Potassium for crop production

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Potassium (K) is an essential nutrient for plant growth. Because large amounts are absorbed from the root zone in the production of most agronomic crops, it is classified as a macronutrient. Minnesota soils can supply some K for crop production, but when the supply from the soil is not adequate, K must be supplied in a fertilizer program. This publication provides information important to the basic understanding of K nutrition of plants, its reaction in soils, its function in plants, and its role in efficient crop production.

Role in plant growth

The exact function of K in plant growth has not been clearly defined. Potassium is associated with movement of water, nutrients, and carbohydrates in plant tissue. If K is deficient or not supplied in adequate amounts, growth is stunted and yields are reduced. Various research efforts have shown that potassium

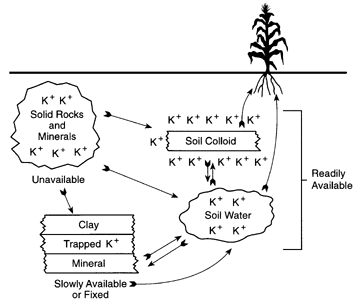
* stimulates early growth,
* increases protein production,
* improves the efficiency of water use,
* is vital for stand persistence, longevity, and winter hardiness of alfalfa, and
* improves resistance to diseases and insects.

These roles or functions are general; but all are important to profitable crop production.

Potassium in soils

The total K content of soils frequently exceeds 20,000 ppm (parts per million). Nearly all of this is in the structural component of soil minerals and is not available for plant growth. Because of large differences in soil parent materials and the effect of weathering of these materials in the United States, the amount of K supplied by soils varies. Therefore, the need for K in a fertilizer program varies across the United States.

Three forms of K (unavailable, slowly available or fixed, readily available or exchangeable) exist in soils. A description of these forms and their relationship to each other is provided in the paragraphs that follow. The general relationships of these forms to each other are illustrated in **Figure 1.**



**Figure 1.** Relationship among unavailable, slowly available, and readily available potassium in the soil-plant system.

***Unavailable Potassium***: Depending on soil type, approximately 90-98% of total soil K is found in this form. Feldspars and micas are minerals that contain most of the K. Plants cannot use the K in this crystalline-insoluble form. Over long periods of time, these minerals weather (break down) and K is released. This process, however, is too slow to supply the full K needs of field crops. As these minerals weather, some K moves to the slowly available pool. Some also moves to the readily available pool (see Figure 1).

***Slowly Available Potassium***: This form of K is thought to be trapped between layers of clay minerals and is frequently referred to as being fixed. Growing plants cannot use much of the slowly available K during a single growing season. This slowly available K is not measured by the routine soil testing procedures. Slowly available K can also serve as a reservoir for readily available K. While some slowly available K can be released for plant use during a growing season, some of the readily available K can also be fixed between clay layers and thus converted into slowly available K (see **Figure 1**).

The amount of K fixed in the slowly available form varies with the type of clay that dominates in the soil. Montmorillonite clays are dominant in many of central and western Minnesota soils. These clays fix K when soils become dry because K is trapped between the layers in the clay mineral. This K, however, is released when the soil becomes wet. Illite clays are dominant in most of the soils in southeastern Minnesota. These clays also fix K between layers when they become dry, but do not release all of the fixed K when water is added. This fixation without release causes problems for management of potash fertilizers for crop production in the region.

**Readily Available Potassium**: Potassium that is dissolved in soil water (water soluble) plus that held on the exchange sites on clay particles (exchangeable K) is considered readily available for plant growth. The exchange sites are found on the surface of clay particles. This is the form of K measured by the routine soil testing procedure.

Plants readily absorb the K dissolved in the soil water. As soon as the K concentration in soil water drops, more is released into this solution from the K attached to the clay minerals. The K attached to the exchange sites on the clay minerals is more readily available for plant growth than the K trapped between the layers of the clay minerals.

The relationships among slowly available K, exchangeable K, and water-soluble K are summarized below

slowly available K

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exchangeable K

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water-soluble K

Notice that when the arrows go in both directions, one form of K is converted to another. The rate of conversion is affected by such factors as root uptake, fertilizer K applied, soil moisture, and soil temperature.

Potassium uptake



**Figure 2.** Potassium deficiency symptoms in corn. A normal corn leaf is on the left. The leaf showing the most severe symptoms is next to the normal leaf.

Potassium uptake by plants is affected by several factors.

