ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2017; **17(2):** 11973-11999 **DOI: 10.18697/ajfand.78.HarvestPlus08**

CHAPTER 8

ORANGE MAIZE IN ZAMBIA: CROP DEVELOPMENT AND DELIVERY EXPERIENCE

Simpungwe E[1]*, Dhliwayo T[2], Palenberg M[3], Taleon V[4], Birol E[4], Oparinde A[4], Saltzman A[4] and MT Diressie[4]

*Corresponding author email: E.Simpungwe@cgiar.org

[1]HarvestPlus, Lusaka, Zambia

[2]International Maize and Wheat Improvement Center (CIMMYT), El Batan, Mexico

[3]Institute for Development Strategy, Munich, Germany

[4]HarvestPlus, Washington DC, USA

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2
April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Biofortified vitamin A "orange" maize can help address the adverse health effects of vitamin A deficiency. By 2016, HarvestPlus and its partners had developed six orange maize varieties and delivery efforts have reached more than 100,000 farming households in Zambia. HarvestPlus has established the proof of concept, that vitamin A maize varieties can be developed without compromising yield levels and that these varieties can deliver sufficient quantities of vitamin A to improve nutrition. The delivery program has also shown that farmers are willing to grow orange maize varieties and consumers are willing to buy and eat orange maize products. This paper summarizes the country's nutritional and consumer backgrounds, the crop development and release of orange maize varieties, the delivery efforts in Zambia and impact measurement. It also synthesizes lessons learned and future challenges.

Keywords: Biofortification, Vitamin A Deficiency, Orange Maize, Vitamin A Maize, Zambia

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

INTRODUCTION

Zambia is afflicted by severe vitamin A deficiency. Despite government programs aimed at reducing vitamin A deficiency, like supplementation and sugar fortification, vitamin A deficiency remains a public health problem in Zambia. At the same time, maize is the most important staple crop in Zambia, both in terms of production and consumption. Zambian hybrid maize varieties that dominate the maize seed and food markets do not contain significant amounts of provitamin A.

The first provitamin A biofortified maize variety was approved for release in Zambia in 2012, eight years after plant breeding activities started at the International Maize and Wheat Improvement (CIMMYT) and International Institute of Tropical Agriculture (IITA) under funding from the HarvestPlus program. Three years after release and eleven years after initial research activities, more than 100,000 farming households in Zambia have been reached by HarvestPlus delivery efforts. They are growing and consuming "orange" maize varieties, which contain significant amounts of provitamin A even after processing. Biofortified maize is now an additional stream of vitamin A intake in Zambian diets.

This chapter provides an overview of: (i) the policy background and justification for developing, introducing, and scaling up use of provitamin A varieties in Zambia, (ii) an overview of crop development activities, (iii) the strategy and experience-to-date with dissemination of orange maize, and (iv) past and planned efforts to measure impact. The concluding section draws lessons learned and describes the steps that will need to be taken to sustainably integrate orange maize varieties into the Zambian seed and food systems.

POLICY BACKGROUND AND JUSTIFICATION: PRE-RELEASE ACTIVITIES

While crop development is ongoing and before the first varieties are released, it is necessary to develop evidence to demonstrate the viability and cost-effectiveness of biofortification and to use this information to convince policymakers to support a biofortification strategy as a means to address micronutrient deficiencies in human diets.These activities focus on understanding the environment of vitamin A deficiency and interventions, as well as existing production and consumption maize patterns in Zambia. This background information was used to set breeding targets, which were then verified through additional studies, including nutritional efficacy trials.

Prevalence of Vitamin A Deficiency, Vitamin A Interventions, and Dietary Sources of Vitamin A

Two forms of vitamin A are available in the human diet: preformed vitamin A (retinol) and provitamin A carotenoids. Preformed vitamin A is found in animal-source foods; provitamin A is found in some plant-source foods, and is metabolized by the body into retinol when consumed. The World Health Organization has established the Estimated Average Requirement (EAR) for vitamin A by age group. For children 4-6 years, this is

275 µg retinol; and for women, 500µg per day. Adequate vitamin A is important for healthy immune function.

Vitamin A deficiency Zambia, a southern African country with 16 million[1] people, is afflicted by severe vitamin A deficiency. More than half of all Zambian children (54%) between 0.5 to 5 years of age are affected, with little variation by season [1]. An estimated 14% of pregnant women are vitamin A deficient as well [2]. Vitamin A is essential for good vision and cell differentiation. Vitamin A deficiency can result in blindness, impaired immune system function, abnormal fetal development, increased child mortality, and increased maternal mortality [3].

Addressing vitamin A deficiency In Zambia, the primary mechanisms for addressing vitamin A deficiency are semi-annual high dosage supplements and mandatory sugar fortification. The national vitamin A capsule distribution program began in 1997, and Zambia has imposed mandatory sugar fortification with preformed vitamin A (retinol) since 1998. The government provides vitamin A doses to women postpartum. In 1999, Zambia pioneered Child Health Weeks (CHW), which are large-scale events undertaken semi-annually to provide an integrated package of child health and nutrition interventions, including vitamin A supplementation. Despite achieving high rates of coverage with CHW, details exist on quantitative impact of programs to address vitamin A deficiency, and the most recent available data on vitamin A deficiency are from 2003, suggesting that vitamin A deficiency is not being adequately monitored in Zambia.

Furthermore, despite the documented value of supplementation and sugar fortification, many Zambians do not have access to these interventions. For example, the 2007 Demographic and Health Survey (DHS) found that more than 41% of children had not received a vitamin A supplement in the previous six months and 56% of women had not received a post-partum dosage, with coverage much lower in rural communities than in urban areas [4].

Sugar fortification with vitamin A has been in place for almost twenty years, and all sugar intended for households is now fortified. Recently, Lividini and Fiedler reported that 63% of the rural population purchases vitamin A fortified sugar [5]. However, sugar consumption has been found to be highly correlated with socio-economic status and may not reach the most vulnerable groups in Zambia. The quality of the fortification and the amount of vitamin A retained at the point of consumption is unclear [6].

Dietary sources Vitamin A in the Zambian diet is found in milk, liver, eggs, fish, butter, mangoes, papayas, carrots, pumpkins, tomatoes, and dark green leafy vegetables. There has been no comprehensive study of vitamin A intakes among Zambians, but available data suggest that variation between regions and among various age groups is significant.

Fiedler and Lividini used the 2006 Living Conditions Monitoring Survey (LCMS) to estimate rates of inadequate vitamin A intake [7]. They found that an estimated 87.2%

---

[1] World Bank for 2014 population of Zambia is 15.72 million. Accessed online on November 30, 2015: http://data.worldbank.org/country/zambia.

of Zambians have inadequate intake of vitamin A, with variability between provinces. Apparent daily intake was highest in Luapula province (mean 783 g/d) and lowest in Southern province (mean 62 g/d). In Luapula province, 41% of the population suffered from inadequate intake, while in Eastern and Southern provinces, up to 99% of the population was estimated to have inadequate intake.

