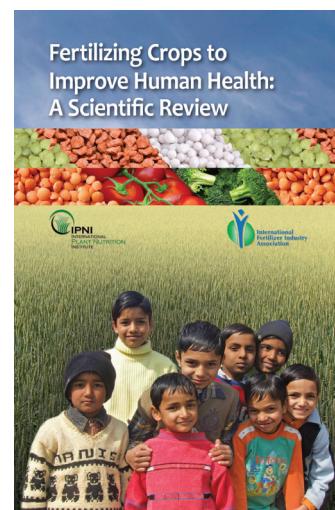


## FERTILIZING CROPS TO IMPROVE HUMAN HEALTH: A SCIENTIFIC REVIEW

A large proportion of humanity depends for its sustenance on the food production increases brought about through the application of fertilizers to crops. Fertilizer contributes to both the quantity and quality of the food produced. Used in the right way—applying the right source at the right rate, time and place—and on the right crops, it contributes immensely to the health and well-being of humanity.

Since 1948, the World Health Organization (WHO) has defined human health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” The awarding of the 1970 Nobel Peace Prize to Dr Norman Borlaug indicates a high level of recognition of the linkage of agricultural sciences to this definition of human health. This issue brief summarizes a joint publication from the International Plant Nutrition Institute (IPNI) and the International Fertilizer Industry Association (IFA) comprised of 11 chapters in three sections described below.

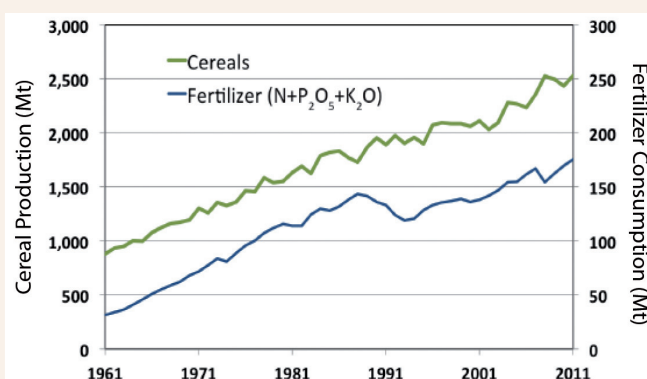


### Section 1: food and nutrition security

**Food security** exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food. Nutrition security means access to the adequate utilization and absorption of nutrients in food, in order to be able to live a healthy and active life (FAO, 2009). Between 1961 and 2008, the world's population grew from 3.1 to 6.8 billion. During the same period, global cereal production grew from 900 to 2,500 million tonnes (Mt) with much of the growth due to the increase in world fertilizer use from 30 to more than 150 Mt. Without fertilizer use, world cereal production would be halved (Erisman *et al.*, 2008).

By doubling the quantities of new nitrogen (N) and phosphorus (P) entering the terrestrial biosphere, fertilizer use has played a decisive role in making possible the access of humankind to food. However, not all have access. Chronic hunger still haunted the existence of one-sixth of the world's people in 2009. By 2050, according to FAO, the human population would require a 70 per cent increase in global agricultural output compared to that between 2005 and 2007 (FAO, 2012). Future yield increases expected through genetic improvement will still depend on replenishment of nutrients removed by using all possible sources, organic and mineral, as efficiently as possible.

Global cereal production and total fertilizer consumption 1961-2011



Source: FAO 2012, IFA 2012



*Applying the right source of plant nutrients at the right rate, time and place enables improvement of crop quality.*

Global and regional estimates of the proportion of the population at risk of inadequate Zn intake (Hotz and Brown, 2004).

Region	Population at risk (%)
N. Africa and E. Mediterranean	9
Sub-Saharan Africa	29
Latin America & Caribbean	25
USA and Canada	10
Eastern Europe	16
Western Europe	11
Southeast Asia	33
South Asia	27
China (+Hong Kong)	14
Western Pacific	22
Global	21

these mineral elements in humans are similar to those in plants, with the striking exception of calcium's major role in bones and teeth. Their content in plants is influenced by their supply in the soil. Thus, in addition to assuring optimal crop production, fertilization practices may contribute to meeting the requirements for these minerals in human nutrition. Calcium deficiencies occur in countries where diets depend heavily on refined grains or rice (e.g. Bangladesh and Nigeria). Adequate Mg intake is not easily defined, but studies suggest a significant number of adults, even in the United States, do not consume adequate amounts. Similarly, a recommended daily allowance for K intake has not been defined, but only 10 per cent of the men and less than 1 per cent of the women in the United States take in as much as or more than the adequate intake of 4.7 g/day.

