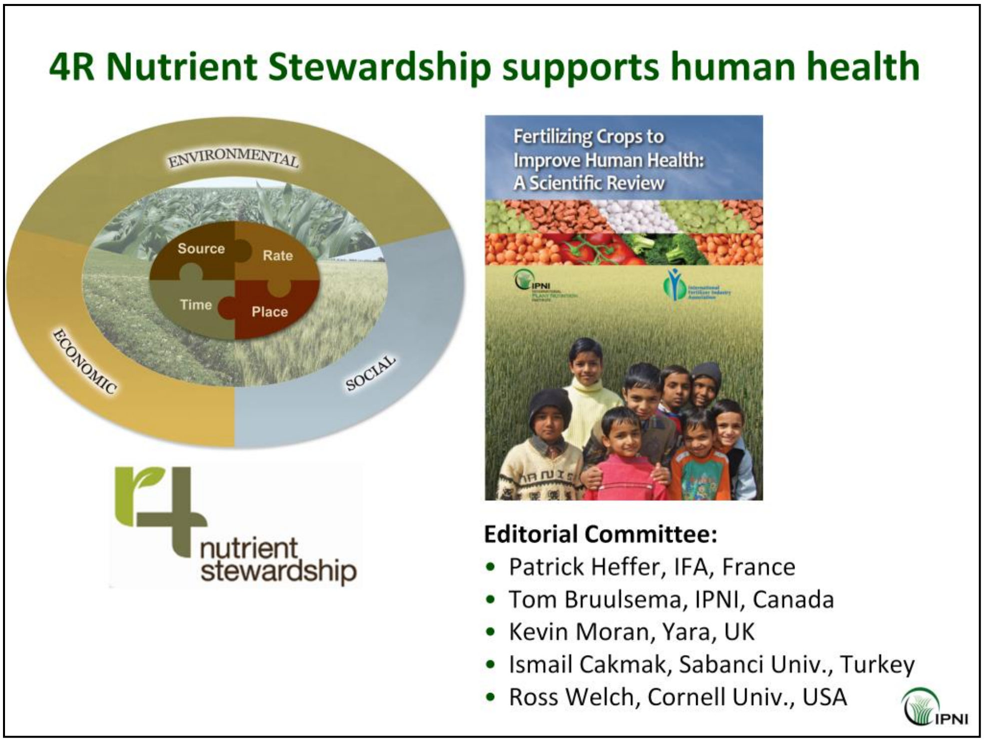
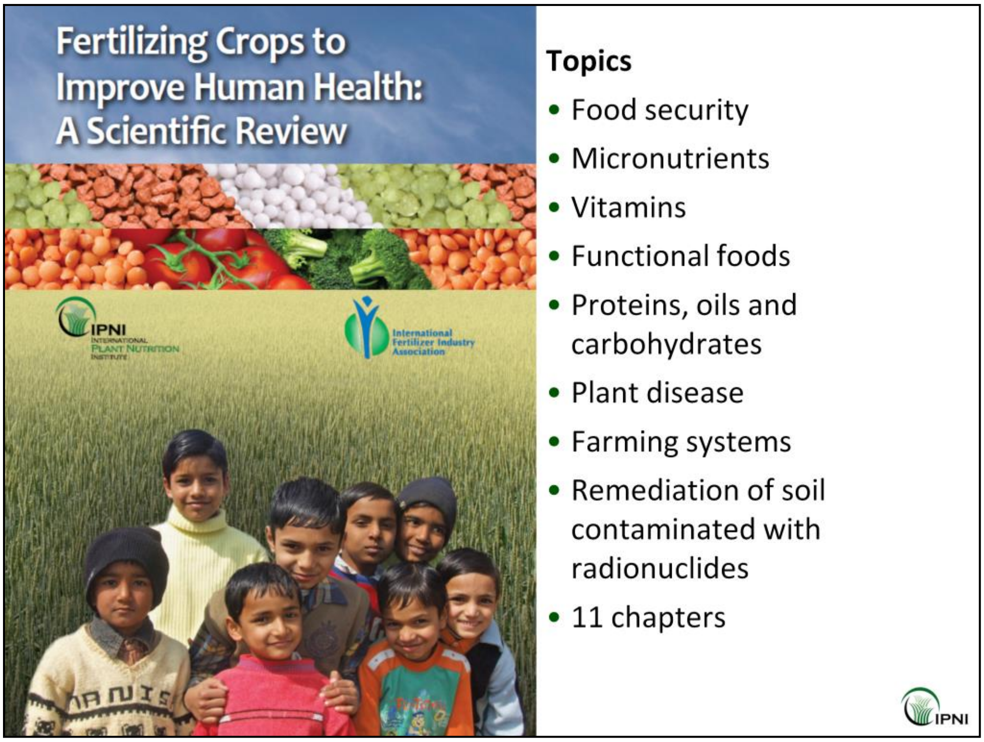
Distinguished guests, ladies and gentlemen, I am delighted to have the privilege to speak to you today. I come from Canada, and over the past few years I've had the opportunity to work in collaboration with the International Fertilizer Industry Association, editing and publishing a book on the topic of Fertilizers and Human Health. But you will note I work for the International Plant Nutrition Institute or IPNI, another fertilizer industry organization.

