Research and Implementation Program for the 3rd Phase of the HarvestZinc Project

The research and implementation program of 3rd Phase of the HarvestZinc project will be realized in China, India, Thailand, Pakistan, Brazil and Turkey. Target crops will be wheat in Pakistan, India, China, and Turkey and rice in China, India, Thailand and Brazil. The project will start on 1st January 2015 and continue for 3 years.

Major Tasks of the project are outlined below.

TASK-1: Determine the Response of New High Zinc Crops to Soil and Foliar Fertilizer: Exploiting Synergies from Genetic and Agronomic Options

After a long-term successful breeding effort and following the identification of high zinc lines and their release, HarvestPlus initiated the delivery of the first biofortified zinc-rice and zinc-wheat lines having up to 8ppm (rice) to 12 ppm (wheat) added zinc in the grain. It is assumed that these biofortified genotypes have high genetic capacity to absorb more Zn (and possibly also other micronutrients) from the soil and/or transport more Zn from vegetative tissues into seeds compared to currently available cultivars. It is, therefore, of great importance to examine the individual response of these genotypes to soil- and foliar-applied micronutrient containing fertilizers to capitalize on synergies from agronomic and genetic options.

It is expected that the identified high-Zn candidate lines for commercialization will respond at a much higher rate to soil and/or foliar applied micronutrient-containing fertilizers compared to currently cultivated varieties. This research task will build on results from the Phase I and Phase II of the project in developing crop management recommendation tailored for individual genotypes to fully exploit the genetic potential of high zinc varieties.

Experiments by using high-zinc lines will be conducted under field conditions in Pakistan and India and under controlled greenhouse conditions at Sabanci University in Istanbul. The studies planned will examine genotypic response to soil and foliar zinc and iodine fertilizer products under field conditions. Short-term root uptake and translocation experiments will be also conducted under controlled conditions by using selected high zinc lines. To assess the effect of Zn fertilizer treatments on Zn bioavailability of individual genotypes, phytate and the phytate-Zn-molar ratio will be determined both in whole grains and in milling products.

TASK-2: Test Next Generation Fertilizers

In recent years, several fertilizer companies increasingly pay attention to the impact of their micronutrient containing fertilizers on improving the nutritional quality of the edible parts of food crops. In the past, the focus was mainly on yield and production economics. By now, next generation fertilizer products for soil and foliar application have been developed and made available for research and test marketing. Studying these new products for their agronomic effectiveness in increasing grain Zn as well as grain selenium and iodine (see below) constitutes a new task in the 3rd phase of the project.

Corresponding field experiments will be conducted in the mentioned target countries and cereal crops by using the fertilizer products provided from the sponsoring companies.

TASK-3: Iodine and Selenium as New Target Micronutrients to the Fertilizer Strategy in Improving Human Health

Besides Zn deficiency, iodine deficiency (ID) is also widespread in human populations and negatively impacts on health in particular in children and pregnant women. Main effects include impaired growth and mental development, rapid growth of goitre and increases in pregnancy loss. Despite significant achievements in reducing ID incidence in human populations through the use of iodized salt, there are, however, still approximately 2 billion people suffering from ID. Due to infrastructural and/or cultural problems, the impact of salt iodization interventions on reducing ID has failed in many places. The global efforts to reduce the daily salt intake also raise concerns for further increases in ID in human populations.

As demonstrated for Zn, agronomic biofortification approach can be an effective tool in improving iodine content of staple crops and contribute to alleviation of ID deficiency in humans. For the 3rd phase of the project, we propose field and greenhouse experiments to study effect of iodine-containing soil and foliar fertilizers in increasing iodine concentration in wheat and rice in the mentioned target countries. This project component will build on the knowledge and experiences gained and lessons learned in the previous phases of the HarvestZinc project.

