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Prostrate Birdsfoot Trefoil -- A Turf For Difficult Sites

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Populated areas have been encroaching into all of California, the land of geographical diversity. Into certain extremities of climate, topography and soil in this state an introduced legume is following the development of new lands. *Lotus tenuis L.*, narrow leaf birdsfoot trefoil (commonly termed the prostrate or creeping trefoil) entered Portland, Oregon, in 1917 accidentally from ballast. It soon naturalized in the Pacific-northwest.

The presence of this evergreen ground cover in California can be attributed to the extensive use of it on heavy, poorly drained, saline and alkali lands (1, 2). Irrigated pastures of this deep rooted perennial have been reported successful in the Sacramento Valley, except where heavy freezes have killed it, and also in the Imperial Valley, where extended periods of heat have not deterred it.

Single plants form a dense reticulum of prostrate wiry stems creeping up to 40 inches away from the crown (fig. 1). Leaves of three leaflets are on a short rachis subtended by two conspicuous stipules resembling leaflets. These are lanceolate ovate to obovate up to one inch long and almost one-half as long as they are wide. Stems and leaves are dark green and smooth, except in saline and drought conditions, when leaves are gray and pruinose. Papilionaceous flowers up to one-half inch in size are three to five in unbels on peduncles rising vertically just above the body of foliage. The bright yellow flowers may present a conspicuous sight in late summer on unmowed stands.

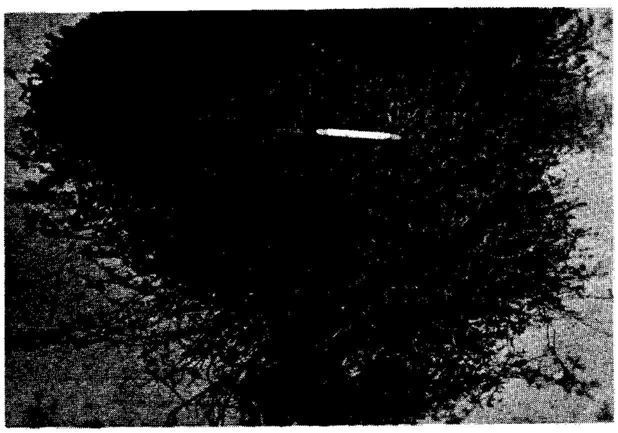

FIG. 1. THE PROSTRATE AND CREEPING GROWTH HABIT OF *LOTUS TENUIS.*

Since the narrow leaf birdsfoot trefoil was observed to have desirable turf characteristics in the Sacramento Valley, the Volkman Seed Company of San Francisco initiated a limited research program at U.C.L.A. in 1958. The studies conducted by the author included ecological observations in a field plot of 1900 square feet. In the laboratory environmental, nutritional, salinity, and moisture relations were investigated.

Experimental results provided information of a practical aid in the culture of this specific trefoil. The seed germination rate was 87% in a week at daily temperatures ranging from 65° to 75°F. Germination time at a constant 80°F. was three days and at a constant 40° was 56 days. The minimum temperature for shoot elongation was between 40° and 50°F. The maximum was above 100 F Optimum temperature was between 70" and 80°F.

Shoot elongation was affected more by the length of the light period than by the light intensity. Stems grew longer at 400 foot candles for 16 hours than at 3200 f.c. for 12 hours. However, a greater number of shoots were produced at a moderate light intensity.

The development of the root system as measured by fresh weights was favored by a long light period or a high light intensity at a moderate temperature. Extreme temperatures were deleterious.

Results of mineral nutrient studies showed that, as with most plants, nitrogen is the most important element for plant growth. When phosphorus or potassium were added singly to the nitrogen the phosphorus yields were significantly better than the potassium. Of course, all three of the major elements together gave the best results. The use of commercial Rhizobia inocula demonstrated these to be parasitic upon the plants, since they did not grow as well, even with addition of a nitrogenous fertilizer. Therefore, only a strain of Rhizobium specific for *Lotus tenuis* can be beneficial, and a commercial source is unknown.