**Soil Moisture:** Higher soil moisture usually means greater availability of K. Increasing soil moisture increases movement of K to plant roots and enhances availability. Research has generally shown more responses to K fertilization in dry years.

**Soil Aeration and Oxygen Level:** Air is necessary for root respiration and K uptake. Root activity and subsequent K uptake decrease as soil moisture content increases to saturation. Levels of oxygen are very low in saturated soils.

**Soil Temperature:** Root activity, plant functions, and physiological processes all increase as soil temperature increases. This increase in physiological activity leads to increased K uptake. Optimum soil temperature for uptake is 60-80°F. Potassium uptake is reduced at low soil temperatures.

**Tillage System:** Availability of soil K is reduced in no-till and ridge-till planting systems. The exact cause of this reduction is not known. Results of research point to restrictions in root growth combined with a restricted distribution of roots in the soil.

Potassium deficiency symptoms

Some crops exhibit characteristic deficiency symptoms when adequate amounts of K are not available for growth and development. Potassium is mobile in plants and will move from lower to upper leaves. For corn, the margins of the lower leaves turn brown (**Figure 2**). This development of dead tissue is accompanied by a striped appearance in the remainder of the leaf. The entire leaf has a very distinct light green appearance when viewed from a distance. The striping associated with K deficiency in corn can be easily confused with deficiency symptoms for sulfur (S), magnesium (Mg), and zinc (Zn).



**Figure 3.** Potassium deficiency symptoms in soybeans.

The margins of the leaflets turn light green to yellow when K is deficient for soybean production ( Figure 3 ). As with corn, these deficiency symptoms first appear on the lower leaves. With maturity, the deficiency symptoms expand to leaves closer to the top of the canopy. Potassium deficiency in alfalfa is characterized by yellow or white spots on the margins of the leaflets ( Figure 4 ), with symptoms first appearing on the older plant tissue. Potassium deficiency in alfalfa can be easily confused with damage caused by the potato leafhopper.

Predicting the needs for potash

The K status of soils can be monitored with either plant analysis or routine soil testing procedures. Plant analysis can be used to either confirm a suspected deficiency indicated by visual symptoms or routinely monitor the effects of a chosen fertilizer program. An interpretation for K levels in plant tissue is provided in**Table 1.**

Table 1. Interpretation of plant analysis for K for major agronomic crops grown in Minnesota.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | **Interpretation** | | | | |
| **Crop** | **Part  Sampled** | **Time of  Sampling** | **Deficient** | **Low** | **Sufficient** | **High** | **Excessive** |
|  | | | - - - - - - - - - - - - - - - - - - % K - - - - - - - - - - - - - - - - - | | | | |
| alfalfa | top 6 inches | bud | <1.8 | 1.8-2.4 | 2.5-3.8 | 3.9-4.5 | >4.5 |
| barley | whole plant | head  emergence | <1.25 | 1.25-1.49 | 1.50-3.00 | >3.00 | - |
| corn | ear leaf | silking | <1.30 | 1.30-1.70 | 1.80-2.30 | 2.40-2.90 | >2.90 |
|  |  |  |  |  |  |  |  |
| soybean | most recently  matured trifoliate | early  flower | <1.30 | 1.30-1.70 | 1.80-2.50 | 2.60-4.50 | >4.50 |
|  |  |  |  |  |  |  |  |
| wheat | whole plant | head  emergence | <1.25 | 1.25-1.49 | 1.50-3.00 | >3.00 | - |



**Figure 4.** Potassium deficiency symptoms in alfalfa. Note the white spots on the margins of the leaves.

If amounts of K in the root zone are more than enough to meet crop needs, K will be absorbed by plants in amounts higher than required for optimum yield. This can lead to higher than normal concentrations of K in plant tissue and is referred to as "luxury consumption." Luxury consumption has no known negative effect on plant growth. Plant analysis is a management tool that can be used to look back at nutrient supplies during the growing season. This tool cannot be used to predict the amount of potash needed for any crop in the next growing season.