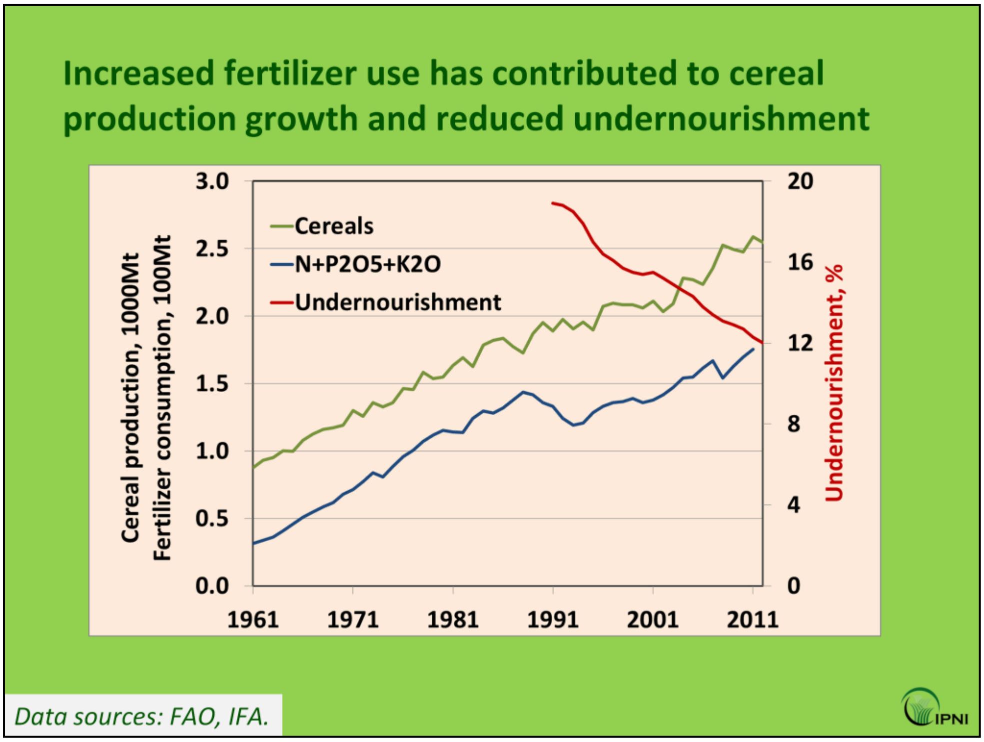
IPNI is supported by producers of plant nutrients as a not-for-profit research and education organization. Its mission is to promote scientific information on responsible management of plant nutrition. I represent IPNI as regional director for Eastern Canada and the Northeastern USA. My background is in crop and soil sciences, from the University of Guelph in Canada and Cornell University in the USA. I also have past experience working in agricultural development in Bangladesh.



