AGRONOMIC APPROACHES TO INCREASE SELENIUM CONCENTRATION IN LIVESTOCK FEED AND FOOD CROPS

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Contents

Summary

Selenium is an example of an essential element becoming more and more insufficient in food crops as a result of intensive plant production in many countries. In some areas, for example, Scandinavia and parts of North America, the soil properties accentuate the Se deficiency problem in animal and human nutrition.

This chapter reviews the present knowledge of the Se situation in those countries where the Se status has been surveyed, which is not the case in most of the world. A number of factors affecting the plant uptake of native and applied Se are discussed.

Different means of increasing the Se content of field crops are described, and the effect of these procedures is discussed, based on publications covering a range of countries, soil types, crops and other factors. The bioavailability to animals of Se in the crops as affected by these factors is also discussed.

In conclusion, this review shows that soil fertilization with about 10 g Se per ha, as selenate, or foliar application of about 3g Se per ha are effective, safe, and economical ways to remedy a situation of inadequate Se concentrations in field crops.

1. Introduction

In recent public discussions about the quality of food products in modern agriculture, lack of selenium (Se) in food has often been viewed as an example of a mineral imbalance related to intensive crop production. Selenium has been recognized as an essential mineral for human and livestock nutrition for more than 30 years (see *Global Importance of Selenium and its Relation to Human Health*). Several attempts have been made to demonstrate its essentiality for plants by omitting Se in their growth medium, but so far, it has been without success. Furthermore, none of the Se-containing enzymes active in animals are found in plants. Consequently, interest in the Se content of plants is related to the quality of crops as animal fodder and as human food. The main source of Se for animal fodder and human food is the soil-plant system. Therefore, field treatments with Se are possible ways to improve the Se-nutrition of livestock and humans.

2. Geographic Distribution of Se

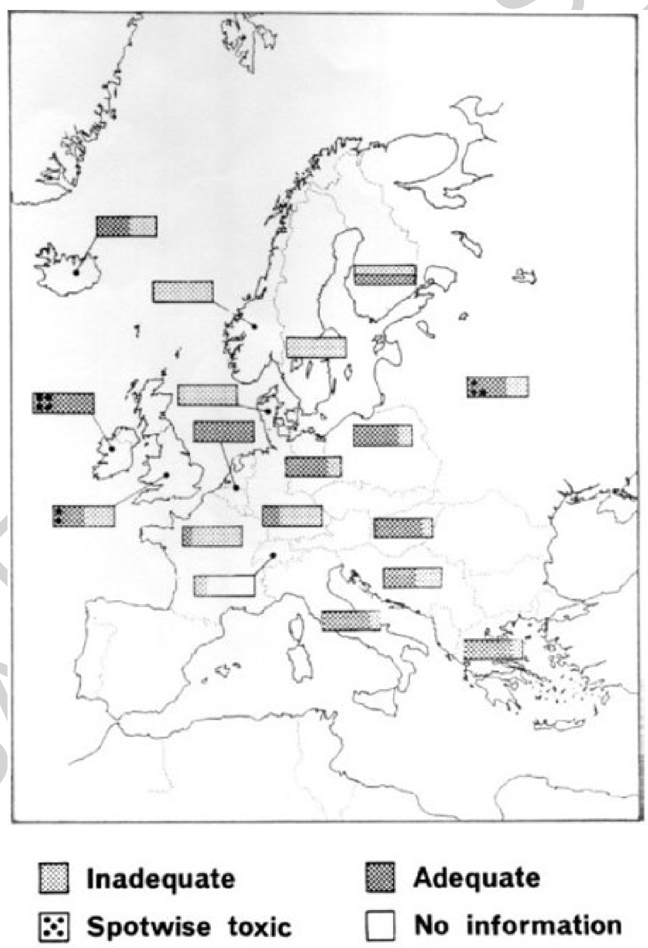

Figure 1. Distribution of Se in fodder crops in Europe. The upper and lower symbols for Finland refer to before and after 1985, respectively (Gissel-Nielsen, G. 1998. Effects of selenium supplementation of field crops. In *Environmental Chemistry of Selenium*. pp. 99-112. Ed. W.T. Frankenberger,Jr. and R.A. Engberg. Marcel Dekker, Inc. New York).