In these experiments concentrations of the fertilizer above 22.8 milliequivalents per liter proved depressing to the growth of the trefoil plants. This concentration of soluble fertilizer salts is equivalent to 1.1 pounds of actual nitrogen applied to 1000 square feet when at least a quart of water is added to each square foot.

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Salinity tests on potted plants in sandy soil revealed the trefoil to be a plant tolerant of salt concentrations about half that of sea water (about 35,000 ppm). Plants in this hyper solution grew much slower than the check plants. At thirteen weeks, when daytime temperatures exceeded 100° F. leaves wilted.

To study the response of trefoil at low and high soil moisture the weighed pot technique was used. The moisture release characteristics of the soil were found, and plants in the soil were watered when the weight of the pot showed a certain quantity of water remaining. Plants were grown wet, moderate, and dry. At the end of a 120 day period differences in growth were slight between the wet and moderate moisture treatments. Plants in dry soil were significantly smaller. Wilt occurred when available moisture was only 2% of the soil volume. Leaves curled and later abscissed, yet new leaves were produced on the wiry stems when the soil was irrigated.

From these studies, in addition to the observations of the author, and others, suggestions for the use of the prostrate trefoil have become apparent.

In a southern California cemetery situated in a coastal valley the prostrate trefoil has developed a verdant surface on slopes of meager moisture and fertility(fig.2). In low, wet places the cover of trefoil was dense. However, in the shade of trees dichondra prevailed.

FIG.2. NARROW LEAFED BIRDSFOOT TREFOIL IN NITROGEN DEFICIENT TURF

At U.C.L.A. the trefoil was seeded at 15 pounds per acre on an old bermuda grass plot, where some of the rhizomes escaped the effects of fumigation. On the margins with inadequate irrigation the bermuda grass is dominant, but not so in the deeply irrigated center of the plot. At present ecological observations are incomplete. However, this trefoil has been seen to live with other turf components to provide the dark green surface where other members of the turf community are dormant.

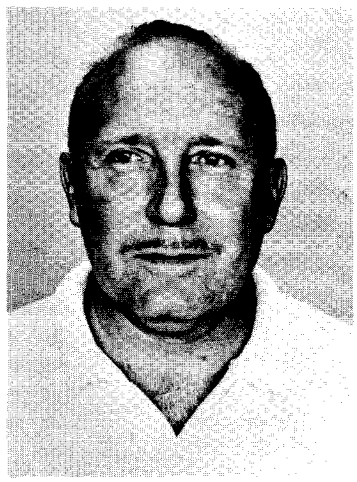
Since Lotus tenuis L. has been found to thrive in extreme environments and provide a low cover either mowed or unmowed, this plant is possibly the answer for difficult sites needing turf. As the wiry stems tolerate moderate foot traffic and a fair lie for the golf ball, rundown fairways could be improved by an overseeding with this Lotus. Dry and sparse roughs could benefit with trefoil. When unmowed, competition between plants will induce an upright growth habit, but it is certainly not unsightly. At least one Southern California golf course is known to have the prostrate trefoil. Whether intentionally planted or not, the author observed trefoil in a heavy, poorly drained soil both under conditions away from the sprinklers and in low spots under irrigation.

Perhaps in some lawn situations the presence of trefoil could be considered a weed, as is dichondra. Either may be eradicated with a 2,4-D herbicide. However, in most conditions where Lotus tenuis may abound it could not be termed a weed for the verdant cover of this long-lived legume is certainly needed.

LITERATURE CITED

1. *Ayers, Alvin D., 1948, Salt tolerance of birdsfoot trefoil. Jour. Amer. Soc. Agron. 40 : 331 - 334.*
2. *Peterson, M.K., Jones, L.G., and Oaterli, V. P., 1953, Birdsfoot trefoil in California. Calif. Ag. Ext. Bull. 421.*

Stanley Spaulding



Stanley Spaulding has recently become the laboratory technician to assist Dr. Victor B. Youngner in turfgrass research at U.C.L.A. Mr. Spaulding, a native of Inglewood, California, practiced landscape horticulture from 1935 to 1955, when he returned to U.C.L.A. for further studies in horticulture. The Master of Science degree in Horticultural Science was conferred upon "Stan" by the University in 1960.