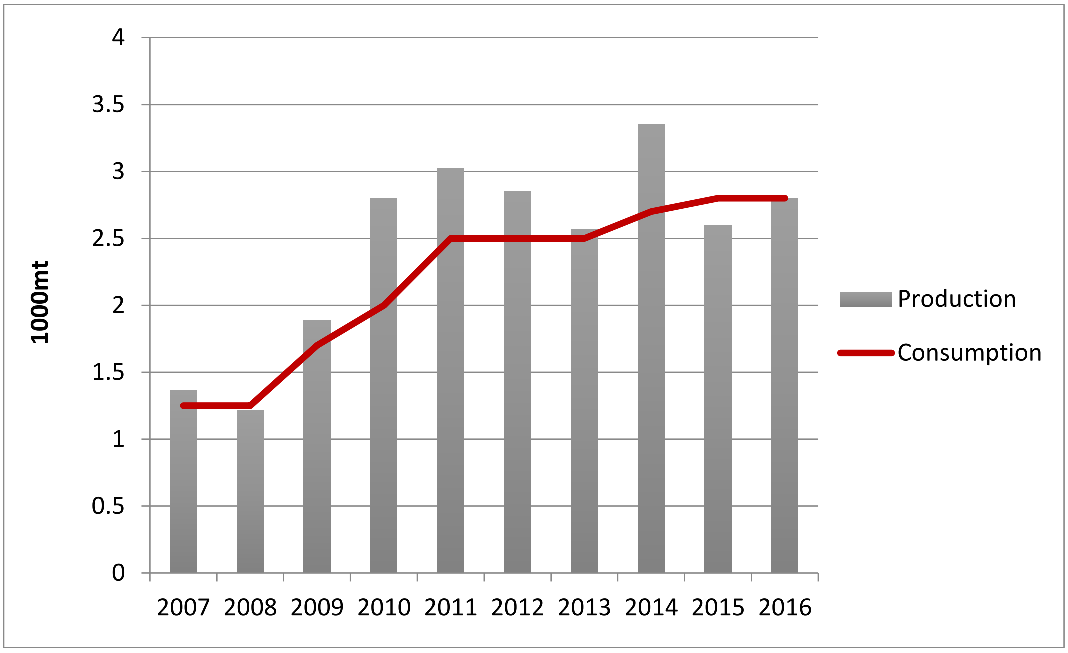
This study did not disaggregate intake by age or sex. However, the Zambia DHS collected information on the incidence, but not level, of consumption of foods rich in vitamin A among children [8]. Seventy-five percent of children age 6-23 months consumed foods rich in vitamin A during the day or night preceding the survey. The proportion of children consuming foods rich in vitamin A increases with age, and breastfed children are less likely to consume vitamin A-rich foods than non-breastfed children. Children of young mothers (age 15-19) are least likely to consume vitamin A-rich foods compared to children of older mothers. The study found little variation by mother's education or household wealth. The survey also assessed whether post-partum mothers had received vitamin A supplements, but did not assess their intake of dietary sources of vitamin A.

Maize Production and Consumption Patterns

Maize is the most important staple crop for Zambia. Maize cultivation occupies over 44% of all cropped land and provides 57% of daily caloric intake for Zambians. Over 90% of smallholder farming households grow maize and 75% of smallholder farms in Zambia are primarily subsistence-oriented, growing maize largely for home consumption. Depending on harvest and year, 20 to 50% of rural households sell maize after satisfying their domestic needs while 20 to 35% of smallholder households purchase maize grain to cover the deficit between their own production and consumption needs. By income bracket, high-income rural households are generally sellers of maize, while low-income households are buyers of maize [9, 10, 11, 12].

In most years over the past decade, Zambia has produced sufficient white maize to meet its food balance sheet of maize required for human consumption, industrial use and other commitments. In 2014, Zambia recorded the highest white maize harvest in history amounting to 3.4 million metric tons that exceeded national consumption requirements by more than 20% (Figure 8).

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2
April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374



mt: metric tons

Figure 8.1: Annual production and consumption of white maize in Zambia (Zambia Central Statistics Office)

It should be noted, however, that not all regions of Zambia produce maize equally well. Zambia has three agroecological zones: Region I, the most southerly swath of land where rainfall is relatively low; Region II, the middle belt of the country, which receives more rainfall and has generally good soil quality; and Region III, in the north of the country, which receives the most rain but has some areas of highly acidic soil that reduce the potential of nitrogen fertilizer to contribute to crop productivity. Region II is sub-divided into IIa and IIb. Region IIa covers the Central Lusaka, Southern and Eastern fertile plateau of the country and has inherent fertile soils and, therefore, achieves high yields for most crops, including maize and irrigated wheat. Region IIb covers Western Province and consists largely of sandy soils. While it supports maize production in some areas, Western Province is mostly suitable for production of rice and millets.

Figure 8.2 depicts Zambia's agroecological zones. Maize production is concentrated in the southern and eastern provinces.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2
April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

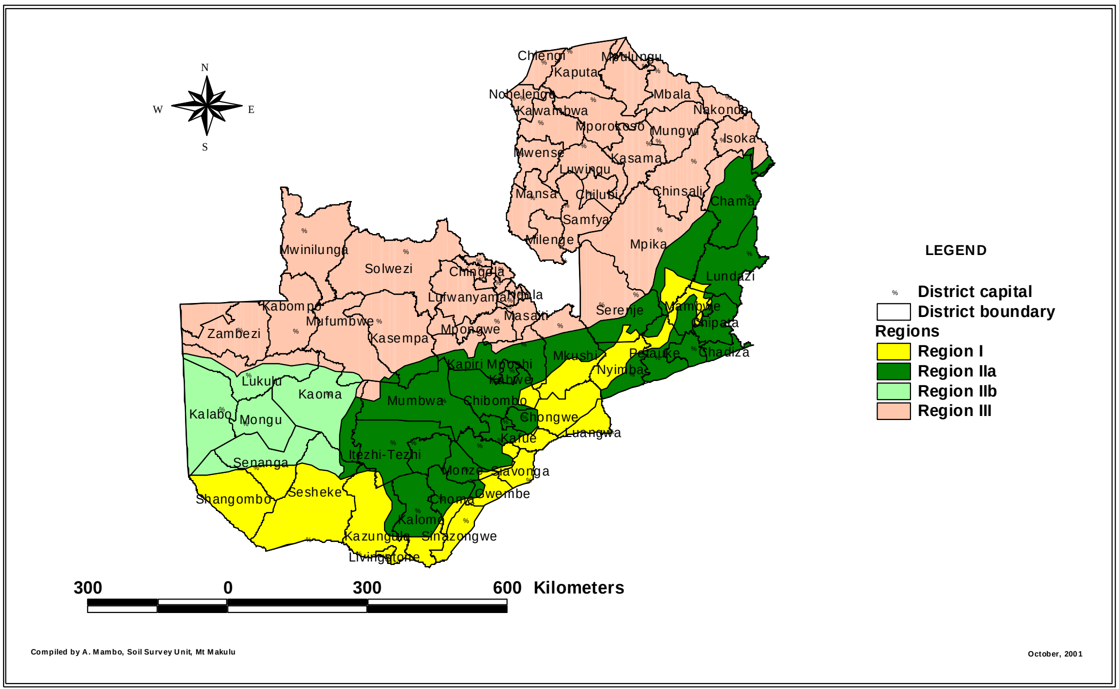


Figure 8.2: Zambia's Agroecological Zones

Based on the central and dominant position of maize in the Zambian economy and food sector, biofortified maize is an effective mode of delivering vitamin A to the target population of smallholder farming households.

Setting Provitamin A Target Levels for Maize Breeders and Establishing Nutritional Efficacy

The general methodological approach for setting target levels for plant breeders has been discussed in Chapter 1. As discussed, targets are based on age- and gender-specific nutrient requirements; daily consumption amounts of maize and maize products; nutrient retention after traditional storage, processing, and cooking; and the bioavailability of provitamin A in maize, that is, the degree to which the human body can absorb provitamin A from maize and convert it to retinol, the form of vitamin A used by the body.

Maize intake HarvestPlus-assessed maize intakes by children 2-5 years of age in Eastern and Central Zambia of 172 g/day are in line with the initial assumption of 200 g/day for children 2-6 years of age (Table 8.1). However, daily maize intake of 287 g/day by women from the same populations appears to be substantially lower than the initial assumption of 400 g/day [13].

Provitamin A retention Nutritionists measure retention of micronutrients in food under typical storage, processing, and cooking practices to be sure that sufficient levels of vitamins and minerals will remain in foods that target populations typically eat. A retention study conducted in Zambia showed provitamin A losses of 50% in four genotypes after 15 days of grain storage in ambient conditions, after which additional provitamin A degradation was minimal during six months of storage [14]. Beta-carotene degradation associated with traditional African household processing methods was approximately 25% for fermented and unfermented porridges [15]. However, retention of 90–100% was observed with milled products, *nshima*, and porridge [14]. Overall, average retention was lower than originally assumed, particularly during storage (Table 8.1). Carotenoid stability and retention vary by genotype and thus may differ for specific varieties. Retention studies have been completed for all biofortified varieties currently released in Zambia, and plant breeders and nutritionists are working together to better understand the genetic mechanisms that might lead to greater provitamin A retention in future varieties.

