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ICARDA
Science for Better Livelihoods in Dry Areas

Research Brief 1

Combating Micronutrient Malnutrition With Biofortified Lentils

The Challenge

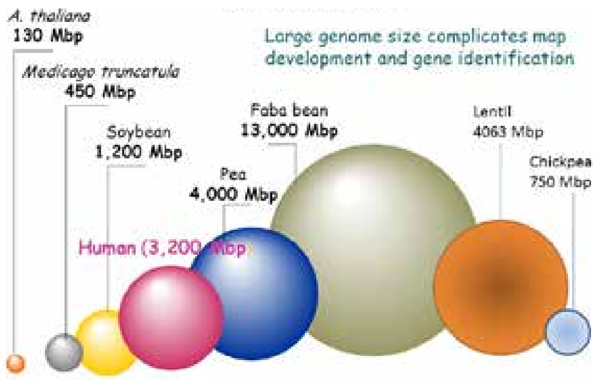
Over two billion people in the developing world are malnourished and affected especially by micronutrient malnutrition. More than 47% of women and pre-school children in developing countries suffer from iron deficiency that impairs physical and mental growth. Zinc deficiency is also prevalent in the developing world that hampers growth and development, and weakens the immune system.

Through genetic enhancements, ICARDA scientists have developed micronutrient-dense varieties of lentil, a staple diet of many poor people in the regions of South Asia and Sub-Saharan Africa. This biofortification of lentil with iron and zinc, has proved to be an effective measure to combat micronutrient malnutrition, the hidden hunger.

Combating Micronutrient Malnutrition With Biofortified Lentils

Lentil, an important pulse crop, is predominantly grown and consumed in South Asia, West Asia, North Africa and East Africa. Despite its role in nutritional well-being among consumers and farmers across the developing world, over two billion people suffer from micronutrient malnutrition - iron and zinc deficiencies in particular - that lead to anemia, impaired physical and mental growth, and decreased learning capacity. Women and children are the worst affected.

Micronutrient malnutrition can be addressed through food diversification, food fortification and nutrient supplementation, but these measures are beyond the reach of the poor. To address this challenge, ICARDA has adopted a new approach, Biofortification, under the HarvestPlus Program of CRP-A4NH, where international and national research bodies are engaged to enrich the staple foods with micronutrients. Legumes have large variations in the size of their genomes, as shown in the adjacent figure. Lentils are seen to have 4063 million base pair (Mbp). These massive genomic resources are used in applied breeding, which is a complicated process.



Comparison between some pulses genome and other genome models

Developing micronutrient-dense varieties

Biofortification, the process of breeding crops to increase their nutritional value, is done by using genetic diversity stored in gene-banks. ICARDA's Biodiversity and Integrated Gene Management Program, as a partner of HarvestPlus Challenge Program and national agricultural research systems and partners in Bangladesh, India, Nepal, Ethiopia, Morocco and Syria, is long engaged in research on this subject. It is also involved in the identification of new germplasm sources with high iron and zinc content, and deployment of these traits in the best agronomic background.

Alemaya, the iron and zinc enriched lentil variety in Ethiopia

More than 1700 germplasms including wild species, breeding lines, and released cultivars from about 20 countries were analyzed for iron and zinc content. Iron and zinc were found to be present in a wide range of 43-132 ppm and 22-90 ppm respectively in these materials. This high presence of iron and zinc content in cultivated species and wild relatives (ILWL74 and ILWL80) encouraged scientists to proceed further for genetic enhancement through pre-breeding efforts. Some promising lines showed stability in iron and zinc content, and had moderate to high heritability.

Using the high content germplasm, breeding lines and popular cultivars, hundreds of crosses were made at ICARDA during 2006-2015 in various combinations, and about 36 final products were developed every year. Some of these varieties were released and a special international nursery, LIEN-MN (Lentil International Elite Nursery-Micronutrient), was made available to NARS partners to select high yielding and high iron and zinc content materials based on local adaptation. Significant genotype-by-environment (GxE) interactions were observed in many cases; iron content is more sensitive to environmental fluctuations compared to zinc content. A few genotypes were identified with stable high-iron and zinc contents (IPL 320, L4704).

Many of these lines are under advanced testing by collaborating partners for eventual release. Identification of high-iron and zinc genotypes has encouraged breeders to use these in hybridization programs.

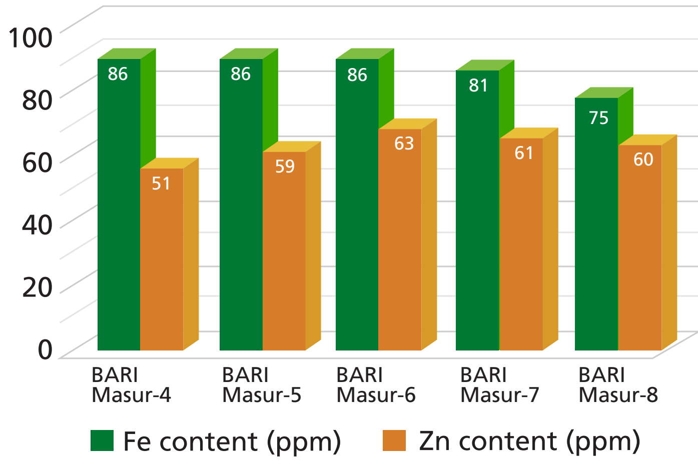
Disseminating biofortified cultivars on a massive scale

Several released varieties were discovered in Bangladesh, Ethiopia, Nepal, Morocco, Turkey, Syria, Lesotho, and Portugal with high iron and zinc content. This has encouraged the national programs to disseminate these varieties as 'Fast Tracking'.