**Carbohydrates, proteins and oils.** Applying N to cereals adds to the protein they produce, as well as their yields. In rice, while N has its largest effects on yield, it can slightly increase protein amount and quality, since the glutelin it promotes has higher concentrations of the limiting amino acid, lysine, than do the other proteins it contains. In maize and wheat, protein may increase with N rates higher

**Nutrition Security.** In addition to yield, plant nutrition affects other important components of human nutritional needs, including the amounts and types of carbohydrates, proteins, oils, vitamins and minerals. Many of the healthful components of food are boosted by the application of nutrients. Since most farmers already fertilize for optimum yields, these benefits are easily overlooked. Trace elements important to human nutrition can be optimized in the diet by applying them to food crops.

Opportunities exist to improve yields and nutritional quality of food crops such as pulses, whose yields and production levels have not kept pace with population growth. Ensuring that such crops maintain economic competitiveness with cereals requires policies that reward farmers for producing the nutritional components of greatest importance to human health.

**Micronutrient malnutrition** has been increasing, partially as a consequence of increased production of staple cereal crops. Other micronutrient-rich crops, particularly pulses, have not benefited as much from the Green Revolution. Having become relatively more expensive, they now comprise a smaller proportion of the diets of the world's malnourished poor.

Biofortification of crops can be an effective strategy for moving large numbers of people from deficient to adequate levels of iron (Fe), vitamin A, and zinc (Zn). The choice of genetic or agronomic approaches to biofortification depends on the micronutrient.

The two approaches can also be synergistic. In staple crops, genetic approaches are most effective for Fe and vitamin A, while agronomic approaches including fertilizers can boost the Zn, iodine (I), and selenium (Se) levels in foods. While deficiencies of I and Se do not limit the growth of plants, correction of Zn deficiency can benefit both crops and consumers of crops. Fertilizing cereals with Zn and Se improves both concentration and bioavailability of these trace elements. A large proportion—49 per cent—of soils worldwide are considered deficient in Zn (Sillanpaa, 1990). The proportion of people at risk of Zn malnourishment, while varying regionally, is also substantial.

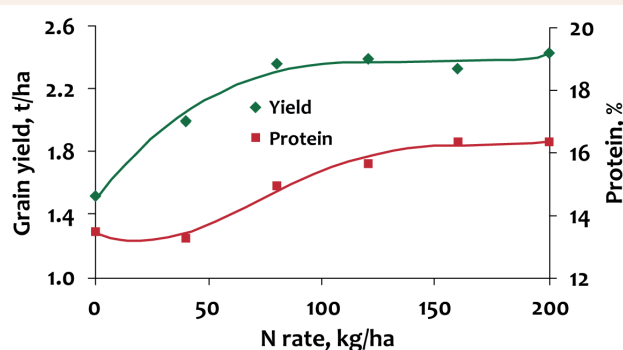
## Section 2: functional foods

**Calcium (Ca), magnesium (Mg), and potassium (K)** are essential macro mineral nutrients for humans. The essential functions of

than needed for optimum yield, but the improvement in nutritional value may be limited by low concentrations of the essential amino acid lysine. An exception is the Quality Protein Maize developed by plant breeding: its lysine concentration remains high when more N is applied. In potatoes, N increases starch and protein concentration while P, K and S enhance protein biological value. Oil composition of crops changes little with fertilization, though oil production is increased wherever yield limiting nutrient deficiencies are alleviated.

Management tools that more precisely identify optimum source, rate, timing and placement of N will help improve the contribution of fertilizer to production of healthful proteins, oils and carbohydrates. Genetic improvements to N use efficiency may require careful attention to impact on protein quantity and quality in cereals. However, nutrient management practices such as late foliar applications or controlled-release technologies can boost N availability for protein production while keeping losses of surplus N to a minimum.

Yield and protein of wheat respond to applied N fertilizer



**Health-functional quality of fruits and vegetables.** Scientific evidence from numerous sources has demonstrated that judicious fertilizer management can increase productivity and market value as well as the health-promoting properties of fruits and vegetables. Concentrations of carotenoids (Vitamin A precursors) tend to increase with N fertilization, whereas the concentration of vitamin C decreases. Foliar K with S enhanced sweetness, texture, color, vitamin C, beta-carotene, and folic acid contents of muskmelons. In pink grapefruit, supplemental foliar K resulted in increased beta-carotene and vitamin C concentrations. Several studies on bananas have reported positive correlations between K nutrition and fruit quality parameters such as sugars and ascorbic acid, and negative correlations with fruit acidity.

In addition to effects on vitamins, fertilizers can influence levels of nutraceutical (health-promoting) compounds in crops. Soybeans growing on K-deficient soils in Ontario, Canada had isoflavone concentrations about 13 per cent higher when fertilized with K. Potassium has also been reported to promote concentrations of lycopene in grapefruit and in tomatoes. Broccoli and soybeans are examples of plants that can contribute Ca and Mg to the human diet.



When crops like these are grown in acid soils of limited fertility, applying lime can boost the levels of these important minerals. The potent antioxidant pigments lutein and betacarotene generally increase in concentration in response to N fertilization. Together with vitamins A, C and E, they can help lower the risk of developing age-related macular degeneration, which is one of the leading causes of blindness.

