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The role of agriculture and biofortification in the UN Decade of Action on Nutrition

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The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) correctly assert that current food systems are not delivering on the quality diets needed to sustain optimal health (Work Programme of the UN Decade of Action on Nutrition (2016-2025) (2017), Action Area 1: Sustainable, resilient food systems for healthy diets). In particular, "solutions should include: improved production, availability, accessibility and affordability of a variety of cereals, legumes, vegetables, fruits and animal-source foods, including fish, meat, eggs and dairy products, which should be produced and consumed sustainably" (para. 24).[1] The Second International Conference on Nutrition (ICN2) Framework for Action (FFA) refers to the need for improved local agricultural production, diversification of agriculture, and for reliance on food markets and international trade, including better transport, storage, preservation, and storage (recommendations 9, 10, 11). The FFA also calls for improved intake of micronutrients through consumption of nutrient-dense foods and, where necessary, through fortification and supplementation strategies (recommendation 42).

This article will focus on biofortification, which adds to the supply of minerals and vitamins provided by agriculture by increasing the density of bioavailable nutrients in staple foods. To fully understand and appreciate the role of agriculture in the UN Decade of Action on Nutrition, and the potential impact and comparative advantages of biofortification, it is important to first understand the trends and economic factors that are driving diets in developing countries, in particular, the intakes of food groups that provide dietary quality – legumes, vegetables, fruits and animal-source foods, which are dense in bioavailable minerals and vitamins. A fundamental argument to be made here is that agricultural systems are the most cost-effective and sustainable sources of minerals and vitamins in the diet (nutrient supply). Thus, the long-term vision should be for governments to invest in agriculture, including nutrition-smart agricultural policies. However, there is a current need to fill the gap between nutrient requirements and nutrient supply (see e.g., Table 1 in Saltzman et al. 2017) through familiar and proven non-agricultural micronutrient interventions, such as supplementation and fortification. As the gap between nutrient requirements and nutrient supply grows smaller (assuming that the agricultural sector responds to the nutrition challenge), these more expensive, gap-filling programmes can be scaled back (although never eliminated). In theory, there would be sufficient funding to cover both investments in agriculture and the gap-filling. In reality, however, there is currently insufficient funding available for both types of investments. Very difficult decisions are being made (implicitly or explicitly) in choosing between short- and long-term welfare.

It is important to note at the outset that the supplies of nutrient-dense foods that are presently available in insufficient amount in any given country (typically the foods that provide dietary quality) in effect are "rationed" to families through the primary driving mechanism of household incomes and food prices. Rising incomes, if equitably distributed, and lower food prices allow the poor to gain a more equal share of available supplies.

1 United Nations Decade of Action on Nutrition (2016-2025) (2017). Work Programme. www.unscn.org/uploads/web/news/Work-Programme_UN-Decade-of-Action-on-Nutrition-20170517.pdf.