I am here to explain how fertilizer supports human health by contributing not only to a greater quantity of food, but also to increasing its quality. Since 1948, the World Health Organization has defined human health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” This state of well-being is closely related to the goal of sustainability with its emphasis on economic, environmental and social pillars. Our industry’s 4R Nutrient Stewardship approach--applying the right source of plant nutrient at the right rate, time and place—therefore needs to ensure that these 4 are right for food quantity, right for food quality, and right for the environment to support human health. Five years ago, IFA and IPNI decided to launch an extensive scientific literature review of the state of knowledge in the complex domain of human health enhancement through fertilization. The five people listed here formed the editorial committee. The end result was this book, released last year and available from either IPNI or IFA.



This book has 11 chapters covering topics of food security, micronutrients, vitamins, and many more components of foods related to human health. Each chapter was written by internationally recognized scientific authorities. All the chapters have been peer-reviewed by academic scientists in order to ensure a thorough and balanced analysis. The rest of this talk is largely an overview of the main topics, with a focus on major opportunities for extension program support further research. The book serves as a reference documenting the facts I will present.



Growth in global cereal production continues much as it has through the past 50 years, and much—although not all—of this growth can be attributed to more and better use of fertilizer. Cereal production here is shown in thousand millions of tonnes, and global fertilizer consumption in hundred millions of tonnes, on the left axis. Over the same period of time, we believe there has been a reduction of undrenourishment, although global figures from FAO are available only since 1990. The reduction in undernourishment over the past twenty years is remarkable, though we must remember it is a decreasing percentage of an increasing world population, and 12% of over 7 billion people is still an unacceptable number. In addition, percent undernourishment is an indicator of calorie deficiency; the prevalance of stunting, wasting and other symptoms of nutritional deficiencies are not included. These need our attention. They have various causes and require site-specific solutions.

1986 – Bangladeshi farmers: *rabi* soybeans or *boro* HYV rice?

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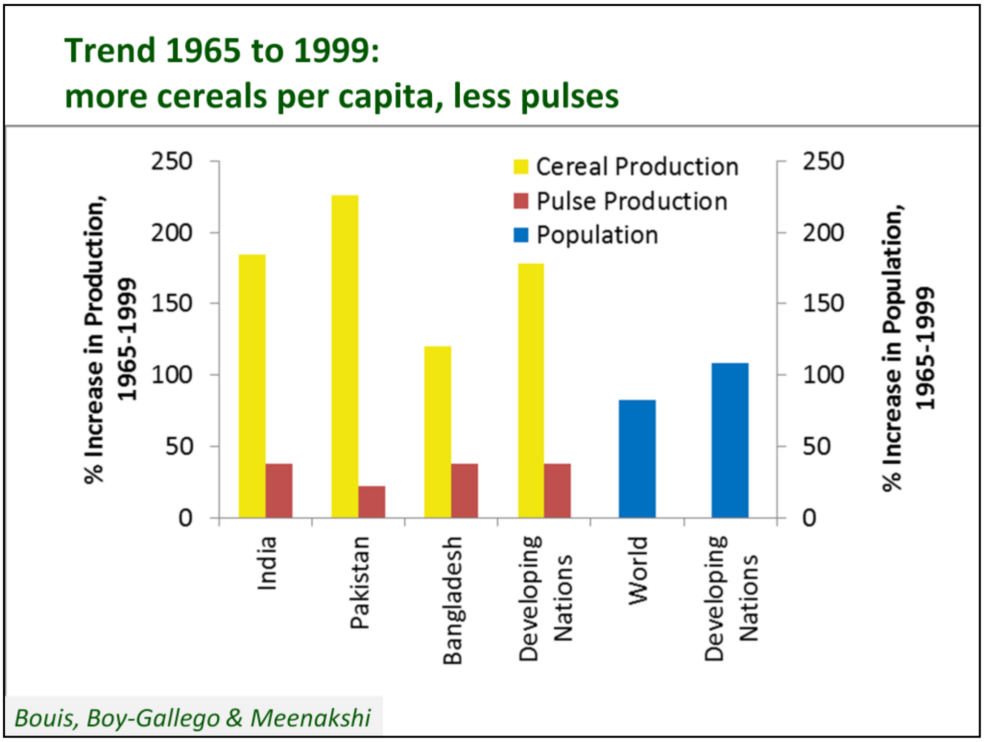
During my time as an agronomist in Bangladesh in the late 1980s, I personally witnessed the growth of cereal production. Irrigated rice and wheat were increasingly taking land away from pulses like mungbean, chickpea, and lentils, and made the introduction of soybeans into the cropping system more difficult.