### Section 3: risk reduction

**Plant disease.** In cereals deficient in copper (Cu), ergot (*Claviceps sp.*) is an example of a food safety risk caused by a plant disease that can be controlled by application of Cu fertilizer. By immobilizing and competing for mineral nutrients, plant pathogens reduce mineral content, nutritional quality and safety of food products from plants. While many other specific diseases have known plant nutritional controls, there is a knowledge gap regarding the optimum nutrition for controlling the plant diseases most relevant to food safety. Managing nutrition influences diseases and their control.



Strategies to reduce plant disease through plant nutrition include:

- the development of cultivars that are more effective in taking up manganese (Mn);
- balanced nutrition with optimum levels of each nutrient;
- attention to forms and sources suited to the crop (e.g. nitrate vs. ammonium, chloride vs. sulphate);
- timing, applying N during conditions favouring plant uptake and growth response;
- integration with tillage, crop rotation and soil microbes.



*Application of Cu fertilizer ( $\text{CuSO}_4$  crystal on the right) has been an effective treatment in ergot-prone soils.*

**Farming systems.** Organic farmers apply strategies for plant nutrition that differ from those of other producers. Do these differences influence the healthfulness of the food they produce? Owing to the restricted sources for nutrient supply, organic farming cannot provide sufficient food for the current and growing population in the world. Also, because organic production systems rely heavily on ruminant animals and forage crops for the cycling of nutrients, the proportions of food types produced do not match the requirements of healthy diets.

An imbalanced dietary composition can cause health problems as a result of insufficient supply of essential nutrients or excessive supply of other food constituents.

The composition of foods produced does show small changes explained by plant physiological responses to differences in N supply. Vitamin C is increased, but A and B vitamins, protein and nitrate are reduced under organic farming. Higher levels of nitrate in conventionally grown foods do not threaten and may be beneficial to human health. Despite the great interest in food quality among supporters of organic agriculture, focusing on food supply and dietary composition is most important for human health.

**Remediating radionuclides.** When soils become contaminated with radionuclides, as for example after accidents with nuclear reactors in Chernobyl or Fukushima, limiting plant uptake becomes an important goal for protecting human health. Studies on soils from the Gomel region of Belarus showed that levels of radiocaesium ( $^{137}\text{Cs}$ ) and radiostrontium ( $^{90}\text{Sr}$ ) in crops declined in response to increasing soil exchangeable K, with K applied as either fertilizer or manure. These radionuclide levels also declined with addition of dolomitic limestone, and N and P fertilizers. The involvement of rural inhabitants in processes of self-rehabilitation and self-development is a way to improve people's life quality on radioactive contaminated territories.

## References

- Erismann, J.W., M.A. Sutton, J. Galloway, Z. Klimont, and W. Winiwarter. 2008. *Nature Geoscience* 1:636-639.
- FAO. 2012. [faostat.fao.org/site/339/default.aspx](http://faostat.fao.org/site/339/default.aspx) and [www.fao.org/worldfoodsituation/wfs-home/csdb/en/](http://www.fao.org/worldfoodsituation/wfs-home/csdb/en/).
- FAO. 2009. The State of Food Insecurity in the World 2009. Food and Agriculture Organization of the United Nations. [www.fao.org/docrep/012/i0876e/i0876e00.HTM](http://www.fao.org/docrep/012/i0876e/i0876e00.HTM).
- Hotz, C. and K.H. Brown. 2004. *Food Nutr Bull* 25(1): S94-204
- IFA. 2012. [www.fertilizer.org/ifa/HomePage/STATISTICS](http://www.fertilizer.org/ifa/HomePage/STATISTICS).
- Sillanpaa, M. 1990. *FAO Soils Bulletin* 63. Food and Agricultural Organization of the United Nations, Rome.

---

### Fertilizing Crops to Improve Human Health: a Scientific Review.

T.W. Bruulsema, P. Heffer, R.M. Welch, I. Cakmak, K. Moran  
IPNI, Norcross, GA, USA; IFA, Paris, France, 2012

To download the book: [www.fertilizer.org/ifa/HomePage/LIBRARY/Our-selection2/Fertilizer-use.html](http://www.fertilizer.org/ifa/HomePage/LIBRARY/Our-selection2/Fertilizer-use.html)

**Feeding the Earth** represents a series of issue briefs produced by the International Fertilizer Industry Association to provide current information on the role of fertilizers in sustainable agriculture and food production.

International Fertilizer Industry Association (IFA) - 28 rue Marbeuf, 75008 Paris, France  
For further information on 'Feeding the earth' contact: Morgane Danielou, Director, Information and Communications Service  
Tel: +33 1 53 93 05 00 - Fax: +33 1 53 93 05 45/47 - [mdanielou@fertilizer.org](mailto:mdanielou@fertilizer.org) - [www.fertilizer.org](http://www.fertilizer.org)