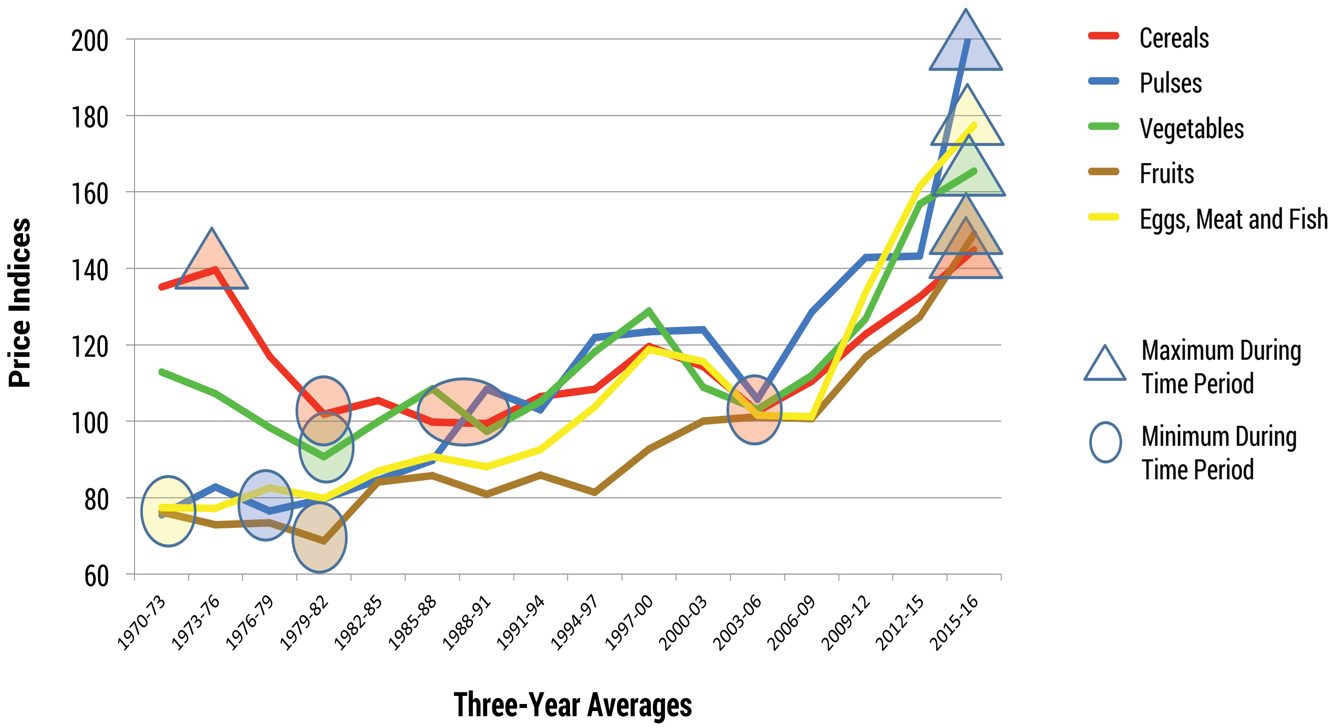
TRENDS IN AGRICULTURE IN DEVELOPING COUNTRIES

There is nothing more fundamental to human behaviour than seeking to avoid hunger, i.e. in securing sufficient dietary energy. During 1960-2000, the Green Revolution successfully addressed a situation of high population growth where limited land was available to expand agricultural production. Through the application of agricultural science, modern, high-yielding varieties of rice, wheat and maize were developed, which were widely adopted by large- and small-scale farmers. Production of cereals increased more rapidly than population growth, and cereal prices declined dramatically (Bouis, Eozenou and Rahman 2011).

Importantly, investments in agricultural research and extension, particularly in staple food groups, were sustained over three decades (around 1960-1990) to achieve this success. Plant breeding is highly effective and cost-effective in increasing agricultural output (and the supply of minerals, vitamins and nutrients contained therein), but its cumulative impacts occur slowly over time (Hurley et al. 2016; Ponniah et al. 2008; Meenakshi et al. 2010; Qaim, Stein and Meenakshi 2007).

However, there were not the same investments in increasing agricultural productivity for non-staple food groups. Consequently, prices for these food groups, which provide dietary quality, rose rapidly, as shown for example in Figure 1 in India. The prices that consumers pay for iron, zinc and provitamin A have increased significantly.

Figure 1. PRICE INDICES BY FOOD GROUP FOR INDIA, 1970-2016, DEFLATED BY NON-FOOD PRICE INDEX



Source: *Personal Communication, JV Meenakshi, Delhi School of Economics*

ECONOMIC FACTORS THAT DETERMINE DIETARY QUALITY

Tables 1 and 2 show the pattern of consumption, as income increases, of food staples, non-staple plant foods, and animal products for Bangladesh, Kenya and the Philippines. Food staples tend to be poor sources of minerals and vitamins, while animal products are the most dense foods in bioavailable minerals and vitamins. Non-staple plant foods are also good sources of minerals and vitamins.