Next to music and family, both the new researcher and his wife, Frances, enjoy the study of plant life as a hobby. Since Stan believes that true happiness comes from sharing knowledge with others, he has taught landscape horticulture to adults since 1949.

Chemotherapy* Breaks Par

E. M. Stoddard and Raymond J. Lukens

A tournament was coming up in three weeks and the greens at the Golf Club were in considerably less than satisfactory condition. They had "brown patch," "melting out," and chemical injury from too many applications of various fungicides at excessive concentrations. The fungicides had been put on in a losing last ditch battle against the "brown patch" and "melting out". At this point the problem of getting these greens in condition for the tournament was given to us along with a fervent prayer of hope that we could solve the problem at once.

We relate the story of what was done and the attendant results, not as a technique based on experimental data but as an application to this specific problem of various facts already known about nabam, a fungicide capable of controlling the causal fungus of "brown patch" and accelerating the formation of roots on plants when injected into the soil where the plants are growing. It was also known that another fungicide, thiram, used as a spray, would control "melting out".

We reasoned that if nabam were injected into the affected greens, it would control the "brown patch" and accelerate the formation of new roots on the grass, thus enabling the grass to come back quickly to a condition of normal growth. Given normal growth, we believed that less frequent and more thorough sprayings of thiram would control the "melting out."

Accordingly, we suggested a program of treatment, which was put into operation on the stricken greens. Nabam at a concentration of 1 to 600 in water was injected at 150 pounds pressure into the greens to a depth of one foot at four-foot intervals. (Incidentally, this operation excited much curiosity and caused some chagrin among the golfers playing through the greens.) Subsequent to the soil injection, appropriate sprayings of thiram were made as planned. As we tell you of the results please do not ask what happened to the untreated greens. There were none; this was an emergency program, not an experiment, and untreated greens had no place in it.

Now, what about the results of this program. It worked, and at tournament time three weeks later the greens were in acceptable condition for play! Both diseases had been adequately controlled and thanks to the ability of nabam to accelerate root growth, the grass was putting out many new roots. With the resultant increased growth the grass was filling in the thin spots satisfactorily. The players apparently were not concerned about the few bare spots that still remained but were enthusiastic about the fact that the balls "stuck" to the greens and their scores were in the low 60's. This characteristic, we found, was due to the loosening of the compacted soil by the injection of liquid under pressure, making a softer surface and reducing the bounce of the ball. This effect was not foreseen in the original planning.

At the time of this writing, two months after treatment, the greens are almost completely covered with a vigorous turf, with roots penetrating to a depth of six inches in the loosened soil and with practically no evidence of disease.

*The cure of plant diseases by chemicals taken into plants.

Editorial Comments:

This article by Plant Pathologists at the Connecticut Agricultural Experiment Station, presents the interesting idea of controlling turf diseases by injecting the fungicide, Nabam (Dithane D-14) into turf at high pressures. Because the liquid fungicide is applied at high pressure it moves rapidly in all directions, up as well as down and to the sides. This may have several benefits. The first, is the reduction of disease-producing organisms throughout the area of soil and thatch penetrated by the fungicide (providing, of course, that it is effective). Fungicides applied to the foliage fail to reduce appreciably the numbers of disease-producing organisms in the thatch and soil: they therefore must be reapplied at frequent intervals.

The second advantage is that the green is essentially aerified throughout, since the authors point out that the compacted soil is loosened. This benefit may extend throughout the entire soil mass penetrated by tbe fungicide and not to a very small area, such as the area of turf immediately around the bole produced by aeifiers. A third benefit results from the fungicide, Nabam, which apparently stimulated root formation. Thus this technique not only may reduce the pathogen in tbe soil, but also may stimulate the growth of roots, and tbe growth of turf plants by restoring favorable conditions of aeration. In a recent letter, Mr. Stoddard reports that control from the single treatment in 1959 also was very apparent in 1960.

Those who are interested in trying this new experimental technique may write to: R. M. Endo, Department of Plant Pathology, University of California at Los Angeles, California.