Howath Bouis and his colleagues at IFPRI, through their socio-economic research, have shown that indeed, the global growth of cereal production has exceeded the growth in population, both for the whole world and for developing nations. However, the production increase in pulse crops has been lower than that of population growth. Thus prices have increased and consumption has declined. Pulses are more micronutrient-dense than cereals, so a smaller fraction of pulses in diets leads to lower levels of micronutrient consumption.

Thus it is important that efforts be made to increase the yield, production and utilization of these crops rich in micronutrients. There is also considerable reason to ensure that the cereals consumed contain adequate or increased levels of micronutrients like zinc, iron, selenium and vitamins – through biofortification.

Biofortification can be either genetic or agronomic. Genetic approaches can be helpful and can interact positively with agronomic approaches. For some nutrients, like iron, plant uptake is less easily increased with fertilization than with genetic approaches. Genetic approaches also modify the bioavailability of the micronutrient, not just its content.

Prevalence (%) of micronutrient malnutrition is high in developing regions and substantial in developed

Region	Zn	Fe	I	Vitamin A
North America	8-11	18-29	11	2-16
Latin America	13-37	18-29	11	2-16
Europe	6-16	19-25	52	12-20
Sub-Saharan Africa	13-43	48-66	44	14-44
Southeast Asia	27-39	46-66	30	17-50
South Asia	18-36			
Global	**10-32**	**30-47**	**32**	**15-33**

Bouis, Boy-Gallego & Meenakshi

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Micronutrient malnutrition is most common for iron, iodine and zinc. Worldwide, vitamin A is also a common deficiency. Compare these global figures to the total of 12% for calorie undernourishment, and it is clear that micronutrient malnutrition is more prevalent.

Solving the deficiencies can follow different paths, for different micronutrients. Fertilizing staple crops can solve zinc, iodine and selenium deficiencies, and it is straight forward for the fertilizer industry to play a role in such solutions. Plant genetics can also play a role – genetic biofortification includes enhancing the ability of staple crops to take up micronutrients and store them in bioavailable forms.

In addition, the industry could play a role in ensuring that production of micronutrient-dense non-staple crops flourishes – through good support for production and crop nutrition recommendations. Nevertheless improving the productivity of a diverse set of non-staple food crops is a challenging goal. Increasing crop diversity is a goal that requires large investments in plant breeding, agronomic research, and market development.

We also need to recognize that fertilizer can play a role in enhancing vitamins in crops. Generally, carotenoids including provitamin A are enhanced by nitrogen fertilization. B vitamins, and of course, protein, can also enhanced by nitrogen.

Almost as many soils are deficient in Zn as in K

Table 1. Proportion of agricultural soils deficient in mineral elements (based on a survey of 190 soils worldwide – Sillanpaa, 1990).	
Element	**%**
N	85
P	73
K	55
B	31
Cu	14
Mn	10
Mo	15
Zn	**49**

"…it is imperative that fertilizer technology be used to improve the nutritional quality of staple food crops that feed the world's malnourished poor. "

