Report Stakeholder Workshop

Micronutrient management for improving harvests, farmers' incomes, human nutrition, and the environment

April 5, 2016

Food & Business Knowledge Platform

IFDC

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Colophon

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Key background reference for this workshop report is the preparatory Essay "Micronutrient management for improving harvests, human nutrition, and the environment"
By Anne W. de Valença & Anita Bake from Wageningen UR
http://knowledge4food.net/micronutrient-management-improving-harvests-human-nutrition-environment/

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Table of Contents

Executive summary

On April 5, 2016, the stakeholder workshop “Micronutrient management for improving harvests, farmers’ incomes, human nutrition, and the environment” was held in Utrecht, the Netherlands. It brought together stakeholders from different scientific disciplines and sectors to explore the potential roles and functionalities of micronutrient management and to identify the agenda for knowledge development. A preparatory Essay by Wageningen UR served as background reading.

Addressing micronutrient deficiencies is an urgent challenge which needs action in the context of efforts to improve food and nutrient security. First of all, because of the serious health consequences of micronutrient deficiencies in resource poor populations, particularly vulnerable groups such as women and young children. Second, because micronutrient deficiencies in soils and plants are among the factors that limit crop growth, which hampers agricultural productivity and farmers’ incomes. Finally, micronutrients can positively impact the agricultural ecosystem.

Research institutes and the private sector are working on micronutrient enriched fertilizers, for example through blending of micronutrients into generic NPK fertilizers and through more advanced technical solutions such as coatings and liquid forms of fertilizers for foliar application. The development and use of these micronutrient enriched fertilizers is at an early stage. There are challenges related to the technical aspects of micronutrient management in the soil, the plant, the food, and the human body. At the same time, it is even more challenging to develop micronutrient solutions that are appropriate for resource poor farmers, taking into account the local production (ecological, soil, water) conditions and socio-economic context.

Key conclusions

Micronutrient management can be portrayed as a jigsaw in which many pieces need to be assembled through an integrated approach: dietary diversification, supplementation, food fortification and (agronomic and genetic) bio-fortification. There is evidence of the efficiency and effectiveness of micronutrient management interventions including some first experiences with agronomic bio-fortification, but this is still limited and not yet sufficiently strong to justify significant business investments. Key conclusions of the workshop were:

- While many knowledge gaps were identified, there is a strong need felt by many participants to move to action and decide which interventions are most effective and which business cases can support action.
- There is evidence that micronutrient (e.g. Se, Zn) containing fertilizers can improve yield, which can serve as an incentive for farmers to start using them. This impact largely depends on specific crops, nutrient and soil conditions.
- Currently, the pathway from agronomic bio-fortification to human micronutrient uptake is insufficiently validated. At present, the business case to improve yields is stronger than the business case to improve consumers’ nutrition.
- Middle-class consumers in developing countries may be willing to pay for micronutrient enriched products, yet the poor are more in need of these products but may not be able to afford these. So government policy should address this problem. The lack of visibility of micronutrients in food makes their marketing more difficult.
- Technological fixes and inputs related to agronomic bio-fortification (in particular, micronutrient enriched fertilizers) are not accessible and available to small-scale farmers in Africa due to high costs or lack of distribution. In addition, current fertilizers have fixed nutrient ratios that might not be suitable for the specific soils and cropping systems.
- All in all, the importance of soil health and soil testing before an intervention was stressed.
- While organic fertilizer should be part of the puzzle, it is debatable whether the overall amount of organic material available on the African continent will be sufficient to sustain soil fertility.
- Supportive policy is important as well. Governments could influence the use of micronutrients through legislation. At the moment, standard fertilizers are often subsidized, but micronutrient-enriched fertilizers are sometimes heavily taxed.
- Industry is interested in finding a general solution through blending one of the most promising micronutrients through regular fertilizers. However, others argued that solutions need to take into account the context specific qualities of the soils and the needs of the farmers.

Looking ahead

1. Further research and evidence is needed about the pathways from agronomic bio-fortification to human micronutrient uptake. A first step would concentrate on whether and how agronomic bio-fortification could lead to an increased product quality. Indicators would not only include the concentrations of micronutrients in the edible parts of the crop, but also their bioavailability when consumed by people.
2. Research initiatives in the field of agronomic bio-fortification need to be connected to those in the field of genetic bio-fortification, because of the multiple relations between both genetic characteristics of crops and the agronomic context in which they are grown.
3. The group suggested a focus on staple crops and Zn enriched micronutrient fertilizers in the first instance to ensure effectiveness since there is evidence that Zn fertilizers could impact nutrition. This should not discourage further exploring the potential of other micronutrients or compositions.

1. Introduction

This report presents the findings of the stakeholder workshop "Micronutrient management for improving harvests, farmers' incomes, human nutrition, and the environment" held on April 5th, 2016 in Utrecht, the Netherlands. The workshop brought together stakeholders from different fields to explore the potential roles and functionalities of micronutrient management and to identify the agenda for knowledge development. Prior to the workshop the essay "Micronutrient management for improving harvests, human nutrition, and the environment" by Anne W. de Valença & Anita Bake from Wageningen UR was presented as background reading.

The essay explains how the management of micronutrients in the African agro-food system is becoming more and more important and describes the increasing interest from business, research and development organisations. In addition to the macro nutrients N, P and K applied in fertilizers to increase agricultural production, micronutrients availability increasingly becomes a limiting factor for plant growth. Adding micronutrients to fertilizers may also have a positive effect on human nutrition as harvested products may have a higher micronutrient content.

Research institutes and private sector are working on improved micronutrient fertilizers, from a more classical mixture or blending of micronutrients into generic NPK fertilizers, to more advanced technical solutions, including coatings, embedding and liquid forms for foliar application. The challenge, as formulated by the Virtual Fertilizer Research Centre (VFRC), a semi-autonomous unit of the IFDC and the initiator of this workshop, is now to clarify and unlock the potential of balanced micronutrient containing fertilizers by making them available to resource poor farmers taking into account the local production (ecological, soil, water) conditions and socio-economic context. It will be important to identify ways to avoid similar adoption problems as encountered with the more classical inputs promoted under the Green revolution umbrella.

1.1 Dimensions of micronutrient management which were addressed

1) *Food and Nutrition*: Malnutrition (hidden hunger) is currently addressed in different ways, including through dietary diversification, fortification of processed food, biofortification (breeding oriented towards enhancing the nutrient containing ability of crops), as well as through sanitary and health measures. These interventions have their merits and shortcomings. Can agronomic fortification, i.e. through balanced micronutrient containing fertilizers add a complementary intervention to fight hidden hunger, while simultaneously improving food security through higher production levels?
2) *Soil fertility and balanced micronutrient containing fertilization*: Soil fertility is highly variable and the challenge is to improve soil fertility management in specific situations. What could be the role of micronutrient-enriched fertilizers in specific situations?
3) *Enabling conditions*: The complexity of agro-food systems, and the development of targeted (and partial) solutions require that the micronutrient management solutions (including fertilizer development) are embedded in specific conditions at various scales from global to local. This means that various stakeholders have to be involved (private sector, research, development organisations, farmers, policy makers) and that knowledge management is important for a successful innovation process in this area.

1.2 Objectives of the stakeholder workshop

- Provide a platform to share information and discuss the most recent knowledge and innovations related to micronutrient management for improving harvests, farmers' incomes, human nutrition, and the environment.
- Explore with stakeholders (private sector, research, development organisations, farmers, policy makers) whether there is potential for micronutrient containing fertilizers to contribute to improved yields, farmers income, human nutrition and the environment, and – if so – the conditions needed along the entire value chain to unlock this potential.
- Explore interest in the development of a Community of Practice or a platform to catalyse processes of 1) increased public awareness about the importance of micronutrients through public debates, 2) build a community of practice of involved stakeholders, 3) (fostering) more systematic coordination of research. In the future, this may lead to the development of innovation programmes around micronutrients with special focus on low- and middle- income countries.