NEW TURFGRASS PUBLICATION

Greenskeeping is the name of a new publication designed primarily for golf course superintendents and others concerned with turfgrass management. The first issue appeared in September, 1960, and contained many excellent articles on turf management. It will be sent free of charge to all people associated with the field of turf maintenance. The address of the publication offices is, P.O. Box 1495, Tampa, Florida.

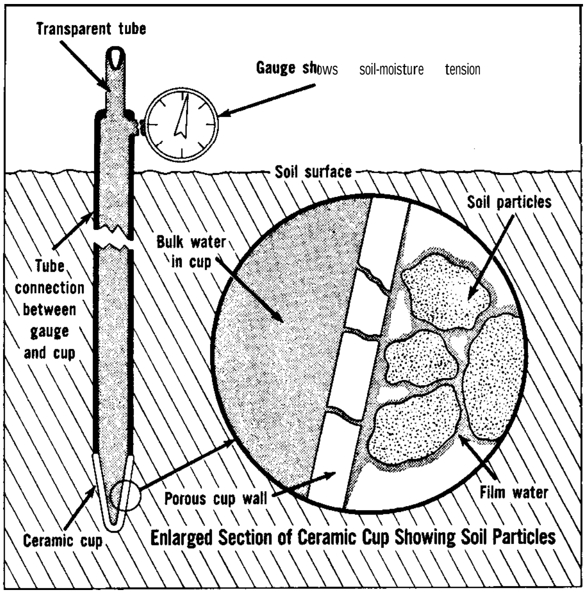
Tensiometers in Turfgrass

Wayne Morgan, University of California,
Agricultural Extension Service

Guesswork has been taken out of irrigation through the perfection of the tensiometer, a sensitive instrument that tells at a glance the exact moisture condition in the vital root zone of your soil.

Tensiometers measure the availability of water held by the soil, irrespective of the soil type. The reading obtained by the instrument is an index to soil "wetness" which does not therefore require further interpretation for each individual soil.

The tensiometer consists of a sealed, water filled tube equipped with a special vacuum gauge and with an unglazed ceramic cup on the end which is porous to water, but its pores are so small that they are sealed to air by the water films when the cup is wet.



Enlarged Section of Ceramic Cup Showing Soil Particles

Water in the soil forms a film over each soil particle. The pore openings in the cup wall provide passageways between the water in the cup and the films covering the soil particles. As the soil dries out, the water films become thinner and more tightly bound to the soil particles. The tension thus produced within these water films causes water to be pulled from the cup, and this movement produces a tension or suction within the tensiometer, which is indicated by a higher reading on the vacuum gauge.

When water from irrigation or rainfall reaches the neighborhood of the cup, the tension within the water films on the soil particles is reduced and water moves back into the tensiometer cup. The tension within the instrument is thus reduced and the gauge shows a lower reading.

Recommended depths of installation depend upon the active root zone. For most turfgrass areas this will mean from 4 to 12 inches. It is most essential that the instruments be placed in an active root area.

In determining where tensiometer stations should be located, perhaps the most important consideration is variation in soil type. The tensiometer installations are generally placed where the soil is most representative of that in the area, and where the surrounding soil will be wet by the irrigations. Sometimes it may be desirable to place additional installations in high or low spots and in areas where soil and drainage conditions may be different.

More work still needs to be done using tensiometers in turfgrass to determine the best places to place the instruments and the correct depth of installation where the roots are most active.

Tensiometers at various points and depths in a field will seldom show the same readings at any time because of the variability in topography, soils, and root activity and in the date and efficiency of the last irrigation. This variation makes it desirable to base irrigations on the responses of several tensiometers placed at representative locations. A few deeper instruments may be desirable for use with trees and ornamentals.

In general, the following interpretations of the tensiometer readings have been found practical for use under most conditions:

READINGS 0 – 10

Excessively Wet Soil. Continued readings in this range indicate over-irrigation, danger of waterlogged soils, inadequate root aeration, root rot, or high water table. This can also contribute to more soil compaction and conditions favorable for diseases to become established.

READINGS 10 – 20

Field Capacity. Irrigations here may waste water by percolation and nutrients by leaching. Root aeration is usually assured anywhere in this range and above.