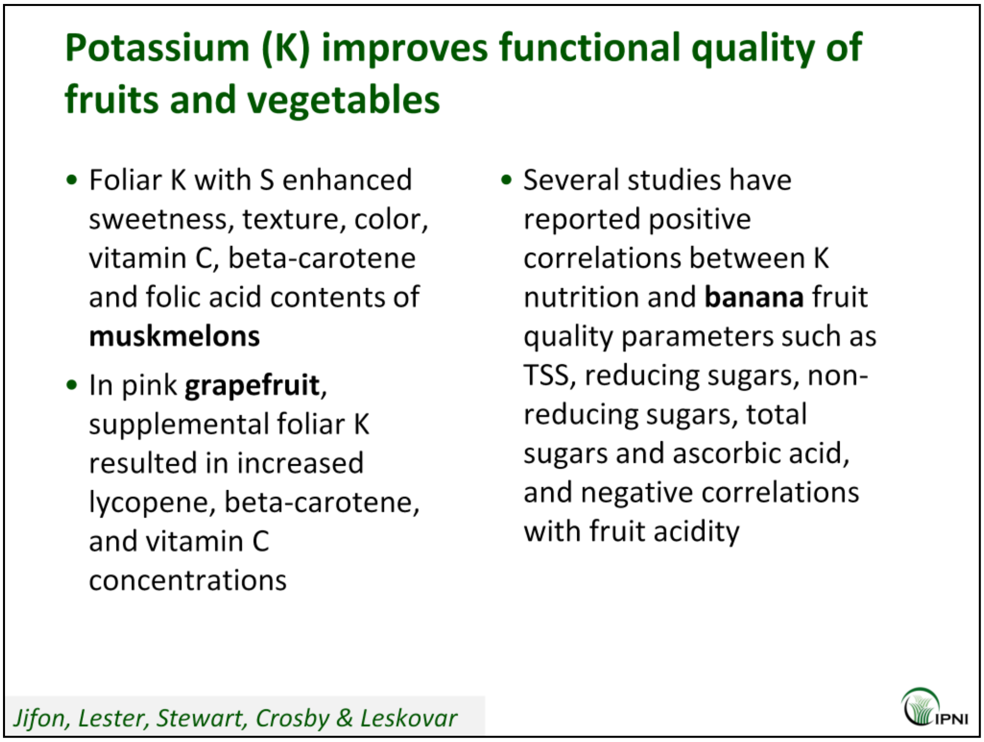
Welch and Graham

IPNI

In Chapter 3, nutrition scientists Ross Welch and Robin Graham note that "Micronutrient malnutrition (which includes both trace element and vitamin deficiencies) is the result of dysfunctional food systems … that do not meet all human nutritional needs." They conclude that "it is imperative …that fertilizer technology be used to improve the nutritional quality of staple food crops that feed the world's malnourished poor. "

Welch and Graham argue that fertilizer enhancement of the trace elements Zn, I, Fe, Co and Se and the deployment of provitamin A carotenoid-rich target crops together are just as important as yield enhancement and environmental sustainability.

They noted that a worldwide survey of soils found large percentages to be deficient in N, P, K, B and Zn. In fact around one-half of the soils in the survey were deficient in zinc. I will leave the discussion of zinc to the two speakers following me on today's program. The only observation I will make on zinc is that in my home province of Ontario, two or three decades ago, research by Dr. Ros Gibson and colleagues found evidence of zinc deficiency in a study of young boys. Thus even in parts of the developed world with an abundant food supply, zinc deficiencies can be important.



Plant nutrition scientist John Jifon and others point to many ways in which potassium can increase the health-functional quality of fruits and vegetables. In muskmelons, foliar-applied potassium enhanced sweetness, texture, color, vitamin C, and beta-carotene and folic acid. Several of the same components were also increased in pink grapefruit. They also noted that banana fruit quality improves in response to potassium nutrition. In addition, these foods also provide good sources of potassium for the human diet, important in reducing risk of cardiovascular disease. Potassium's promotion of vitamin C stands in contrast to the role of nitrogen fertilization, which can tend to reduce it.

Applying potassium (K) fertilizer increased the concentration of isoflavones in soybeans

K_2O application	Genistein	Daidzein	Glycitein	Total[1]
Spring banded	938	967	146	2,051
None	831	854	130	1,851
Increase due to K, %	13	13	12	13

[1] Total isoflavone concentration expressed as aglycone; sum of three components; parts per million (ppm)

Vyn et al., 2002. Journal of Agricultural and Food Chemistry, 50: 3501-3506.