Bioavailability Bioavailability of a nutrient is determined using models and, with the most promising varieties, by direct study in humans in controlled experiments. Bioconversion studies have shown a 3:1 and 6:1 bioequivalence between beta-carotene from maize and retinol, the form of vitamin A used by the body [15, 16].Even the higher ratio, 6:1, is more efficient than initially assumed (Table 8.1).

Based on assumed values for estimated daily average requirements of provitamin A, daily intake, nutrient retention and bioavailability, and taking realistic provitamin A carotenoid increments through conventional breeding methods into account, an overall target provitamin A (beta-carotene equivalents) increment of 15 parts per million (dry weight) was set. This increment aims to provide children and women with 50% of the estimated average requirement of provitamin A (Table 8.1). As non-biofortified white maize does not exhibit any significant baseline density of provitamin A carotenoids, this target increment represents the absolute breeding target. Based on updated values for intake, retention and bioavailability, the breeding target of 15ppm was verified. Orange maize with this target level of provitamin A provides more than 50% of the estimated average requirement for children and women (Table 8.1).

Demonstrating Nutritional Efficacy and Consumer Acceptance

Efficacy trials An efficacy study conducted in the Eastern Province of Zambia with children 5 to 7 years of age showed that after three months of consuming orange maize, the children's total body stores of vitamin A in the orange maize treatment group increased significantly compared to the control group without additional orange maize consumption [17]. Another study in Zambia with children aged 4-8 years showed increased serum beta-carotene as a result of consuming orange maize over six months [18]. Furthermore, in the same study, dark adaptation of eyesight was measured pre- and post-intervention in a random subsample. Among children with marginal or deficient vitamin A status, consumption of orange maize increased pupillary responsiveness, which is a functional indicator of vitamin A nutritional status. These studies demonstrate that beta-carotene in maize is an efficacious source of vitamin A when consumed as a staple crop.

The methodologies used, results, and significance of efficacy trials for a range of biofortified crops are discussed in more detail in Chapter 2.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Consumer acceptance Consumer acceptance for biofortified orange maize hinges on whether consumers like food made with orange maize as much as, or more than, food made with traditionally consumed white maize. Acceptance also depends on whether consumers can differentiate orange maize from yellow varieties, which are perceived as inferior to white ones. For example, in neighboring Zimbabwe, yellow maize mostly entered the country as food aid and developed unacceptable taste and other sensory properties if handled poorly [19]. Orange biofortified maize, because of its similar color, has the potential to be confused with yellow maize, a risk that was evaluated.

Consumer acceptance studies conducted with sensory/organoleptic evaluation and "revealed preference" economic valuation methods found that orange maize is not confused with yellow maize, and has the potential to compete with white maize even in the absence of nutritional information. Although the color change had an effect on consumer evaluation of some of the sensory attributes, none were poorly rated. Overall, Zambian consumers rated the sensory attributes of orange maize higher than those of the yellow maize variety and at par with the white maize variety tested. Therefore, negative connotations associated with yellow maize are unlikely to be carried over to orange maize. The studies also found that the consumers prefer and are willing to pay a premium for orange maize varieties – compared to white varieties – after receiving information on the nutritional benefits of orange maize [20, 21].

Cost-Benefit Analysis

Ex-ante cost/impact Ex-ante impact analysis uses modelling tools and a 30-year time horizon, with pessimistic and optimistic assumptions about future coverage (adoption and consumption rates), costs of breeding and delivery, and achievable micronutrient content of vitamin A maize. Even under pessimistic assumptions of adoption rates, biofortified vitamin A maize is cost-effective.

According to an ex-ante analysis conducted by Lividini and Fiedler, assuming an adoption ceiling of 20% of vitamin A maize over 30 years, implementation will result in average additional intake of 12% of the Estimated Average Requirement (EAR) and a 3 percentage point reduction in the prevalence of inadequate intake [5]. This study assumed that the concentration of provtamin A maize was 7.5 ppm until 2018, thereafter increasing to 15 ppm. An adoption ceiling of 20% was selected given that no single commercial variety has achieved greater than 10% market share, but higher aggregate adoption rates may be possible if the vitamin A trait is included in an increasing number of commercial varieties.

Impacts are concentrated among farming households that have adopted vitamin A maize and consume it from their own production. Among this group, the reduction in the prevalence of inadequate intake is predicted to be 17.5 percentage points, more than 5 times the national average.

Over 30 years, the cost-effectiveness of vitamin A maize in Zambia was estimated to be $24 per Disability Adjusted Life Year (DALY) saved, making it cost-effective. A separate study which used a more optimistic adoption rate, 63%, preliminarily estimated

DOI: 10.18697/ajfand.78.HarvestPlus08

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

the cost-effectiveness at$15per DALY saved. This rate of adoption may be possible if farmers and consumers demand a larger number of maize varieties with the vitamin A trait.

Biofortification priority index (BPI) The BPI prioritizes countries for vitamin A, iron, and zinc biofortification interventions based on their production and consumption of target crops and the rate of micronutrient deficiency among target population [22]. It was developed by HarvestPlus as a decision making tool for governments, investors, and NGOs. Among the 107 countries ranked for investment in orange maize in Africa, Asia, and Latin America and the Caribbean, Zambia ranks as number three, indicating that Zambia is a top priority for investment in orange maize.

DEVELOPMENT OF ORANGE MAIZE VARIETIES

Competitive orange maize varieties with sufficient provitamin A density represent the basis for a successful biofortification intervention in Zambia. This section summarizes breeding progress to date and reviews future breeding strategies.

Breeding Progress to Date

Breeding strategy and activities[2] The choice of strategy for a breeding program depends on the objectives and on the pertinent quality of both the starting material and the available sources of genetic variability for the target traits. The main objective of the provitamin A-biofortified maize project is to develop, through conventional breeding, high-yielding, profitable varieties, with demonstrable effectiveness in reducing vitamin A deficiency, that reflect consumer preferences [23]. As discussed in the previous section, a 15 µg/g (ppm) dry weight of provitamin A carotenoids (beta-carotene equivalents) breeding target was set (Table 8.1). The breeding program first aimed for an intermediate target of 7.5 ppm [24]. However, if maize varieties had very little or no naturally occurring variation for provitamin A carotenoid concentrations, it would be impossible to reach the target concentration of these carotenoids through conventional breeding approaches.The first step, then, was to examine the carotenoid contents and profiles of more than 1,500 maize lines and varieties. A wide range of carotenoids were found in yellow temperate, tropical, and sub-tropical germplasm including landraces, inbred lines, and hybrids (Table 8.2). Most yellow maize grown and consumed throughout the world has less than 2 ppm provitamin A carotenoids but a few temperate germplasm sources were found to have levels as high as 19 ppm [25, 26].

Although source germplasm with provitamin A levels exceeding breeding targets were found during the screening process, none could be used directly without adaptation to Zambia. The exotic provitamin A sources did not have resistance to local diseases and were in several ways unsuitable for local use. The challenge for plant breeders was to develop new, provitamin A-rich, superior varieties by combining the excellent

---

[2]Pixley et al. (2013) and references therein address some fundamental considerations, principles, and challenges to breeding for increased provitamin A content in maize as well as the development of the first high provitamin A hybrids released in Zambia in 2012. Readers are referred to this book for a more detailed treatment of this subject.

agronomic characteristics of already successful varieties with the outstanding provitamin A concentration of unadapted sources lines. The first breeding crosses for the hybrids released in Zambia in 2012 (Table 8.2) were made in 2004 and involved the best (elite) white-grained inbred lines (not containing provitamin A) from the CIMMYT program in Harare, Zimbabwe, and temperate yellow lines with provitamin A concentrations ranging from 5 to 8 ppm that were received from T. Rocheford at the University of Illinois, USA. A step by step description of the breeding process has been provided by Pixley *et al.* [24].