READINGS 30 – 60

Usual Range for Starting Irrigations. In general, irrigations start in the lower part of this range in hot, dry climates, or in coarse-textured soils such as sands. Irrigations start in the upper part of this range in cool climates or in soils with high water-holding capacity such as clays. Irrigation in this range provides a safety factor for maintaining readily available soil moisture at all times.

READINGS 70 AND HIGHER

Stress Range. A reading of 70 does not necessarily indicate that all available moisture is used up, but that readily available moisture is getting dangerously low, especially in the corase-textured soils. The tensiometer cannot indicate soil-moisture conditions in the relatively dry range. If irrigation water is still withheld after readings rise to about 80 on the dial, the readings will not continue to go up, but water will be pulled out of the tensiometer system, and the readings will cease to be valid.

For most turfgrass areas, readings should be made each morning at nearly the same time. It may also be well to record the temperatures and weather conditions for each day. Readings are recorded and plotted on graph paper. In time, one can predict in advance when to irrigate by projecting his charts. Although the exact reading is important, the rate of change in readings is the factor given the most consideration in determining irrigation schedules. Tensiometers can also indicate how long to irrigate so that water infiltrates the entire root zone.

The soil-moisture tensiometer is not as yet a trouble free instrument. It will not function correctly under saline conditions. It should be handled with care during installation, and it must be protected from damage from cultural operations. The water level in the transparent tube should be checked each time a reading is taken and water added, if needed, to maintain water above the gauge.

Tensiometers can tell when to and when not to water as well as showing depth of water infiltration. Results from tensiometers used during the past summer at a golf course and at two cemetery locations indicate that significant savings can be made in water and labor costs. In most cases, readings showed that over-irrigation was being practiced.

At the golf course where their instruments were used on the greens, water use was cut by about one fourth by shortening the length of irrigation. Indications are that too much water is still being applied and greater savings can be had. On the fairway, watering times were cut in half and frequency of irrigation lengthened some. The importance of these savings besides lowering water and labor costs can be found in a healthier turf from better aeration and root growth with less compaction and disease and weed problems.

One of the cemetery locations using tensiometers was able to greatly improve the appearance of their new turfgrass by changing the time of day water was applied and shortening the frequency of applications. They are now using the tensiometers as indicators of when to irrigate and are developing an improved irrigation program.

Tensiometers used at the second cemetery location have resulted in important changes being made. The first of these changes is the revamping of their irrigation system to adjust to soil variations. Another change from rescheduling irrigations should result in cutting their water and labor costs almost in half, savings in fertilizer costs, and improving the appearance of their turfgrass. Readings have shown they were vastly over-irrigating, mainly in an effort to improve a few problem areas (see table). In the future they will irrigate according to the tensiometer reading for the majority of the area and find other means for improving their problem spots.

TABLE 2. SOIL MOISTURE CONTENT AT FOUR LOCATIONS UNDER ONE IRRIGATION VALVE

CEMETERY

Date	Tensiometer readings 1	2	3	4	Irrigation Time minutes
June 27	8	8	10	9	...
28	7	6	8	10	...
29	7	5	8	9	45
30	6	5	5	6	...
July 1	8	9	10	10	60
7	5	5	6	6	...
8	7	8	10	9	45
9	6	5	9	6	...
11	8	12	12	16	60
12	5	3	6	6	...
13	6	5	8	7	45
14	5	3	6	6	...
15	7	8	8	8	45
16	4	6	6	7	...
18	10	16	12	14	45

Costs of one-foot tensiometers range from approximately $10 to $25, depending upon the features included. They can give years of service, so by amortizing the initial instrument investment in accordance with standard accounting practices, the instruments become relatively inexpensive.

Work is now underway to develop a tensiometer with the porous cup located in the green but the gauge in the apron to avoid any interference on the green. This can possibly be accomplished with a longer instrument inserted on an angle. There has been no trouble with installations causing any problems in other areas.

With the results already obtained and these benefits and savings in mind, tensiometers deserve to be tried in your turfgrass management. Anyone desiring more information about the installation and use of tensiometers should contact his local University of California Farm Advisor or Wayne C. Morgan, Farm Advisor's Office, 808 North Spring Street, Room 800, Los Angeles 12, California.

