Potassium Fertilization

By Dr. N. E. Christians
Iowa State University

The last 20 years have brought some major changes in how potassium (K) is used in turfgrass fertility programs. During that time, we've gone from programs that placed little emphasis on K, to modern programs that include fertilizer analyses high in this essential element. Supplemental applications of materials like potassium sulfate (0-0-50) during the growing season have also become popular. The objective of this article is to look at the functions of K in the grass plant, to discuss its role in soil chemistry, and to evaluate how our thinking about this important nutrient element has changed over the years.

Fertilizers

A complete turf fertilizer contains nitrogen (N), phosphorus (P), and potassium (K). These materials are expressed on the label with an analysis that lists the percentage by weight of N, P_2O_5 and K_2O. A 50 pound bag of 20-3-15 contains:

50 X .20 = 10 lbs. of N
50 X .03 = 1.5 lbs. P_2O_5, and
50 X .15 = 7.5 lbs. K_2O

The P_2O_5 is 44 percent by weight elemental P and K_20 is 83 percent by weight elemental K. Therefore this bag of fertilizer contains:

1.5 X .44 = .66 lbs. elemental P, and
7.5 X .83 = 6.2 lbs. elemental K.

The reason that P and K are listed on the fertilizer label as oxides and N as an individual element is due primarily to tradition. It was a convention adopted in the early days of commercial fertilizer production and it has never been changed. It would make a great deal of sense and would simplify fertilizer calculations if labels would be changed to list the three elements on an N-P-K basis. It appears unlikely that the fertilizer industry will change to this system any time in the near future, however. To do so would make it appear that that the bag contains less nutrients. A 10-10-10 (N- P_2O_5-K_2O) fertilizer, for instance, would become a 10-4.4-8.3 on an N-P-K basis. Even though these two analyses have the same meaning, it would appear to the public that the first analysis provides more for their money.

Potassium: Plant Activator

Potassium was often referred to in the past as the mystery element. While more is known about its function today than was known just a few years ago, there are still things about K that are not completely understood. One surprising fact about K is that it does not become a part of any of the plant biochemicals. The chlorophyll, proteins, nucleic acids, and other material in which N plays such an important role, contain no K. This doesn't mean that K is not found within the plant. Plants contain relatively large amounts of K and it is recognized to be the most abundant cation in the cytoplasm of many species (Marshner, 1995). Grasses are particularly heavy users of K and it is found in grass tissue at levels from 1.2 to 3.5 percent on a dry weight basis (Christians, 1977; Christians, 1979).

Plant scientists refer to K as a cofactor (enzyme activator). A cofactor is something that has to be present for certain plant constituents to be formed and for certain plant functions to occur, but it does not become part of the materials being formed. Among the many things that K becomes involved in are carbohydrate formation, meristematic growth, enzyme activation, the synthesis of proteins, and cell elongation (Marshner, 1995). Potassium plays a role in photosynthesis and carbohydrate production is reduced when K is deficient. Root development requires sufficient K levels (Christians, et al., 1979; DePaola, J. M. and J. B. Beard 1977). Potassium deficient plants are known to be less resistant to plant diseases (Goss and Gould, 1967; Salisbury and Ross, 1992; Tisdale and Nelson, 1975). The words that best summarize the role of K in the plant is **stress tolerance**.

Potassium is also involved with the opening and closing of plant stomata. The stomata are small openings in the epidermis (outer cell layer) of the plant leaves. Like the pores in our skin, these stomata can open and close in response to environmental changes. Their function is to allow the entrance of gasses and to help control water release from the surface of the plant. The stomata play an important role in stress management and plants deficient in K are less tolerant of environmental stresses. The tolerance of creeping bentgrass to heat in midsummer, winter hardiness of bermudagrass (Gilbert and Davis, 1971), wear tolerance, and other related stress functions are all affected by K.

Potassium deficiency symptoms on plants can be very subtle and difficult to recognize. It is mobile within the plant and is easily redistributed from mature plant parts to younger tissue, so deficiency symptoms first appear on older leaves (Salisbury and Ross, 1992). The symptoms on K deficient plants generally differ on dicots (broadleaves) and monocots (grasses). Dicots deficient in K can become slightly chlorotic and can form discrete necrotic lesions near the margins of leaves, whereas monocots can show damage at the tip and margin of the leaf (Salisbury and Ross, 1992). For grain crops, the term 'hidden hunger' is often used because reductions in yield can occur without an outward expression of deficiency symptoms (Tisdale and Nelson, 1975). On turf, K deficiency symptoms are more difficult to identify. Likewise, the application of K to deficient turf will not generally show a visible response. The subtle responses of carbohydrate production, stress survival, and disease resistance are very difficult to discern visually.

