is crucial to develop micronutrient standards for maize variety release as it will provide a benchmark for releasing improved maize varieties and equip breeders with essential information for the process. Establishing standards for the release of maize varieties, including biofortified provitamin A and non-provitamin A maize, is critical to ensuring the efficacy and safety of this unique crop. These standards provide guidelines for breeding, registration, and release of nutrient-enriched biofortified provitamin A maize and non-provitamin A maize, with the goal of achieving optimal nutrient levels without compromising yield or consumer acceptance.

This standardisation is expected to address the challenges of inadequate baseline information, which has hindered the Variety Release Committee's evaluation of biofortified maize varieties. To achieve this goal, the Federal Ministry of Agriculture and Food Security in partnership with HarvestPlus and Propcom+, is collaborating with the National Variety Release Committee to develop specifications for the release of both Provitamin A and Non-Provitamin A maize seeds in Nigeria. *The Micronutrient Standards* for Registration and Release *of Biofortified Provitamin A Maize variety* have been formulated in accordance with internationally recognised best practices and procedures, aligning with the highest global standards.

This micronutrient Standard has been developed by the Federal Ministry of Agriculture and Food Security (FMAFS) in collaboration with relevant stakeholders such as Federal Ministry of Innovations, Science and Technology (FMIST), National Agricultural Research Institutes (NARIs), Consultative Group on International Agricultural Research (CGIARs), National Variety Release Committee (NVRC), Agricultural Research Council of Nigeria (ARCN), National Agricultural Seed Council (NASC), National House of Assembly (NASS), Academia, Independent private stakeholders, International Food Policy Research Institute (IFPRI), HarvestPlus and the Propcom+. The document has been critically reviewed by the stakeholders and the comments with feedback received were discussed and incorporated before its finalisation. This Micronutrient Standard for Registration and Release of Provitamin A Maize is subject to review in future, to keep pace with technological advances.

By adhering to these standards, we are sure that Provitamin A maize varieties released in Nigeria will meet the nutritional needs of vulnerable populations, thus contributing to the reduction of vitamin A deficiency and its associated health issues.

Senator Abubakar Kyari, CON
The Honourable Minister of Agriculture and Food Security
Federal Ministry of Agriculture and Food Security (FMAFS),
Abuja, Nigeria.

Acknowledgements

Developing the Minimum Requirements for Registration and Release of Biofortified Provitamin A and Non-Provitamin A Maize Varieties in Nigeria has been a collaborative and multi-faceted effort, bringing together the expertise and dedication of numerous stakeholders committed to improving public health and agricultural productivity in Nigeria.

First and foremost, special thanks go to the Honourable Minister of Agriculture and Food Security, Senator Abubakar Kyari, CON for his unflinching support towards promoting sustainable development in food and nutrition security in Nigeria. Furthermore, we acknowledge the Federal Government Ministries, Departments, Agencies as well as the legislators who have provided the necessary guidance and regulatory supports. Their commitment to establishing robust standards for micronutrient-enriched crops has been crucial in ensuring the quality and efficacy of these varieties.

We extend our sincere gratitude to the researchers and scientists whose groundbreaking works in biofortification has made this initiative possible. Their relentless pursuit of scientific excellence has paved the way for the development of nutrient-enriched biofortified Provitamin A maize varieties that can significantly combat vitamin A deficiency in Nigeria.

The scientific, technical and financial commitments of HarvestPlus to biofortification of maize in Nigeria is duly acknowledged and appreciated. We also wish to acknowledge the invaluable contributions of our partners in national and international research institutions, especially the International Institute of Tropical Agriculture (IITA) and Propcom+. Their support and collaboration have been instrumental in advancing the science of biofortification and ensuring the success of this project.

We are grateful to the members of the National Committee on Registration and Release of Crop Varieties, Livestock Breeds and Fisheries, and the Crops Technical Sub-Committee, for their diligent efforts in reviewing and endorsing these standards. Their expertise and dedication have ensured that the guidelines align with national and international best practices.

We also appreciate the seed producers, Maize Association of Nigeria (MAAN), Small-scale Women Farmers Organisations of Nigeria (SWOFON) and Independent private stakeholders who have participated in field trials and provided valuable feedback on the performance of Provitamin A maize varieties. Their practical insights have been essential in fine-tuning the standard to meet the needs of end-users.

Finally, we recognise the contributions of development partners and non-governmental organisations that have supported the awareness campaigns and capacity-building initiatives to promote the adoption of biofortified maize. Their efforts have been vital in reaching vulnerable populations, and in improving nutrition and health outcomes. Together, we have made significant strides toward addressing micronutrient deficiencies and enhancing food and nutrition security in Nigeria. It is our hope that the successful implementation of this standard will lead to healthier lives and a brighter future for all.

Prof. Olusoji O. Olufajo
Chairman, National Committee on Naming, Registration and Release of Crop Varieties, Livestock Breeds, and Fisheries.