The soil test for K is the best management tool for predicting the amount of potash needed in a fertilizer program. Available K in soils is estimated by measuring the total of solution K (water = soluble K) and exchangeable K. The definitions for the relative levels of soil test K are summarized in **Table 2.**

Table 2. Relative levels of soil test values for K for Minnesota soils.

|  |  |
| --- | --- |
| **Soil Test Potassium** | **Relative Level** |
| - - - - - ppm - - - - - - |  |
| 0 - 40 | very low |
| 41 - 80 | low |
| 81 - 120 | medium |
| 121 - 160 | high |
| 161 + | very high |

An increase in production can be expected if potash fertilizer is added to the fertilizer program when soil test values are in the low and very low ranges. Added yield may or may not be observed if potash is added when the soil test values are in the medium range. Use of potash fertilizer in a starter will produce the best results when soil test values are in the medium range. A response to potash fertilization should not be expected if soil test values for K are in the high or very high range. Potash fertilizer recommendations for various agronomic crops are listed in BU-6240-E, Fertilizer Recommendations for Agronomic Crops in Minnesota.

Sources of potassium

There are a limited number of fertilizer materials that can be used to supply K when needed. These materials are listed in Table 3.

Table 3. Common fertilizer sources of K.

|  |  |  |
| --- | --- | --- |
| **Material** | **Chemical  Formula** | **K 2O  Content  %** |
|  |  |  |
| potassium chloride | KCl | 60 |
| potassium-magnesium  sulfate | K 2SO 4-2MgSO 4 | 20 |
| potassium nitrate | KNO 3 | 44 |
| potassium sulfate | K 2SO 4 | 50 |

Potassium chloride is the most common K source used in Minnesota. Red, pink, and white forms are available. These materials are equivalent as sources of K. The color in 0-0-60 is due to iron impurities that have no effect on the availability of K for crop growth. Most of the potassium chloride used in the United States is mined from underground deposits in Saskatchewan. Some is mined in the western United States.

Potassium-magnesium sulfate is a good source of K when there is also a need for magnesium in a fertilizer program. This product should be considered for fertilizing corn, alfalfa, and small grains grown on sandy soils. The cost of potassium nitrate and potassium sulfate is usually higher so the use of these two products in Minnesota is very limited.

Manure is also a source of K. The K content of manure varies with animal type, feed ration, storage, and handling practices. Manure should be analyzed to determine the amount of K that was applied.

Management Practices for Potassium

Suggested management practices for K vary with crop. There is a higher probability of successful establishment of perennial crops such as alfalfa and grasses if the soil test for K is in the medium range or higher. For these crops, the best strategy would be to apply potash fertilizers before seeding followed by annual topdress applications. The annual applications should be based on the results of routine soil tests for K.

Any potash needed for corn and small grain production can be applied in a band near the seed at planting or broadcast and incorporated before planting. When applied in a band, the recommended broadcast rate of potash can be reduced by one-half without causing a reduction in yield. The effectiveness of banded potash for corn production is illustrated in **Table 4**.

Table 4. The effect of management of potash fertilizer on corn production. Goodhue County

|  |  |  |
| --- | --- | --- |
| **Rate of K Applied** | **Placement** | **Yield** |
| lb./acre |  | bu./acre |
| 0 | - | 114 |
| 40 | starter (band) | 143 |
| 100 | broadcast | 136 |
| 200 | broadcast | 141 |

Soil test (0-6 in.) = 85 ppm

For best results, potash fertilizer needed for soybean production should be broadcast and incorporated before planting. This crop will respond to potash applied in a band. In contrast to corn and small grains, however, highest yield increases have been associated with broadcast applications.

Banded application of potash is essential for corn grown in ridge-till and no-till production systems. A rate of 40-50 lb. K 2 O per acre is suggested even though the soil test for K may be in the high or very high range. Application of the K 2 O in a band in the fall following soybean harvest is a popular management practice for those using reduced tillage in the corn/soybean rotation.

Summary

Potassium is an essential major nutrient for crop production in Minnesota. The supply of total K in soils is quite large. Yet, relatively small amounts are available for plant growth at any one time. The three forms of K (unavailable, slowly available, readily available) exist in an equilibrium in the soil system.

The need for potash in a fertilizer program can be determined from plant analysis and soil testing. Soil testing is the most reliable predictor of this need.

Suggested management practices for this nutrient vary with crop. Topdress applications are appropriate for perennial crops such as alfalfa and grasses. For soybeans, broadcast applications incorporated before planting are most effective. Either banded or broadcast applications can be used for corn and small grain production. Broadcast rates can be reduced by one-half if banded applications are used for these crops. This management practice does not reduce yields but results in a savings of fertilizer dollars.