Cation Exhange Capacity

To understand the role of K in the soil requires a knowledge of a phenomenon known as **Cation Exchange Capacity (CEC)**. The standard definition of CEC is 'the ability of the soil to exchange cations', a definition that usually requires further explanation. Cations are positively (+) charged elements that occur in the soil. Several of the cations that are important as plant nutrients or play other important roles in soil chemistry are listed in Table 1. The cations with single + charges are called monovalent cations and those with two + charges are known as divalent.

The fine particles of the soil, particularly the clays and the organic component (humus) are surrounded with negative (-) charges. These positive and negative charges function in ways similar to magnets. As like poles of magnets repel and opposite poles attract, like charges repel and opposite charges attract one another in the soil. This allows the negatively-charged soil and organic materials to hold the cations so that they can be exchanged with the root systems and be used by the plant .

The units of the CEC test are milliequivalents (meq.)/100 grams of soil. One millequivalent is equal to 6×10^{20} (a 6 with 20 zeroes behind it). Even 1 meq/100 g of soil is a lot of negative charges, although a CEC of 1 would be considered to be very low. A knowledge of relative CEC numbers for various soil types can provide useful information on how soils should be managed (Table 2).

Sands are very low in CEC and have a much lower ability to hold and exchange cations, such as K^+, than do clays. Clays, however, readily compact and do not provide a suitable media for the growth of turf on areas that receive heavy traffic such as golf course greens and athletic fields. In turf management, sands are generally used to construct the most heavily trafficked areas. To help increase the CEC, as well as the water-holding capacity, of the sand, organic matter is usually added to the media during construction. While this is an improvement, sandy media, such as a modern sand green or sand-based athletic field, is still likely to have a very low CEC.

The CEC has a major effect on how fer-

TABLE 1.

CATIONS THAT PLAY AN IMPORTANT ROLE IN SOIL CHEMISTRY.

ELEMENT	CATION
HYDROGEN	H^+
CALCIUM	Ca^{++}
MAGNESIUM	Mg^{++}
POTASSIUM	K^+
SODIUM	Na^+
AMMONIUM	NH_4^+

TABLE 2.

THE CATION EXCHANGE CAPACITY OF SOILS AND SOIL COMPONENTS.

SOIL TYPE OR COMPONENT	MEQ/100 G
SAND	>1 - 6
CLAY	80 - 120
ORGANIC MATTER	150 - 500
CLAY LOAM SOIL	25 - 30
SAND GREEN	>1 - 14

tilization is conducted. The CEC of a fertile clay loam soil, such as found in agricultural regions, will range from 25 to 30 meq/100 g. A soil such as this has sufficient CEC sites that cations like K+ can be applied in larger quantities to build-up available levels. Low CEC sands, however, present a different problem. They have far fewer CEC sites and are not capable of holding as much K as the clay loam soil. Soil tests on these sandy soils will often show very low levels of extractable K. Attempts to build up K levels on these soils are unlikely to be successful and may even result in other nutritional imbalances as will be discussed later.

The CEC is not a measure of soil fertility, but of "potential" soil fertility. It measures the number of negative charges only. Other soil testing procedures must be conducted to determine how much of each element is available in the soil.

Potassium Fertilization

Potassium recommendations for turf have changed considerably in the last two decades. A turf fertilizer analysis such as 20-3-3 was common only a few years ago. Modern fertilizer analyses are more in the range of 20-3-15, or even 30-0-30. Supplemental applications of potassium sulfate (0-0-50) are also quite common on many golf courses. What has changed during that time, is our understanding of turf response to K.

Soil test interpretations traditionally were borrowed from other crops where the primary goal of K fertilization is plant yield. Potassium plays an important role in plant growth, but it also plays very important roles in stress tolerance (Sandburg and Nus, 1990). As mentioned earlier, the ability of creeping bentgrass to survive high temperature stress, the ability of perennial ryegrass to survive cold winters, the ability of a bermudagrass green to tolerate wear stress, and many other things related to the plant's ability to tolerate stress are affected by K. Maximum tissue production is reached at lower levels of available K than are some of these stress related responses.