List of Abbreviations

ARCN – Agricultural Research Council of Nigeria

AOAC – Association of Official Agricultural Chemists (AOAC International)

CGIAR – Consultative Group on International Agricultural Research

CIMMYT – International Maize and Wheat Improvement Centre

CLS – Curvularia Leaf Spot

CODEX – Food Code or Codex Alimentarius Commission (CAC)

FAO – Food and Agriculture Organisation

FAOSTAT – Food and Agriculture Organisation Statistics

FMAFS – Federal Ministry of Agriculture and Food Security

FMIST – Federal Ministry of Innovation, Science, and Technology

HPLC – High-Performance Liquid Chromatography

IAR – Institute for Agricultural Research Samaru

IAR&T – Institute of Agricultural Research & Training

IFPRI – International Food Policy Research Institute

IITA – International Institute of Tropical Agriculture

ISO – International Organisation for Standardisation

MSV – Maize Streak Virus

MAAN – Maize Association of Nigeria

NARIs – National Agricultural Research Institutes

NASS – National Assembly of Nigeria

NASC – National Agricultural Seed Council

NCLB – Northern Corn Leaf Blight

NVRC – National Committee on Naming, Registration, and Release of Crop Varieties, Livestock Release, and Fisheries

OPV – Open-Pollinated Variety

PVA – Provitamin A

RAE – Retinol Activity Equivalents

SDGs – Sustainable Development Goals

SWOFON – Small Scale Women Farmers Organisation of Nigeria

UNECE – United Nations Economic Commission for Europe

VAD – Vitamin A Deficiency

WACOT – West African Cotton Company Limited

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1. Introduction

1.1 Overview of Maize Production in Nigeria

Maize production, an important aspect of Nigeria's agriculture, is prominent in the northern and central regions with favourable climate, vast arable land, and skilled farmers and labour. The global maize market is projected to grow significantly due to increasing demand for maize products, animal feed, and industrial products, driven by population growth and urbanisation.

Nigeria is one of the largest maize-producing countries in Africa, ranking behind South Africa. The primary maize-producing states in Nigeria are Kaduna, Niger, Taraba, Benue, Plateau, Nasarawa, Kano, Katsina, and Bauchi (Wossen *et al*. 2023). Over the past two decades, maize production has fluctuated due to varying weather conditions, pest infestations, and changes in agricultural policies. However, it is important to note that Nigeria's maize production has been on an upward trend, increasing from 12.4 million metric tonnes in 2020 to 12.75 million metric tonnes in 2021 (Statista, 2025).

The quantity of maize produced in the country has generally increased since 2010 despite occasional declines in output due to drought, post-harvest losses, and farmer preference shifts to cash crops. The three major types of maize cultivated in Nigeria are white, yellow and orange maize. White maize is the most widely grown and consumed variety, primarily used for food products such as maize flour, pap, and local dishes. Yellow maize is mainly used in animal feed production and as a raw material for the food processing industry.

In Nigeria, more than two million farmers grew vitamin A (orange) maize varieties in 2023, producing an estimated 1.3 million metric tonnes of vitamin A maize grain (HarvestPlus, 2024). This production level translates to more than 50 million people eating vitamin A maize: 10 million people eating the vitamin A maize grown on their own farms and at least 40 million more eating foods prepared using vitamin A maize, purchased from markets. Maize farming in Nigeria has faced several challenges, including erratic rainfall patterns, pest attacks (such as fall armyworm infestations), soil fertility decline, and inadequate access to modern farming inputs. Despite these challenges, maize remains a crucial staple crop, with ongoing government initiatives and private sector investments aimed at increasing productivity.

The current average yield of maize under traditional farming conditions in Nigeria is approximately 2.2 tonnes per hectare, compared to a potential yield of 7.5 tonnes per hectare under optimal conditions. This yield gap highlights the need for improved farming techniques, better seed varieties, mechanisation, and access to financial support to enhance maize production efficiency in the country (Food and Agriculture Organisation Statistics, FAOSTAT, 2023).

1.2 Importance of Provitamin A Maize

Micronutrient deficiencies, particularly Vitamin A deficiency (VAD), are significant public health concerns in Nigeria. Vitamin A deficiency (VAD) is prevalent among children and pregnant women and can lead to severe health consequences, including impaired vision, weakened immunity, increased risk of infections, and, in extreme cases, blindness and death. VAD affects the immune system, vision, and overall health, particularly in children under five and pregnant women (Abolarin *et al*. 2018). To address this, biofortification has been identified as a sustainable strategy to improve micronutrient intake, with Vitamin A maize being a notable example (Bouis and Saltzman, 2017).

HarvestPlus commenced biofortification efforts on food crops in Nigeria in 2010 with the aim of reducing vitamin A deficiency and transforming the country's food systems to provide accessible and affordable nutritious food for all. HarvestPlus, in collaboration with the International Institute of Tropical Agriculture (IITA) and its partners in Nigeria, the Federal Ministry of Agriculture and Food Security (FMAFS) through its NARIs, have developed and promoted biofortified crops such as vitamin A cassava, maize, iron pearl millet, zinc rice and orange fleshed sweet potato to address micronutrient deficiencies, often termed "***hidden hunger,***" particularly affecting rural and low-resource populations.