Selenium deficiencies are reported in both western and eastern coastal areas of North America, Venezuela, Australia, New Zealand, Japan, and China. However, no information is available about the Se status of people and livestock in most countries of the world. The average Se concentration of the fodder needed to meet the minimum requirements of livestock is considered to be about 0.1 mg kg^{-1} dry matter, and toxic effects can be expected at intakes of fodder that exceed 1-2 mg Se kg^{-1}. According to these limits, different areas of the world are characterized as Se-deficient, Se-adequate, and Se-toxic. Outside Europe, crops containing toxic Se concentrations are found in the Midwestern regions of the US and Canadian prairies, in Venezuela, India, and China. Selenium deficient areas are more widespread than toxicity areas.

The situation for Se in Europe is illustrated in Figure 1. There is a geographic pattern in this map showing Scandinavia as a natural low-Se area, while central Europe ranges between deficiency and sufficiency. Information is scanty from southern Europe. A few samples from Italy point to a range spanning from somewhat deficient to sufficient. This is also the case for Greece. Results presented at the International Symposium on Selenium in Belgrade in 1991 indicated that the Se status of the former Yugoslavia ranges from adequate to inadequate. Selenium toxicity has only been observed in certain areas of Wales, Ireland and Russia.

Country	**Se intake (μg/day)**	**Blood Se (μg/L)**
Belgium	55	123
Canada	98-224	182
China	11-4990	8-3180
Denmark	40	86
Finland before 1985	30	56-87
New Zealand	28-56	59-83
USA	62-216	157-265

Table 1. Human dietary Se intakes and blood-Se levels (Gissel-Nielsen, G. *et al.* (1984). *Adv. Agron*. **37**, 397-460).

The Se concentrations in plants affect Se intake by humans and their blood-Se content. Table 1 provides information on this subject from a few countries. These Se values indicate a relationship between the Se content of food produced in different countries and the blood-Se content of the inhabitants. A multitude of publications indicates a similar correlation between the Se content of animal feed and animal blood-Se.

Sources of Se intake are many, and a number of publications provide the results of surveys on the Se content of foodstuffs. The first comprehensive survey from a low-Se area illustrated the situation in Finland in 1980. Other reports contain information on the Se content of foodstuffs from several Se-sufficient countries. The differences in the Se content of the same foodstuff from different surveys are obvious when comparing the reported results, but when arranged according to the decreasing Se content, the similarities are also obvious. Consequently, no exact values can be given for the Se content of different foodstuffs, but the foodstuff groups can be listed in their relative order of Se content, as shown in Table 2.

Relatively high	Seafood
	Meat High-sulfur vegetables Legume Crops Cereals Other vegetables
Relatively low	Fruits

Table 2. Groups of foodstuffs in order of relative average Se content.

Due to the correlation between Se intake and blood-Se shown in Table 1, the Se intake of humans and livestock living in a certain area can generally be estimated by evaluating Se uptake by the fodder crops grown in the area in question. This is because cereal and vegetables are dominant in the human diet and, along with pasture plants, also in livestock fodder. Therefore, crop plants are responsible for the greater part of Se intake by humans and livestock, even if crop plants are relatively low in Se, as shown in Table 2. Consequently, an increase in the Se concentration of food and feed crops is an obvious way to remedy Se deficiency in humans or livestock.

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Biographical Sketches

G. Gissel-Nielsen. Following five years of practical farming and farming school, Gunnar Gissel Nielsen received his M.Sc. in agronomy in 1961, his PhD in Plant Nutrition in 1965, and his Dr. of Sci. on Selenium in soils and plants in 1979, all three at the Royal Veterinary and Agricultural University of Copenhagen (RVAU).Since 1961, Gunnar Gissel Nielsen has been employed at Risø National Laboratory with the following interruptions: 1962-65 he was a PhD student at RVAU, in 1970-71 he was a visiting professor at the USDA laboratory in Ithaca, N.Y., USA, and in 1982, he was an associate professor at RVAU. In 1972, Gunnar Gissel Nielsen was awarded the silver medal of The Royal Danish Academy of Sciences, and in 1987, The Agronomist Award from the Union of Danish Agronomists.

