HarvestPlus agenda in relation to tropical fruits

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Abstract

HarvestPlus seeks to reduce micronutrient malnutrition among the poor by breeding staple food crops that are rich in micronutrients through a process called biofortification. HarvestPlus has targeted banana and plantain (*Musa* spp.) to deliver higher levels of pro-vitamin A carotenoids (pVAC) to those communities in sub-Saharan Africa with a higher prevalence of vitamin A deficiency. Iron and zinc have also been considered but, to date, the natural genetic variation discovered for Fe and Zn in *Musa* is below 50% of the target increment so the major focus is on improving pVAC concentration. The initial plant breeding strategy has emphasised a fast-track approach that selects pVAC-dense genotypes from existing material that is locally adapted. Working with the International Institute for Tropical Agriculture (IITA), Bioversity International and the National Agricultural Research System (NARS) partners associated with these institutions, considerable testing of the nutrition and agronomic characteristics under relevant conditions in African target countries has taken place. The breeding strategy entails combining best pVAC sources with African adapted elite varieties that carry the productivity, disease and virus resistance, and sensory traits. Rapid generation advance and propagation techniques are used and further developed and the development of molecular markers for micronutrients and those facilitating breeding has increased breeding effectiveness. Plant breeding progress has led to improved sampling procedures and from the screening process, genotypic variation to reach the target of an extra 20 micrograms/gram pVAC has been discovered in *Musa* varieties from the Asian and Pacific regions while progenitors have been identified by IITA, Bioversity and NARS partners. Once pVAC-dense varieties have been fully developed, the *Musa* deployment strategy will capitalise on existing Consultative Group on International Agricultural Research (CGIAR), NARS and Non-governmental Organisation (NGO) partnerships in germplasm development, training/capacity building and germplasm deployment in Africa.

Introduction

The goal of HarvestPlus is to improve the health of poor people by breeding staple food crops that are rich in micronutrients, a process referred to as biofortification. Micronutrient malnutrition, primarily the result of diets poor in bioavailable vitamins and minerals, affects more than half of the world's population, especially women and pre-school children. The biofortification strategy seeks to take advantage of the consistent daily consumption of large amounts of food staples, thereby providing a nutritional boost that was previously not available.

The International Network for Improvement of Banana and Plantain (INIBAP) estimates that 85% of all bananas are grown in smallholdings and eaten locally, more often than not as a staple food. In some areas close to 1 kg of cooking banana are eaten every day.

To reach the Millennium Development Goal's target of halving the proportion of undernourished people by 2015, new technologies and approaches are needed to help address the problem. HarvestPlus seeks to bring the latest advances in agriculture and nutrition science to bear on the persistent problem of micronutrient malnutrition. Improving the nutritional content of banana is one area being explored.

Materials and method

Breeding bananas and plantains (*Musa*) is complex as commercial varieties are sterile triploids (3X), which are developed from crossing fertile diploids (2X) and tetraploids (4X). Among the fertile groups, a high degree of cross-incompatibility can exist. Further, the *Musa* crop cycle is long and consequently, the initial biofortification strategy emphasises a fast-track approach (selected from existing material) that entails evaluating what appears to be existing high pVAC *Musa* that are locally adapted in Africa. HarvestPlus will test the nutrition and agronomic characteristics under relevant conditions in African target countries and deploy material to farmers along with crop management recommendations.

The breeding strategy entails combining best pVAC sources with African adapted elite varieties that carry the productivity, disease and virus resistance, and sensory traits. Rapid generation advance and propagation techniques are used and further developed, and the development of molecular markers for micronutrients and those facilitating breeding has increased breeding effectiveness in HarvestPlus II. Proof-of-concept research using Near Infrared Spectrocopy (NIRS) for pVAC in *Musa* is part of the 2008 agenda.

Results and discussion

Measuring potential impact

A review of consumption patterns of *Musa* was commissioned for several sub-Saharan African countries, supplemented by semi-quantitative surveys of consumption in peri-urban areas. This information was then used to compute the Disability-Adjusted Life Years (DALYs) that could be saved from a biofortified *Musa*.

Nutrition

An initial targeting exercise using estimates of banana/plantain consumption and retinol equivalency determined that an additional increment of 20 micrograms/gram provitamin A would need to be added to a baseline of 16 micrograms/gram provitamin A in banana/ plantain. Based on an intake of 300 g of banana/plantain (fresh weight) per day for adult women or 150 g/day for children 3–5 years of age, a 50% loss of provitamin A following processing and cooking, and a provitamin A retinol equivalency of 12:1, this target increment of 20 µg/g fresh weight would provide approximately one half of the current estimated average requirement for total dietary vitamin A (Food and Nutrition Board/Institute of Medicine, 2002).