Consumption of food staples remains more or less constant with income. At very low incomes, the poor are able to secure sufficient food staples to keep them from going hungry, and then as their income increases, they are to able purchase non-staple plant foods and animal source foods (Bouis, Eozenou and Rahman 2011).

This is the context, then, for the underlying causes of high rates of mineral and vitamin deficiencies – low incomes and rising prices over time for dietary quality. Government policies with respect to agriculture are focused on keeping cereal prices low; however, when cereal prices rise unexpectedly in the short term, there can be considerable political discontent. There is insufficient acknowledgement and priority given by governments to the problem of rising non-staple food prices.

Table 1. PER CAPITA ENERGY INTAKES AND BUDGET SHARES OF FOOD GROUPS IN TOTAL FOOD EXPENDITURES, BY INCOME TERCILE OR QUARTILE, BY BROAD FOOD GROUPS, RURAL BANGLADESH, KENYA AND THE PHILIPPINES

			Per capita energy intake				Food group budget share in total food expenditures			
			Staples	Non-staple plant	All animal	**Total**	Staples	Non-staple plant	All animal	**Total**
Bangladesh	Income tercile	1	1 805	281	44	**2130**	46	32	22	**100**
		2	1 903	347	61	**2 311**	41	35	24	**100**
		3	1 924	394	89	**2 407**	36	36	28	**100**
	All households		1 879	340	64	**2 283**	40	34	26	**100**
Kenya	Income quartiles	1	1 283	256	112	**1 651**	Data not available			
		2	1 371	348	120	**1 839**				
		3	1 388	363	161	**1 912**				
		4	1 394	464	187	**2 045**				
	All households		1 360	357	145	**1 862**				
Philippines	Income quartiles	1	1 361	197	67	**1 625**	43	30	27	**100**
		2	1 431	229	102	**1 762**	36	36	28	**100**
		3	1 454	304	118	**1 876**	28	39	33	**100**
		4	1 381	395	207	**1 983**	24	37	39	**100**
	All households		1 406	281	124	**1 811**	33	35	32	**100**

Table 2. PER CAPITA FOOD EXPENDITURES, FOOD AND NUTRIENT INTAKES, AND FOOD PRICES TO PURCHASE 1,000 KCAL BY BROAD FOOD GROUP, BY INCOME TERCILE, BY URBAN AND RURAL AREAS, BANGLADESH, 2005

