value crops such as tomatoes, peppers, blueberries, raspberries, strawberries, apples, vine crops, and cole crops.

As with overhead irrigation, nitrogen is the primary nutrient applied through the system. Nitrogen solutions are the most economical source of nitrogen to apply; potassium nitrate and ammonium sulfate are soluble and can also be used. Calcium nitrate is also water soluble but may precipitate if injected in high pH water. Drip irrigation, in combination with plastic mulch, allows for precise timing (spoon feeding) of nitrogen. Small amounts can be applied daily (1-2 lb N/A) or weekly (5-10 lb N/A) to meet the growth demands of the crop.

Potassium can also be injected without any precipitation problems, although in most Minnesota soils a broadcast and starter application can meet plant requirements. Phosphorus may precipitate with micronutrients or with calcium and magnesium in the irrigation water, resulting in clogging problems. Some micronutrients such as copper, iron, manganese, and zinc may also precipitate in high pH water. For most situations, phosphorus, and micronutrients, if needed, should be applied before planting. These elements can be injected alone in the drip system without precipitation problems. For phosphorus applications, phosphoric acid should be used. For micronutrients, chelated forms should be used. Clogging problems in drip lines can be corrected by injecting acids into the line to dissolve precipitates. If clogging is caused by bacteria or algae growth, then chlorine should be mixed with water. In all cases, the cause of clogging should be determined before treatment, and injection rates of chlorine or acid should be carefully monitored to avoid damaging the plants.

Calibration of fertilizer injection for drip irrigation is similar to that of a solid set sprinkler system in that a batch type injection is used. The area to be fertilized is first calculated and then the amount of fertilizer needed for that area is determined. In most cases, nutrients should be injected over a 15-20 minute period followed by a 15-20 minute flushing period.

Foliar Fertilization

For all fruit and vegetable crops, the major pathway for mineral nutrient uptake is via the roots. Nutrients applied to the leaves can be absorbed and utilized by the plant; however, for nitrogen, phosphorus, and potassium the quantity absorbed at any one time is small relative to the larger levels required for growth by the plant. Foliar application of these three nutrients cannot be expected to supply the total amount required for crop production.

An appropriate time to consider foliar fertilization would be when a shortage of a nutrient is evident as indicated by tissue analysis or visual symptoms. In these situations, foliar fertilization provides the quickest means to correct the problem. Certain soil conditions, such as high pH, excess moisture, or cool temperatures, may render a nutrient or nutrients unavailable to the plant root. If these conditions exist, the problem may be more effectively corrected by foliar applications compared with soil applications. For the macronutrients, foliar applications are a short-term solution. Refer to the potassium section **(page 15)** for suggestions on using potassium foliar sprays and **page 26** for using magnesium foliar sprays. Some crops have inefficient mechanisms for translocating calcium to fruits of young tissue. See the calcium section **(page 26)** for recommendations on using calcium foliar applications. For micronutrients, two to three applications may be all that are needed to meet crop demands. Even for micronutrients, the application is only effective during the year of application. Recommendations for rates of micronutrient foliar fertilizers to apply are provided in the micronutrient section **(pages 26-29)**.

Routine use of foliar fertilizers without a documented need is not recommended. Furthermore, foliar fertilization should not be used as a substitute for good soil fertility management. Have your soil tested and fertilize according to soil test recommendations.

Selecting a Yield Goal

Higher yielding crops generally require more nutrients than low yielding crops. For most fruit and vegetable crops listed in this bulletin, fertilizer recommendations are based on the yield obtained under optimum field conditions (i.e., water is not limiting and soil drainage is not a problem). If certain management practices such as plastic mulches, drip irrigation, row covers, or high tunnels are used, yield potential may be substantially higher than that reported in this bulletin. In those cases, an increase in fertilizer rates over those recommended may be warranted.

For the major processing crops (peas, sweet corn, snap beans, lima beans, and potatoes) where larger acreage is planted and soil conditions and water availability may not be as favorable as for the higher value fruit and vegetable crops, yield may vary as a function of the area in which the crop is grown as well as management practices. Selecting a realistic yield goal for these crops will improve fertilizer use efficiency. Reasonable yield goals are usually set at 15-20 percent higher than a grower's average yield for the past 5 years.

Primary Macronutrients

Nitrogen, phosphorus, and potassium are often referred to as the primary macronutrients because of the general probability of plants being deficient in these nutrients and the large quantities taken up from the soil relative to other essential nutrients.

Nitrogen

Of all the essential nutrients, nitrogen is the one most often limiting for crop growth. Many soils contain large amounts of nitrogen, but most of the nitrogen is tied up in the organic fraction and only slowly released. For most nonlegume crops, some nitrogen fertilizer is required for adequate yields. Nitrogen is available to the plant in two forms—ammonium (NH_4^+) and nitrate (NO_3^-). In most soils, ammonium is quickly converted to the nitrate form, a process called nitrification. This nitrate form is not tightly held on soil particles and is soluble in water. Consequently, nitrogen management is important both from a production and environmental standpoint. On sandy soils, nitrogen applied early in the season can be easily leached out of the root zone with heavy rainfall or excess irrigation. Nitrogen deficiency may result, as well as an increased potential for nitrate contamination of the groundwater. On irrigated sandy soils, nitrogen should be split applied—a small portion at planting and the remainder during the growing season after the