In turf management, the goal is not maximum tissue production, but the maintenance of a quality turf area that is capable of surviving stress conditions. Soil test laboratories that interpret tests on yield response data borrowed from other crops will generally underestimate the amount of K needed by turf.

Table 3 includes ranges of extractable K for turf. These are considerably higher than those used for many other crops (Christians, 1993). Exactly where these levels should be is somewhat controversial. While yield is easy to measure, stress-related responses are much more difficult to observe and to document. Some feel that the ranges should be higher, while others feel that they should be lower. These ranges are the opinion of this author. They are much closer to the needs of turf than are those currently used by many testing laboratories, but they may change with time as more data on turf response to K are collected.

Note that the K levels are listed in both ppm and pounds/acre (lb/A). The way of expressing K test levels may vary among laboratories. Some express the results in lb/A of available nutrients. Others use parts per million (ppm), where one ppm is equiv-

TABLE 3.

POTASSIUM TEST LEVELS RECOMMENDED FOR TURF.

PPM		LB/A
0-40	VERY LOW	0-80
41-175	LOW	81-350
175-250	ADEQUATE	350-500
250-	HIGH	500-

alent to one lb. of available nutrient per million pounds of soil. Soil tests in the U.S. are traditionally based on the 'acre furrow slice,' the soil in the upper six to seven inches of the profile. This term originated in the early days of soil test development. It relates to the depth of soil turned by a standard plow. This amount of soil is considered to weigh 2,000,000 pounds. Two pounds per acre is equivalent to two parts per two million or one ppm, and ppm will always be one-half of the lbs/A. A soil test of 20 ppm and 40 lbs/acre are equivalent. When interpreting soil tests, be sure to identify whether the values are in lbs/A or ppm.

There is a tendency among some turf managers to take this idea to extremes by applying very high levels of K and very low levels of N. Some turf managers now report applying N levels as low as 1 lb./1000 ft^2 and K levels as high as 8 lbs./1000 ft^2 per season. Remember that K is a cation. On soils with higher cation exchange capacities (25 to 30meq/100 g) increasing levels of K may be practical. On low CEC soils, such as sand greens on golf courses and sand-based athletic fields, excess levels of K have the potential of saturating CEC sites at the expense of other essential cations such as Ca^{++} and Mg^{++}. By default, any CEC site that has a K^+ attached to it does not have one of the other cations. On these sandy soils, **spoon feeding** K to the plant as it needs it is a better approach.

Spoon Feeding Programs for Turf

In a spoon feeding program, the fertilizer is applied in the liquid form. The amounts of materials applied in each treatment are so low that application in the dry form would not be possible on close mown turf. Attempts to do so generally result in a turf speckled with green dots. The advantage of a spoon feeding program is its flexibility. It can be adjusted to meet exactly the needs of the area being treated.

There are no effective soil tests for N and application rates are based on the color of the turf and the amount of clippings in the catch basket. Nitrogen rates in a spoon feeding program are usually in the range of 0.1 to 0.25 lbs. N/1000 ft^2/application. The amount will vary with rainfall, soil type, temperature, etc. and the amount should be adjusted to meet local conditions. Applications are made on 7 to 14 days intervals depending on the needs of the grass.

The other nutrients in the solution and their amounts will depend on a careful evaluation of the soil test and perhaps on turf tissue tests. If P is needed, available phosphoric acid (P_2O_5) should equal approximately one third the amount of N. If a liquid fertilizer base mix is 12 percent N, approximately 4 percent P_2O_5 should be applied. If 0.25 lbs N is applied per 1000 ft^2, 0.08 lbs P_2O_5 should be included. No P will be needed in many situations. In that case, none should be included in the solution.

The amount of K_2O included in the solution will again vary with soil test. Where K levels are sufficient, which will be rare on a sandy soils, no K should be included in the mix. A more likely situation will be that K soil test levels are very low. Liquid fertilizer solutions are limited by the solubility of K in the solution and liquids are often in the range of 3 to 4 percent K_2O. Where dry materials designed to be dissolved in water are used, K_2O levels can be higher. Soluble dry products with analyses like 23-0-23 or 23-8-16 are readily available. They generally must be applied with a recirculating sprayer to keep the materials in solution and suspension.