National Agricultural Research Institutes such as Institute for Agricultural Research (IAR) Samaru, Institute of Agricultural Research and Training (IAR&T), Consultative Group on International Agricultural Research (CGIAR), and private seed companies have focused on enhancing the nutritional quality of high-yielding crop varieties, including maize, using conventional breeding methods. Between 2012 and 2024, a total of eighteen biofortified maize varieties with high yields and stable provitamin A/beta-carotene content (ranging from 5.30 μg to 20.1 μg/g) were developed in Nigeria through collaboration with partners like IITA, NARIs, and private seed companies (Appendix I). These varieties received approval for commercial release and registration from the National Committee on Naming, Registration, and Release of Crop Varieties, Livestock Breeds, and Fisheries in Nigeria. Developing standardised micronutrient thresholds for Vitamin A maize seed varieties is crucial for ensuring the effectiveness and consistency in this intervention.

1.3 Why Provitamin A Crops are needed in Nigeria

a) **Prevalence of Vitamin A Deficiency:** A substantial portion of the Nigerian population suffers from VAD, particularly in rural and low-income areas where diets lack diversity. Staple foods like maize, cassava, and rice are low in vitamin A, contributing to widespread deficiency.
b) **Impact on Child Health:** VAD is a leading cause of preventable blindness in children and increases the risk of severe infections, such as measles and diarrhoea, which are major causes of child mortality. Providing provitamin A can significantly reduce these health risks and enhance child survival rates.
c) **Maternal Health:** Pregnant and lactating women require higher levels of vitamin A to support foetal development and breastfeeding. Inadequate vitamin A intake can lead to

complications during pregnancy and childbirth, adversely affecting maternal and infant health.

d) **Immune System Support:** Vitamin A is crucial for maintaining a robust immune system. In regions with high VAD, populations are more susceptible to infectious diseases, exacerbating public health challenges and increasing healthcare costs.
e) **Cost-Effective Solution:** Biofortification of staple crops like maize, cassava, and sweet potatoes with provitamin A is a sustainable and cost-effective strategy to combat VAD. Unlike supplementation programmes, biofortification does not require ongoing external inputs, making it a practical long-term solution.
f) **Economic and Educational Impacts:** Improved vitamin A status enhances cognitive development in children, leading to better educational outcomes. Healthier populations are also more economically productive, contributing to national development and poverty reduction.
g) **Government and Global Health Initiatives:** Aligning with global health initiatives such as the Sustainable Development Goals (SDGs), particularly Goal 2 (Zero Hunger) and Goal 3 (Good Health and Well-being), Nigeria has acknowledged the importance of addressing micronutrient deficiencies. Incorporating provitamin A into staple foods supports these national and international health objectives.

2. Importance of Micronutrient Standards

Establishing micronutrient standards for Vitamin A maize is essential for:

a) **Ensuring Efficacy:** Standards help guarantee that micronutrient levels are sufficient to support human health.
b) **Maintaining Quality:** They minimise the risk of contamination and variability in nutrient content.
c) **Facilitating Regulation:** A standardised framework aids regulatory bodies, such as the National Committee on Registration and Release of Crop Varieties, Livestock Breeds, and Fisheries, in oversight and compliance.
d) **Supporting Trade:** Consistent standards enhance both domestic and international trade by providing a common reference for quality assessment.
e) **Quality Assurance**: Ensuring newly released maize varieties meet the required pro-vitamin A (beta-carotene) levels to combat VAD effectively (Saltzman *et al*., 2013).
f) **Policy Alignment**: Supporting the government's efforts in achieving food security and nutritional goals as part of the Sustainable Development Goals (SDGs) (FAO, 2021).
g) **Consumer Confidence**: Building trust in biofortified products by guaranteeing nutrient content through rigorous standards (HarvestPlus, 2020).

3. Current Legal Frameworks on Malnutrition, Seeds and Biofortification in Nigeria

Over the course of 14 years (2010 – 2024), the Biofortification initiative in Nigeria has aimed to integrate biofortification into regular practices among key institutions and stakeholders to enhance nutrition. This effort involved formulating policy recommendations, conducting advocacy, and building capacity. Research was also conducted to inform critical measures, thereby establishing biofortification as a fundamental component of the nation's strategy for improving nutritional outcomes.

3.1 The Nigerian Agricultural Sector Food Security and Nutrition Strategy (AFSNS) (2016–2025)

Published on May 1, 2017, this policy was developed to guide the Federal Ministry of Agriculture and Food Security (FMAFS) and the agricultural sector in Nigeria towards achieving better nutritional outcomes. It focuses on enhancing food and nutrition security for all Nigerians, empowering women, and promoting resilience among the most vulnerable populations, through sustainable agricultural practices. A key priority of the policy is biofortification, with an emphasis on increasing the nationwide utilisation and consumption of biofortified crops. The AFSNS also includes budgetary support provisions for the biofortification of crops.