Most of the breeding work up to 2009 was based entirely on phenotypic selection using high performance liquid chromatography (HPLC) to quantify carotenoids. Subsequently, genetic association mapping studies using three diverse maize germplasm panels, selected to encompass a wide range of carotenoid contents and ratios, were used to identify favorable alleles of genes encoding two key enzymes in the carotenoid biosynthetic pathway, lycopene epsilon cyclase (lycE) and beta-carotene hydroxylase 1 (crtRB1), which substantially affect the accumulation of beta-carotene in grain [27, 28, 29, 30]. By using DNA markers identified for these two enzymes, the screening of germplasm has become faster and cheaper than selection based on HPLC methodology. However, DNA markers alone cannot pick the best lines for provitaminA content and validation with HPLC is required. Germplasm carrying the favorable crtRB1 allele in homozygous form has been identified with beta-carotene concentrations up to 26 ppm and total provitamin A as high as 30 ppm. These newly identified sources of provitamin A were used to develop the second wave of hybrids, three of which were released in Zambia in 2015 (Table 8.2), and continue to be used in breeding programs to develop hybrids that meet or exceed the full 15 ppm provitamin A breeding target.

Experimental hybrids which meet or exceed the breeding target are being developed in CIMMYT and IITA breeding programs. The challenge is to identify hybrids which are not only high in provitamin A, but also superior in grain yield and agronomic performance. Fortunately, several breeding datasets and published studies have consistently shown no association between grain yield and agronomic performance with provitamin A content [31]. This suggests that breeders can meet or exceed breeding targets without compromising agronomic performance. However, the added nutritional quality traits mean that the rate of genetic gain for grain yield and agronomic performance is slower in a provitamin A maize breeding program than in a conventional breeding program focusing primarily on grain yield and agronomic performance. The disparity between non-provitamin A and provitamin A breeding programs is not surprising considering the latter has a much shorter breeding history. However,the gap will narrow with the ongoing integration of biofortification efforts in CGIAR maize breeding programs. Integration, or mainstreaming, of provitamin A maize breeding efforts into product development is currently estimated at 10% for CIMMYT‘s global maize breeding effort, 80% for the relevant mid-altitude target zone, and 40% of all IITA maize breeding.

Regional testing HarvestPlus, together with CIMMYT and NARS (National Agricultural Research System) partners in Africa, expanded regional testing and established an Elite Hybrid Trial in 2012, comprised of released hybrids and leads along with respective inbred lines. The National Agricultural Research System (NARS) in Malawi, Zimbabwe, Ethiopia, Uganda, Democratic Republic of Congo (DRC), and Rwanda test products (open-pollinated varieties [OPVs], hybrids, and inbred lines) at different stages of development depending on their needs. HarvestPlus, in concert with IITA, has also organized regional variety trials and dispatched them to partners in Benin, Ghana, Liberia, Sierra Leone, Mali, and Nigeria. Agronomic and provitamin A data from multiple sites per country allows high precision identification of promising hybrids, OPVs, and inbred lines for use in breeding, as well as higher effectiveness in targeted breeding for yield and provitamin A stability based on adaptive pattern. By using temporal-by-spatial environmental variation in large-scale regional testing, testing steps can be eliminated and time-to-market shortened by up to two years. Vitamin A maize varieties are also being tested in Brazil, China, Colombia, India, Mozambique, and Panama.

Released orange maize varieties In Zambia, six hybrid orange maize varieties have been released to date with provitamin A densities of 50-70% of the micronutrient target (Table 8.2), competitive grain yield and strong farmer preferences.

Future releases ProvitaminA levels of the 2015 releases in Zambia were at about 70% of the breeding targets. The next set of hybrids to be released, scheduled for the end of 2017, will meet or exceed the breeding target. Hybrid and open-pollinated varieties (OPVs) with 50 to 80% of the provitamin A target have been released in DRC, Ghana, Malawi, Mali, Nigeria, and Rwanda, and the first full-target variety was released in Malawi in 2016. Third-wave hybrid leads were evaluated at seven to nine sites in Zambia and Zimbabwe, and in Ghana and Nigeria during 2014/15. Further evaluation of hybrids was completed during the 2015/16 season in both southern Africa and West Africa. Most hybrids in these trials include lines carrying CrtRB1 and other alleles, with levels of provitaminA exceeding 15 ppm.

Capacity development In order to sustain and strengthen Zambian plant breeding, capacity to conduct carotenoid analysis using high-performance liquid chromatography (HPLC) has been strengthened at Zambia Agricultural Research Institute (ZARI), Mt. Makulu. Additional HPLC capacity was established at the Tropical Disease Research Centre (TDRC). To accelerate breeding at National Agricultural Research Systems (NARS) and seed companies, HarvestPlus and CIMMYT provide technical assistance and support outsourcing of provitamin A molecular marker application and the use of double haploid production.

Future Directions in Variety Development

Reducing post-harvest degradation While it has been demonstrated that reaching and exceeding the HarvestPlus breeding targets is possible with current tools, reducing post-harvest degradation of provitamin A carotenoids through plant breeding remains challenging. Beta carotene and beta cryptoxanthin, the two carotenoids with significant provitamin A activity, are susceptible to oxidation and degradation. While data is still limited, preliminary results suggest that the degradation process starts soon after physiological maturity in maize and continues through harvest and storage (N. Palacios, CIMMYT Nutritional Quality Specialist; personal communication). In addition to retention data cited earlier, breaking down the amount of losses to post-harvest storage and processing has shown that losses are not significant during grain/ear drying, but that most carotenoid degradation occurs at a fast rate during the first three months of storage, and is higher in milled grain than in whole kernels [2].

While it is clear that degradation of provitamin A carotenoids takes place in maize and that environmental factors such as oxygen and moisture are known to play a role, it is less clear if any of the degradation is enzymatic, i.e. if it is triggered by native maize genes. Data indicating that the rate of degradation is dependent on the genotype and can range from 60–90 percent after 12 months of storage suggests that some of the degradation may be enzymatic. Following this hypothesis, genetic variation for degradation could be exploited through breeding to develop hybrids with slower provitamin A degradation rates. This, however, would be a long term strategy to address this problem. In the meantime, breeders attempt to address the issue by making the provitamin A levels high enough that degradation does not lower the levels below what is required to have an impact on human health.

Breeding for beta-cryptoxanthin Selection for provitamin A in maize has emphasized beta-carotene more than beta-cryptoxanthin in both CIMMYT and IITA breeding programs. Discovery of the CrtRB1 locus and its association with beta-carotene concentration in temperate germplasm allowed breeders to double and even triple the levels of beta-carotene in tropical maize [28]. Tropical germplasm sources at CIMMYT and IITA were however higher in beta-cryptoxanthin than beta-carotene.

Historically, breeding targets for the two carotenoids were based on calculating total provitamin A as equivalent to the sum of one molecule of beta-carotene and half molecule of beta-cryptoxanthin. Recent observational, *in vitro*, animal model, and human studies, however, suggest that beta-cryptoxanthin has greater bioavailability and nutritional value than beta-carotene [32]. Preliminary data also show that beta-cryptoxanthin is less susceptible to biodegradation than beta-carotene [33]. Therefore, in hindsight, focusing on beta-carotene instead of on beta-cryptoxanthin may not have been the optimal choice in provitamin A maize breeding programs. More emphasis is now being placed on beta-cryptoxanthin, as reflected in the CIMMYT breeding program that has begun selecting for increased beta-cryptoxanthin content. Inbred lines with up to 20 ppm beta-cryptoxanthin and more than 15 ppm total provitamin A based on the formula (provitamin A = beta-carotene + 0.5 beta-cryptoxanthin) have been developed and hybrids with higher levels of beta-cryptoxanthin than current releases should be available in the next two to three years.

Open-pollinated orange maize varieties Although all products released in Zambia to date are hybrids, open-pollinated varieties (OPVs) are also being developed for those countries without a strong seed industry. The existence of a strong seed industry in Zambia influenced the decision to partner with seed companies and focus on hybrids in the development and deployment of provitamin A maize. The most successful OPVs in southern Africa are currently being converted to contain provitamin A, and release is expected in countries such as Angola and Malawi in the next 2 – 3 years.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Additional breeding for zinc In addition to breeding for provitamin A, both CIMMYT and IITA are also breeding for increased zinc content. Elite tropical maize inbred lines and hybrids with zinc content at about 90% of the breeding target of 37 ppm have been identified in these breeding programs. Hybrids and OPVs have been developed from the best inbred lines and are being evaluated in multi-location trials in Central America and West Africa. Zinc maize varieties are being tested in Angola, Colombia, Guatemala, Honduras, Mexico, and Nicaragua.