To our knowledge, studies of the bioavailability of provitamin A from banana have not yet been conducted. It is of interest to determine the nutrient bioavailability from banana, particularly for provitamin A. Conventional varieties rich in provitamin A vary a lot in their ratio of α-carotene to β-carotene. In a selection of banana cultivars from Australia, Englberger and colleagues reported ranges of β-carotene content from 0.5 to 14.1 $\mu g\ g^{-1}$ fresh weight and of α-carotene content from 0.6 to 10.6 $\mu g\ g^{-1}$; the ratios of β-carotene to α-carotene ranged from 0.5 to 4.8 (Englberger et al., 2006). This is of interest for the bioefficacy of such bananas to contribute to improved vitamin A status because it is currently believed that the conversion of α-carotene to the active form of vitamin A in humans is only half as efficient as it is for β-carotene. That is, while it is generally accepted that 12 µg β-carotene in a typical diet are required to produce 1 µg of retinol and this ratio would be 24:1 for α-carotene (Food and Nutrition Board, Institute of Medicine, 2002). Nonetheless, these conversion rates would need to be established specifically for Musa and in the context of the diets of potential target populations.

Plant breeding

Sampling protocols for *Musa* have been developed and published (Davey et al., 2007; Stangoulis and Sison, 2008). Further, the long crop cycle along with the extra resources required to establish nurseries due to the large size of the plant and quarantine restrictions, complicated screening. More than three hundred genotypes have been assayed by IITA, Bioversity and NARS partners, and more than five hundred core collection accessions have been pre-screened/described for pVAC indicative pulp color. Maximum values for pVAC discovered in African varieties and final products developed at IITA are close to the target increment and are subject to further validation in genome × environment (G × E) trials. Variation to reach the target for pVAC has been discovered in *Musa* varieties from the Asian and Pacific regions. HarvestPlus research revealed differences in the carotenoids profiles. The variation discovered to date for Fe and Zn in *Musa* is below 50% of the target increment.

Progenitors have been identified by IITA, Bioversity and NARS partners. Diploid populations for genetic analysis of minerals have been developed from more than twenty crosses. First generation crosses for high pVAC have been conducted.

Adapted genotypes have been evaluated for use as parents and/or to fast-track in multi-location trials in Nigeria and Cameroon along with local checks. The G × E effect has been evaluated from more than thirty on-station and on-farm trials in Nigeria and Cameroon and results from the various experiments and partners are currently compiled. Preliminary results reveal stability for pVAC. Preliminary results on agronomic performance and micronutrient content of a high-micronutrient cultivar in high-density systems with different fertiliser applications are also available.

Dissemination activities

The Musa deployment strategy capitalises on existing CG, NARS and NGO partnerships in germplasm development, training/capacity building and germplasm deployment in Africa. Multilateral cooperation includes projects such as: Building Impact Pathways for Improving Livelihoods in *Musa*-based Systems in Central Africa (Bioversity/INIBAP—IPGRI (International Plant Genetic Resources Institute) led); Sustainable and Profitable Banana-based Systems for the African Great Lakes Region (IITA led); Enhancing the resilience of agro-ecosystems in Central Africa: a strategy to revitalise agriculture through the integration of natural resource management coupled with resilient germplasm and marketing approaches (Tropical Soil Biology and Fertility Institute of CIAT–led), and supported by strategic research and capacity building by the Katholieke Universiteit Leuven and the Université Catholique de Louvain-la-Neuve. Further, lead centres already operate regional and national multiplication centres and have experience in successful large scale rollout in Africa.

In the context of the Rwanda crises, the Belgium Development Cooperation Agency (BTC/CTB) project multiplied 2.5 million plants of 24 varieties that reached 0.5 million people. On a country specific basis, additional partnerships will be formed in deployment strategies based on stakeholder meetings and gap analysis. Furthermore, strategies will be harmonised with deployment efforts for other biofortified crops in the same country.

Future activities

Measuring potential impact

DALY analysis will be conducted to determine potential cost-effectiveness, which in turn will determine target countries.

Nutrition

The true retinol equivalency will need to be determined to better evaluate the feasibility of this crop in meeting target levels, and hence to improve vitamin A status. Ideally, a human study to estimate the retinol equivalency of pVAC rich banana/plantain from a test meal using the modified 'area under the curve' method, as used for maize and cassava, will be undertaken.

Plant breeding

Additional varieties will be assessed for pVAC, and the variation in micronutrients, anti-nutrients and fruit quality traits evaluated. Furthermore, different sampling and screening procedures will be compared for a set of representative genotypes.

Additional parents will be identified and the inheritance pattern for minerals established. Guidance on more efficient breeding and selection methods for *Musa* will be documented. Additional crosses for high pVAC will be conducted and a seedling nursery will be established from 2007 crosses following embryo rescue.

Effects of environment and influence of harvest cycle on micronutrient variability will be assessed from more than ten multi-location trials in Nigeria and Cameroon, and at least one candidate variety will be planted on-farm for evaluation in Nigeria. The effects of fertiliser input in high-density planting and associated technologies on micronutrient variability will be evaluated on-farm in Cameroon.

Literature cited

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