Bangladesh

The Government of Bangladesh has involved farmers, extension department, Pulse Research Center of Bangladesh Agricultural Research Institute (BARI) and NGOs in a massive dissemination program to out-scale biofortified cultivars, BARI Masur-4, BARI Masur-5, BARI Masur-6 and BARI Masur-7 in traditional and non-traditional areas. It is estimated that about 145,600 ha (out of a total of 182,000 ha) have been covered by these varieties and with an average production of 1.3 t/ha, the country is producing more than 186,000 t of micronutrient-dense varieties for the local population. These varieties have been released by BARI by single plant selection from segregating populations developed at ICARDA through cross-breeding. In early 2015, BARI released another micronutrient-dense variety BARI Masur-8. Most of these varieties have high level of resistance against prevailing diseases with attractive seed traits and are adapted to sole planting, and intercropping with sugarcane.

Fe and Zn contents of lentil varieties released in Bangladesh



Note: In the commonly available local varieties, iron and zinc content are in the range of 55-62 ppm and 32-41 ppm, respectively.

A woman farmer in BARI Masur-6 lentil field being interviewed by the national media in Bangladesh

Ethiopia

In Ethiopia, the popular variety Alemaya, which has high and stable yield, resistance to diseases and wide adaptation, covers a substantial area (~10% of the lentil area).

Ethiopia's Alemaya lentil variety gives high and stable yield

Syria

In Syria, Idlib-2 and Idlib-3 are under an extensive dissemination program.

Nepal

Biofortified varieties Khajurah-1, Khajurah-2, Shital and Sisir are under fast tracking in the Terai region of Nepal. Cultivation of these varieties helps in meeting iron and zinc deficiency in the country. Similar efforts are underway in India for promoting Pusa Vaibhav, a high iron content variety.

Syrian farmers pleased with the harvest of Idlib 3

Dr. P. Wolfgang of HarvestPlus (third from the left) with farmers in Syria

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Moving Forward

An important scientific finding of this research is that iron and zinc syntheses in lentil seed are positively correlated and they have a positive correlation with protein content synthesis. Therefore lentil varieties with high iron, zinc and protein content can be developed together. However, the development of high-yielding and high-micronutrient varieties with stable performance across environments is still a challenge.

Advanced research is being carried out to further explain genetic control and molecular mechanisms affecting the accumulation of iron and zinc in lentil grain. Recombinant populations have been developed for molecular research in tagging genes/QTLs (Quantitative Trait Loci) responsible for high iron and zinc synthesis in lentil seeds. A comprehensive knowledge of this will further help in combating micronutrient malnutrition.

Country of dissemination	Biofortified Cultivars	Micronutrient Content (Fe - Iron; Zn - Zinc)
Bangladesh	Barimasur-4	Fe 86 ppm and Zn 51 ppm
	Barimasur-5	Fe 86 ppm and Zn 59 ppm
	Barimasur-6	Fe 86 ppm and Zn 63 ppm
	Barimasur-7	Fe 81 ppm and Zn 61 ppm
	Barimasur-8	Fe 75 ppm and Zn 60 ppm
Ethiopia	Alemaya	Fe 82 ppm and Zn 62 ppm
India	Pusa Vaibhav	Fe 102 ppm
Nepal	Khajurah-1	Zn 58 ppm
	Khajurah-2	Fe 94 ppm and Zn 59 ppm
	Shital	Zn 59 ppm
	Sisir	Fe 98 ppm and Zn 64 ppm
	Shekhar	Fe 83 ppm
	Simal	Fe 82 ppm
Syria	Idlib-2	Fe 72 ppm
	Idlib-3	Fe 73 ppm

ICARDA's Crop Improvement Program

ICARDA has a global mandate for the improvement of barley, lentil, grasspea and faba bean. With partners in more than 40 countries, ICARDA produces science-based solutions for new crop varieties (barley, wheat, durum wheat, lentil, faba bean, kabuli chickpea, grasspea pasture and forage legumes). The Marchouch research station near Rabat in Morocco is host to a model crop improvement program that develops crop production technologies for both high and low potential agroecosystems. This research station, with cutting edge biotechnology labs, over 100 hectares of experimental fields, seed system infrastructure and a pool of world class scientists, builds on ICARDA's longstanding partnership with Institut National de la Recherche Agronomique (INRA). ICARDA has decentralized its genetic resources activities in Tel Hadya, Syria, and continues to strengthen its genebank holdings in Morocco, Lebanon and Tunisia while safely duplicating them in Svalbard in the Arctic. The crop improvement activities are well supported by facilities created at different platforms including Terbol in Lebanon, Amlaha in India and Cairo in Egypt.

Partnership of: ICARDA Science for Better Livelihoods in Dry Areas; CGIAR Research Program on Agriculture for Nutrition and Health, Led by IFPRI; HarvestPlus

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