Food Group	Per Capita Consumption Per Day (grams)	Price Paid Per Kilogram (Taka)	Taka Expenditure	Taka to Purchase 1,000 Kcal	Per Capita Kcal Intake	Per Capita Iron Intake (mg)	Per Capita Zinc Intake (mg)	Per Capita Vitamin A Intake (mcg RAE)	Per Capita Consumption Per Day (grams)	Price Paid Per Kilogram (Taka)	Taka Expenditure	Taka to Purchase 1,000 Kcal	Per Capita Kcal Intake	Per Capita Iron Intake (mg)	Per Capita Zinc Intake (mg)	Per Capita Vitamin A Intake (mcg RAE)
	Rural Low Income Tercile								Urban Low Income Tercile							
Staple Foods	473	16.95	8.02	4.74	1,690	1.61	5.90	0.88	417	17.90	7.46	5.02	1,485	1.97	5.74	0.84
Non-Staple Plant Foods	303	13.98	4.23	14.46	292	7.88	1.83	231.07	302	16.24	4.91	14.73	334	8.01	1.92	218.33
Animal and Fish Products	55	50.20	2.77	43.69	63	0.46	0.55	21.70	58	56.07	3.26	47.18	69	0.52	0.63	22.41
Total All Foods	831	18.08	15.02	7.34	2,046	9.96	8.28	253.65	777	20.12	15.63	8.28	1,888	10.50	8.29	241.57
	Rural Middle Income Tercile								Urban Middle Income Tercile							
Staple Foods	498	17.26	8.60	4.83	1,780	1.84	6.40	0.95	427	18.48	7.89	5.19	1,520	2.44	6.32	1.02
Non-Staple Plant Foods	341	15.68	5.34	14.97	357	8.70	2.06	261.48	340	19.10	6.50	15.78	412	9.39	2.30	260.70
Animal and Fish Products	82	50.62	4.17	45.72	91	0.65	0.84	31.72	84	61.36	5.17	52.93	98	0.72	0.94	32.14
Total All Foods	921	19.66	18.11	8.13	2,229	11.19	9.30	294.15	851	22.97	19.56	9.64	2,029	12.55	9.55	293.86
	Rural High Income Tercile								Urban High Income Tercile							
Staple Foods	519	17.90	9.28	5.01	1,852	2.15	6.90	1.58	425	20.17	8.57	5.70	1,503	3.84	7.69	1.42
Non-Staple Plant Foods	413	18.01	7.44	15.83	470	10.06	2.44	290.15	441	22.99	10.14	17.40	583	11.63	2.95	304.29
Animal and Fish Products	145	50.54	7.31	48.23	152	1.04	1.48	54.84	154	66.76	10.31	59.96	172	1.17	1.69	57.95
Total All Foods	1,076	22.33	24.03	9.72	2,474	13.24	10.82	346.57	1,020	28.44	29.02	12.85	2,258	16.64	12.33	363.66

Income Tercile	Rural					Urban				
	Per Capita Income ($US)	Average Age (years)	Weighted Average EAR FE (mg)	Weighted Average EAR ZN (mg)	Weighted Average EAR VA (mcg RAE)	Per Capita Income ($US)	Average Age (years)	Weighted Average EAR FE (mg)	Weighted Average EAR ZN (mg)	Weighted Average EAR VA (mcg RAE)
Tercile 1	94	23.2	17.25	11.76	453	97	23.0	17.52	11.95	459
Tercile 2	189	25.9	18.23	12.90	481	195	24.7	18.12	12.82	479
Tercile 3	511	28.1	18.72	13.54	497	676	26.9	18.74	13.73	499
All		25.4	17.97	12.62	474		25.5	18.32	13.12	486

Notes:

- FE= Iron, ZN = Zinc, VA = Vitamin A, RAE = Retinol Activity Equivalent, EAR= Estimated Average Requirement, IOM=Institute of Medicine.
- FE, ZN, and VA EAR based on IOM values; FE values for women ages 19+ are adjusted for Hambidge updates; EAR for ZN based on IOM physiological requirements and bioavailability based on IZiNCG unrefined cereal-based diet.
- Exchange rate: BDT 63.59 = US$1

Source: *Bangladesh Bureau of Statistics (2005)*

INTERVENTIONS TO ADDRESS THE PROBLEM OF MINERAL AND VITAMIN DEFICIENCIES

The ultimate solution and vision for solving the problem of mineral and vitamin deficiencies is adequate dietary quality for all, which eventually can be achieved through increasing incomes, controlling rises in non-staple food prices, and nutrition education. Globally, for a high percentage of the poor, this will take several decades to achieve; in the meantime, several types of cost-effective interventions are available to address mineral and vitamin deficiencies. These include various programmes on the diversification of diets, supplementation, fortification, and biofortification. The challenge during the UN Decade of Action on Nutrition is to foster commitment by governments, the private sector, civil society and all relevant stakeholders to increase the overall level of investments across all of these interventions, and to work together to implement the most cost-effective mix of interventions.

Biofortification is a relatively new intervention. It has particular advantages over more established interventions, which justifies the introduction of biofortification into the mix of viable options. But it is also has disadvantages. The advantages and drawbacks with respect to the more established interventions in addressing mineral and vitamin deficiencies are first discussed briefly as background for the more detailed discussion of biofortification that follows.

