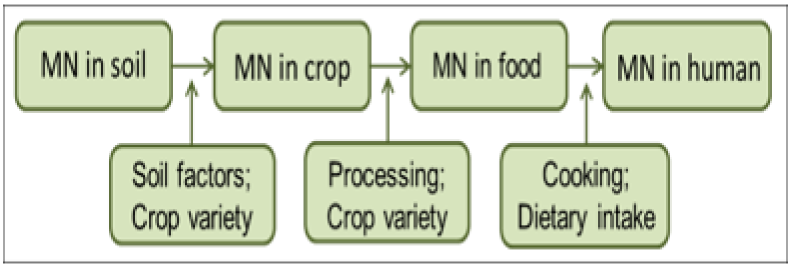
Micronutrient management for improving harvests, human nutrition, and the environment

Executive Summary

Micronutrient deficiencies in soils limit crop yields and nutritional quality, which in turn negatively affect human health. Especially in sub-Saharan Africa, soils have multiple micronutrient deficiencies what makes soils non-responsive to NPK fertilization. Poor crop yields in combination with diets that are mainly based on staple crops, causes widespread micronutrient deficiencies among the population, with severe health problems as a consequence. A suggested strategy to alleviate micronutrient deficiencies in this region is agronomic biofortification, particularly of staple foods. This is the fertilization of soils or plant leaves with mineral micronutrient fertilizers in order to increase certain micronutrient contents in the edible part of crops to alleviate micronutrient deficiencies among humans. The impact of agronomic biofortification largely depends on the bioavailability of micronutrients throughout the entire pathway from soil to plant, from plant to food and uptake by the human body. Factors that determine bioavailability are mainly soil conditions, crop variety, food processing, concentration of micronutrient inhibitors or enhancers in food, dietary intake, the forms of micronutrients in food, interactions among nutrients, and physiological condition of individuals. The effects of agronomic biofortification on yields, nutritional quality of crops and human health are discussed in this paper.



Schematic overview of micronutrient (MN) pathway from soil to humans and the factors that influence MN bioavailability to the next level. Based on Mayer et al. (2011).

Some studies have shown a positive impact of agronomic biofortification on yields and nutritional quality of crops, but the impact largely depends on interactions between specific soil conditions, crop (varieties), nutrients and fertilizer blends, fertilizer application techniques and further soil management practices. Positive impacts on yields and nutritional quality of crops have been observed in several studies, mainly on Se and Zn. Also Fe has been studied regularly, but has so far shown little potential for successful impact through fertilizer application. From the two fertilizer application techniques, foliar application seems to be more effective than soil application in increasing nutrient content in the harvested product, and the combinations of both give the strongest impact. However, foliar application is often rejected as suitable strategy, because it is costly and difficult to implement for resource poor farmers. Unfortunately, studies from Africa are scarce, so it is difficult to make strong conclusions and recommendations for this region. Interactions between micro- and macro-nutrients influence the effectiveness so that generally best yield and nutritional quality improvement is observed when micronutrient-enriched NPK fertilizers are used. Soil micronutrient availability for crop uptake is even further enhanced under good soil conditions, which highlights the importance of proper soil management. Integrated Soil Fertility Management (ISFM) is suggested as a robust approach to optimize nutrient use efficiency, using a combination of improved germplasm, mineral fertilizers and organic inputs. The bioavailability of micronutrients within the edible part of the crop depends on characteristics of the crop (variety), which determines the (re-) localization pathways. Breeding is still considered as the most effective way to influence these characteristics. Agronomic biofortification is mainly seen as a complementary approach next to breeding to make micronutrients available for the improved breed to allocate within the harvestable food.

The impact of agronomic biofortification on human health depends on the bioavailability of micronutrients within the edible part of crops and following the bioavailability of processed foods for uptake in the human body. The current approach to measure the impact of agronomic biofortification in human is to measure the phytate level for Zn bioavailability , GSHPx activity in serum/blood for Se and using feeding trials for Fe. Using micronutrient-containing fertilizer could lead to decrease on phytate concentration increasing bioavailability of Zn and Fe. However, studies that link micronutrient-enriched fertilizer application to increased bioavailability leading to improved human health status are scarce, especially for sub-Saharan Africa. This might be because there are many factors affecting the micronutrient status even after the consumption of the staple foods. The physiological status of an individual also determines the capacity to absorb and metabolise these micronutrients. The fact that studies to estimate the accurate bioavailability are costly and determination of micronutrient absorption and its utilization in the human body is practically not feasible, makes it difficult to reach firm conclusions about increased bioavailability and impacts on human micronutrient intake. The lack of evidence hampers definite conclusions about the effectiveness of agronomic fortification to alleviate micronutrient deficiencies among humans.

When micronutrient demand and supply are synchronized, there should be no serious negative environmental effects within the agricultural ecosystem. Micronutrients generally bind strongly to the soil and thus are not susceptible to be lost in the environment which minimizes risks of environmental pollution. Furthermore, micronutrients improve crop health, which reduces the need for agrochemicals (pesticides, herbicides, fungicides, etc.). Accumulation in soils due to overuse may cause toxicity problems. The globally available mineral reserves of micronutrients are limited, which highlights the importance of nutrient recycling for long-term sustainable micronutrient availability for agricultural production.

There are many cost efficacy and effectiveness studies of other food-based approaches, and they are proven to work or not work in specific settings or countries. For instance, supplementation and fortification require sound medical and technical infrastructure in place which is not currently the case for many African countries which have predominantly rural populations that are difficult to reach. Similarly, dietary diversification also needs a high investment for implementation. Foods rich in bioavailable micronutrients tend to be expensive, unaffordable for poor people and require changes in dietary behaviour that are difficult to achieve. Regarding the cost-effectiveness of agronomic biofortification, there are few studies showing that foliar application could be cost-effective in sub-Saharan Africa. As financial analysis of agronomic biofortification was not a core part of this review, we cannot make any conclusive judgement on cost-effectiveness of agronomic biofortification.

Using agronomic biofortification in sub-Saharan Africa would require several technical as well as social-economic and infrastructural development steps. Firstly, accurate diagnostic tools should be developed and applied that give insight into the micronutrient availability as influenced by soil, climate and land use conditions. This would provide a basis for appropriate soil management and fertilizer use recommendations to farmers. Secondly, market and transport infrastructure need to be in place to give access to the necessary organic and/or mineral fertilizers and markets for the surplus produce. Finally, a number of other factors play a role in the effectiveness of the intervention, not all described here. These will be further explored during the workshop in April 2016.

Source
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