2. Plenary: Recent research and case studies

The first part of the workshop presents recent research into micronutrient management and its value for improving harvests, human nutrition, and the environment. It builds on the literature compiled in the preparatory essay for this workshop (see introduction).

2.1 The potential of micronutrient application in fertilizer

Prem Bindraban, Virtual Fertilizer Research Centre (Download his presentation here)

Prem Bindraban argued that fertilizers have been essential to push the green revolution, but have mostly been used on relatively fertile soils and have heavily impacted the environment through excessive use. We need to scrutinize the use of fertilizer again, to ensure that nutrients reach the edible parts of the plant. Fertilizers are currently produced by chemists, sprayed on plants or placed on soils with the expectation for biology to deal with the chemical products for nutrient uptake. Rather than fertilizers bening designed by chemists, it is Bindraban's opinion that fertilizer design and delivery to plants is best determined by biologists from understanding plant biological and uptake processes. Hence, we are in need of a more advanced way of packaging and delivering fertilizer to plants with a technology that starts from the plant's needs.

In addition, the focus of using fertilizer has been on improving yields, however, the nutrient content of many food crops is decreasing. So, while yields have been pushed up, nutrient concentration loss in crops has been observed in grain crops but also in fruits and vegetables. The reasons for this are breeding for higher yields only and the depletion of the soil's micronutrients. Agronomic fortification could simultaneously increase yields, ensure better uptake of NPK fertilizers, and improve the resistance of plants to pests and diseases. However, this is not a free lunch. We have to ensure that there is no overuse of micronutrients, since these include heavy metals that may end up in the environment. We should target the low uptake of micronutrients by plants by developing fertilizer products that minimize input amounts and lead to minimal residual effect on the environment.

2.2 Human nutrition

Saskia Osendarp, Micronutrient Initiative (Download her presentation here)

Saskia Osendarp elaborated on the impact of micronutrient deficiencies on health, especially among the most vulnerable groups being children and women. She argued that we need to combine the different strategies available (supplementation, food fortification, biofortification and dietary diversity). Which combinations of solutions are most optimal will depend on the context and the time horizon in which strategies are pursued. For example, while dietary diversity is an effective way to improve micronutrients intake, small children only consume small amounts of food and will therefore not consume enough micronutrients for their daily need. Biofortified products might be the best solution in this case. Agronomic and genetic biofortification may improve intake of essential minerals (Iron (Fe), Zinc (Zn), and others) and have potential to impact associated health outcomes. This has been demonstrated for some micronutrients for genetic biofortification (breeding), however, not yet directly for agronomic biofortification. Evidence for direct agronomic biofortification impacts on health is lacking and only based on modelling. Agronomic biofortification alone will not automatically impact health. It is a long stretch from adding more Zn to the soil, to a higher Zn uptake into the body.
We also have to take into account the cost-effectiveness of interventions. Dietary diversity, supplementation (with for example Vitamin A) and biofortified foods have shown positive impacts on nutritional outcomes.

Micronutrient deficiencies are caused by poor diets, poor infant feeding practices and diseases that induce excess losses, malabsorption or impaired utilization. Deficiencies of Fe, Zn, vitamin A, iodine and folic acid have the biggest health impact, while even small micronutrient deficiencies can also have detrimental impacts on human health and productivity. When assessing the impact of micronutrients on health, the bioavailability of the different micronutrients to the body is an important determinant for the success of their uptake. Not all micronutrients are equally accessible for the body. The bioavailability is influenced by the amount of nutrients present in the food; efficiency of digestion and the transit time; deficiency of the person (leading to higher absorption rates); the food preparation (can increase bioavailability by reducing inhibitors); the form of the nutrient; and its interaction with other nutrients. Plant-based diets in general have low bioavailability of micronutrients.

2.3 Agronomic and soil fertility research

Shamie Zingore, International Plant Nutrition Institute, Nairobi (Download his presentation here)

The presentation of Shamie Zingore focused on the experiences in the field of agronomic biofortification in Africa.

In developing countries, farmers depend largely on the produce from their farms and therefore human nutrition and health are closely linked to agriculture. Most micronutrient deficiencies can be detected in the soil as well as in humans. However, they are often latent, and will therefore only be noticed if other deficiencies have been tackled first. Biofortification technologies have been effective in improving human nutrition. With regard to genetic biofortification, progress has been made for Fe, Zn, and Vitamin A, but challenges related to stability, density, yield penalty, public acceptance, and regulation of transgenic crops remain. During the green revolution there was a focus on investing in staple crops involving high yielding varieties and the use of nitrogen and phosphorous fertilizers. The latter interventions have been reported to cause micronutrient deficiencies in soils, leading to lower

accumulation of micronutrients in cereal crops. Cereal production increased in Asia during green revolution, while the production of pulses and other foods decreased. In SSA the current fertilizer recommendations focus on N and P fertilizer, however, as micronutrients are interrelated, they can't be dealt with in isolation. Soil micronutrient deficiencies are part of a set of interrelated biophysical and agronomic factors underlying low crop productivity. Several countries in East Africa start to recommend to include micronutrients in fertilizer. However, across the countries there are inconsistent approaches regarding micronutrients in fertilizer recommendations. This might be because micronutrient fertilizers have shown positive yields but its results are highly variable. In addition to this, research on micronutrients has been fragmented.

In SSA, smallholder groups are highly heterogeneous and cereal crops dominate farming systems. The combination of manure and fertilizer already provides large increases in yields. Micronutrient fertilizer blends have wide scale distribution possibilities for the micronutrients Zn, boron (B), magnesium (Mg), molybdenum (Mo) and copper (Cu). It is important to map the soil micronutrient content before applying these blends. However, there is high inconsistency in the methods of soil micronutrient mapping. Currently, crop yield has been used as only indicator for this, but there is more need for soil analysis and fertilizer trial based mapping. In addition, there is a need for a holistic assessment of agronomic biofortification, in the context of smallholder farming systems taking into consideration the economic, social and environmental output. Similarly, sustainable intensification should be done while taking human health into account. There is a need for closer connection between research organizations, industries and policy stakeholders. Jointly, these actors could further explore genetic and agronomic biofortification in an integrated manner, while taking into account environmental factors and managing the complexity. The use of rapid and effective soil diagnosis methods is important in this. Integrated soil fertility management (ISFM) can further support sustainable crop production intensification.

2.4 Highlights from discussion

Knowledge gaps

Questions were raised regarding the current knowledge status related to agronomic biofortification's impact on human health. Is there enough knowledge on how this strategy increases micronutrient uptake by humans and on the interaction between different micronutrients in the human body? While Osendarp argued that it is hard to give precise numbers since the uptake depends on current consumption and deficiencies, others argued that an increase of micronutrients in plants of 20-30% could close the intake gap. However, there are only few studies available which focus particularly on this issue, with a large variation in results. In addition to this, it was mentioned that not just bioavailability needs to be taken into account but also bioconversion of micronutrients. For example, while bioavailable vitamin A-forming carotenoids can be absorbed by the body, whether or not these will be converted to Vit A remains a question mark. The antagonistic interaction of minerals in plants and the human body was also addressed, as it could be considered as major problem for using enriched fertilizer and bioavailability too. Finally, it was observed that studies done on micronutrients are often executed on different types of crops, with different fertilizers and on different soils and therefore it is difficult to identify overall trends and what explains them.