3.2 The National Strategic Plan of Action for Nutrition (2021–2025)

This policy serves as the health sector component of the National Policy on Food and Nutrition and provides a comprehensive framework to address food and nutrition insecurity in Nigeria at individual, household, community, and national levels. Its goal is to achieve optimal nutritional status for all Nigerians, with a particular focus on vulnerable groups such as children, adolescents, women, the elderly, and those with special nutritional needs. The policy identifies biofortification as a long-term strategy to combat malnutrition and encourages the promotion of biofortification of staple food crops.

3.3 The National Multi-Sectoral Plan of Action for Food and Nutrition (NMPFAN) (2021–2025)

This was published in November 2020 by the Ministry of Finance, Budget, and National Planning, and addresses the multifaceted causes and significant social and economic impacts of malnutrition. It underscores the need for comprehensive solutions and a strong commitment to enhancing living standards and the nation's socioeconomic development. This policy framework aims to tackle food and nutrition insecurity across all levels in Nigeria, reflecting the growing acknowledgment of nutrition's critical role in national development, as emphasised in the

Millennium Development Goals, the post-2015 Sustainable Development Goals (SDGs), and the Scaling Up Nutrition movement.

3.4 The Plant Variety Protection Act, 2021

This was enacted to safeguard plant varieties and stimulate investment in plant breeding and crop variety development in Nigeria. The legislation seeks to boost staple crop productivity for smallholder farmers, encourage investment in plant breeding, enhance mutual accountability in the seed sector, and protect new plant varieties.

3.5 National Crop Varieties and Livestock Breeds (Registration, etc) Decree 33 of 1987 (now Act of Parliament 2016)

The Act sets up the National Crop Varieties and Livestock Breeds Register, which records both old and new crop varieties and livestock breeds in Nigeria. It also establishes the National Crop Varieties and Livestock Breeds Registration and Release Committee, responsible for the validation, registration, naming, and release of crop varieties and livestock breeds in the country. Although the Act does not currently recognise biofortification, the committee, in collaboration with HarvestPlus, is working on drafting relevant regulations that will outline the standards for biofortified crop varieties to ensure they meet specific criteria.

3.6 National Seed Policy, 2022

The Seeds Act established a National Agricultural Seeds Council in Nigeria, responsible for regulating seed quality standards. This Council plays a crucial role in advising the government on all matters related to seeds, ensuring that policies and practices align with national agricultural goals. It also encourages private sector participation in the seed industry, fostering innovation and investment. Furthermore, the Council is tasked with protecting farmers from counterfeit seeds, thereby safeguarding agricultural productivity and farmers' livelihoods. An essential part of its mandate is determining seed quality assurance standards to maintain high-quality seeds for farmers. However, the Act does not address biofortification, this omission highlights a potential area for future policy development to enhance nutritional outcomes in agriculture.

4. Key Parameters for Developing Micronutrient Standards in Nigeria

To determine the micronutrient standards for the release of biofortified Provitamin A maize varieties, several key parameters must be considered:

i. **Provitamin A Carotenoid Content**: Provitamin A maize should contain at least 10–15 µg β-carotene per gramme of dry seed weight for varieties to be considered biofortified and eligible for release (HarvestPlus, 2018; CIMMYT, 2020*)*

ii. **Bioavailability and Efficacy**: The exact value for bioavailability and efficacy of provitamin A maize is typically measured in terms of:

a) **Conversion Factor (Retinol Activity Equivalents - RAE)**: The bioavailability of Provitamin A carotenoid, such as β-carotene in maize, is commonly expressed as a ratio of β-carotene to retinol. The conversion efficiency of β-carotene from maize to retinol is approximately **12:1**, meaning 12 µg of β-carotene from maize is equivalent to 1 µg of retinol (National Academies of Sciences, 2001).

b) **Efficacy in Improving Vitamin A Status**: Studies have shown that regular consumption of biofortified provitamin A maize can significantly improve serum retinol levels. For instance, consuming biofortified maize with a provitamin A concentration of **15 µg/g** dry weight for a period of 3 months has been shown to improve vitamin A status comparably to vitamin A supplementation (Gannon *et al*., 2014).

iii. **Agronomic Performance**: The biofortified maize varieties should exhibit agronomic traits comparable to or better than conventional varieties, including yield, disease resistance, and adaptability to local growing conditions. This ensures that farmers are willing to adopt and cultivate the biofortified varieties.

5. Nigeria Maize Variety Release Standard

This standard outlines the requirements for releasing biofortified provitamin A and non-biofortified provitamin A maize varieties in Nigeria, and it has been developed to consider the following:

i. The needs of the breeders to conform to standards and for the National Committee on Registration and Release of Crop Varieties, Livestock Breeds and Fisheries (NVRC) to certify, through a simplified form, that the variety is fit for commercialisation and has the minimum micronutrient requirements for healthy living;

ii. The need to promote good agricultural practices that will enhance wider market access and the involvement of small-scale traders hence making farming a viable means of wealth creation, and meeting nutritional needs of the poor;

iii. The requirements for cultivating both biofortified and non-biofortified maize varieties for enhanced nutrition;
iv. The need to prevent technical barriers to innovations by establishing a standardised language for breeders. This will in turn facilitate fair domestic, regional and international development and research opportunities;
v. The need to facilitate fair domestic, regional and international trade and prevent technical barriers to trade by establishing a common trading language for buyers and sellers;
vi. The structure of the Codex Alimentarius, UNECE, ISO and other internationally significant standards;
vii. The needs of the producers, breeders in gaining knowledge of market variety release standards, conformity assessment, commercial cultivars and crop production process;

5.1 Scope of the Nigerian Standard

i. This Nigerian Standard pertains to maize seeds intended for cultivation or for planting to yield grains designated for human consumption, presented in packaged form.
ii. This Standard does not apply to maize grain.
iii. It specifies the requirements for Maize intended for variety development and release.
iv. It is intended for use by National Variety Release Committee and Maize breeders.