Supplementation and fortification

Vitamin A supplementation is one of the most cost-effective interventions for improving child survival and is often integrated into national health policies. Supplementation for other micronutrients is less common. Commercial food fortification, where trace amounts of micronutrients are added to staple foods or condiments during processing, helps consumers reach the recommended levels of dietary intakes of specific minerals and vitamins. Supplements are targeted at particular age-gender groups, while fortificants are added to foods widely eaten by most age-gender groups. Both modalities of delivering vitamins and minerals have been shown to increase a target group's nutrient intake and improve their nutritional status when they can be accessed (Allen et al. 2006; Bhutta et al. 2008; Bhutta et al. 2013). The strengths of supplementation and fortification are that the deficits in multiple mineral and vitamin intakes can be met quickly at relatively low cost, and cost-effectively. In some cases, the consumer bears the cost of the added fortificant or supplement; in others, governments and international agencies bear the annual costs.

The drawbacks are that supplementation and fortification may not reach all intended beneficiaries (particularly in rural areas) due to required behaviour change, implementation constraints and costs. Both interventions involve yearly recurrent costs in every country; the cumulative annual costs of supplements and fortification can reach billions of dollars globally, especially if coverage rates improve over time.[2] The need for supplements and fortification will decline as food systems provide the necessary intakes of vitamins and minerals through diverse diets at more affordable prices.

Mineral and vitamin requirements of infants and pregnant and lactating women are particularly high. Implementing exclusive breastfeeding in the first six months is crucial for child health and development. In the absence of quality diets, micronutrient powders and ready-to-eat, nutrient-dense foods provide the required nutrients. The benefits of consuming them are particularly high during this crucial, early period of growth. The drawbacks are that per person costs are relatively high and more often borne by the families rather than governments or international agencies.

Interventions to diversify diets

Although the marginalized poor devote relatively high percentages of increased income to the purchase of high-quality, non-staple foods; nutrient requirements (especially of women and

2 The World Bank (2006), Table 1.2, provides the following annual unit costs for the following interventions:

Salt Iodization	$0.20-$0.50
Vitamin A supplementation	$1.01-$2.55
Vitamin A sugar fortification	$0.69-$0.98
Iron supplementation	$0.55-$3.17

The United Nations Children's Fund (UNICEF) database on iodine (UNICEF 2016a) estimates that 50 per cent of households in Least Developed Countries (LDCs) have access to iodized salt (e.g. 70 per cent coverage in India). If there are 3 billion people in LDCS, and taking the median cost of US$.35 per person per year, this would amount to a total cost of $525 million/year ($0.35/person x 1.5 billion people).

UNICEF (2016b) estimates that it has distributed 8 billion vitamin A capsules since 1998 at a cost of 60 cents per capsule, including distribution costs, i.e. at a total cost of $4.8 billion dollars since 1998, or $240 million per year when divided by 20 years. The UNICEF per unit cost estimate is at the low end of the range given by the World Bank (US$.60 x 2 capsules = $1.20 annually). Neidecker-Gonzalez, Nestel and Bouis (2007) estimated $1 per capsule, or $2.00 per child per year, in the upper part of the range given by the World Bank, for a total cost of $400 million per year – not counting vitamin A capsule distribution by agencies other than UNICEF.