The importance of soils

Better information on the actual status of soils is needed to ensure that the right soil health measures are taken, and - if applicable - the right micronutrients are applied. The connection needs to be made between the data that is available on soils and its micronutrient content and the farmers who actually manage the micronutrient content of their soils. A participant asked whether the use of organic resources to increase soil organic matter and micronutrients availability, isn't equally effective as using biofortification. The answer was that adding organic matter in soil can indeed help the uptake of micronutrients by the plant, but that it is often only available in limited quantities.

A discussion followed on the availability of micronutrients in soils. Bindraban said that if for example the availability of Zn in the entire agro-ecosystem is limited, an external intervention is needed. Some people argued that there actually are a lot of micronutrients present in the soil, however, they are not bioavailable. Further, there is a

knowledge gap, a lack of diagnostic tests, inadequate soil tests, and poor indicators of micronutrient availability. In addition the importance of enabling the function of mycorrhizal fungi and other soil micro-organisms was mentioned. The wide mycorrhizal network around roots can increase micronutrient uptake, as it acts as an extension of the root system.

Some participants stressed the strong connection between soil mineralogy and soil fertility. It was suggested that soil mineralogy should be a parameter to study soils. The use of NPK in Africa has been less successful because soils do not have proper soil minerals that would weather and release micronutrients. It was also argued that silicic acids are a missing link as these can increase the uptake of calcium by the plants.

All in all, the discussion showed the high level of complexity with which micronutrient management is enlaced.
In relation to these gaps in the current understanding, several questions need to be addressed: can agronomic biofortification alleviate micronutrient deficiencies and replace other interventions such as supplementation? How much time is still needed to gather evidence, before practitioners can start to act? Bindraban commented that spatial information is yet to be developed for soil micronutrient deficiencies, using a resolution that covers sufficiently large areas. This would be a basis for fertilizer companies to deliver a sufficiently large product volume. Osendarp stated that there is no silver bullet to solve micronutrient deficiencies and there is need for holistic approach rather than focusing on either one intervention or one micronutrient.

3. Plenary: Perspectives from different stakeholders

The second part of the plenary focused on the perspectives of different stakeholders towards micronutrient management and existing policy, practice and knowledge questions. Representatives from government, the private sector and civil society shared their insights with the participants followed by a discussion.

3.1 Insights from stakelholders

Wijnand van IJssel, Ministry of Foreign Affairs

The Dutch government does not have an explicit policy for micronutrients. In the context of the three objectives of the Global Food Security policy letter of November 2014, the issue of micronutrient management fits both in objective 1 – better nutrition – and in objective 3 – ecologically sustainable food systems. The government wants to put a nutrition perspective to their programmes but doesn't exactly know how to implement that; the Essay for this workshop is informative. The government mostly facilitates opportunities for others to act and for research and private-public partnerships to develop. Most important for the government is to find effective and efficient solutions that can be scaled up to achieve impact. Strategies that seemed most effective so far are genetic biofortification, dietary diversification and food fortification. The ambition of dietary diversification is difficult to reach because poor people cannot afford nutrient dense food such as meat, fish and fruits. Integrated soil fertility management is also a solution, however, this is not yet scaled up and applied in farming systems as a whole. Research questions that need to be explored are: what is a business model for scaling integrated soil fertility management? It is important to be aware that people are not driven by (our) logical arguments but by the incentives that they get out of their systems.

Marc van Oers, Van Iperen International

Van Iperen International is a small start-up company, emerging 5 years ago from its mother company Van Iperen, supplying fertilizer. Since they are a small player they are close to their (potential) customers and can quickly respond to markets. Their fertilizers are meant to increase yield, shelf life and the taste of produce. The only exception are Zn and Fe, which are included to enrich foods. Different carriers of Zn are used for uptake by the plant from the soil; significant differences exist between the carriers in the extent of Zn uptake. The use of chelated Zn-HBED decreases the amount of fertilizer needed and increases the concentration of micronutrient in the crops compared to only zinc sulphate ($ZnSO_4$).

Another important factor of the enriched fertilizers is the application method: soil, foliar, fertigation, pop-up fertilization (fertilizer is placed with the seed at planting) or broadcasting. Biostimulants are also important for Van Iperen International's work; the company explores whether these can be mixed with mineral fertilizer to foster mineral uptake by the roots of the plants. Besides these technical aspects the biggest challenge is that there is fertilizer and crop protection law, but often there is no regulation for new products. Legislation and registration is needed.

Rik Overmars, SNV

Rik Overmars presented four A's for successful application of micronutrient management: Acknowledgement, Affordability, Access/availability and Appropriateness/additionality. First, is there acknowledgement at the policy level in developing countries of the importance of micronutrients? Are the farmers aware? Is there recognition of Zn deficiency? Second, is there a business case in which farmers can actually afford fertilizers with micronutrient? Will these fertilizers be more expensive, and would farmers be willing to invest in them with or without the knowledge about yield responses? One may also wonder why the fertilizer industry did not invest yet in micronutrient blendings if there is evidence of its benefits. Overmars notices that foliar nutrients are applied in high value crops in Latin America, but not in Africa. Third, accessibility of improved fertilizer is important. In some countries there is already a structure, an agro-dealer network through which everything can become available. Lastly, how appropriate is investment in micronutrient management when improving on some basics such as the use of manure is not considered? Addressing farmers' lack of knowledge about organic matter and ISFM is important, as well as practical issues related to composting and labour constraints. Also, appropriateness on the consumer side is important. There are few programmes to promote dietary diversity, while often culture and food habits are hard to change. Overmars argued that to overcome the challenges and improve micronutrient management there is a need for a localised multi-stakeholder approach without generalization of the issue.

Peter van Erp, SoilCares Research

SoilCares Research provides soil laboratories that fit on two tables and are easily transportable within a small truck, to ensure soil testing can be done everywhere, even in remote places. They use different sensors and enable farmers to develop context specific soil strategies. They analyse growth-limiting factors for plants, both in grasslands and crop production. Van Erp referred to research data that show concentration of Zn is much lower than the target value in soil. According to him it is inevitable to assess the complete soil parameters for the gradual increase of soil micronutrient restoration and micronutrient fractionalization. Van Erp argues that first cheap, quick, and affordable soil testing is needed before you can determine which micronutrients are needed.

However, remaining challenges are the availability of fertilizers and the fact fertilizers have fixed ratios that are not necessarily suited to the different soils. He also raised the issue of the content of micronutrient fertilizer: shouldsingle micronutrient fertilizers or multiple micronutrient enriched fertilizers be used? Which use, type, method and timing is needed and how do these translate to cost for farmers?

3.2 Highlights from plenary discussion

Feeding the soils, the plant or the people?

In the discussion, it was suggested that there are different ways of looking at possible pathways to avoid micronutrient deficiencies in human beings. A participant highlighted that it is important to consider the ongoing research in soil microbiology and microbial activity. Van Erp agreed it is important to look at microbial activity in soils. Osendarp called for attention for the spectrum of all interventions, including dietary diversity and the range of other existing micronutrient interventions. Dietary diversity as an end-point or 'Holy Grail' is not realistic; in a complex way it is linked to food price issues and to the challenges of changing eating culture. Several participants and panellists agreed on the need of a diverse spectrum of solutions, multiple approaches. It was suggested that more evidence is needed on how effective each intervention is. And to know the focus of efforts to alleviate micronutrient deficiency? The soil, the plant or people?