Other nutrients included in the solution will vary widely depending on soil conditions. This again is the advantage of a spoon feeding program. In a low pH and low

CEC soil where Mg++ may be deficient, Epsom salts or some other source of Mg^{++} may be included. The amount will vary with conditions but a target rate would be in the range of 0.02 to 0.1 lb Mg^{++}/1000 ft^2.

Iron will be the key material on high pH soils. There are several good Fe sources available. The label should be followed carefully with each product. Application rates are generally in the range of 2 to 3 oz/1000 ft^2.

Other elements like Mn, molybdenum (Mo), zinc (Zn), and copper (Cu) will rarely be deficient but situations may exist where they will be needed. These materials can usually be provided by micronutrient packages that can be added to the solution and provide trace amounts of these elements. They add very little to the cost of the application and they are usually included in small amounts as insurance against deficiencies. They should be used as directed on the label.

Supplemental K Applications

In situations where supplemental applications of K in addition to those provided by the spoon feeding program become necessary, there are more concentrated K containing fertilizers that can be used. Potassium sulfate (K_2SO_4) with an analysis of 0-0-50 is one of the most widely used. Potassium chloride (KCl) with analysis of 0-0-60 and potassium nitrate (KNO_3) with an analysis of 13-0-36 are also available.

Potassium sulfate has a lower burn potential than the other two materials. In cool weather, it can be applied at rates of 1 lb. K_2O/1000 ft^2 /application with little concern over burning. The other two materials can be applied at 0.5 to 1.0 lb. K_2O/1000 ft^2. They should be watered in shortly after application. Remember that the potassium nitrate will supply 0.36 lbs. of N for every lb. of K_2O. This should be taken into account when determining the N need of the turf.

Dr. Christians is a professor of horticulture at Iowa State University

Literature Cited

Parts of the text are used with permission from a new text book titled 'Fundamentals of Turfgrass Management' by Nick Christians. The book will be available in April, 1998 from Ann Arbor Press, 121 South Main St., Chelseas, MI 48118. phone 313-475-8852. ISBN 1-57504-051-4.

Christians, N.E. 1977. The effect of nitrogen, phosphorus, and potassium on the quality and chemical composition of merion Kentucky bluegrass and penncross creeping bentgrass. MS thesis. Ohio State University. p. 97.

Christians, N.E. 1979. The interrelationships of nutrient elements and their effects on the growth and quality of turfgrasses. Ph.D. Dissertation. Ohio State University. p. 80-93.

Christians, N.E. 1993. The fundamentals of Soil Testing. Golf Course Management. June. p. 88.

Christians, N.E. 1996 a. Phosphorus nutrition of turfgrass. Golf Course Mgt. 64(2):54-57.

Christians, N. E. Martin, D. P., and J. F. Wilkinson. 1979. Nitrogen, phosphorus, and potassium effects on quality and growth of Kentucky bluegrass and creeping bentgrass. Agron. J. 71:564-567.

DiPaola, J. M. and J. B. Beard. 1977. The root growth of St. Augustinegrass <italic>(Stenotaphrum secudndatu</italic>m) during establishment from sod and subsequent drought as influenced by potassium. Agron. Abs. p. 110.

Gilbert, W. B. and D. L. Davis. 1971. Influence of fertility ratios on winter hardiness of bermudagrass. Agron. J. 63:591-593.

Goss, R. L. and C. J. Gould. 1967. Some interrelationships between fertility levels and Ophiobulus Patch disease in turfgrass. Agron. J. 59:149-151.

Marschner, H. 1995. Mineral nutrition of higher plants. 2n ed. Academic Press, Harcourt Brace & Co. p. 299-312.

Salisbury, F. B. and C. W. Ross. 1992. Plant Physiology, 4th edition. Wadsworth Publishing Co. p. 131.

Taiz, L. and E. Zeigler. 1991. Plant physiology. Benjamine/Cummings Publishing Co. p. 114.

Tisdale, S. L. and JW. L. Nelson. 1975. Soil fertility and fertilizers 3rd ed. Macmillan, New York. p. 66-80.

Tisdale, S.L., W.L. Nelson, J.D. Beaton, and J.L. Havlin. 1993. Soil fertility and fertilizers. Macmillan Publishing Co. p. 51-52.