The amounts spent on these two interventions alone have been conservatively estimated at $750-925 million per year.

preschool children because of their increased requirements for reproduction and growth) are such that consumption of non-staple foods must increase by several multiples before requirements are met. For example, as shown in Table 2, incomes are 5-6 times higher in the high-income terciles compared with the low income terciles, but still even average adequacy is not met. Therefore, incomes must increase by several multiples, which requires several decades of economic growth.[3]

Social protection programmes increase current incomes. Modestly higher incomes will lead to marginally better dietary adequacy (Table 2). Nutrition education programmes can indicate how to re-allocate the income that is available to poor households for purchasing the most nutritious foods that may be available at a relatively low cost and could be consumed in greater quantities within existing food budgets (World Bank 2006). An analogous intervention that involves substantial behaviour change to diversify diets is to teach farm households to diversify their produce for home consumption, most often through the introduction of home gardens (Sibhatu, Krishna and Qaim 2015).

All of these interventions can be cost-effective, but the fundamental constraint is the limited resources available to poor households, the costs, especially in terms of social protection, of mitigating those constraints, and the requirement for changes in behaviour to be effective, particularly in nutrition education and crop diversification.

Interventions through agricultural research: Biofortification

Biofortification involves breeding staple food crops to increase their micronutrient content, targeting staple foods widely consumed by low-income families globally. Biofortification contributes to solving the underlying problem of mineral and vitamin deficiencies by increasing the amount of iron, zinc and provitamin A produced by food systems.

The fundamental concepts and comparative advantages that justify biofortification are that biofortification:

- Saves on recurrent costs through plant breeding, in which plants relocate more trace minerals to the edible portions of seeds and synthesize higher levels of vitamins in these seeds; this is achieved by crossing mineral and vitamin dense varieties with high-yielding varieties.
- Taps into the effectiveness and cost-effectiveness of plant breeding as well as of seeds to replicate themselves, where the results of research undertaken in a central location can be replicated in other countries.
- Minimizes the need for behaviour change by: (i) piggybacking on an existing system of agricultural research institutes (international and national) that produces a stream of increasingly productive and climate-adapted crop varieties that are adopted by farmers and eventually account for a high percentage of total food supplies; and (ii) focusing on food staples that the poor already eat in large quantities.
- Provides extra iron, zinc and provitamin A to farmers and consumers at no extra cost by growing and eating biofortified varieties of everyday foods in a one-for-one substitution for non-biofortified varieties.
- Initiates the delivery of these micronutrients in the relatively hard-to-reach rural areas where a majority of the poor reside.

The primary drawbacks to biofortification, which diminish over time, are as follows:

- The impacts of agricultural research through plant breeding take a long time to develop; plant breeding can involve ten years or more of research before a variety with full target levels[4] of micronutrients can be developed and first releases are approved; moreover, new crop varieties are adopted gradually over time.
- Therefore, the density and number of minerals and vitamins in seeds cannot be as quickly manipulated as can levels of minerals and vitamins supplied by supplementation and fortification of foods. Single target levels (specific mineral or vitamin densities in seeds for particular crops) need to be reached in released varieties, whose densities will increase over time. Multiple nutrients can be added through plant breeding, however one at a time sequentially. A conventional plant breeding advanced technique, "marker-assisted-selection", is now being applied to speed up this process (Bouis and Saltzman 2017b).

3 Certainly, incomes for particular households or communities can increase markedly in a relatively short span of time. However, to increase incomes several multiples broadly across an entire nation, takes several decades. Similarly, new crop varieties may be adopted rapidly by individual farmers and in particular communities in a relatively short period of time. However, for biofortified varieties to capture, for example, 70 to 90 per cent of total supply of a particular, major staple crop for an entire nation, one to two decades are needed, depending on a number of factors (e.g. agronomic superiority, the number of diverse growing environments within the same country, the presence of well-developed seed markets and extension systems, and population size in relation to investments available to catalyse scaling-up).

4 The concept of breeding "target level" can be explained through an example. White maize has zero provitamin A. The target level density that plant breeders have been given to achieve is 15 mg/kg (sometimes referred to as ppm, or parts per million) provitamin A in maize kernels as harvested. Taking in account per capita consumption in maize eating populations, bioavailability, and losses of provitamin in storage, processing, and cooking, the remaining provitamin A that is consumed should provide an estimated extra 40% of the Estimated Average Requirement for adult, non-pregnant, non-lactating women and preschool children. Further details on targets for all biofortified crops are provided in Bouis and Saltzman 2017a and 2017b.