Van Erp prefers to start with the soil since most of nutrients are released from the soil to the plant. A certain level of nutrients needs to be available in the soil, to ensure the roots can take them up, but if this level is reached they will be taken up efficiently. He questioned the effectiveness of foliar application arguing that this could lead to a decrease in micronutrients contents in the soil. Van Oers would focus on feeding the plants since in case of stress (drought, heat), the root system would not be able to take up the nutrients while the leaves could. Another important aspect to investigate is how to deal with the fixation of micronutrients in the soil. A participant argued adding nutrients to seeds may be a more effective option, instead of adding them to soils, plants, or as supplements for people.

The local context

The availability of fertilizers in general to smallholder farmers in Africa was discussed in relation to the challenges in the local context and in particular the high local variability of soils. Are companies like Van Iperen able to deal with this variability in their business model? Van Oers confirmed developing small amounts of a certain fertilizer blend is difficult, if there is a relatively low demand. It was noticed that the perspectives of farmers were not really addressed in the workshop so far. Affordability and accessibility are the main problem for them. Farmers have access to manure on their farms. What are the visible incentives for farmers to use micronutrient enriched fertilizers? Should there not be a focus on this instead of making farmers more dependent on industry and obliging them to make extra costs?

Prices of fertilizers?

Fertilizer price issues were discussed thereafter. Should fertilizers really be so expensive? Particularly if the intention is to move from using fertilizers not only on high value cash crops but also on food and cash crops benefiting small holder farmers? While profit is made and needs to be made from trade in fertilizers throughout the value chain, the costs per hectare might go down if the correct amounts were applied.

Government interventions?

The role of governments was also discussed related to this theme. Should they subsidise micronutrient management solutions? Fertilizers are already subsidized, sometimes with adverse impact on the availability of fertilizers in other countries. Often there is not enough of a business case for small scale farmers. Van Iperen starts its interventions at big plantations since these companies are knowledgeable and are aware of what they need. Next step is providing fertilizer for retail. Van Erp also noted the limited availability of different fertilizers to local farmers and smallholders. Overmars recommended to look at the different cost structures to deliver fertilizers, as this differs between countries, and mentioned that agricultural policy and governance structures are crucial. He posed the question if there is need for specific policy for enriched micronutrient fertilizers.

Ken Giller argued that the policy issue is important. In Zimbabwe for example, the liberalisation of the market had perverse consequences since S and Zn that were obligatory elements in fertilizer earlier were not added anymore. He also mentioned that some large fertilizer companies do see a business case in the agricultural development of

the African continent. In most cases they start investing in cash crops and on commercial farms, but they are building large blending facilities in Africa to provide fertilizer. Change is happening.

It was mentioned that this discussion shows a classic example of longing for simple solutions in an environment of complexity. This will most likely not lead to sustainable solutions. There are different dimensions related to stakeholders (who is willing to pay for better micronutrient management), application (what works and for which goal), and the context (which combination works in which situation). There needs to be a better understanding on which combination of fertilizer could work in most cases. What can be distilled from the discussion is that while there is a lot of knowledge, significant gaps are remaining. However, there is a belief that even though not all details are in place yet, there is a need to decide which interventions are likely to be the most effective and what business case is there to support action. Some participants said that forming public-private partnerships in this field is still difficult and therefore does not happen a lot yet, because of conflicting interest and lack of comprehensive information. To this, another participant pointed out the possibility of social entrepreneurship. A private sector participant sees a lot of PPP that are working and considers social entrepreneurship as an option. Van IJssel argued that they need to know what exactly the nutrition perspective is and what is effective and can be brought to scale, before more steps can be taken to create PPPs. Also a consumer perspective might be needed. How can demand be created for healthy nutrition and fertilizer?

4. Breakout sessions

Three breakout sessions were held where stakeholders debated more specific topics related to micronutrient management. Short summaries can be found below. Afterwards a final plenary discussion took place on the findings of the different groups.

4.1 Micronutrient management for increased production and increased bioavailability of micronutrients in edible parts of products

Chair: Ken Giller, Wageningen University and Research (WUR), Plant production systems, Rapporteur: Levi Bin

This session focused on micronutrient management to increase production and increase the bioavailability of micronutrients in the edible parts of produce.

The importance of soils

It was emphasized that an area which needs more attention both in research and in practice, is the underlying mechanism of micronutrient deficiencies of soils. The imbalance in soil mineral composition today is caused by heavy fertilizer use in the past, however, the solution often presented now is to again use fertilizers to increase micronutrient levels of the soil. Long-term sustainable solutions are needed, which also take the impacts of micronutrient fertilizer in the long-run into account. Susan Klinkert of the Soil Quality Group, WUR is investigating the underlying soil chemical mechanisms of soil micronutrient deficiencies. Improving soil organic matter content was suggested as a potential part of the solution for micronutrient deficiencies, however, there is often restricted availability of organic residues in smallholder farming – as noticed in the plenary session already. There is a need to integrated approaches that combine all possible solutions. For example, applying micronutrients to deficient soils will increase crop biomass production, which (if applied to the soil and not fed to cattle) will increase the bioavailability of micronutrients in the soil, continuing the cycle of soil improvement.

In addition to this, specific attention for soil geology might be needed when researching micronutrient deficiencies. Regarding the timescale in which geological processes take place, minerals that contain micronutrients weather the fastest.

ISRIC wants to know how they can help the fertilizer industry with good information on soils, for example as a basis for the production of location specific fertilizer blends. ISRIC would like to know what information on soil characteristics is lacking that they can provide. Others agreed that good reliable analytics are a must for providing location specific solutions.

Two important knowledge gaps are: 1) the geology behind micronutrient deficiencies in soils and 2) how can micronutrient enriched fertilizer be applied to the soil in a sustainable manner?

Research on micronutrient fertilizer

To investigate micronutrient fertilizer application in the field, a 'trial and error'-approach could help to determine which method is effective and to find best practices. Referring again to geology, Van Erp would like to be able to make generalizations based on the mineralogy of the soil and generalizations on nutrient interactions in the soil.

Ken Giller noted that current research has not investigated direct links between agronomic biofortification and reduced micronutrient deficiencies in humans. This was identified as a major knowledge gap, also in the preparatory Essay for this workshop. Some research is available on the impact of genetic biofortification of crops. The group was asked whether they knew relevant research including direct evidence for the soil-plant-human

pathway of biofortification. It was noted that Se biofortification in Finland might be promising to look into, as well as Se in China. However, again, this evidence is indirect. Zn in Turkey has also been investigated, but again this is indirect. For Fe the evidence is even less substantial since even in areas with soils containing sufficient bioavailable Fe, anemia is found in humans. Therefore it was recommended that the main focus for biofortification could be on Zn and Se.

What is the role of micronutrient application in improving the nutritional quality of food? Is an agronomic pathway for biofortification useful and efficient enough?

Some argued that there is a need to apply micronutrients smartly, through applying chelating micronutrients that can help bypass adverse chemical interactions in the soil or in the fertilizer product (as is the case with Zn in NPK fertilizers). It was noted that in the paper and in general, agronomic biofortification is commonly mentioned as a complimentary strategy to genetic biofortification. It was also noted that the importance of agronomic biofortification is closely related to the importance of soil health. Giller added that soil organic matter management can help increase the fraction of bioavailable micronutrients. Phytosiderophores exuded by certain crop species (notably legumes) can also help increase the bioavailability of micronutrients. Another participant said that education of local farmers regarding deficiency symptoms in plants could help increase the adoption of micronutrient fertilizer products by farmers and that the knowledge of farmers is often underestimated. Zingore noted that there is already much knowledge on deficiency symptoms in plants with local African farmers; however the knowledge on more complex interactions between nutrients and the soil is lacking.