DELIVERY STRATEGIES AND RESULTS TO DATE

Biofortification delivery programs aim at sustainably integrating biofortified varieties into the seed and food systems of target countries. These strategies take into account country-specific factors such as the capacities of national agricultural systems, the characteristics of seed and food systems, and the preferences of users and consumers of the biofortified seed and food products.

Country-specific factors vary considerably between the four countries currently targeted by HarvestPlus delivery programs for orange maize. For example, maize seed systems for DRC and Nigeria are mainly informal, dominated by a few large private seed companies with significant involvement by government and community based organizations. In Zambia and Zimbabwe, seed markets are dominated by a robust private sector [34, 35]. White varieties dominate the markets in Zambia and Zimbabwe, while in DRC and Nigeria yellow, orange and red-pigmented maize varieties are also commonly accepted and regularly consumed. The delivery approach in each country and region, then, must be tailored to the existing seed systems and farmer and consumer preferences. The case of Zambia, discussed below, focuses on delivery through the private sector and to farmers who typically grow white maize.

Delivery Strategy for Orange Maize in Zambia

Delivery may be conceptualized and discussed as three broad sets of activities, which to some extent are interdependent and must be implemented simultaneously: (i) supporting seed multiplication and extension to farmers, (ii) creating and building consumer demand, and (iii) connecting supply and demand through markets. The foundation of the successful introduction of vitamin A maize in the Zambian food system and its ultimate sustainability is ***consumer demand***. However, a certain investment and momentum in the supply chain must be established before investing heavily in building consumer demand, so that consumer demand can be satisfied.

The delivery strategy for orange maize in Zambia was informed by a baseline study conducted in 2011 [36] that brought to the fore several important findings:

- The majority of maize currently produced in Zambia is white in color;
- The average land size ownership was 5 hectares per household with 2.6ha planted with white maize, achieving average yields of 3.6 metric tons per hectare;
- A majority of farmers (85%) planted hybrid varieties in the 2010 planting season;

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2 April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

- Over 50% of households consumed their own maize until the following season and only one season was utilized for crop production, from November to April of the following year (this is the only rainy season in Zambia);
- The largest market share that any one single maize variety occupied was 10%; and
- The public extension system was the most trusted and most popular source of agricultural information.

Given the above scenario, HarvestPlus developed its delivery strategy to contain the following elements:

Focus on hybrid maize Priority was given to the development of hybrid orange maize varieties. The choice for hybrid varieties was motivated by the fact that at least 85% of maize growers use hybrid seed. The remaining smallholder producers rely on recycled local open pollinated varieties (OPVs), which yield less than half that of hybrids [37, 37].

Government support Considering that maize is the most important and a highly politicized crop in Zambia, creating government support and ownership for orange maize was a crucial element in the development and delivery strategy. HarvestPlus utilized the following approaches:

*Partnership with the Zambia Agricultural Research Institute (ZARI):*HarvestPlus formalized its partnership in 2009 with ZARI, a national government research organization, to expand local breeding and testing of orange maize. The Zambia Agricultural Research Institute (ZARI) took responsibility for the release of the first wave of three varieties of orange maize hybrids as well as licensing of the varieties to seed companies for commercialization.

Partnership with the Department of Agriculture: As with ZARI, HarvestPlus forged a strong link with the Department of Agriculture (Extension Services and the Food and Nutrition Directorates). The Extension Services, which run over a thousand extension camps servicing over 1.5 million smallholder farming households, became the main agent in the promotion of orange maize. Working with lead farmers, extension officers started orange maize demonstration plots in selected extension camps to deliver knowledge on agronomic practices and to demonstrate crop performance in comparison to existing white maize varieties. The Food and Nutrition Directorate developed training manuals and conducted training programmes for agricultural staff and farmers on nutrition benefits, utilization, and post-harvest handling. HarvestPlus provided technical support and back-stopping.

Influencing government policy: HarvestPlus encouraged the government to allow orange maize to enjoy similar policy benefits as white maize. In due course, government included orange maize seed under the Farmer Input Support Programme (FISP), which provides at leasta 50% subsidy for maize seed and fertilizer to farmers considered economically disadvantaged ("vulnerable but viable"). The quantity of orange maize seed distributed under this government scheme grew by 400% over two years. In addition, HarvestPlus and its partners continue to work with government for the inclusion

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

of vitamin A maize grain on the list of crops procured by the Food Reserve Agency (FRA), a government parastatal with an extensive nation-wide procurement network for agricultural commodities.

Through HarvestPlus advocacy initiatives, consumption of biofortified crops (orange maize, orange sweet potato, high-iron and zinc beans) is recognized as an important food-based intervention to combat micronutrient deficiencies. Biofortification is included in the National Food and Nutrition Strategic Plans advocated by the National Food and Nutrition Commission of the Ministry of Health.

The strategy to create government ownership and support for orange maize was crucial in facilitating widespread acceptance of a new crop in the short-term, because farming communities in Zambia have a high degree of trust in government-supported initiatives.

Licensing to private seed companies Because private seed companies dominate the hybrid maize seed market in Zambia, the biofortified varieties were licensed to private seed companies for commercialization of seed production and distribution. This strategy improves the prospects for sustainable seed production and distribution. The private seed companies that were assigned the first three orange maize varieties had a combined market share of over 50% in the maize seed industry. The seed companies produce and distribute quality orange maize seed through their extensive network of agro-dealer outlets in the country. While commercialization is the responsibility of private seed companies, HarvestPlus plays an active role in seed bulking of parental lines, improving distribution systems, and promotions to enhance seed access by farmers. HarvestPlus is also working with agro-dealers to strengthen their nutrition knowledge and improve their ability to serve as agronomic advisers to farmers.

According to a survey of agro-dealers conducted after the 2014/15 growing season, agro-dealers believe that there is a promising future for large-scale adoption of vitamin A maize in Zambia, provided that there is demand for vitamin A maize grain from entities like the FRA and commercial millers [38]. Agro-dealers also noted the need for more awareness-raising among farmers and the general public about the nutritional benefits of vitamin A maize, and for a wider variety of seed pack sizes to allow farmers to try growing small amounts of vitamin A maize before committing to more extensive cultivation.

As biofortified maize is scaled up to reach more households in more provinces, the main challenge is to ensure extensive distribution of vitamin A maize seed in outlying agro-dealer outlets and to inform farmers of seed availability. Because many rural households purchasing from agro-dealers cannot afford large quantities of seed, HarvestPlus is working with the private seed companies to ensure that large quantities of affordable pack sizes will be available. HarvestPlus is also partnering with the Zambia National Farmers Union to disseminate information to farmers about the availability of vitamin A maize seed in their local areas, and will provide agro-dealer outlets with printed materials to advertise the availability of orange maize seed.

DOI: 10.18697/ajfand.78.HarvestPlus08

Involving the NGO sector HarvestPlus also sought the buy-in of various non-governmental organizations (NGOs) and civil society organizations to promote and popularize orange maize. A partnership platform encourages collaboration and advocacy activities, and offers NGO partners a venue for sharing lessons learned through delivery. While the majority of the seed in Zambia is distributed through FISP or agro-dealers, NGOs are uniquely positioned to facilitate access to orange maize seed for vulnerable households. Many NGOs run assistance programs that provide cash and input credit to farmers to facilitate the purchase of inputs, and working with NGOs ensures that farmers receive the nutrition message together with the seed. The NGO channel is also important for ensuring that women have access to vitamin A maize seed, as previous studies have indicated that traveling a long distance to buy seed is a barrier for women farmers. Value addition training programs are also conducted through women's groups, with the aim of providing women with recipes to improve household diets and also products for sale to improve household incomes.

Creating markets and linking farmers to markets To further stimulate adoption of orange maize, it became apparent that creating markets for surplus production was essential, considering that 20 to 50% of rural households sell maize after satisfying their own food needs. Furthermore, orange maize is a hybrid crop that requires purchase of new seed and fertilizer every season if farmers are to realize its full yield potential. Therefore, it is expected that farmers would want to recoup their production costs by selling their surplus production.