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Acknowledgement:

The schematic diagram and other information for this article has been provided from a University of California bulletin – "The Soil Tensiometer" by S. J. Richards and R. M. Hagan.

Appreciation is also expressed to A. W. Marsh, University of California Extension Irrigation and Soils Specialist for his aid in developing this program.

What We Should Know About Nutrients Other Than Nitrogen

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Today we recognize 16 elements as being essential for plant growth, namely:

Mainly supplied from air and water:

carbon C - hydrogen H - oxygen 0

Macronutrients:

nitrogen N - sulfur S - phosphorus P
potassium K - calcium Ca- magnesium Mg

Micronutrients:

iron Fe - boron B - manganese Mn
zinc Zn - copper Cu- molybdenum Mo
chlorine Cl

These 16 elements are essential for plant growth. An element is considered essential if in its absence the plant cannot fulfill a life cycle and if the resulting disease can be cured only through the addition of this particular element. Until about 35 years ago the list consisted of the first ten elements of the above group. Since then six more elements have been added to the list of essential elements. Five of them have reached economic importance. Of the 16 elements 7 are required in much smaller quantities than the rest and they are therefore called micronutrients. Terms like minor elements or trace elements may be misleading: the elements are not of minor importance since the absence of any one will prevent plants from growing, and the term trace element is frequently used for impurities in "chemically pure salts". If we include animals and some microorganisms we would have to include presently five more elements, namely:

cobalt Co; iodine I; sodium Na; vanadium V; fluorine F.

It is possible that with more refined research techniques the above list of essential nutrients is enlarged. It is, however, not possible to demonstrate the non-essentiality of a certain nutrient since, no matter how much we purify our culture medium, some impurities of an element in question may be present. These impurities may be below detection but they may be sufficient for plant growth.

This paper is concerned only with the elements essential for plant growth:

Carbon, hydrogen, and oxygen ate mainly taken up from air and water and are usually not considered fertilizer elements.

Nitrogen is of such importance that it is the topic of a separate discussion.

Phosphorus in soils shows a high tendency to be changed into rather insoluble inorganic forms. This process is called fixation. Usually one talks of fixation when a soluble material is converted into a relatively insoluble, unavailable form. (In case of nitrogen fixation the term is used with a different meaning.) In a normal soil only about one per cent of the total phosphorus is usually available.

Acid ←	Slightly Acid	→ Basic
Phosphorus rendered insoluble through fixation by hydrous iron and aluminum oxides	best solubility	phosphorus rendered insoluble through precipitation of calcium phosphates

The above diagram indicates that the solubility of phosphorus is best in a slightly acid soil. If the soil is made more acid, phosphates are absorbed by certain iron and aluminum compounds which are present in high amounts in acid soils.

If the soil is made more basic the phosphorus is precipitated as calcium phosphate. These precipitates probably undergo slow changes to very insoluble forms, The presence of limestone will complicate this picture: an excess of calcium carbonate (limestone) is said to increase the solubility of calcium phosphate under basic conditions.

Another important fraction of the soil phosphorus is the organic phosphorus. The fraction of organic phosphorus in soils varies considerably, it can amount to three-fourthsof the total phosphorus present. This organic phosphorus is gradually changed to inorganic forms by microorganisms and thus made more available to plants.

The addition of organic matter to a soil may induce rapid microbial growth and temporarily some of the available and possibly unavailable phosphorus is tied up in microorganisms. With the decomposition of the organic matter phosphorus is released again and the organic matter actually could have increased the availability of phosphorus.

With respect to management of phosphorus, various points have to be considered. Among them:

The plant species: Some species can take up phosphorus much easier than others. In some places lupines are used as cover crops. They take up phosphorus and, when plowed under, this nutrient is more available to other plants. Some grasses are known to be poor extractors of phosphorus from rock phosphate.

The kind of fertilizer used: Rockphosphate is changed through chemical treatments to the much more soluble superphosphates.