There is also a cultural aspect of eating diverse crops (with for example added micronutrients), sometimes, even though micronutrient rich foods can be grown in certain areas, the main staple food primarily consists of starch. In Ethiopia sometimes micronutrient rich foods are sold, while only starchy foods are eaten. Farmers (and, for that matter, other consumers) are also not always aware that their diets lack certain micronutrients.

Resource availability

It addition, it was brought up that many micronutrients are a limited resource. Ton Kram (PBL Netherlands Environmental Assessment Agency) reiterated this by stating that they have been investigating this as part of the long-term sustainability of micronutrient application and have concluded that some minerals indeed will not be available in the long-term.

Yields or malnourishment?

The discussion focused on strategies to increase yields, since strategies to increase the micronutrient content of crops had not yet been extensively discussed during the preceding plenary. An important question is whether the applied micronutrient will reach the consumer suffering from micronutrient malnourishment. This is not always the case because some crops in which micronutrients will be applied will be exported, or the micronutrients will be in inedible parts of the crop. It was mentioned that more attention is needed on ensuring that people who are malnourished in micronutrients do consume biofortified crops. Now the focus is on yield increase. How to ensure that the increased yield still contains sufficient micronutrients for human consumption? However, others noted that the focus on yield increase is not necessarily bad since it is an incentive to increase micronutrients. Nevertheless, it remains important to monitor the impact of biofortified crops on health.

Some discussion followed about whether a focus should be taken to feed the soil, the plants, or the people directly. This generated some lively interaction, laughter and the conclusion that we need both a healthy soil and productive crops to ensure healthy people.

What is needed in the future?

The aim should be to gradually increase the bioavailability of all limiting nutrients. Increasing general soil fertility will help with this. Cooperation between all stakeholders (including farmers, knowledge centers, and industry) will be needed to solve the issue of biofortification with micronutrients. A balance is needed between specific products for specific crops or regions, feasibility for the fertilizer industry and clarity for the farmers on which products are needed for which crops and soils. Making micronutrient recommendations location specific will be useful; for example recommending Cu fertilizer in a Zn deficient soil is counterproductive

Concluding remarks

- There is a need to raise more awareness on the topic of hidden hunger with African farmers. Both nutrition and agronomic knowledge need to be disseminated. The topic of plant nutrient deficiencies also needs to be addressed. Education is a must.
- Part of the micronutrient deficiency problem could be solved by reducing food wastage
- Micronutrients are seen as luxury (they are taxed as such, while macronutrients are not taxed), while they should be seen as necessity. This is something for policy makers.

- More direct evidence is needed on whether agronomic biofortification increases yields, increases crop micronutrient content, and leads to reduced micronutrient deficiencies in humans.
- Genetic biofortification was missed at the meeting
- It wouldn't be effective to try to achieve higher yields by supplying only one element, because probably more (micro)nutrients will appear to be deficient (Liebig's law). Therefore more integrated approaches should be used which deal with all (micro)nutrient deficiencies (and, for that matter, all yield reducing factors). It would be relevant to find out how 'hidden hunger' in plants ties into this.
- Diverse crop consumption does not necessarily result in increased micronutrient intake.

Questions

- Should the focus be on short, intermediate, or long-term solutions? Which region should be prioritized? Which crops?
- What percentage of the required daily intake of micronutrients will be solved by agronomic and/or genetic biofortification of crops?
- The issue is not only supplying humans with more micronutrients in their diet. There is also a huge challenge growing enough food to feed a growing global population. How can these two ambitions be brought together? More and better food is needed, so yield increase and biofortification go hand-in-hand.

4.2 Human health and nutrition issues related to micronutrient management

Chair: Inge D. Brouwer, Wageningen University and Research (WUR), Human Nutrition

This breakout session focused on human nutrition. It was a rather small group of eight people with mostly nutritionists representing research, private sector and civil society.

Interest in Human Nutrition

The discussion started with a major observation: Why was this breakout group that focused on human nutrition so small and what does this reflect? Although it might have been a consequence of the organisation of the working groups according to disciplinary lines and participants were asked to indicate their interest for a working group beforehand, it might also relate to a lower interest in nutrition. It was concluded that there is need for more advocacy about the importance, need and benefit of agronomic biofortification for improved human health, and that nutrition considerations should be taken into account when discussing the potential of agronomic biofortification for food and nutrition security by all stakeholders (and not only nutritionists).

Nutrition perspective

The question was: How can we achieve the adoption of a nutrient perspective in agricultural interventions and what is the possibility for integrated approaches? It was mentioned that improving nutrition is not a sufficient goal to convince agricultural sector players to adopt nutrition-sensitive approaches, but that it should be linked to other related objectives such as livelihood and food security improvement.

Responsibilities of nutrition expertise

The majority of group members in the discussion group were nutritionists. As experts in nutrition and health, what can they offer to the agronomic biofortification discussion and what can we expect from this intervention? The evidence found in the literature, as described in the Preparatory Essay for this workshop, is limited. It was noted that there is some additional evidence of the potential of agronomic biofortification to improve yield and human nutrition. Affordable Nutritious Foods for Women (ANF4W) is an agronomic biofortification program in Bangladesh. This intervention has demonstrated that agronomic biofortification of rice and potatoes with Zn, improved the intake of Zn and improved nutritional status of women.

There should be more research-based evidence that agronomic biofortification does improve human nutrition and health. There are many factors determining health even after consumption of foods, like bioavailability, absorption by the individual due to physiological state. This information is scarce and more research is needed that investigates bioavailability of micronutrients from foods produced using enriched fertilizer. On a positive note, agronomic biofortification has a potential to reach many consumers in communities. Therefore, the intervention could have the potential to reach the larger population quickly and relatively easily.

Could agronomic biofortification be the solution for micronutrient deficiency in humans?

One participant suggested that micronutrients like Zn or Se are not the most important minerals for soils or plants itself. Agronomic fortification's main aim is to increase micronutrients in crops that are consumed by humans to improve human health. However, agronomic biofortification is not a solution in itself. It is a complementary approach to breeding, supplementation and diversification of the diet. The amount of micronutrients in the edible parts of plants needs to be increased. There should be a combination of different strategies including supplementation, food fortification and also (agro) biofortification interventions.

Acceptability of biofortified crops/foods
Osendarp pointed out that increasing specific mineral content in crops (through breeding or agronomic biofortification) could change taste, colour or smell of foods. Therefore, it is important to investigate the possible changes in food appearance, taste and colour before implementing agronomic biofortification, and to determine the acceptability of these changes in crops and food products by the farmers and/or consumers.

Understanding the feasibility of increasing concentration of minerals in real life
Tjeerd-Jan Stomph (Wageningen UR) said that he could successfully increase the Zn content of rice by 45 ppm in lab conditions through using micronutrient enriched fertilizers. However, this is not comparable to the real scenario. The results in the field are confounded by various other factors like soil quality, weather, crop variety, application process. This could even completely alter the results and make it an inefficient approach. It is important to understand the efficiency and cost-effectiveness in terms of yield, before conducting agronomic biofortification. Also, how much more effective enriched fertilizers is needed to make a physiologically meaningful impact on human nutrition? The case of Turkey is an example of how enriched micronutrient fertilizers can increase the yield of crops. However, in China there was no effect on yield with enriched fertilizers. It is important to understand the drivers of success of enriched fertilizer and to identify suitable locations for agronomic biofortification with proper soil analysis and other factors.