HarvestPlus, therefore, embarked on the expansion of grain markets for orange maize by linking two major grain buyers to farmers. HarvestPlus worked to motivate millers and food processorsto incorporate orange maize in their product lines. Initial large quantities of orange maize grain were offered for free to millers and food processors for testing. In all cases, participating millers and food processors found orange maize appealing and a suitable addition to their product lines. Consequently, two commercial food processors added orange maize to their product lines and sought to buy the grain from farmers, while an initial number of four large-scale industrial millers incorporated orange maize into their food product lines, which supply major retail chain shops in urban centers.

Industrial millers are interested in orange maize if the grain can be purchased at the same price as white maize. The medium- and large-scale millers that currently process white maize rely on the government for the cost of handling, transporting, and storing these varieties. To incentivize millers to create demand for orange maize, the multilateral AgResults Initiative, which is jointly financed by the Bill & Melinda Gates Foundation and the governments of Australia, Canada, the United Kingdom, and the United States, piloted performance-based grants to millers to offset the initial costs of milling and marketing vitamin A maize products. Commencing in 2014 and working directly through the industrial millers to stimulate a market for orange maize products, the AgResults Zambia Biofortified Maize Pilot Project is expected to fundamentally change the consumption preferences and buying habits of a sizeable number of Zambian consumers**.** It is expected that the program will directly deliver 128,000 metric tons of vitamin A maize to roughly 560,000 consumers over four years, and consumers will receive an additional 124 µg of provitamin A per day. HarvestPlus collaborates with the AgResults

Zambia Biofortified Maize Pilot Project to distribute vitamin A maize seed to smallholder farmers and farmer groups.

In addition to advocating for inclusion of orange maize in the government's Food Reserve Agency purchasing program, HarvestPlus continues to identify commodity markets where farmers can sell their orange maize. Emerging grain markets, coupled with information on the nutritional benefits of the crop, result in demand for seed in rural retail agro-dealer outlets. To strengthen these markets, HarvestPlus continues to offer interested processors and merchants sample quantities of grain to test as inputs for their product lines.

Strengthening consumer demand As part of the consumer acceptance studies, two sources of media were tested to convey the nutrition message: simulated radio messaging and community leaders. The study revealed that consumers who received the information through radio and those who received it through face-to-face interactions with community leaders showed similar willingness to pay for orange maize. This implies that radio broadcasting, which is significantly less costly than face- to-face message delivery, can effectively deliver nutrition information. Supporting the use of radio, a varietal adoption study conducted in the major maize growing provinces (Central, Copperbelt, Eastern, Lusaka, Northern, and Southern Province) revealed that 75% of maize farmers owned a radio; 60% listened to the radio daily and 19% weekly; and 86% cited radio as their most important source of agricultural and health information [37].

A survey of maize farmers in Eastern Province, conducted after the 2014/15 growing season, found that more than 80% of vitamin A maize growers cited the nutritional benefit as the primary reason for growing vitamin A maize [39]. Cooperatives and women's groups were major sources of information for the farmers surveyed, suggesting that these groups will continue to be important segments for promoting production and consumption of vitamin A maize. Hence HarvestPlus activities intentionally emphasized benefits for women and children. Women are essential in agricultural production, especially for subsistence production of maize. Most Zambian farmers are smallholder producers with women mainly providing the labor for cultivation of subsistence crops such as maize. In addition, there are growing numbers of female- headed households, due to the death of a spouse and because of the high rate of male out-migration for off-farm employment. Many households may technically have a male household head but who is absent and so, in reality,they have a *de facto* female head who is making the critical decisions in the production cycle. In addition, women are primarily responsible for provisioning the foods, preparing meals, and feeding young children – in essence, in charge of preparing food for consumption as well as most of the production.

Children are the segment of the Zambian population that would most directly benefit from routine consumption of vitamin A rich maize, especially those between 6 and 60 months of age, when the risk of under nutrition and mortality is most significant. The foods consumed by children are controlled by their mothers, so it makes sense to use women farmers as the primary target group for the introduction of vitamin A maize, with the messages focusing on its healthy benefits for their children. It is envisaged that

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2 April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

mothers will subistitute orange maize for white in the prepartion of children's porridge, which is the common weaning food in Zambia.
A central element of the delivery strategy is to create awareness and acceptance of orange maize through the use of social marketing campaigns and advertisements placed in public media, including TV, radio, newspapers, and popular music, and at agricultural exhibitions as well as to train partner groups and agro-dealers on more extensive nutrition messaging. Educational and awareness-creation activities stimulate consumer demand for orange maize products.

Delivery Results and Future Plans
Since the official release of the first vitamin A maize varieties in 2012, HarvestPlus and its partners have been working to scale up delivery. HarvestPlus achieved the following milestones within the first three years of delivery (2012-2015):

- A supply of 400 metric tons of seeds marketed;
- Over 100,000 farmers producing orange maize;
- Participation of five milling companies in the buying and milling of grain to supply orange maize meal in the retail shops for the first time in Zambia; and
- A private food processing company has developed orange maize-based infant and young children instant porridge.

The early success in the uptake of the crop in Zambia can be attributed largely to the consumption and production attributes of orange maize. In addition to the consumer acceptance studies outlined earlier in this article, unpublished studies that followed the official release of orange maize in Zambia indicated that, based on sensory characteristics of both freshly boiled maize and nshima, orange maize was superior to white maize. A participatory evaluation of biofortified orange maize varieties during farmer field days revealed a strong appreciation for both the agronomic (that is, production) and the sensory (that is, consumption) qualities of biofortified orange maize, compared with the conventional white varieties. Farmers appreciated the yield, cob size, and cob-filling characteristics of the varieties, as well as the taste and aroma of the orange maize preparations during the field days [39]. The varieties released to date are of medium maturation, a trait which farmers like because they are adaptable to the shortened rainfall season arising from climate change.

As in other countries, there is a tension between promoting nutrition and consumption at the level of the farming household and strengthening markets such that farmers may prefer to sell their vitamin A maize grain. A careful rollout and scale up of vitamin A maize has mitigated these concerns to some extent, but must continue to be monitored as consumers demand more vitamin A maize products.

Looking ahead, HarvestPlus is striving to achieve the following by 2020:

- Popularize orange maize to the extent that it gains at least 10% market share on the seed market. This is the maximum market share that any single maize variety occupies in Zambia.

- Ensure that over half a million Zambian farmers are growing and consuming orange maize. This figure will represent one third of the total number of smallholder farmers in Zambia.

MONITORING AND MEASURING IMPACT

Monitoring

HarvestPlus and partner staff regularly collect and report on process, output, and outcome indicators. All data from the monitoring system is disaggregated to improve its usefulness for planning. Wherever necessary, data is disaggregated by gender, distribution channel, variety, and geographic region.

The objectives of the Monitoring, Learning, and Action (MLA) system are to:

(i) Contribute to and set the basis for accountability for management, donors, and other stakeholders; and

(ii) Generate and share delivery progress data and results that feed into evidence-supported operational decision making, business planning, communication, and advocacy messaging.

The MLA systems captures data on seed sales, grain production and marketing, which are used to advise the private sector on areas requiring improvement in terms of seed distribution to improve farmer access to seed as well to inform grain buyers on sources of grain.

A Zambia vitamin A maize forecasting model is currently being developed. The model will be used to estimate values for three impact indicators:

(i) Percent of expected average requirement (EAR) delivered;

(ii) Change in prevalence of inadequate intake of target micronutrient in project intervention areas; and

(iii) Number of disability-adjusted life years (DALYs) averted.

The forecasting model seeks to consistently model what has been achieved to date and to forecast future outcome and impact variables for medium-term strategies of the country programs.

Impact Assessment

A small-scale impact assessment study was conducted in 2015 in Eastern Province following the first season of large scale orange maize seed sales, promotion and delivery activities. The results suggested that the first wave of vitamin A maize growers liked the production and consumption traits of vitamin A maize, as much as, if not more than those of the white hybrid varieties [39]. The agronomic characteristics (for example, yield) of vitamin A orange maize was comparable to white maize, while orange maize scored higher in terms of consumption attributes, such as taste. Almost all, 97%, of orange maize growers stated that they wanted to plant orange maize in the coming season. Orange maize growers recommended the variety to 10 others and gave the grain to 4 others in their networks. The study shows that the vitamin A maize varieties are liked by farmers and the seed supply needs to be increased in the subsequent seasons.

