13 Introduction to Soil Fertility

13.1 Soil Fertility

Many years ago, the term 'fertility', as in soil fertility, referred to the ability of the land to support continual crop growth and high grain or forage yields. There were several reasons for the soils' "fertility" but one of the primary reasons was due to the abundant availability of certain elements in the soil that the crop needed to both grow and produce a high yield. In many areas of the world, including during the colonial period in American, land would be farmed until it was spent, the fertility had been used up or the land had been"played out" The land would then be abandoned, or sometimes remain fallow for a time, and new land would then be planted to exploit its fertility.

In the tropics, slash and burn agriculture is built on the ancient principle that land can only be farmed for a few years before new land must be found. The land, once farmed, must be allowed to go back to nature or be fallowed for a time in order for fertility to be regained from the weathering of parent material or the natural cycling of nutrients and activity of native plants.

In contrast, some early landowners in the U.S., particularly those on Southern plantations out of necessity (because of the vase size of the land holdings rendering the "slash and burn" and moving practice unviable) experimented, with some success, using different management strategies such as crop rotation, manures and green manures to sustain the natural productivity level of the land. The writings and diaries of George Washington are filled with entries on his use of amendments, crop choices and attempts to sustain fertility in the land that he owned (Library of Congress, n.d.).

13.2 Essential Crop Nutrients

In order for a ground to be "fertile" for crop growth, it needs to have a suite of elements essential to sustain plant life, referred to appropriately as "essential nutrients" that enable the plant to grow, make seed and complete its life cycle. There are 17 essential nutrients to all crop plants in North Dakota. They are the following:

- **Three non-mineral nutrients:**
  - Carbon (C) from carbon dioxide in the atmosphere
  - Hydrogen (H) from water (H_2O)
  - Oxygen (O) from water
- **Fourteen essential mineral nutrients to all North Dakota crops:**
  - Nitrogen (N)
  - Phosphorus (P)
  - Potassium (K)
  - Sulfur (S)
  - Calcium (Ca)
  - Magnesium (Mg)
  - Chloride (Cl^-)
  - Iron (Fe)
  - Zinc (Zn)
  - Manganese (Mn)

- Copper (Cu)
- Molybdenum (Mo)
- Nickel (Ni)
- Boron (B)

When addressing the elemental requirements of crops, the mineral elements are categorized into three groups, macro, secondary, and micro, based on their relative amounts of uptake requirements by a crop and frequency of their deficiency/absence affecting yield: N, P, and K are considered the “Macronutrients” named as such because of their relative amount of abundance required for plant growth, and the frequency of deficiencies of these three nutrients far exceed those of the other elements. The secondary nutrients are Ca, Mg and S, with required amounts being lower and nutrient deficiencies of these elements occurring less frequently than the macronutrients. The micronutrients are used in relatively small amounts compared to macronutrients and secondary nutrients; consisting of B, Cl^-, Fe, Zn, Mn, Cu, Mo and Ni.

13.3 Concentration of Mineral Nutrients in Crops

Each essential mineral nutrient provides a specific and necessary purpose to crop growth and reproduction. The absence or deficiency of any of these nutrients will result in reduced crop yield and/or quality. The soil itself contains most of the crop nutrients necessary for crop production in North Dakota. The availability of plant nutrients can change over time as nutrients are removed from the soil solution, by factors such as plant uptake or leaching. With the high historic yields achieved by North Dakota farmers, the fields need frequent soil testing and assessment to make sure that continual high levels of nutrients are available for future productive crop production. Table 13.1 indicates the estimation levels of most elements accumulated in the grain or the crop residue during their growing season. It is not necessary to replace every nutrient taken from the field by crop at harvest. For example, manganese, iron and molybdenum exist in such great supply in North Dakota soils that farming them for thousands of years would still result in their adequate supply. Other nutrients, such as N, P and K, require frequent supplementation through fertilization to maintain yield due to continual crop removal.

