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ABSTRACT No.5

Biofortification of Staple Food Crops: Six Questions

Penelope Nestel, Howarth E. Bouis, J.V. Meenakshi, and Wolfgang Pfeiffer

More than half the world's population suffers from micronutrient malnutrition. Biofortification of staple food crops is a new public health approach to control vitamin A, iron, and zinc deficiencies in poor countries. Biofortification is the development of micronutrient-dense staple crops using traditional breeding practices and modern biotechnology. It has multiple advantages: it capitalizes on the regular daily intake of a consistent and large amount of the food staples that predominate in the diets of the poor, recurrent costs are low (germplasm can be shared internationally), it is sustainable, and it can reach undernourished populations in remote areas. This paper addresses six questions:

1. Is breeding for high nutrient content scientifically feasible?
There is potential to increase the micronutrient density of staple foods by conventional breeding, and micronutrient-density traits are stable across environments. In all crops studied, it is possible to combine the high micronutrient density trait with high yield, economically. For example, orange-fleshed sweet potato lines with high levels of β-carotene have been identified, and beans with improved agronomic traits and grain type and 50–70% more iron have been bred through conventional means. Transgenic approaches are in some cases necessary, or potentially advantageous, as for example, in the case of Golden Rice.

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2. Will farmers adopt new varieties?
The biofortification strategy requires widespread adoption by farmers. The visibility of the trait and infrastructural development are critical to adoption. Biofortified crops with visible traits will require that producers and consumers accept this change in addition to equivalent productivity and end-use features. Crops with invisible traits do not require behavior change, and thus productivity and improved end-use features will be important. Market networks and information flow will affect uptake once a new improved variety is released. Where infrastructure is strong, such as in Asia, uptake should be rapid; but where infrastructure is poor, such as in Africa, constraints to farmer adoption must be overcome.

3. What is the target breeding level?
Retention of the nutrient following processing and cooking, bioavailability and nutrient requirements of target populations is needed to set breeding targets. For example, true retention of β-carotene in a variety of orange-fleshed sweetpotato averages 80% after processing and cooking. The target level set will vary depending on whether people rely upon the sweetpotato as their sole source of β-carotene or if they eat a mixed diet. If children and women can

consume up to 200 g and 400 g sweetpotato each day, respectively, and if these daily intake levels supply 100% of EAR, the target breeding level would be 75 μg/g β-carotene (to provide 50% of the EAR would require a target of 37 μg/g β-carotene).

4. What is the impact on nutritional status?
Orange-fleshed sweet potato varieties that are naturally rich in β-carotene can be an excellent food source of provitamin A. A randomized controlled study showed that feeding β-carotene-rich sweet potato to primary school children improved vitamin A liver stores. In a study carried out in the Philippines on the iron status of women of reproductive age, undermilled iron-enhanced rice provided an additional 1.41 mg of iron/d. This 17% increase in dietary iron in the diets of the women was efficacious in improving serum ferritin concentrations and body iron levels in nonanemic subjects compared with the locally used rice.

5. Is biofortification cost effective?
The largest cost in biofortification is the research to develop biofortified varieties at the outset. However, because an international agricultural research system is in place to develop modern varieties of staple foodstuffs, research costs are essentially the incremental costs of enhancing micronutrient density. Once biofortified varieties have been developed, implementation costs for in-country trials and local adaptation research are incurred, after which routine maintenance breeding will ensure the trait remains stable.

Where there are no systems for disseminating modern varieties in place, there will be additional costs to establish seed multiplication and delivery systems and create both markets and consumer demand. Applying the disability-adjusted life years (DALY) framework to HarvestPlus target crops and countries suggests that benefits far outweigh costs. For example, dissemination of β-carotene-enhanced orange-fleshed sweetpotato in Uganda is likely to cost less than US$5 per DALY saved, while vitamin A supplementation is estimated to cost US$12 per DALY saved.

6. Can we get consumers to adopt?
Biofortified crops must be incorporated into existing markets or new markets must be developed. One strategy is to facilitate dissemination of, and create demand for, biofortified crops by linking producers and consumers through product and market development. Diagnostic research can identify tools to encourage consumption of biofortified crops and develop strategies to achieve desired behavior changes in the production-marketing-consumption chain. Parameters will differ by crop and target area, and will be affected by the extent of trait visibility.

Summary
Biofortification is technically feasible and breeding for micronutrient concentrations that can have biological impact, without compromising agronomic traits, has been demonstrated. Predictive cost-benefit analyses show biofortification to be important for controlling micronutrient deficiencies. Getting consumers to accept biofortified crops will be a challenge, but with the advent of good seed systems, the development of markets and products, and demand creation, this can become a reality.

SOURCE: Nestel, P., H. E. Bouis, J. V. Meenakshi, and W. H. Pfeiffer. 2006. Biofortification of staple food crops. *Journal of Nutrition* 136: 1064–1067.