Placing of the fertilizer: In acid soils band placement may increase the availability because the localized phosphorus is exposed to less "fixing surfaces". When the phosphorus is well mixed with the soil it is much

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more in contact with the iron and aluminum compounds.

Time of application: Some crops seem to take up most of their phosphorus during the first few weeks of growth and it is therefore important that the supply of this nutrient be adequate during this period.

Water management: If a soil dries out, phosphorus becomes less available, hence adequate irrigation management is important.

Potassium: Soils usually contain large quantities of potassium often two to three per cent in a surface foot. A large part of this potassium is present in silt and sand, that is in the larger particles of the soil. The potassium contained in these particles is mainly unavailable to plants.

fixed by clays ⇄ held (adsorbed) on the surfaces of clays ⇄ in soluble form

In soils we are mainly concerned with three forms of potassium. If a potassium fertilizer is added to a soil it is usually dissolved without difficulty and it is thus present in a soluble form. Immediately it will react with clay surfaces and some of it will be held on them. Such potassium is called adsorbed. This adsorbed potassium shows much less tendency to be leached out. When the concentration of the soluble form is decreased, either through uptake by plants or by leaching, some of this absorbed potassium is released and changed back to the soluble form. Some of the originally soluble potassium is changed into a form from which it is released with much greater difficulty. This potassium which is held strongly by certain special types of clays is called fixed. Depending on the composition and the contents of clays our soils vary quite a bit in their ability to fix potassium. For example, prune trees on certain soils in northern California suffered from a die-back disease which was diagnosed as potassium deficiency. Potassium fertilizers added to the soil surface did not bring the expected relief because the potassium was fixed in the top soil layer before it reached the absorbing roots of the trees. Such problems might be solved e.g. through different placements of fertilizers or through the choice of crops with suitable root systems.

A few remarks about the management of potassium: Potassium is lost from soils through uptake by crops, leaching and erosion. Losses are more severe in coarse textured soils, that is in sandy soils. Such soils contain little clay, therefore a low capacity to adsorb potassium. Also, the supplying power from natural minerals and from fixed potassium is low. In these cases small and frequent applications of potassium are advisable. Large applications may result in severe leaching losses.

As the crops grow larger they usually require more potassium. It is important that a balance exists between nitrogen, phosphorus and potassium. For example, relative high supplies of nitrogen and phosphorus may first induce rapid plant growth, cause a depletion of the inadequate potassium supply and result in a deficiency. On the other hand, excess potassium results in luxury consumption of this nutrient and is economically undesirable.

It may be of interest to you that grasses can grow with lower levels of potassium than certain other crops. If, for example, legumes and grasses are grown together on a soil relatively low in potassium, the legumes will gradually disappear and the grasses will take over.

Sulfur: Except for known deficiency areas sulfur is not added purposely as a fertilizer. Such deficiency areas occur on the west coast and in the southeastern part of the United States. However, phosphorus, nitrogen and potassium fertilizers may contain sulfur (e.g. superphosphate, ammonium sulfate, potassium sulfate). Frequently, western irrigation water contains a sufficient amount of sulfur to satisfy the requirement by plants. Near industrial cities large quantities of sulfur are added to the soil by rain. It is claimed that the yearly amount exceeds 200 lb./acre near Chicago.

Sulfur and some sulfur compounds like gypsum and iron sulfate ate often added to western soils as a treatment against alkali conditions. The immediate purpose of this action is not to supply the nutrient sulfur but to improve some other soil conditions. Calcium and magnesium occur in various minerals in the soil, many of these minerals are primary. These minerals usually break down more readily than those containing potassium. Calcium also occurs in limestone as the carbonate. Dolomite consists of calcium and magnesium carbonate. Similar to potassium, calcium and magnesium are also held, i.e. adsorbed on clays, and are present in a soluble form.

Calcium deficiency is rather rare. It may occur on very acid soils though the beneficial effect of liming an acid soil is often due to other reasons than relieving a calcium deficiency. If the per cent of calcium among all the particles held on clays does not exceed a certain minimum value, plants cannot obtain sufficient quantities of calcium and will turn deficient.