5.2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements for this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

i. ISO 711, Cereals and cereal products — Determination of moisture content - Basic reference method
ii. ISO 712, Cereals and cereal products — Determination of moisture content — Routine reference method
iii. ISO 5223, Test sieves for cereals
iv. CODEX CXS 153-1985 Standard for Maize
v. AOAC 2017.04 [N2]- Standard method of analysis of Provitamin A or equivalent

5.3 *Terms and Definitions*

For the purpose of the Nigeria Standard, the following definitions shall apply:

i. **Provitamin A carotenoids (PVAC)**: all-trans beta-carotene, alpha-carotene, cis-beta carotene and beta-cryptoxanthin.

ii. **Maize grain:** the shelled grains of the species Zea mays.

iii. **Variety:** An assemblage of cultivated individuals which are distinguished by any character (morphological, physiological, cytological, chemical or others) which when reproduced (sexually or asexually) retain their distinguishing characters.

iv. **Hidden hunger**: Also known as micronutrient deficiency, occurs when the quality of food that people eat does not meet their nutrient requirements, so they are not getting the essential vitamins and minerals they need for their growth and development

v. **Micronutrients**: Micronutrients are essential nutrients that organisms including human beings need in small quantities for proper growth, development, and physiological functioning, micronutrients are needed in minute amounts but are crucial for maintaining health.

vi. **Breeder**: A person who develops or discover a new crop variety.

vii. **Release**: A process whereby a crop variety has satisfactorily undergone trials and tests for distinctness, uniformity and stability, for yield or other special attributes, and is approved for cultivation by the National Variety Release Committee.

6. Benchmarks of Micronutrient Standards for the Release of Biofortified Provitamin A Maize Variety

6.1 *Provitamin A Carotenoid Content*

Provitamin A content in maize ranged from 5-25 μg β-carotene per gramme.

Benchmark: At least 12 μg β-carotene per gram of dry seed weight for varieties to be considered biofortified and eligible for release (Table 1).

6.2 *Agronomic Performance*

a) **Yield**: Grain yield must be competitive with or exceed that of existing conventional maize varieties in the same agro-ecological zones.

Benchmark: At least 5 **tonnes per hectare for variety and 7 tonnes per hectare for hybrid**.

b) **Maturity Period**: Provitamin A maize varieties should fall within the same maturity range as commonly grown varieties to ensure suitability

Benchmark: **90–120 days** to physiological maturity, depending on the region and variety (HarvestPlus, 2021).

c) **Drought Tolerance**: Drought-tolerant varieties should perform well in areas with water scarcity.

Benchmark: Grain yield reduction should not exceed **20–30% under moderate drought stress** compared to non-stressed conditions (CIMMYT, 2019).

d) **Resistance to Pests and Diseases**: Resistance to common diseases like maize streak virus (MSV), curvularia leaf spot (CLS), and northern corn leaf blight (NCLB) is critical.

Benchmark: **Less than 10% damage/infection rates** under high disease pressure (CIMMYT, 2020).

e) **Kernel Colour**: The provitamin A maize should have a **deep orange kernel colour,** as this correlates with higher β-carotene content.

Benchmark: Reflectance-based colour scores of **4–6 on a scale of 1–7**, with deeper orange preferred (HarvestPlus, 2021).

f) **Lodging Resistance**: Plants must have strong stems and roots to withstand lodging.

Benchmark: **Less than 10% lodging incidence** under normal conditions (CIMMYT, 2020).

g) **Plant Height**: The height should be within a range that balances ease of harvesting and resilience against wind damage.

Benchmark: **1.5–2.5 metres**, depending on the variety (HarvestPlus, 2021).

h) **Seed Production Traits**: High seed germination rate and seedling vigour are essential for farmer adoption.

Benchmark: **Germination rate ≥ 85%**, with uniform seedling emergence (CIMMYT, 2020).

These agronomic benchmarks ensure that provitamin A maize seeds are not only nutritionally superior but also agriculturally viable and attractive to farmers.

6.3 *Sensory and Cultural Acceptability*

The colour change due to increased provitamin A carotenoids can affect consumer acceptance. Therefore, sensory evaluations are necessary to ensure that the biofortified maize is acceptable in taste, appearance, colour, aroma, texture and overall acceptability to local communities.

a) **Overall Acceptability**: Overall acceptability reflects how well the biofortified maize meets consumer preferences across all sensory attributes.