Gunnar Gissel Nielsen is a member of The Danish Academy of Technical Sciences, four years as member of the board. From 1988-95, he was a member of the Danish Agricultural and Veterinary Research Council, from 1991-95 as vice president. He has been a member of the boards of The Danish Research Service for Plant and Soil Science and of the Research Centre for Organic Farming. Further, he is or has been a member of numerous national and international committees and evaluation panels related to plant nutrition and environmental protection. Gunnar Gissel Nielsen's publication list consists of 52 original scientific papers, 26 scientific reviews, and 35 popular reviews, most of them on selenium in soils and plants, but also on other trace elements and on nitrogen pollution of the Danish environment.

Umesh C. Gupta received his B.Sc. Agr. (1955) and M.Sc. Agr. (1957) degrees with first-class honors from Agra University, India, and his Ph.D. in Soil Biochemistry from Purdue University, U.S.A. in 1961. From 1961 - 1963, he was a postdoctoral fellow at the Soil Research Institute, Agriculture Canada, Ottawa. After working for more than 34 years as Research Scientist, with Agriculture and Agri-Food Canada, he retired in 1996. Dr. Gupta was a Principal Research Scientist (1985 - 1996) and served as Program Leader of Soil Management and Conservation Program (1986 - 1991). In 1997, he was named Emeritus Research Scientist at Agriculture and Agri-Food Canada's Crops and Livestock Research Centre in Charlottetown. Dr. Gupta is an acknowledged worldwide authority on micronutrients and selenium nutrition of crops and livestock. Methods as developed and modified by him for determining boron in soil and crops and molybdenum in plants, are used worldwide.

Dr. Gupta has authored/co-authored 136 research publications in scientific journals and 17 chapters/review articles for national and international books. He is the editor and principal author of two books, one on *"Boron and Its Role in Crop Production"* published by the CRC Press in 1993, and the other on *"Molybdenum in Agriculture"* published by Cambridge University Press, N.Y. in 1997. He is the co-editor of a third book on *Trace Elements* published in 1996 by Oxford and IBH Publishing Co. PVT. Ltd. He has written and edited several crop and soil bulletins for use by farmers, extension personnel, and researchers.

He has been invited to lecture on the field of trace element requirements of crops and livestock in many countries on all continents. In February 1999, upon invitation, he delivered the keynote address "Micronutrients and Toxic Elements in plants and animals" at the International Symposium "Micronutrients and Toxic Elements in Agriculture" held at the UNESP campus of Jaboticabal, S.P., Brazil. He was one of the two invited speakers from Canada for the 2001 International Grassland Congress. Dr. Gupta has been invited to participate in scientific exchange programs for scientists with France (1980), the U.K. (1987), Nigeria (1990), Germany (1991), and Brazil (1995). He has received numerous awards and made several television and radio appearances to disseminate his research findings. He has served on several regional and national committees.

He was made a Fellow of the Canadian Society of Soil Science (1978); American Society of Agronomy (1981); Soil Science Society of America (1981); and Agricultural Institute of Canada (1991). He was the Chief Editor of the Canadian Journal of Soil Science (1984 - 1986); President of the Canadian Society of Soil Science (1995 - 1996); and President of the Prince Edward Island Institute of Agrologists (1990 - 1991). At the sixth International symposium on Soil and Plant Analysis held in Brisbane, Australia, in March 1999, Dr. Gupta was honoured with the J. Benton Jones award for his dedicated service to the methods of soil and plant analyses. In November 2002, Dr. Gupta was invited to deliver a series of lectures, as a visiting professor, in the Resources and Environment Department, Huazhong Agricultural University, Wuhan, Hubei province, Peoples Republic of China.