Chapter 15

Optimizing Food Production

THE MAIN IDEA

Agriculture employs much chemistry.

15.4 Natural and Synthetic Fertilizers

As a soil loses its plant nutrients to harvested crops and to leaching, it loses its fertility. Farmers amend soil by adding *fertilizers*, which are replacement sources for these lost nutrients. Naturally occurring fertilizers are compost and minerals. **Compost** is decayed organic matter, which can be animal manure, food scraps, or plant material. Mineral fertilizers are mined. Saltpeter, $NaNO_3$, for example, was once used extensively as a source of nitrogen, but by the late 1800s, the supply of this nitrogen-containing mineral was almost exhausted. A new source of nitrogen for fertilizers came along in 1913, when Fritz Haber (1868–1934), a German chemist, developed a process for producing ammonia from hydrogen and atmospheric nitrogen:

This technique is now the primary means of producing ammonia, which can be stored in high-pressure tanks as a liquid and injected into the soil. Alternatively, the ammonia can be converted to a water-soluble salt, such as ammonium nitrate, NH_4NO_3, that is then applied to the soil either as a solid or in solution. The mining of other nutrients, such as phosphorus and potassium, still remains an important endeavor.

READING CHECK

Most ammonia used today as fertilizer is made from what process?

$$\underset{\text{Nitrogen}}{N_2} + \underset{\text{Hydrogen}}{3\,H_2} \rightarrow \underset{\text{Ammonia}}{2\,NH_3}$$

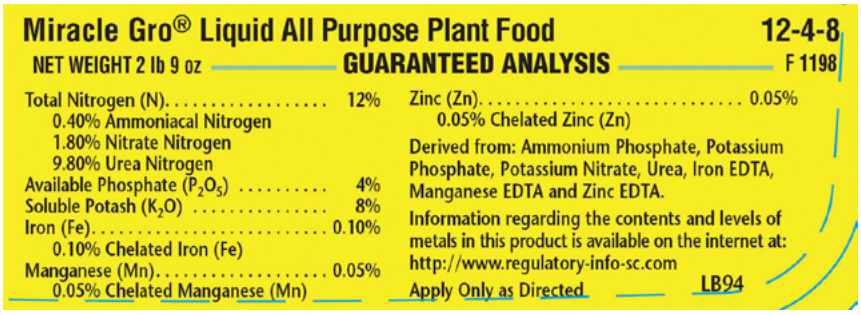
In times past, mineral fertilizers were used just as they came from the ground. Today, however, chemists have learned how to mix and match minerals to obtain many different formulations, each suitable for a different soil problem or the specific requirements of a particular plant. All these formulated mineral fertilizers are referred to as *chemically manufactured fertilizers* or, more frequently, *synthetic fertilizers*. Don't take the word *synthetic* literally, though, because except for what is produced by the Haber reaction, all the minerals in synthetic fertilizers originally came from the ground.

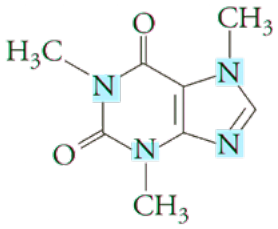
A fertilizer that contains only one nutrient is called a straight fertilizer. Ammonium nitrate, NH_4NO_3, is an example of a straight fertilizer, yielding only nitrogen. Any fertilizer containing a mixture of the three most essential nutrients (nitrogen, phosphorus, and potassium) is called either a *complete fertilizer* or a **mixed fertilizer**. All mixed fertilizers are graded by the N-P-K system, which lists the percent of nitrogen (N), phosphorus (P), and potassium (K) they contain, as **Figure 15.12** shows. A typical mixed fertilizer might be graded 6-12-12. A typical compost, by contrast, might be rated anywhere from 0.5-0.5-0.5 to 4-4-4. Compost N-P-K ratings are much lower because of their high percentage of organic bulk. This organic bulk helps to keep the soil loose for aeration, however, and serves as food for beneficial organisms that live in the soil. Because of the negative electric charges it carries, the organic bulk also attracts positively charged nutrient ions, which are then not so readily leached away.

The effect that nitrogen-containing synthetic fertilizers can have on yields is significant. It requires a lot of energy to mine and refine synthetic fertilizers, however, so they are expensive. For example, of the total energy required to produce corn in the United States, at least one-third is needed to produce, transport, and apply the fertilizer. Nevertheless, synthetic fertilizers are widely used, and our present food supply depends on them.

Figure 15.12 >

Fertilizers are rated by the percentages of nitrogen, phosphorus, and potassium they contain.





Caffeine

CONCEPT **CHECK**

Which N-P-K rating would you expect for coffee grounds, which contain significant quantities of the alkaloid caffeine: 2-0.3-0.2, 0.3-2-0.2, or 0.3-0.2-2?

CHECK YOUR ANSWER The fact that caffeine is a nitrogen-containing compound means that coffee grounds must contain a relatively high proportion of nitrogen, as is indicated by their N-P-K rating of 2-0.3-0.2.