   Benchmark: Overall acceptability scores ≥ **6 on a 9-point hedonic scale** (HarvestPlus, 2024).

b) **Cultural and Regional Preferences**: Preferences for food color, taste, and preparation methods vary by region. In regions where white maize is traditionally preferred, consumer education and awareness campaigns may help to increase acceptability.

   Benchmark: Adoption rate > **50%** in pilot consumer surveys conducted in target regions after introduction. (Oparinde *et al.*, 2021).

6.4 *Nutrient Stability*

The stability of provitamin A carotenoids during storage and typical cooking processes should be assessed to ensure that the nutritional benefits are retained from harvest to consumption.

a) **Retention During Storage:** Provitamin A maize should maintain β-carotene levels during typical storage conditions. Stability is affected by storage time, temperature, and packaging.

   Benchmark: At least **50% β-carotene retention** after **3–6 months** of storage under ambient conditions (20–30°C) in appropriate packaging (e.g., hermetically sealed-bags) (Muzhingi *et al*., 2017).

b) **Retention During Cooking**: Cooking processes such as boiling, steaming, and roasting should retain sufficient β-carotene to meet nutritional targets.

   Benchmark: At least **50% β-carotene retention** after common cooking methods, such as boiling maize porridge for 15–20 minutes. (Li *et al*., 2007).

c) **Light and Oxygen Sensitivity:** β-carotene in provitamin A maize is sensitive to light and oxygen. To preserve nutrient stability, maize should be stored in light-resistant and airtight containers.

Benchmark: Nutrient degradation due to light and oxygen exposure should not exceed **20% within 3 months** under optimal storage conditions. (Taleon *et al.*, 2017).

d) **Milling Stability:** Milling maize into flour or meal accelerates β-carotene degradation due to increased surface area exposure.

Benchmark: At least **40% β-carotene retention** after milling when stored in airtight and light-resistant conditions for up to 3 months. (Pixley *et al*., 2013).

e) **Overall Nutritional Adequacy**: After storage, processing, and cooking, the provitamin A maize should still provide a significant contribution to dietary vitamin A requirements.

Benchmark: At least **6 µg β-carotene/g** dry weight in the final food product (e.g., porridge) to meet 50% of the daily vitamin A requirement for children. (HarvestPlus, 2018).

Table 1: Minimum requirements for registration and release of biofortified Provitamin A (PVA) and Non-provitamin A (Non PVA) maize varieties in Nigeria

Parameter	PVA	Non PVA	Methods
Provitamin A	12 µg/g	Not Applicable	HPLC
% Starch	60	60	AOAC
% Ash	1	1	
% Protein	8	8	
% Fat	3	3	
% Crude Fibre	2.5	2.5	
% Carbohydrate	60	60	
Grain colour	Orange	White/Yellow	Physical colour chart
Potential Yield (ton/ha)	OPV: 5 Hybrid: 7	OPV:6 Hybrid: 8	

Note: A maize variety is accepted to be biofortified only if it has a minimum level of 12 µg/g PVA.
Non-Provitamin A (Non-PVA) maize, including white and yellow maize, contains negligible amounts of provitamin A carotenoid[13,17].
White maize has virtually no provitamin A content. Yellow maize contains small amounts of provitamin A carotenoid, but not enough to significantly impact vitamin A status[12].
HPLC: High-Performance Liquid Chromatography
AOAC: Association of Official Agricultural Chemists

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Appendix I: Registered and Released Biofortified/ProVitamin A Maize Varieties in Nigeria

S/N	Variety Name	Origin/Source	Developing Institute	Micronutrient(s)	Yield and other traits	Adaptation	Year of registration/ Release
1	Sammaz 70	IITA, Ibadan	IITA, Ibadan and IAR, Zaria	High provitamin A content (17.2 µg/g).	7.6t/ha	Northern Guinea and Sudan Savanna ecologies	2024
2	Oba Super 8	IITA, Ibadan	IITA, Ibadan & Premier Seed Nigeria	High provitamin A content (20.10 µg g-1)	tolerance to Striga, drought and low nitrogen. (8.3t/ha)	Southern and Northern Guinea Savanna ecologies	2023
3	HAKIMI 1	IITA, Ibadan	IITA, Ibadan	Intermediate level of provitamin A content (11.1 µg/g)	7.4 t/ha	Northern and Southern Guinea Savanna ecologies	2022
4	SAMMAZ 67	IITA, Ibadan	IITA, Ibadan/IAR, Samaru, Zaria	Intermediate provitamin A content (13.5µg/g)	High grain yield 9.7t/ha	Northern and Southern Guinea Savanna ecologies	2022
5	WAC58PVEE	IITA, Ibadan	IITA, Ibadan/WACOT	Intermediate level of Provitamin A content, (8.12µg/g)	High yielding, 6.70 t/ha	Derived Savanna, Southern and Northern Guinea Savanna ecologies	2022
6	WAC 42PVEE	IITA, Ibadan	IITA, Ibadan/WACOT	Provitamin A (5.30µg/g)	High yielding, drought tolerant, 6.20 t/ha	Derived Savanna, Southern and Northern Guinea Savanna ecologies	2022