There is a body of evidence concerning the effect of selenium (Se) fertilizers on improving grain Se concentrations, and commercial products enriched with Se are available. However, information on the effect of Se fertilization in target countries such as Pakistan and India is very limited. Further, the development of a combined foliar spray containing Zn, I and Se ("coctail spray") and testing its effectiveness in wheat and rice biofortification is of great importance. Experiments will be carried out under field and controlled greenhouse conditions to monitor root uptake, root-to-shoot transport and seed translocation of these multiple elements when they are applied together to the soil or foliar. A cocktail foliar spray of Zn+Se+I will be developed after the tests under greenhouse conditions at Sabanci University.

TASK-4: Development of a Best Agronomic Foliar Spray Practice for Maximizing Grain Zinc Based on Lessons Learned and New Knowledge Generated

The second phase of the project generated new results, information and experiences which are highly relevant for practical application for improving the Zn density in grains. The following factors were identified having a particular influence on grain Zn: i) the form of Zn in soil applied NP and NPK fertilizers (e.g. chelated Zn versus inorganic Zn); ii) pH of the spray solution and its acidification; iii) inclusion of urea and adjuvant in the spray solution; iv) the form and rate of Zn in foliar-applied fertilizers, and, v) timing and frequency of foliar Zn application spray. These factors will be considered and harmonized to develop the best agronomic practice of foliar spray and soil fertilizer application to maximize grain Zn in targeted countries and crops.

TASK-5: New Research to Understand the Differential Response of Wheat, Maize and Rice to Foliar Zinc Fertilization

Large number of previous fertilizer trials of this project conducted under field conditions in different countries revealed that wheat is very responsive to foliar Zn application and exhibits large increases in grain Zn (up to 2-fold). Significant increases were also obtained in rice grain Zn concentrations with foliar Zn spray, but the magnitude of the increases are lower compared to wheat. In contrast to wheat and rice, the reaction of maize to Zn fertilization was variable and insignificant. At the last annual meeting of the HarvestZinc project in 2013, all participating partners stressed the importance of research to understand the low response to foliar Zn spray in maize. This topic will be a further TASK of the Phase III.

Research will first examine the structure of the leaf surfaces at the cuticular and stomatal level and the number of stomata on the adaxial and abaxial parts of the leaves. This study will be complemented by short-term experiments to study the leaf penetration and absorption of radio-labelled Zn (^{65}Zn) in wheat and maize leaves. These experiments will clarify whether leaf penetration/absorption of Zn is an important factor in the differential response of wheat and maize to foliar Zn spray. Since the nitrogen status of plants (e.g., grain protein) is positively associated with grain Zn accumulation, additional experiments will be designed to study the role of N fertilization on grain Zn accumulation in wheat and maize under greenhouse and field conditions. It is known that maize has lower grain protein than wheat. Results of this task will have significant practical and agronomic implications.

TASK-6: Promote and Create Awareness to Facilitate the Adoption of the Zinc Fertilizer Strategy at the Farmer and Policy Maker Levels

Delivery and implementation of the project results will continue as an important element of the HarvestZinc project. Organization of the **"Zinc Days Events"** will be extended by **including iodine** to introduce and deliver project results and related knowledge to farmers and governmental organizations in each target country. This event represents highly useful forum for farmers/growers and agronomists, and provides very valuable basic information on Zn and iodine through oral presentations and educational materials such colour brochures/booklets and factsheets.

In addition, **large-scale farmer-participatory field trials** will be established to demonstrate to farmers the benefits of using high Zn-seeds on germination, seedling vigour and final yield. In these on-farm trials, a larger part of farmer's field (e.g. from 1/5 to 1/2 of the field depending on the size of field) will be planted with Zn-enriched seeds. As the farmers are engaged in monitoring crop development, they will observe and experience the benefit of high Zn seed.

Studies regarding the **cost/benefit analysis of agronomic biofortification** initiated in the 2nd Phase of the project, and the results obtained will be validated in the 3rd Phase of the project including iodine. Planned activities will consider country specific circumstances and the lessons learned in the past to evaluate the costs and benefits associated with fertilizer applications and to understand the potential value of the fertilizer concept in biofortification of cereals with Zn and iodine. This program will be conducted jointly with the project partners in Pakistan and India.