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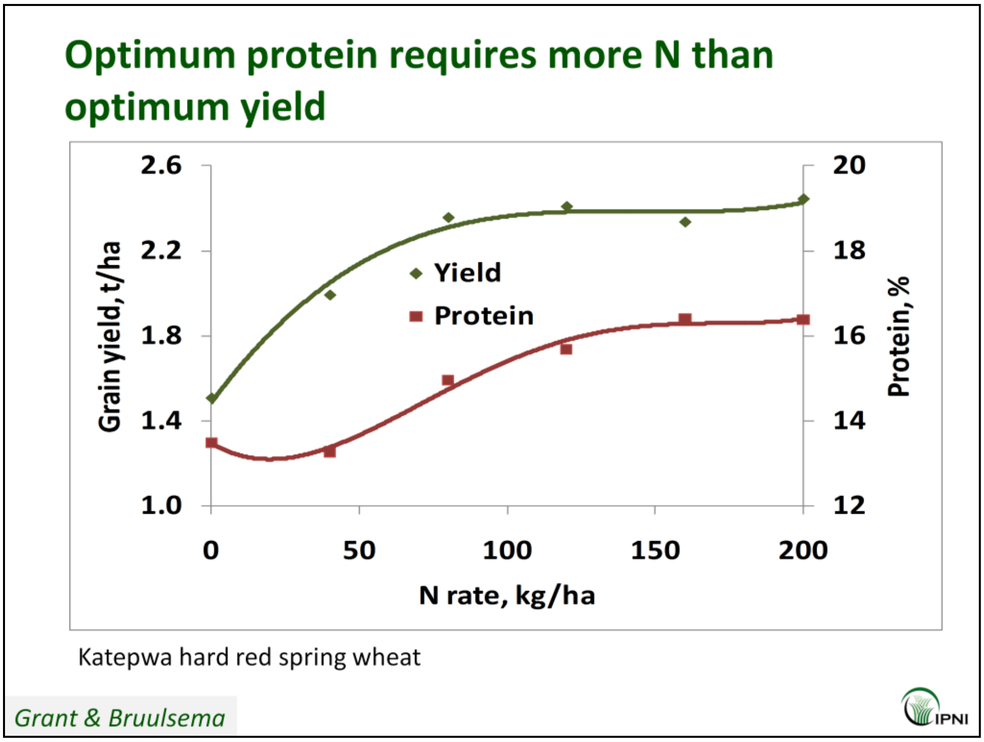
Another role for potassium has been demonstrated with respect to health-functional components of soybeans. Isoflavones, considered among the most effective of nutraceutical compounds, can be limited by potassium nutrition of soybeans. Comparing soybeans fertilized and unfertilized with potassium, in soils deficient in the nutrient, the concentration of each of the three major kinds of isoflavones increased by about 13%. Other research in soils with adequate levels of potassium found no differences in isoflavone concentrations. Thus additional inputs of potassium are not necessary, but potassium deficiencies would inhibit one of these vital health-protecting components of soybean seeds for human consumption.



The major macronutrient nitrogen strongly influences the protein content of crops. In general, optimum protein concentrations require higher rates of application than optimum grain yields, as shown in this example for Canadian hard red spring wheat. In maize and wheat, higher rates of N can reduce protein quality, because the low-lysine proteins zein and gluten can increase, but in the high-lysine maize cultivar opaque-2 or QPM this does not occur, and in rice lysine actually increases with N fertilizer rate.

Potato starch and protein influenced by NPKS

N-P-K-S	Potato yield, g/pot	Starch, %	Crude protein, %	Protein biological value, %
2-3-3-3	124	70	8.3	89
4-3-3-3	**317**	**72**	**12.9**	**80**
6-3-3-3	266	69	15.9	75
4-1-3-3	134	68	14.9	74
4-4-3-3	**454**	**74**	**10.3**	**81**
4-3-1-3	50	59	22.9	65
4-3-4-3	**332**	**68**	**11.5**	**82**
4-3-3-0	173	65	14.7	45

Eppendorfer and Eggum, 1994

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Potato growers are keenly aware of the critical role that fertilizers play in enhancing marketable qualities. These data from a pot experiment with varying combinations of N, P, K and S show that nutrient addition levels

producing the higher yields generally resulted in high protein and starch levels as well. Applications of N strongly increased crude protein content of potato, but reduced its biological value. Increasing levels of P and K reduced crude protein but increased its biological value. Sulphur deficiency strongly reduced biological value of protein as well, owing to reductions in methionine and cysteine.