The study found that first time growers prefer to try small seed pack sizes and also want timely delivery of orange maize seed. Therefore, the supply side (seed companies) are advised to avail small seed pack sizes (especially in areas where the orange maize will be introduced for the first time) and the delivery agents should be cognizant of the ever-changing maize planting time in different areas of the country.

The impact assessment also found that the main determinant of growing orange maize is availability of a market for the grain. The success of efforts to generate demand for orange maize, such as the inclusion of orange maize in the Food Reserve Agency (FRA) acquisitions and facilitation of medium and large scale processors' acquisition and processing of orange maize for the urban market (for example, through the AgResults project), are pivotal for the sustained adoption.

Finally, this study revealed that farmers' main source of information about the new varieties is the agro-dealers. It is very important for agro-dealers to be trained about the nutritional benefits of vitamin A maize.

CONCLUSIONS, LESSONS LEARNED, AND WAY FORWARD

Through the development and delivery of orange maize in Zambia, HarvestPlus has established the proof of concept that vitamin A maize varieties can be developed without compromising yield levels and that these varieties can deliver sufficient quantities of micronutrients to improve nutrition. It has also shown that farmers are willing to grow orange maize varieties and consumers are willing to buy and eat the products. In 2015, about 100,000 farming households were growing orange maize, and several companies actively marketed and processed orange maize seed and orange maize food products.

Lessons Learned

Over the last years, the breeding and delivery programs of HarvestPlus and its partners have gathered experience and synthesized several lessons learned, some of which are described below.

Since the hybrid maize seed market in Zambia is firmly in private sector hands, seed and food processing companies needed to be encouraged to adopt orange maize in order to allow for cost-effective and sustainable orange maize delivery. This was done through public-private partnerships also including the government to increase ownership and sustainability. For example, co-branding was used as a tool to create an alliance between HarvestPlus, Government and the private sector. Co-branding also allowed farmers and consumers to associate orange maize with the government and Zambian companies, resulting in acceptance of the product as a proudly Zambian product; the logos on the in-store packages immediately created a visible identity of the product in terms of ownership as is depicted in Figure 8.3 below.

Logo 1: Milling Company;

Logo 2: Zambia Agriculture Research Institute (ZARI);

and Logo 3: HarvestPlus

Figure 8.3: Vitamin A Maize Package Depicting Three Logos

The visible color difference to established white maize varieties required that promotion actively addressed the nutrient benefits of orange maize. In Zambia, the optical similarity of orange to unfavorably reputed yellow maize required clearly positioning orange maize as a separate product.

Two tools were of particular use in orange maize promotion. First, enlisting opinion leaders as champions for provitamin A orange maize. Opinion leaders included traditional leaders such as tribal chiefs and political leaders. For instance, the tribal leader from Eastern Province of Zambia became the first adopter and largest grower of orange maize in Zambia. His influence among his subjects resulted in the Eastern province taking the lead in biofortified maize production in Zambia during the first three years.

Second, undertaking widespread food tasting fairs whereby orange maize nshima was served to consumers to prove its superior taste. For example, HarvestPlus offered a free orange maize lunch in the Parliament's cafeteria to expose parliamentarians to the new food product. Food tasting events were effective in convincing consumers that orange maize tasted as good as, if not better than, the traditional white maize.

The Way Forward

Future delivery of orange maize in Zambia hinges on the degree to which seed and food companies can establish and operate profitable orange maize-based businesses. This, in turn, depends on how competitive future orange maize varieties are agronomically, and how the value-added orange maize products perceived by consumers. Marketing for orange maize in Zambia thus aims at building a robust "orange" umbrella brand that clearly differentiates orange from yellow maize as grain and as a food product. Long-term sustainability will be further addressed by assisting seed companies in developing their own plant breeding capabilities so that the future orange maize varieties can be developed without the involvement of HarvestPlus.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2
April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 8.1: Nutrition target setting for orange maize

	Children 4-6 years	Non-pregnant, non-lactating women
Estimated Average Requirement (EAR) of bioavailable retinol (micrograms per day)	275	500
Preliminary provitamin A (beta-carotene equivalents) target density (parts per million)	+15	
Average daily maize consumption (grams dry weight)	172	287
Provitamin A retention – composite of storage and cooking (percent)	37%	
Provitamin A bioavailability and conversion (beta-carotene: retinol)	6:1	
Percentage of the EAR provided through increased provitamin A content of +15 ppm (full target)	59	54

Table 8.2: Orange Maize varieties released in Zambia

Variety Name	Year of release	Seed Company	Maturity days	Prov A content (ppm)	Average yield under smallholder management Mt/ha	Grain Type	Disease resistance		
							GLS	LB	Cob Rot
GV 662 A	2012	Kamano Seed	115-125	7	4	Semi flint, orange	G	VG	VG
GV 664 A	2012	Zamseed Seed	115-125	7	4-5	Semi dent, orange	G	VG	VG
GV 665 A	2012	SeedCo	115-125	8	4	Flint, orange	VG	VG	VG
GV671A	2015	Not assigned	115-125	11	4-5	Flint, orange	VG	VG	VG
GV672A	2015	Not assigned	115-125	9	4-5	Flint, orange	VG	VG	VG
GV673A	2015	Not assigned	115-125	9	4-5	Flint, orange	VG	VG	VG

GLS: Gray leaf spot; LB: Leaf blight; G: Good; VG: Very good

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

REFERENCES

1. **Micronutrient Operational Strategies and Technologies (MOST), United Nations Children's Fund (UNICEF), Centers for Disease Control and Prevention, Food and Nutrition Commission of Zambia, and University of Zambia.** Report of the national survey to evaluate the impact of vitamin A interventions in Zambia, July and November 2003.

2. **World Health Organiztion (WHO).** Global Prevalence of Vitamin A Deficiency in Populations at Risk 1995–2005. WHO Global Database on Vitamin A Deficiency. Geneva: WHO, 2009.

3. **Haskell MJ** The Challenge to Reach Nutritional Adequacy for Vitamin A: β-carotene Bioavailability and Conversion—Evidence in Humans. *Am. J. Clin. Nutr*. 2012; 96(5): 1193S-1203S.

4. **Central Statistical Office (CSO) [Zambia], Ministry of Health (MOH) [Zambia], and ICF International.** Zambia Demographic and Health Survey 2013-14. Rockville, Maryland, USA: Central Statistical Office, Ministry of Health, and ICF International, 2014.

5. **Lividini K and JL Fiedler** Assessing the promise of biofortification: A case study of high provitamin A maize in Zambia. Food Policy, 2015; **54**: 65–77.

6. **Blankenship J and J Gorstein** Landscape Analysis of Vitamin A Deficiency Control Programs in Zambia. 2014. National Food and Nutrition Commission – Zambia and HarvestPlus – Washington DC.

7. **Fiedler JL and K Lividini** Managing the Vitamin A Program Portfolio: A Case Study of Zambia, 2013-2042. *Food Nutr Bull*, 2014; ***35*****(1):**105-25.

8. **Central Statistical Office (CSO) [Zambia], Ministry of Health (MOH) [Zambia], and ICF International.** Zambia Demographic and Health Survey 2013-14. Rockville, Maryland, USDA: Central Statistical Office, Ministry of Health, and ICF International, 2014.

9. **Japan Association for International Collaboration of Agriculture and Forestry (JAICAF).** The Maize in Zambia and Malawi. 2008 Retrieved from http://www.jaicaf.or.jp/publications/Zambia.pdf Accessed June 2016.

10. **Jayne TS, Zulu B, Kajoba G, and MT Weber** Access to Land and Poverty Reduction in Rural Zambia: Connecting the Policy Issues. FSRP Working Paper No. 34. Lusaka: FSRP, 2009.

11. **Zulu B, Jayne TS and M Beaver** Smallholder Household Production and Marketing Behaviour in Zambia: Implications for Policy. FSRP Working Paper No. 22. Lusaka: FSRP, 2007.

12. **De Groote H, Gitonga Z, Smale M, Kasuta E, Asare-Marfo D, Sonder K and E Birol** Adoption and Diversification of Modern Maize Varieties in Zambia in 2011: A Baseline Report. HarvestPlus, Washington, DC, 2011.

