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Assessing the promise of biofortification: A case study of high provitamin A maize in Zambia

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A B S T R A C T

Introduction: Biofortification is the breeding of new varieties of staple foods for increased micronutrient content. It is seen primarily as a complementary, rural-targeted strategy for better reaching remote populations. This paper presents an *ex ante* analysis of HarvestPlus' provitamin A maize (PVAM) in Zambia and highlights an empirical approach based on the Zambian 2005/06 Living Conditions Monitoring Survey (LCMS). Because more than 115 countries regularly conduct a Household Consumption and Expenditure Survey (HCES), the approach developed in this LCMS-based study can be applied in many other countries to analyze varietal adoption and conduct *ex ante* studies.
Methods: Data from the LCMS and health statistics were used to characterize baseline indicators of vitamin A intake and Disability Adjusted Life Years (DALYs) lost. The introduction and scaling up of PVAM was modeled based on program plans, expert opinion and data on key adoption parameters. An adoption function was specified and expressed in terms of the percent of farmers expected to adopt PVAM over the next 30 years. A logistic regression adoption function was estimated and used to identify the specific LCMS households adopting, producing and consuming PVAM each year. Information from the IFPRI International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) of yearly maize production and demand were used to produce annual estimates of PVAM planted, harvested and consumed. Taking into account an LCMS-empirically-informed, specified market structure, individuals' additional vitamin A intake was calculated. The number of DALYs saved were estimated using the change in vitamin A intake. Combining these estimates with cost data, the cost-effectiveness of PVAM was calculated.
Results: Assuming an adoption ceiling of 20% over 30 years, implementation of PVAM will result in average additional intake of 12% of the Estimated Average Requirement (EAR), a 3 percentage point reduction in the prevalence of inadequate intake, and savings of 23% of total DALYs. Impacts are concentrated among farming households that have adopted PVAM and consume it from their own production. Their consumption will result in an average additional vitamin A intake of 172 μg/day, more than 3 times the additional 54 μg/day among the entire population. Among this group, the reduction in the prevalence of inadequate intake will be more than 5 times the national average (17.5 percentage points). Valuing a DALY at $1000, PVAM's cumulative value of DALYs saved comes to exceed its cumulative total costs starting in 2019. Over 30 years the cost-effectiveness of PVAM in Zambia was estimated to be $24 per DALY saved, making it very cost-effective.
Conclusion: The methodologies employed in this study provide insights and inputs that can be used to target farmers who are most likely to adopt, to measure their vitamin A intake and to craft messages to promote adoption. PVAM is a long term investment that shows great promise in becoming a highly cost-effective addition to the public health arsenal for combatting micronutrient deficiencies if the 20% adoption rate can be achieved and maintained. Doing so will require effective marketing strategies, including efforts to couple this nutrition-sensitive intervention with nutrition-specific activities, such as targeted nutrition messaging and education, in order to increase the likelihood that adopting farmers will prioritize production for home consumption.

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Introduction

Between 1990 and 2010, the global burden of micronutrient deficiencies fell by more than half (Wang et al., 2012). Among vitamin A, iron and zinc deficiencies, the largest disease burden reductions were in the burden of vitamin A, yet it still accounts for the greatest disease burden among these three deficiencies. Despite these positive trends, micronutrient deficiencies remain major public health problems and still rank among the top causes of death and disability, particularly in Sub-Saharan Africa (Lim et al., 2012). Globally, the micronutrient disease burden is shouldered disproportionately by a highly vulnerable group in the most vulnerable countries—children under 5 years of age in sub-Saharan Africa.

Data on Zambian nutrition status, and particularly on vitamin A, is dated. That which is available shows the prevalence of vitamin A deficiency (VAD) has remained persistently and unacceptably high. According to the most recent nationally representative survey, 53% of children 6–59 months old are VAD (MOST, 2003)—a level well above the 20% threshold WHO uses to define when deficiencies constitute a public health problem—and among non-pregnant women of childbearing age (15–49 years) VAD was found to be 13.4%. These most recent available data are 12 years old, suggesting that there is considerable uncertainty about the current situation.

Over the past 15 years, Zambia has made and maintained major commitments to a number of nutrition programs. It has been a pioneer in what have come to be the key programmatic foundations of nutrition policy in the developing world. In 1998, it became the first country in Africa to fortify sugar with vitamin A (Fiedler et al., 2013a), and in 1999 it became the first country in Africa to implement what has come to be known as Child Health Week/Child Health Days (UNICEF, 2011). Child Health Weeks (CHW) are large-scale, mass mobilization-based events undertaken semi-annually to provide an integrated package of high impact child health and nutrition interventions, including vitamin A supplementation, de-worming and vaccinations, growth monitoring and promotion and, intermittently, the distribution of or re-impregnation of insecticide-treated mosquito nets (Fiedler et al., 2012b). From its inception, CHW has been a priority program of the MOH and has achieved high rates of coverage. Still, Zambia's pace of progress in improving nutrition status has been slow, particularly among young children among whom the prevalence rates of VAD is thought to remain high (NFNC, 2010).[1] We estimate that VAD is annually responsible for roughly 3700 lost lives and nearly 110,000 disability adjusted life-years (DALYs) in Zambia.