7	SAMLAK 1608LY	IITA, Ibadan	IITA, Ibadan/SAMLAK Nig Ltd	High Provitamin A and Beta Carotene. (10.51 t/ha)	Drought Tolerant, high yielding, (10.51 t/ha)	Rainforest, Southern and Northern Guinea Savanna ecologies	2022
8	SAMMAZ 43	IITA, Ibadan	IITA, Ibadan/IAR, Samaru, Zaria	Intermediate levels of pro-vitamin A content (8.4ug/g)	high grain yield (9.9t/ha)	Northern and Southern Guinea Savanna ecologies	2015
9	SAMMAZ 44	IITA, Ibadan	IITA, Ibadan/IAR, Samaru, Zaria	Intermediate levels of pro-vitamin A content (8.8ug/g)	high grain yield. (9.7t/ha)	Northern and Southern Guinea Savanna ecologies	2015
10	SAMMAZ 59	IITA, Ibadan	IITA, Ibadan/ IAR, Samaru, Zaria	High level of provitamin A content (16.3µg/g)	(5.0t/ha)	Guinea Savanna Ecologies	2020
11	SAMMAZ 60	IITA, Ibadan	IITA, Ibadan/ IAR, Samaru, Zaria	High level of provitamin A content (15.53µg/g)	5.0t/ha	Guinea Savanna Ecologies	2020
12	SAMMAZ 57	IITA, Ibadan	IITA, Ibadan & IAR, Samaru, Zaria	High level of provitamin A content (15.2µg/g)	8.4t/ha	Northern and Southern Guinea Savanna ecologies	2019
13	SAMMAZ 52	IITA, Ibadan	IITA, Ibadan and IAR, Samaru	Intermediate levels of provitamin A content (9.8µg/g)	6.0t/ha	Northern Guinea and Sudan Savanna Ecologies	2017
14	SAMMAZ 49	IITA, Ibadan	IITA, Ibadan and IAR, Samaru	Intermediate levels of pro-vitamin A content (11.3µg/g)	7.8t/ha	Northern Guinea and Sudan Savanna ecologies	2016
15	SAMMAZ 38	IITA, Ibadan	IITA, Ibadan & IAR, Samaru, Zaria	Intermediate level of pro-vitamin A content (5.7µg/g)	high yield potential, 6.4t/ha	Nigeria Savanna	2013

16	SAMMAZ 39	IITA, Ibadan	IITA, Ibadan & IAR, Samaru, Zaria	Intermediate level of pro-vitamin A content (6.4µg/g)	high yield potential (6.8t/ha)	Nigeria Savanna	2013
17	Ife Maizehyb-3 (SC510)	IITA, Ibadan	IITA, Ibadan & IAR&T Ibadan	High pro-vitamin A	High yield, good seed quality (6.65t/ha)	Forest and Southern Guinea Savanna	2012
18	Ife Maizehyb-4	IITA, Ibadan	IITA, Ibadan & IAR&T Ibadan	High pro-vitamin A	High yield, good seed quality, and nitrogen use efficient. (6.65t/ha)	Forest and Southern Guinea Savanna	2012

Appendix II: List of Contributors

S/N	NAMES	DESIGNATION	ORGANISATIONS
1	Dr Marcus Olaniyi Ogunbiyi	Permanent Secretary	Federal Ministry of Agriculture & Food Security
2.	Nuhu Adamu Kilishi	Director	Department of Nutrition & Food Safety, Federal Ministry of Agriculture & Food Security
3	Munirat Abubakar	Deputy Clerk	Senate Committee on Science and Technology, House of Senate, National Assembly of Nigeria (NASS), Abuja
4.	Prof. Olusoji O. Olufajo	National Chairman	National Committee on Naming, Registration and Release of Crop Varieties, Livestock Breeds and Fisheries
5.	Prof. Shehu G. Ado	Chairman, Technical Sub-Committee (Crops)	National Committee on Naming, Registration and Release of Crop Varieties, Livestock Breeds and Fisheries /Institute of Agricultural Research, Zaria
6	Dr. Anthony U. Okere	Registrar	National Committee on Naming, Registration and Release of Crop Varieties Livestock Breeds and Fisheries / National Centre for Genetic Resources and Biotechnology (NACGRAB)
7.	Dr. Ibidun S. Adetiloye	Assistant Director/ Desk Officer	National Committee on Naming, Registration and Release of Crop Varieties, Livestock Breeds and Fisheries / National Centre for Genetic Resources and Biotechnology (NACGRAB)
8.	Prof. Julius O. Olasoji	Seed Scientist	Institute of Agricultural Research &Training, Ibadan
9.	Dr. Sunday E. Aladele	Research Director	National Centre for Genetic Resources and Biotechnology (NACGRAB)