13. **Hotz C, Palaniappan U, Chileshe J, Kafwembe E and W Siamusantu** Nutrition Survey in Central and Eastern Provinces, Zambia 2009: Focus on Vitamin A and Maize Intakes, and Vitamin A Status among Women and Children. HarvestPlus, Washington, DC, 2011.

14. **Mugode L, Ha B, Kaunda A, Sikombe T, Phiri S, Mutale R, Davis C, Tanumihardjo S and FF De Moura** Carotenoid Retention of Biofortified Provitamin A Maize (*Zea mays* L.) after Zambian Traditional Methods of Milling, Cooking and Storage. *J. Agric. Food Chem.* 2014; **62**: 6317–6325.

15. **Li S, Tayie FA, Young MF, Rocheford T and WS White** Retention of Provitamin A Carotenoids in High β-carotene Maize (*Zea mays*) during Traditional African Household Processing. *J. Agric. Food Chem.* 2007; **55**: 10744–10750.

16. **Muzhingi T, Gadaga TH, Siwela AH, Grusak MA, Russell RM and G Tang** Yellow Maize with High β-carotene is an Effective Source of Vitamin A in Healthy Zimbabwean Men. *Am. J. Clin. Nutr.*2011; **94**: 510–519.

17. **Gannon B, Kaliwile C, Arscott SA, Schmaelzle S, Chileshe J, Klungwana N, Mosonda M, Pixley K, Masi C and SA Tanumihardjo** Biofortified Orange Maize is as Efficacious as a Vitamin A Supplement in Zambian Children Even in the Presence of High Liver Reserves of Vitamin A: A Community-based, Randomized Placebo-Controlled Trial. *Am J Clin Nutr.* 2014; **100(6)**: 1541-1550.

18. **Palmer A, Siamusantu W, Chileshe J, Schulze K, Barffour M, Craft, N, Molobeka N, Kalungwana N, Arguello M, Maithilee M, Caswell B, Klemm R and KP West Jr** Provitamin A-Biofortified Maize Increases Serum Β-Carotene but not Retinol in Marginally Nourished Children: A Cluster-Randomized Trial in Rural Zambia. *Am J ClinNutr* 2016; **104**: 181-190.

19. **Muzhingi T, Langyintuo AS, Malaba LC and M Banziger** Consumer Acceptability of Yellow Maize Products in Zimbabwe. *Food Policy* 2008; **33**: 352–361.

20. **Meenakshi JV, Banerji A, Manyong V, Tomlins K, Mittal N and P Hamukwala** Using a Discrete Choice Experiment to Elicit the Demand for a Nutritious Food: Willingness-to-pay for Orange Maize in Rural Zambia. *J. Health Econ.*2012; **31**: 62–71.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 17 No. 2 April 2017 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

21. **Tomlins K, DeGroote H, Haleegoah J, Ewool M, NsiahFrimpong B, Chowdhury ABS and JV Meenakshi** Evaluation of Hedonic and Willingness-to-pay Behaviour Patterns (With and Without Nutrition Information) of Consumers Who Evaluated a Product with Differing Vitamin A Contents. HarvestPlus Working Paper. Washington, DC: International Food Policy Research Institute, 2014.

22. **Asare-Marfo D, Birol E, Gonzalez C, Moursi M, Perez S, Schwarz J and M Zeller** Prioritizing Countries for Biofortification Interventions Using Country-Level Data. HarvestPlus Working Paper No. 11. International Food Policy ResearchInstitute, HarvestPlus, Washington, DC, 2013.

23. **Bouis H and R Welch** Biofortification – A Sustainable Agricultural Strategy for Reducing Micronutrient Malnutrition in the Global South. *Crop Sci*. 2010; **50**: S20–S32.

24. **Pixley K, Palacios Rojas N, Babu R, Mutale R, Surles R and E Simpungwe** Biofortification of Maize with Provitamin A Carotenoids. **In:** Tanumihardjo SA (Ed.). Carotenoids and Human Health. Totowa, New Jersey: Humana Press, 2013: 271–292.

25. **Menkir A, Liu W, White WS, Maziya-Dixon B and T Rocheford** Carotenoid Diversity in Tropical-Adapted Yellow Maize Inbred Lines. *Food Chem*. 2008; **109**: 521–529.

26. **Menkir A, Pixley K, Maziya-Dixon B and M Gedil** Recent Advances in Breeding Maize for Enhanced Pro-Vitamin A Content. **In:** Worku M, Twumasi-Afriyie S, Wolde L, Tadesse B, Demisie G, Bogale G, Wegary D, and BM Prasanna (Eds.). Meeting the Challenges of Global Climate Change and Food Security through Innovative Maize Research. Addis Ababa: National Maize Workshop of Ethiopia, 2012.

27. **Harjes CE, Rocheford TR, Bai L, Brutnell TP, Kandianis CB, Sowinski SG, Stapleton AE, Vallabhaeneni R, Williams M, Wurtzel ET, Yan J and ES Buckler** Natural Genetic Variation in Lycopene Epsilon Cyclase Tapped for Maize Biofortification. *Science* 2008; **319(5861)**: 330-333.

28. **Yan J, Kandianis CB, Harjes CE, Bai L, Kim EH, Yang X, Skinner DJ, Fu Z, Mitchell S and Q Li** Rare Genetic Variation at *Zea mays* crtRB1 Increases [beta]-carotene in Maize Grain. *Nat. Genet.*2010; **42**: 322–327.

29. **Kandianis CB, Stevens R, Liu W, Palacios N, Montgomery K, Pixley K, White WS and T Rocheford** Genetic Architecture Controlling Variation in Grain Carotenoid Composition and Concentrations in Two Maize Populations. *Theor. Appl. Genet*. 2013; **126**: 2879–2895.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 17 No. 2 April 2017
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

30. **Babu R, Rojas NP, Gao S, Yan J, and K Pixley** Validation of the Effects of Molecular Marker Polymorphisms in LcyE and CrtRB1 on Provitamin A Concentrations for 26 Tropical Maize Populations. *Theor. Appl. Genet.* 2013; **126**: 389–399.

31. **Suwarno WB, Pixley K, Palacios-Rojas N, Kaeppler SM and R Babu** Formation of Heterotic Groups and Understanding of Genetic Effects in a Provitamin A Biofortified Breeding Program. *Crop Sci* 2004; **54**: 14-24.

32. **Burri BJ** Beta-cryptoxanthin as a Source of Vitamin A. *J. of the Sci. of Food and Agric.* 2015; **95**: 1786-1794.

33. **Palacios N**, CIMMYT, unpublished data, May 2016.

34. **Smale M, Simpungwe E, Birol E, Kassie GT, de Groote H and R** Mutale The Changing Structure of the Maize Seed Industry in Zambia: Prospects for Orange Maize. *Agribusiness* 2015; **31**: 132–146.

35. **Tahirou A, Sanogo D, Langyintuo A, Bamire SA and A Olanrewaju** Assessing the Constraints Affecting Production and Deployment of Maize Seed in DTMA Countries of West Africa. Ibadan, Nigeria: International Institute for Tropical Agriculture, 2009.

36. **De Groote H, Gitonga Z, Smale M, Kasuta E, Asare-Marfo D, Sonder K and E Birol** Adoption and Diversification of Modern Maize Varieties in Zambia in 2011: A Baseline Report Prepared for HarvestPlus. Washington, DC: International Food Policy Research Institute, HarvestPlus, 2012.

37. **M Smale and E Birol** Smallholder Demand for Maize Hybrids and Selective Seed Subsidies in Zambia HarvestPlus Working Paper No. 9. Washington, DC: International Food Policy Research Institute, HarvestPlus, 2013.

38. **Diressie MT, Zulu E, Smale M, Simpungwe E and E Birol** An Assessment of the Vitamin A Maize Seed Delivery Efforts to Date: Agro-dealer Sales and Farmer Production in Zambia. Washington, DC: International Food Policy Research Institute, HarvestPlus, 2016.

39. **Chibwe E, De Groote H, Gitonga Z and E Birol** A Participatory Evaluation of Vitamin A Biofortified Maize in Zambia. Washington, DC: International Food Policy Research Institute, HarvestPlus, 2013.