In addition to Zambia's established portfolio of VAD control programs—which, since 1998, has consisted of CHW and sugar fortification—the country has other options for combating VAD. While not mandated, wheat flour and maize meal fortification programs are under active consideration by the Zambian government which has drafted regulations for their fortification levels (Fiedler et al., 2013a). Vitamin A-fortification of vegetable oil is another possibility, but one that the country has yet to consider. The most recent addition to Zambia's VAD control portfolio is biofortification – the production and consumption of varieties of maize that contain increased levels of provitamin A.

Biofortification is the breeding of new varieties of staple foods for increased macro- and micronutrient content (Bouis et al., 2011). It is seen primarily as a complementary, rural-targeted micronutrient program strategy for better reaching remote populations, which often comprise the majority of the malnourished. Biofortification is the latest micronutrient intervention strategy, with the first releases of biofortified varieties having begun in just the last five years (Gilligan, 2012).

HarvestPlus – a global consortium co-led by the International Food Policy Research Institute and the International Center for Tropical Agriculture – has promoted and released seven, conventionally bred, biofortified crops in 13 countries, and has established an accelerating rate of progress in both the number of countries and the varieties with which it is working (Saltzman et al., 2012). Until 2012, HarvestPlus worked in only Sub-Saharan Africa and South Asia. Starting that year, it teamed with AGROSALUD, a program working to improve the nutrition content of food staples in Latin American and the Caribbean (AgroSalud, 2011). While there are a number of other organizations working on the development of biofortified staples, to date only HarvestPlus has begun actually distributing new varieties. Other efforts include four projects that use genetic engineering and have targeted bananas, cassava, rice and sorghum: Golden Rice Project (2011), Bio-cassava Plus (Sayre et al., 2011), African Biofortified Sorghum (ABS, 2010) and Better Bananas for Africa (QUT, 2011). In addition, there are three smaller, more specialized projects (INSTAPA, 2011; BAGELS, 2008; HarvestZinc, 2011).[2]

This paper presents an *ex ante* analysis of one of the HarvestPlus projects, Zambia's provitamin A maize (PVAM). Since the 1960s, over 60% of the total agricultural area planted in major crops (i.e., sugarcane, rice, wheat, cassava, maize, potatoes, sorghum, and soybeans) in Zambia has been planted in maize (JAICAF, 2008). Maize dominates the Zambian diet, accounting for more than half of available dietary energy (FAO, 2012). The biofortification of maize in Zambia provides an ideal case study for better understanding the potential of biofortification and the key factors that condition its impact. The objectives of this *ex ante* impact study are to analyze the costs and health benefits of PVAM in order to assess its promise as an investment and to estimate its cost-effectiveness to enable readily comparing it to alternative health investments.

This study highlights a data-driven, highly contextualized approach based on the Zambian 2005/06 Living Conditions Monitoring Survey (LCMS) (CSO, 2011). The LCMS is a large scale, recurrent, multi-purpose, nationally representative household survey, very similar to a number of other such surveys that are commonly conducted throughout the world (e.g., household budget surveys, integrated household surveys, household income and expenditure surveys and living conditions monitoring surveys), which together have been referred to as "household consumption and expenditure surveys" or HCES (Fiedler et al., 2012a). More than 115 countries regularly conduct an HCES (Dupreiz et al., 2014). The approach developed in this LCMS-based study, therefore—which features empirically developing many of the program and market parameters—can be applied in many other countries to analyze varietal adoption and conduct *ex ante* studies. To facilitate others replicating the approach, we provide considerable detail about several of the empirical-methodological innovations. It is noteworthy that PVAM is now being introduced in four other countries (Saltzman et al., 2012), each of which has a recent HCES-type of survey available that could be used to conduct a similar study.

[1] The only additional data on vitamin A since the 2003 national survey is from a 24 HR survey conducted in two districts in 2009. That survey estimated the prevalence of VAD (based on serum retinol concentration levels) at 57% among 24–59 month olds, roughly the same percentages as the 2003 national survey level estimates reported in Table 2 and 3. After adjusting serum retinol levels for infection, the 24HR survey found the VAD level was 48%, and using another methodology (MRDR) to adjust for infection, it found the prevalence rate was markedly less, 22%, but still above the 20% threshold above which WHO defines VAD as constituting a public health problem (NFNC, 2010).

[2] For a discussion of the political controversies involved in the conventionally bred versus genetically engineered approaches see Pray et al. (2007) and Stein (2014).