How to make the impact of agronomic biofortification visible to stakeholders, including farmers?
If long term interventions with agronomic biofortification are conducted, how can the outcomes from different aspects of development i.e. soil, plant, food security, human nutrition and environment be assessed and made visible to stakeholders? Improved nutrition is often not an outcome that will trigger farmers to adopt an agronomic biofortification approach. It may be challenging to attract the interest of farmers for interventions using micronutrient enriched fertilizers. Farmers care for their children. Enriched micronutrient fertilizers may improve the micronutrient intake and could improve the health of children. As these are long term changes, it is difficult to attribute these to use of enriched micronutrients. A collaboration strategy in which using school feeding programs to increase demand for micronutrient rich food was proposed. Could this increase the interest of farmers to use enriched fertilizers? Inge Brouwer mentioned that not all school feeding programs have been successful in terms of nutrition improvement, so it might not be successful strategy. But, if it is possible to create a proper market for micronutrient rich foods with a distinctive label on it, it might trigger interest of farmers. It is necessary to make farmers understand and accept the importance of an agronomic intervention, once it is proven to be a cost-effective measure to improve human health.

Scalability of agronomic biofortification
If it could be established that agronomic biofortification can be efficient and cost-effective to improve human health, is it a scalable intervention? There might be problem at the business level. It is important to promote local business for fertilizer production, blending and packaging rather than multinational companies. There has been research in Finland, with national Selenium agronomic biofortification, proving its feasibility and potential to improve human health nationally. However, it was noted that Finland is a developed country and fertilizers use is strictly controlled by the government. Thus, there is an clear need for proper policy, control, monitoring and evaluation for scaling up agronomic biofortification to national level.

Use of enriched fertilizers on livestock feed
The intervention and research conducted in Finland with selenium enriched fertilizers both on crops for human consumption and for livestock feeds is a success story of agronomic biofortification. What is the potential of using enriched fertilizers in the production of livestock feed? Will this increase the intake of micronutrients in human through consumption of dairy products, meat or poultry? No evidence based research could be found to answer this. Osendarp, mentioned that a food value chain including micronutrient rich feed going through livestock is a complicated approach and a simpler food value chain should be studied first. Developing countries have very low intake of animal products and most of diets are plant based. Therefore, the focus should be on staple crops consumed by people. An interesting research question emerged: Does consumption of enriched feeds, increase the reproducibility/use of livestock e.g. increase milk production, high meat yield? If there would be any evidence, this could be one of the incentives for farmers to adopt agronomic biofortification. This was considered a possible pathway, although no evidence is available yet.

Conclusions
It is necessary to understand and make stakeholders aware that the common goal of policies and interventions is to improve human health through healthy plants via healthy soils. Micronutrient deficiencies are a worldwide problem, with immense health effects. There is need for additional strategies to fight the deficiencies around the globe, preferably with multi-micronutrient approaches that could deal with a range of deficiencies at the same time.
Agronomic biofortification should be focused on staple foods in developing countries with priority for Zn since there is evidence of its effectiveness. In addition, agronomic biofortification with selenium, calcium and Mg might be possible. Evidence so far has indicated that agronomic biofortification to improve Fe levels in crops might be less successful. Additional discussion should be conducted with stakeholders to make a selection of the crops that could be used for further agronomic biofortification tests.

The group discussion formulated a key question that should be answered before conducting large scale agronomic biofortification interventions: What can agronomic biofortification contribute to intake and is this beneficial to improve nutritional status and functional outcome? To answer this main question, several subquestions were formulated:

- Crop selection: Should therebe a continued focus on major staple crops, or divert also to the minor grains or nutrient dense foods such as vegetables and pulses?
- Is it scientifically possible to increase the amount of bioavailable micronutrients in the plant parts that are consumed by humans (preferably the vulnerable groups being women and children)?
- If so, can there be a proof-of-principle under 'ideal' circumstances, that using micronutrient enriched fertilizer on selected crops can potentially improve nutrition status and functional outcomes of these target groups?
- If so, what is the effectiveness of implementing micronutrient enriched fertilizer at a larger scale?
    - How cost-effective is agronomic biofortification compared to other interventions? Under what conditions? What are the drivers and constraints of this approach?
    - What are the trade-offs for different stakeholders?
    - Is it scalable for business levels?
- In terms of sustainability: What will be its long term effect from a social-ecological point of view and can this be used to improve the willingness of farmers to use agronomic biofortification? What would be the specific incentives for farmers?

4.3 Business models of various options to improve the management of micronutrients in value chains

Chair: Bart de Steenhuijsen Piters, Royal Tropical Institute (KIT)

The first part of the workshop focused on gathering already existing business cases and understanding them. At the start of the workshop three cases were briefly presented in which the management of micronutrients was improved in different parts of the value chain. Marjolijn Koornstra (BoP) presented a case in Bangladesh where in collaboration with the private sector, a consumer-oriented approach was introduced. They used a social marketing toolkit with different tools to raise awareness on hygiene and nutrition. Rainer Nerger (Soil&More) explained their model in which they focus on improving the usage of what smallholders already have available on their farms (manure, slurry, crop rotation, intercropping with cash crops, tillage, proper composting) to improve micronutrients in the soil. Their business model tries to reduce farmers' dependency on fertilizers, reduce costs, attain long-term stable yield and a secure income through using carbon-credits for sustainable soil management and sequestration of carbon in soil. Sjoerd Smit (AkzoNobel) presented how AkzoNobel focuses on chelated fertilizers that make micronutrients available to the roots of the plants. However, these fertilizers are more expensive than normal fertilizers and are currently mainly bought by commercial horticulture farmers. AkzoNobel is looking for opportunities to scale this technology up to other types of agricultural production. A significant impediment for the use of micronutrient enriched fertilizer is that the price is high since in many countries it has a higher tax tariff than normal fertilizer.

After the presentations, participants of the workshop were asked to list their known cases in which interventions to increase micronutrient uptake have *worked* and of cases in which it *could work* in the future. This exercise looked at two dimensions, application method, and potential investors (farmer, industry, government, consumer). The cases that were identified are listed in Box 1. Some cases showed that success was highly dependent on proper extension systems and that strategies were mostly directed to highly remunerative export crops. For example, in Peru SNV works with smallholder farmers in a commercial organic and chemical fertilizer project in the cocoa sector. Here, micronutrients are blended into the fertilizers. One reason for the success was the existence of an effective extension system. Another example was from India where the government subsidized neem-coating of urea. The composting of tea was also seen as a successful example to make nutrients available to the plants.

Box 1: Successful micronutrient management cases

1. Composting tea to make nutrients available from compost
2. University trials in India leading to knowledge exchange in districts and farmers
3. Smallholder farmers in Peru use foliar fertilizer (Zn, Bo, Mn, Mg) in cocoa sector
4. Farmers testing soils for micronutrient availability
5. Indian government subsidizing neem-coating urea
6. Chinese government cap on fertilizer use, leading industry to invest more effective fertilizers
7. Fertilizer vouchers for poor families in Malawi
8. Soil fertigation with chelated micronutrients (Fe, Zn, Cu, Mn)

In addition to these cases, ideas were presented that had potential to improve micronutrient management (see Box 2). The potential of Integrated Soil Fertilizer Management (ISFM) was discussed. However, there is the need for a business case for this as well. Farmers will not be willing to invest in chemical fertilizer if they can use compost from their farms. It would be wise to focus on the most profitable crops with ISFM strategies. You could target farmers with this strategy, but also have to align with the middlemen to ensure supply. Related to this, the importance of the availability of water was also discussed since for ISFM, you need a stable water supply. Therefore, investment and focus on the improvement of small scale irrigation is important. There are some examples of community operated irrigation that have had a big impact and in which micronutrient availability and soil fertilization improved. Irrigation can ensure a higher yield and better micronutrient uptake. However, the success of collective irrigation depends on the context and on which micronutrients are missing in the soils.