Nevertheless, the plant breeding and nutrition research under HarvestPlus, the global leader in biofortification science and policy, began 14 years ago. More than 100 biofortified varieties across 12 crops have been released in 30 countries. Biofortified varieties are under testing for release in an additional 25 countries (Bouis and Saltzman 2017a).[5] Crops are granted release because they meet stringent agronomic standards of high yields and disease and pest resistance set forth by national governments. In the future, analogous to universal fortification, it is hoped that mineral and vitamin density can be included as standards for varietal release as well, but no country has yet taken this important step.

The efficacy and evidence of acceptability of iron and provitamin A is positive and extensive for iron and vitamin A. Improved function outcomes have been shown as well – better cognitive function and work performance for iron, better eyesight adaptation to darkness for provitamin A, and reduced morbidity for zinc.[6,7]

BIOFORTIFICATION AND THE MIX OF INTERVENTIONS BY THE END OF THE UN DECADE OF ACTION ON NUTRITION

Many doubts about whether biofortification will work have been laid aside, e.g. combining high crop yields with nutrient density in plant breeding, providing rigorous evidence on nutritional efficacy, and whether consumers will accept orange (in place of white) staple food crops. We now know that biofortification can work, and is working in specific countries.

The key unknowns at this point are the time trajectory and upper limit of the percentage of total staple food supplies that will be captured by biofortified crops. For example, consider addressing zinc deficiency in Bangladesh. Currently, an estimated 73 per cent of Bangladeshis have inadequate zinc intakes. Simulations suggest that improved dietary intakes due to increases in incomes over the next 30 years will reduce this prevalence modestly to 63 per cent. Two out of three Bangladeshis will still suffer from inadequate zinc intakes, despite an assumed quadrupling of per capita incomes (Fiedler and Lividini 2014).

Consider that most Bangladeshis (99 per cent) consume rice daily as their main food staple, and that 93 per cent of the national supply of rice is derived from in-country production of modern varieties of rice. For the most part, traditional varieties of rice were consumed in Bangladesh 40 years ago.[8]

Thirty years from now, it can be expected that most currently sown modern varieties will have been replaced by a new wave of even higher-yielding modern varieties. If breeding of high zinc varieties becomes mainstreamed in rice agricultural research systems such that all modern varieties are dense in zinc, average per capita zinc intakes can be increased by 75 per cent through biofortified rice alone, reducing the prevalence of inadequate zinc intakes to 25 per cent (Fiedler and Lividini 2014). Because new crop varieties replace existing crop varieties only gradually over time, such success will not be achieved by the end of the UN Decade of Action on Nutrition. However, as agricultural research centers begin the practice of exclusively developing only high zinc varieties with ever-higher densities of zinc, this success can be set in motion and virtually locked in by the end of the Nutrition Decade.

This example demonstrates the essence and potential impact of biofortification. Supplementation, fortification, and several other non-agricultural interventions should be seen as relatively expensive, stop gap measures that provide temporary relief for the failure of agricultural systems to deliver sustainable supplies of minerals and vitamins. These interventions are cost-effective because the consequences of these deficiencies for human welfare are so severe.

Although progress in biofortification is relatively incremental, it improves each year. Biofortification is dynamic, sustainable and highly cost-effective, with accelerating momentum to add to the supply of minerals and vitamins supplied by food systems, thereby contributing to a diminution in the underlying cause of mineral and vitamin deficiencies.

5 See Figure 2 in Bouis and Saltzman (2017a) for a map of these 55 countries.

6 Sazawal Sunil (personal communication, 2017), Zn-biofortified wheat decreases morbidity but does not modify serum zinc among preschool children and their mothers in a RCT in India..