10.	Prof. Omolayo Johnson Ariyo	Experienced Breeder & Member of National Varietal Release Committee	National Committee on Naming, Registration and Release of Crop Varieties, Livestock Breeds and Fisheries / Federal University of Agriculture Abeokuta (FUNAAB)
11.	Prof. Emmanuel Suleiman Salau	Head of Department & Agricultural Extensionist	Department of Agricultural Economics & Extension, Nasarawa State University, Keffi.
12.	Prof. Muhydeen. Oyekunle	Maize Breeder	Institute for Agricultural Research (IAR), Samaru Zaria
13.	Grace O. Samuel	Assistant Director, Plant Resources Department (PRD)	Agricultural Research Council of Nigeria (ARCN)
14	Obinna Nwokolo	Senior Intervention Officer	Propcom+
15.	Ifeoluwa Olaopa	Policy Officer	Propcom+
16.	Dr Popoola Ayodele Mustapha	Special Assistant to Minister of Agriculture on Nutrition	Federal Ministry of Agriculture & Food Security
17.	Dr Musa Umar	Special Adviser to the Permanent Secretary	Federal Ministry of Agriculture & Food Security
18.	Dr Muhammad Liman	Chief Research Officer	National Cereal Research Institute (NCRI)
19.	Victoria Ashe Alabi	Assistant to the Director, Department of Nutrition and Food Safety	Federal Ministry of Agriculture & Food Security
20	Godwin Patience Godfrey	Assistant to the Director, Department of Nutrition and Food Safety	Federal Ministry of Agriculture & Food Security
21.	Mewase Tolulope Rebecca	Senior Molecular Scientist	National Agricultural Seed Council (NASC)
22.	Stephen Adigun	Acting Executive Secretary	Seed Entrepreneurs Association of Nigeria (SEEDAN)
23.	Adeniran Ayodeji	Deputy Director	Department of Nutrition and Food Safety, Federal Ministry of Agriculture & Food Security
24.	Mal. Ubandoma Hudu	Director Seed Certification and Quality Control	National Agricultural Seed Council (NASC)

25.	Enjuyu Achuku	Seed Scientist	National Agricultural Seed Council (NASC)
26.	Adeyemi Adewoye	Special Adviser on Media to the Honourable Minister of Agriculture and Food Security	Federal Ministry of Agriculture & Food Security (FMAFS)
27.	Prof. Samuel A. Olakojo	Maize Breeder/Member of National Varietal Release Committee	Institute of Agricultural Research Institute (IAR&T), Ibadan
28.	Dr. Jonathan. O. Aligbe	National Desk Officer, Maize Value Chain	Federal Ministry of Agriculture & Food Security
29.	Agoro Olayiwola	Deputy Director	Federal Ministry of Innovations, Science and Technology
30.	Prof. Christopher O. Alake	Plant Breeder	Federal University of Agriculture, Abeokuta (FUNAAB)
31.	Dr. Zakari. G Turaki	Research Director/Plant Breeder	Lake Chad Research Institute (LCRI)
32.	Dr Wende Megasa	Senior Maize Breeder	International Institute of Tropical Agriculture (IITA)
33.	Cyril Inegbedion	Lead Consultant	Development Initiatives
34.	Prof. Muhammad Lawan Umar	Cowpea Breeder/Member of National Varietal Release Committee	Institute for Agricultural Research, Zaria
35.	Ndukwe Nnanna Moses	Agricultural Research Officer, Plant Resources Department (PRD)	Agricultural Research Council of Nigeria (ARCN)
36.	Bello Abubakar	National President	Maize Association of Nigeria
37.	Engr Joseph Sunday Bamidele	National Coordinator	Maize Association of Nigeria (MAAN)
38.	Usman Balla Daudawa	Member, Technical	Maize Association of Nigeria
39.	Mrs Oluseyi Deborah Moemeke	Managing Director/Chief Executive Officer	Unique Analytical and Diagnostic Lab Services Ltd, Kubwa Abuja.
40.	Pascal Hemar	Market Leader for Food and Agriculture	Bureau Veritas Africa

41.	Asabe Charity Emmanuel	Women Leader	Village Savings & Loan Association (VSLA), Nasarawa State
42.	Comfort Sunday	FCT Coordinator	Small Scale Women Farmers Organisations of Nigeria (SWOFON)
43.	Misra Rewa	Head, National Policy and Innovative Finance	HarvestPlus/IFPRI, Washington DC
44.	Dr Govindaraj Mahalingam	Senior Scientist	HarvestPlus- Alliance Bioversity, CIAT Cali Colombia
45.	Dr Yusuf Dollah	Country Manager	HarvestPlus Nigeria
46.	Aremu Fakunle John	Policy Advisor	HarvestPlus Nigeria
47.	Olatundun Kalejaiye	Nutrition and Food System Manager	HarvestPlus Nigeria
48.	Dr Bolanle Falade	Monitoring & Evaluation Manager	HarvestPlus Nigeria
49.	James Isang Pius	Finance and Administrative Manager	HarvestPlus Nigeria
50.	Esanju Seyifunmi Mary	Admin and Finance Assistant	HarvestPlus Nigeria

Minimum Requirements for the Registration and Release of Biofortified Provitamin A and Non-provitamin A Maize Varieties in Nigeria