Table 13.1: Table 13.1. Approximate concentrations of mineral elements in crops grown within the North Central Region at harvest. There is considerable variation in elemental concentrations within each crop. (From Franzen, 2022)

Crop	N (%)	P2O5 (%)	K2O (%)	S (%)	Ca (%)	Mg (%)	Cl (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Mo (ppm)
Alfalfa hay	2.25	0.50	2.25	0.20	1.400	0.27	0.300	75.0	75.0	100	55	54	0.11
Barley, grain	1.80	0.80	0.50	0.15	0.050	0.10	0.150	21.0	16.0	80	16	32	0.25
Barley, straw	0.75	0.25	1.50	0.20	0.400	0.10	0.250	25.0	50.0	25	16	25	0.12
Canola seed	3.10	0.50	1.00	0.45	0.230	0.16	0.030	75.0	25.0	50	20	25	0.75

Crop	N (%)	P2O5 (%)	K2O (%)	S (%)	Ca (%)	Mg (%)	Cl (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Mo (ppm)
Canola straw	1.80	0.30	2.00	0.90	0.600	0.10	0.030	25.0	30.0	50	20	10	0.10
Chickpea	3.40	0.35	2.00	0.25	0.100	0.11	0.020	30.0	35.0	70	35	35	0.50
Corn grain, 15%	1.50	0.57	0.39	0.11	0.040	0.01	0.030	70.0	25.0	36	24	18	0.09
Corn Stover 15%	1.00	0.24	1.20	0.10	0.450	0.30	0.080	22.0	75.0	14	75	20	0.30
Corn silage, 65%	1.80	0.18	1.00	0.20	0.230	0.22	0.040	30.0	50.0	25	25	25	0.25
Dry bean	4.00	0.07	2.10	0.80	0.120	0.20	—	50.0	20.0	20	14	16	0.75
Field Pea grain	3.80	0.30	1.00	0.40	0.250	0.10	0.050	70.0	15.0	50	10	30	0.80
Field Pea straw	1.20	0.08	1.30	0.15	0.150	0.10	—	37.0	23.0	30	8	15	0.30
Flax grain	3.20	0.60	1.00	0.35	0.250	0.45	—	16.0	12.0	50	30	40	—
Flax straw	1.20	0.30	0.60	0.15	0.300	0.20	—	30.0	36.0	—	42	12	—
Lentil grain	4.00	0.40	1.00	0.30	0.100	0.10	—	10.0	10.0	85	15	45	0.10
Lentil straw	1.40	0.10	0.55	0.30	0.100	0.04	—	5.0	15.0	95	20	45	0.05
Oat grain	1.80	0.40	0.60	0.15	0.100	0.10	0.030	20.0	46.0	70	50	45	0.40
Oat straw	0.65	0.23	2.10	0.23	0.300	0.15	—	25.0	50.0	—	—	—	0.10
Potato tubers	0.43	0.13	0.56	0.03	0.015	0.03	—	12.0	20.0	28	—	15	—
Potato Vines	2.20	0.60	2.20	0.22	0.180	0.10	—	28.0	8.0	55	43	28	—

Crop	N (%)	P2O5 (%)	K2O (%)	S (%)	Ca (%)	Mg (%)	Cl (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Mo (ppm)
Rye, cereal	2.40	0.70	0.30	0.15	0.050	1.50	0.050	15.0	4.0	40	30	40	0.05
Sorghum grain	1.60	0.80	0.50	0.30	0.020	0.06	—	—	6.0	32	—	28	—
Sorghum stover	1.40	0.30	1.50	0.17	—	—	—	—	—	33	—	66	—
Soybean 13%	5.60	1.10	2.00	0.30	0.270	0.19	0.020	28.0	8.0	80	22	50	0.16
Soybean Straw 10%	1.30	0.17	2.60	0.10	0.100	0.05	0.100	33.0	10.0	80	20	10	0.30
Sugar beet roots	0.26	0.03	0.01	0.06	0.040	0.04	0.008	3.0	1.1	80	13	13	0.13
Sugar beet tops	1.70	0.10	1.60	0.06	0.160	0.09	0.020	25.0	0.6	80	20	12	0.50
Sunflower	5.00	1.00	2.00	0.15	0.200	0.30	—	10.0	20.0	30	30	35	—
Sunflower stover	0.50	0.22	2.00	0.25	0.300	0.13	—	50.0	5.0	10	5	28	—
Wheat grain 12%	2.20	0.80	0.44	0.12	0.060	0.13	0.030	5.5	2.8	80	50	33	0.80
Wheat Straw 10%	0.44	0.20	1.20	0.06	0.040	0.14	0.140	11.0	3.0	80	14	20	0.11

13.4 References for Introduction to Soil Fertility

- Franzen, D. W. (2022). Effectiveness of using low rates of plant nutrients. North Dakota State University Extension. https://www.ndsu.edu/agriculture/extension/publications/effectiveness-using-low-rates-plant-nutrients

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