7 A list of selected, published nutrition studies for biofortified crops is provided in Annex 1. Brief summaries of findings are provided in Bouis and Saltzman (2017a) and Saltzman et al. (2017); longer summaries are provided in Bouis and Saltzman (2017b).

8 Keith Lividini (personal communication, 2017); analysis of Bangladesh Bureau of Statistics (2005) data.

A FUTURE VISION

To reach its full potential, biofortification must be integrated as a core activity within a range of global actions as follows:

Policy

National and international public officials recognize the significant impact of biofortification for improving and sustaining public health, as well as the high economic return to investments in biofortification – with its legitimacy conferred and underpinned by international recognition, especially by standards bodies such as Codex Alimentarius and WHO.

Significant progress has already been made in integrating biofortification into regional and national policies. At ICN2, high-level government representatives from Bangladesh, Malawi, Nigeria, Pakistan and Uganda highlighted the role of biofortification in their national strategies to end malnutrition by 2025. More than 20 additional countries, including Colombia, Panama, Rwanda and Zambia, have included biofortified crops in their national agriculture and nutrition plans. Regional and global processes, such as the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) and the Scaling Up Nutrition (SUN) Movement, are building an enabling environment for biofortification. In countries where the first biofortified varieties (typically the most widely eaten food staple in that country) have been introduced, governments have requested that additional biofortified crops also be tested and released.

Partnerships

Scaling up will require building new and expanding partnerships, maintaining engagement, and increasing partner capacity. A range of delivery partners have already trained thousands of extension staff on agronomic practices and nutrition messages for biofortification, and developed technical packages for use in delivery programming. Going forward, such diverse partners as development banks, food processing companies and retailers, United Nations agencies and non-governmental organizations will include biofortified crops among their services and products.

For example, the World Bank now recommends scaling up of biofortified crops among the technical advice it provides to its member countries in Africa. Orange sweet potato flour is being used as an ingredient in a range of processed products being sold in several countries in Africa. The World Food Programme has included iron beans in its Purchase for Progress programme in Rwanda. World Vision has incorporated biofortified crops in its agricultural programs in several countries as a way linking its agriculture and nutrition/health activities (Bouis and Saltzman 2017b).

Supply

Agricultural research entities, both public and private, recognize high mineral and vitamin content as core plant breeding objectives; varietal release committees make minimum levels of minerals and vitamins a requirement for approval for release (in addition to the standard agronomic traits, such as high yield).

The key to continued supply of biofortified crops is to move beyond a biofortification-focused breeding program, with funding specifically for biofortified crops, to mainstream the nutrient traits into all relevant crop pipelines being developed by Consultative Group on International Agricultural Research (CGIAR) centres and National Agriculture Research Systems (NARS). Recent progress in developing molecular markers will help facilitate mainstreaming (Babu et al. 2013; Swamy et al. 2016). As new varieties are developed and released, they should include the biofortified trait as a matter of standard practice.

Demand

To ensure that vitamin A biofortfied crops are sustainable, both rural and urban consumers must demand high vitamin A content in their staple foods; i.e. they must prefer yellow and orange varieties over white staple foods – preferences influenced through nutrition messaging that the change in color is associated with better nutritional quality. Superior agronomic traits drive demand by rural smallholders for iron and zinc varieties, minerals that are invisible in terms of colour and taste. Eventually they capture a high percentage of the total supply that is available to consumers.

The vision of HarvestPlus is that one billion people will be benefitting from biofortified crops by 2030. If 20 to 25 per cent of the primary staple food supplies are biofortified in a subset of the 55 countries where biofortified crops will have been released (see Figure 2 in Bouis and Saltzman 2017a), then one billion people will have been reached. If fully committed to, biofortification will be one of largest nutrition interventions ever implemented.

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Annex 1: Evidence on the Bioavailability, Efficacy, and Effectiveness of Biofortified Foods

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