Box 2: Cases with possible success

1. Improved small-scale irrigation (based on collective action) to improve nutrient availability to crops
2. Reusing wastewater/ toilet water
3. N + micronutrients for large scale commodity agriculture (fertilizer producers and governments)
4. Governments subsidizing micronutrient fertilizers
5. ISFM combined with site specific fertilizer, compost application specific to crops
6. Risk-sharing between buyers and farmers for micronutrient fertilizer, and seeds coated with micronutrient fertilizer

In addition, human waste and waste water were mentioned as sources of micronutrients. For this, government investment and awareness raising are needed. This recycling is rather easy, however, the water is often polluted with heavy metals. Therefore, to use the micronutrients from wastewater, it is either needed to get single nutrients out of the water, or remove the pollutants in waste water.

It was also mentioned that industry would be most likely to invest in less fancy add-ons that will have a significant impact. Can we think of micronutrients that could be added to fertilizers and that can pay-off, and for which sufficient evidence is available to invest?

It was observed that discussions and suggestions for micronutrient management referred mainly to improving crop production, and to much lesser extent business cases were considered with the aim to improving human health.

In the second part of the session, four general questions were answered by the group.

1) Can the industry become interested in producing and marketing fertilizer with micronutrients to address food producers (small holder farmers) of staple foods, and high value exports?
There are some examples in which very basic fertilizers are coated and applied in the US Midwest. However, in this case the industry worked with very advanced farm practices, well-organized cooperations and highly educated farmers. The transferability of these products to the African context is questionable. Some would even say that there does not even exist a business case for regular fertilizers in Africa, since the costs are too high due to bad infrastructure. Given the great diversity of the soils, different solutions may be needed in addition to just fertilizers. Also,, the industry prefers simple, scalable solutions, like blending a micro nutrient with the regular fertilizer and then market it at large scale. However, it might be better for farmers if companies market single nutrient fertilizers and blend this on the spot according to the needs of the people and the soil. Nevertheless, it was mentioned that this is difficult to do for micronutrients since the quantities are so small and knowledge of soil fertility needs might not be sufficient. It also needs to be considered that most fertilizer companies are part of chemical companies, and only a few businesses have an agronomic division that markets the products as well. Many other companies do not have this knowledge.

Some argued that legislation is important to enhance micronutrient uptake. In Zimbabwe it was compulsory to add micronutrients in fertilizers and this worked. Which nutrients could be added to normal fertilizers through legislation? It was mentioned that this really depends on the quality and soil fertility status of the soils. Some are drained quickly. While a detailed soil analysis of every field is not needed, there is a need for context-specific strategies. It would be interesting to see whether there is a common denominator that would target 30% of the soils and that could be produced at reasonable prices by industry

2) *How can we market e.g. micronutrient rich rice that consumers are willing and able to pay for? Is there enough consumer demand for biofortified foods?*
In the first part of the discussion no examples had been presented in which consumers were willing to pay for micronutrient-rich foods. It therefore might be that the investment most often needs to be made by industry, government and farmers since buyers' incentives for biofortified food are low in general. The more unhealthy people are often the poorer people who will and can not invest in biofortified foods, but do need it. Richer people will invest in biofortified health food, but may not really need it. However, the middleclass in LMICs is also micronutrient deficient, is more aware of the health benefits, and may be willing to buy such foods, so there might be a business case for this group. Here social marketing could work. There are examples (micronutrient fortified salt in China, biofortified maize in Ugandan hospitals) where this worked. For the poorer consumers who are not willing or able to pay, the government could make an investment. However, if you want to market biofortified products, a clear differentiation of products is needed, to ensure that the higher costs for micronutrient rich foods will be acceptable. To do this, there is a need for more evidence that the micronutrients added to the soil or fertilizer end up in the products and contribute to the health of by the consumer.

3) How can uptake be promoted among farmers? Is cost the main reason why farmers do not buy the fertilizer? There are also examples of innovations that farmers could afford but did not take up. Is there a need for farmer-driven innovation?
One business case that could work is the sharing of risks between farmers and the fertilizer company with agronomic expertise. They would provide the product, but also take a share of the extra yield achieved through the products. However, whether this also works with smallholder farmers will depend on how they are organized. In the US this strategy has worked with farmer cooperations. The use of vouchers could also support the use of micronutrient-rich fertilizer. In Malawi poor farmers received vouchers to buy fertilizer in local shops. This improved farmer's access to fertilizer and improved the soils and yields. In Burundi a similar fertilizer programme with urea had no impact since the soils were not well managed before and therefore the urea did not improve yields. Another strategy is to focus on the collaboration between universities and farmers to transfer knowledge to improve nutrition. In India, there are cases in which university trials reach many farmers. Here also the role of the distributors of fertilizers was capitalized on. They would provide the product and share expertise.

These cases are however not examples of successful commercial introductions. It seems that due to the costs related to innovation (extension, building capacity) development policies need to address this issue. There is a role for NGOs and for governments to provide pre-competitive funding, and ensure public investment to make a start.

4) Can we think of a pilot case that will work in an ideal case?
Maybe a pilot case could focus on adding micronutrients within a fertilizer subsidy scheme to ensure farmers apply a micronutrient (like Zinc) in combination with other nutrients and explore the effect on the quality of food. However, what is the business case? Who will buy this fertilizer and make the investments in it?
Maybe instead of pilots that are context specific, a meta-analysis of data and different tests that have been done could help to determine which solution is most suitable. Within all these cases, what is the common denominator that adds value to the products?

There is no evidence that all nutrients added to the soil or plants will improve human health directly. It would be important to figure out which intervention has the most impact on human nutrition and health.
Organic fertilization should also be considered. With organic fertilization most nutrients are saved and returned to the soil, and there is no need for an intervention by multinational companies. However, it is debatable whether the amount of organic material available on the African continent will be sufficient; as discussed earlier in the workshop a focus may be considered that combines the use of organic and chemical fertilization in ISFM.

All in all, this workshop showed that the business-case to improve yields is stronger than the business case to improve health for the consumers. Since the knowledge on the impact of agronomic biofortification on health is limited it is hard to create a business case for consumers. While the industry is eager to find a universal solution through blending one or more 'promising' micronutrients through regular fertilizers, others were sceptical of these solutions that cannot take into account the context-specific qualities of the soils and the needs of the farmers.

5. Plenary discussion about remaining knowledge questions and opportunities for follow-up

5.1 Reports from breakout groups

Brief Nutrition

- The group agreed that micronutrient deficiencies cause enormous health problems, and that there are multiple solutions.
- Efficacy: more research on the efficacy of enriched fertilizers is needed with priority attention for Zn, Selenium, Cu and Mg. Based on the available evidence, enrichement of Fe seems not the an obvious approach.
- Still remaining for discussion: whether the focus of further research on agronomic biofortification needs to be on staples, legumes or nutrient dense foods. The group tended to prioritize research on staple foods, but recommended that this needed to be further discussed with various stakeholder groups.
- The target group of these efficacy studies should be children, particularly during the first 1000 days.
- Effectiveness: research on the cost-effectiveness of agronomic biofortification at population level, its trade-offs, stakeholders acceptability and other related factors is needed.
- Another point was the level of scalability for the market in order to involve the private sector.
- Research questions on chain sustainability: is agronomic biofortification feasible for farmers in the long run and what are the incentives for farmers? And at the other end of the spectre: can public awareness raising about the importance of fortified food support efforts? Possibly publicly funded?
- Is it possible to use micronutrient fertilization for livestock feeds? Is there any research on this possibility?