These data suggest that well-nourished potatoes become nourishing potatoes.

Plant nutrition suppresses plant diseases, reducing mycotoxins and increasing food safety

Crop	Disease	Toxin	Nutrient
Cereals	Ergot (*Claviceps sp*)	Ergotamine (alkaloid)	Cu
Grain, peanuts	*Aspergillus*	aflatoxin	Mn + ?
Cereals	*Fusarium graminearum* (*Gibberella zeae*)	deoxynivalenol zearalenone trichothecene	Mn + ?

Huber

IPNI

The most well-known example of a plant disease controlled by a nutrient and causing health risks is the ergot disease. Copper deficiency predisposes cereals to ergot because of pollen sterility that causes the glumes to open so that stigmas are exposed to infection by *Claviceps purpurea*, the cause of ergot. Ergot can be controlled by copper applications.

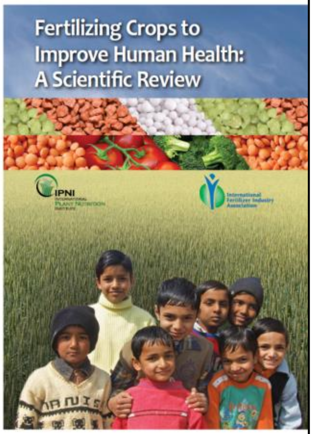
Several other mycotoxins are important to food safety. They include aflatoxin from Aspergillus and deoxynivalenol from Fusarium. While the degree of control by plant nutrition is less clear than with copper for ergot, manganese deficiencies are know to potentially increase these mycotoxins. There is a knowledge gap on the nutritional control of some of the plant diseases most relevant to food safety.

Benefits of this publication effort

1. Compilation of benefits for public awareness.
2. Foundation to build on for further research and investment.
3. Builds relationships with research scientists.

Continuing efforts:

1. Encourage evaluation of impacts on human health in research supporting 4R Nutrient Stewardship.
2. Include human health impacts in messaging related to food and nutrition security.



nutrient stewardship

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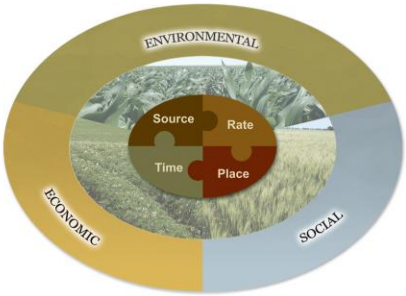
Summary

- Fertilizer contributes immensely to the health and well being of humanity.
  - Quantity and quality
  - Protein, minerals, vitamins and nutraceuticals
- Research and investment supporting 4R Nutrient Stewardship has great potential to improve human health.



4R nutrient stewardship

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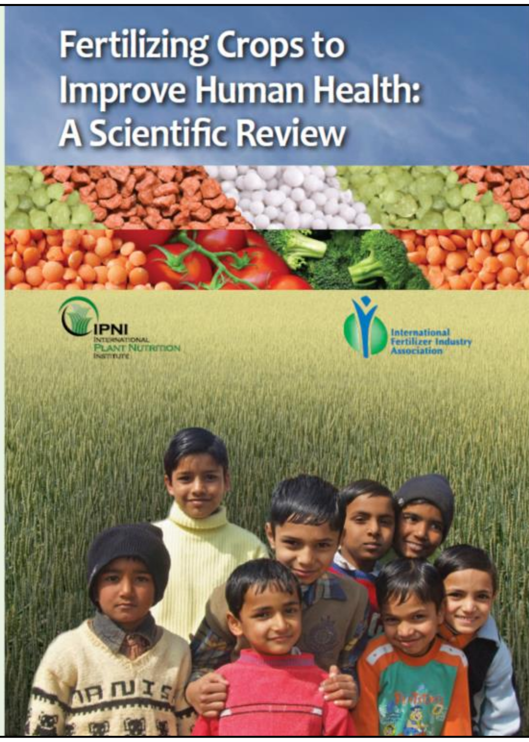

Thank You

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