Brief Plant Production

- Definitely need for more research, building on the indirect evidence that is available for example in the work by Cakmak in Turkey. The upcome work by Susan Kinkert (WUR, PhD) is interesting.
- Zn enriched micronutrients fertilizers can be produced, and it is necessary to do so. There is a direct role for policy and governance to support their production and use, for example NPK are not taxed while Zn enriched fertilizers are. The group considered Fe could only be tried in very specific circumstances, and Se could offer opportunities too. Point of attention is the interaction between Zn and Fe.
- Focus on staple crops and legumes along with research on possibilities for other diverse food crops.
- Agronomic biofortification does increase yield. It is also important to have a diagnosis of the soil condition through mapping and soil tests.
- There is need for more research on types of fertilizer blends and how stakeholders can be involved throughout the chain.

Brief Business Models

- There is need for publicly funded awareness programs to stimulate the sale offortified foods. However only for the middleclass, the poorest of the poor need to be reached through other programmes
- Create a market for food produced from agronomically fortified crops through government intervention and subsidies.
- Initiatives for farmers may be for example that cooperatives pay for the fertilizers
- Would local blending of fertiliser ingredients including micronutrients be an option for staple food crops? And would international companies collaborate? The industry would not provide ‘the silver bullet’, but the ingredients. If there is more evidence that agronomic biofortification works, would farmers start applying it? Not likely without incentives. Could fertilizer industry play a role, e.g. in risk sharing, insurance?

5.2 Final discussion

The final discussion brought up a few previously discussed issues and some fresh ideas. It was agreed that the overall ambition is healthy people through healthy soils and plants. Similarly, that there is need for a combination of different strategies to fight micronutrient deficiencies. So far, there is no specific evidence of direct impact of micronutrient enriched fertilizers on human health, but a lot of research has shown the potential.

The consumer perspective

The first part of the discussion concentrated on the demand side. Could the food industry somehow increase consumer demand for food products rich in micronutrients? The demand from the middle class in LMICs seems most promising. However, the evidence base is still too limited to convince consumers to buy these products for a premium price.

This may be tackled by introducing certification of micronutrient enriched food products, which governments of some Asian countries have done already, and which also addresses the problem of the lack of visibility of micronutrients in food. Fe in fortified rice is not visible for buyers in comparison with new forms and shapes of a fruit or vegetable.

Since it seems that there is a business case for yield but not for nutrition, government policy is probably needed to create demand for biofortified foods. The market alone is not likely to facilitate consumption of micronutrient rich foods.

Scaling up

Thereafter, it was explored how one could foster upscaling of promising or good practice. Better data are necessary to guide actions before scaling-up. Approaches may be doing a meta analysis about what is known – e.g. on impact of fertilization experiments with micronutrients on yield or on nutritional content; on spatial distribution of potential (micro)nutrient limitations. These can serve as background information to identify the impacts both in terms of yield/nutritional effect and spatial requirements (magnitude of volumes needed). Subsequently an analyses would be needed related to enabling conditions to introduce micronutrient-containing fertilizers (business case for farmers and industry, policy conditions, etc.).

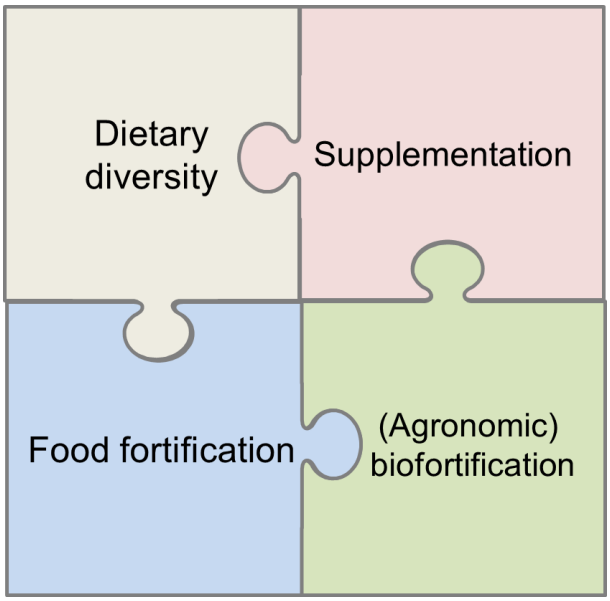
Environmental impacts and availability of minerals

The long-term availability of micronutrients was a concern several participants shared. The discussion focused on business cases and concepts to face the problematic availability of some micronutrients in the (near) future. For example available Zn reserves may become depleted in about 20 years. There is a reliance onthe mining industry finding more sources of micronutrients, however, there is no certainty they will. In this context, micronutrient recycling is important, and the question is to what extent it is possible. In the Fertile Grounds Initiative Alterra/WUR and others join efforts to close the gap of nutrients on different levels of scale, including recycling (micro)nutrients. The initiative brings together knowledge from different stakeholders. Challenging is that organic matter generally contains small micronutrient amounts, these are almost too small to recycle. The effectiveness of the recycling of waste water is also explored and appears to depend very much on the context. Participants also mentioned that micronutrients are used as ingredient for other, non-food products as well, which would merit a broader discussion in society. A lot of Zn is used in cosmetics, the metals are used in other industry applications.

The final discussion showed a lot of research is still needed. A priority should be whether agronomic biofortification could indeed solve micronutrient deficiencies in people and if the technologies developed so far can be applied in various contexts, and both in OECD countries and LMICs. The scientific research and practical knowledge available so far is not yet sufficiently connected. While there are indications for opportunities, there is insufficient basis for immediate large scale implementation of a straight forward strategy, as there are still a lot of factors and actors (‘dots’) that need to be connected.

6. Concluding remarks

Coosje Hoogendoorn summarised the key conclusions from the presentations and discussion sessions of the day. The stakeholder workshop showed that the issue of micronutrient management is still in need of a lot of research and clarification. Especially, the pathway from agronomic biofortification to human micronutrient uptake is still insufficiently clear. In addition, technological inputs related to agronomic biofortification (in particular, micronutrient enriched fertilizers) are not accessible and available to small-scale farmers in Africa due to high costs or lack of distribution. All in all, micronutrient management can be portrayed as a jigsaw in which there are different pieces that need to be put together in an integrated approach: dietary diversification, supplementation, food fortification and (agronomic and genetic) biofortification. There is some evidence of the efficiency and effectiveness of interventions including some first experiences with agronomic biofortification, but this is still limited and not strong enough to justify significant business investments yet. The key knowledge question is which of the parts of the jigsaw are most important to contribute to improved human nutrition, and how to improve the fit between the different interventions?



Looking more closely at agronomic biofortification, different elements could be explored in a further knowledge and research agenda: technical knowledge; knowledge about the value chain(s) (what business cases are there, what is working and why?); and knowledge systems (science, farmers, processors). In addition, it is important to look at the policy and enabling environment for successful interventions.

The following assumptions were formulated as a start for further research and improving practice:

- Zn is one of the micro-elements with which practitioners could start developing (pilot) programmes. It has been shown to work both at a plant and human level.
- The focus of further research about agronomic biofortification is probably best targeted to staple foods.
- Blending of micronutrients with NPK fertilizer needs to be considered. However, the challenge is to develop an appropriate micronutrient enriched NPK fertilizer mix for different types of soils with different levels of micronutrient deficiencies. Related questions are therefore which soil tests are most appropriate for LMIC conditions, and how would farmers be supported to use these? And could the possibility of blending on-the-spot be considered?
- Pilots could be important to help understand what works and what doesn't, however the scaling of pilots is known to be difficult. In addition to this, how much nutrients can be extracted sustainably by the mining and fertilizer industry, and what role is there for recycling micronutrients?

Finally, while the workshop identified the lack of knowledge around the micronutrient pathways from soils via crops to plates of people suffering from hidden hunger, participants stressed that any future research should not be just academic but involve and/or reach out to all relevant stakeholders.

Annex – Participants List

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