Magnesium deficiency often occurs under similar conditions as calcium deficiency, i.e. on acid sandy soils. Instead of liming with calcareous limestone we add dolomitic limestone to the soil. Magnesium deficiency can also be caused by unbalanced fertilization, in particular by very large dressings of potassium and sodium salts.

Micronutrients

The stable form of iron in well aerated soil water is very insoluble and it is therefore not surprising that the essentiality of this element has been recognized for more than a hundred years. It is indeed rather more difficult to explain how plants can obtain iron from some basic soils than why they turn iron deficient. Iron

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deficiency is characterized by a typical yellowing of leaves. This disease, called iron chlorosis, occurs frequently on western soils, especially on soils with a high content of calcium carbonate. In such a case we speak of lime induced chlorosis. Treatments of soils seldom were satisfactory because of the rapid precipitation of iron. Within the last decade new iron containing compounds were made available. These compounds, designated chelates by the chemist, can keep iron in solution at high concentrations. Encouraging reports were made about spraying of plants with solutions of the proper chelate concentration, and even soil treatments were successful. Certain aspects of chelate treatments still remain to be investigated.

Boron: is deficient in many areas in the eastern United States, in the Pacific Northwest and in northern California. Such deficiencies can be alleviated by adding small quantities of boron as fertilizers. The difference between a deficient and a toxic level of boron is small and one has to be cautious with the application of this fertilizer. The boron content in some grasses that have been investigated is smaller than for many other plants. In some plants with parallel leaf veins, as grasses, we found that boron moved mainly to the tip of the leaves. With repeated mowing we might remove most of the boron taken up by plants. Boron toxicity will occur after excess fertilization or when irrigation water with a high boron content is used. Tip burns and burnt margins will occur. The distribution of these symptoms is thus in accordance with the distribution of boron in leaves which we observed in our laboratory.

Manganese is very available in acid soils. Under these conditions its concentration may be so high that toxicity symptoms are produced. Excess manganese can also induce iron chlorosis in plants. The availability of manganese is reduced in basic soils and deficiency diseases may occur. Changing the soil acidity may be a way to manage manganese problems. Manganese fertilizers added to soils frequently will cure manganese deficiencies. Only small amounts of this element are required. Therefore, as with most other micronutrients, it is sometimes more practical to spray this nutrient onto plants. This is particularly true if crops are sprayed anyway for other purposes. In soils with a high capacity to fix manganese spraying plants is the best way to add this element.

Zinc deficiencies are well known with tree crops of Florida and in western states. Soils may often contain enough zinc to support crops for thousands of years but the zinc is present in an unavailable form. Zinc deficiencies occur in soils with basic reactions or with soils high in phosphorus. Many types of cures have been tried: spraying plants, adding zinc chelates to soils, in case of trees driving galvanized nails into trunks, or after pruning one might paint the cut areas with zinc salts.

Copper deficiency is predominating on peat soils (e.g. Everglades). This deficiency can be enhanced by heavy nitrogen fertilization. Copper salts can be added to soils or plants may be sprayed, especially if soils have a high tendency to fix copper. Crops that are sprayed with Bordeaux mixture usually are provided with sufficient amounts of copper. Over long periods even toxic concentrations of copper will accumulate in soils. It is almost impossible to remove such toxic amounts of copper from soils.

Molybdenum is required in extremely small quantities, yet large areas, particularly in Australia and New Zealand, are suffering from this deficiency. The disease is more dominant in acid soils because the nutrient is rendered more unavailable under such conditions. An ounce of molybdenum per acre, usually added to the phosphate fertilizer, may supply sufficient quantities of this element for many years. Decreasing the acidity also will make molybdenum more available. Plants can also take up excess amounts of molybdenum. Even if no toxicity symptoms are observed on the plants the molybdenum may be toxic to animals using such plants as forage.

Chlorine compared with other micronutrients is required in rather high amounts. Rain water probably contains enough chlorine necessary for plant growth. Although chlorine is readily leached from soils we know of only one report where the level of chlorine in the field might have been too low for optimum plant growth.

This completes a brief survey of the fertilizer elements – other than nitrogen – which are essential for plant growth. It is important that all of them be present in proper amounts. From the point of view of fertilization we are mainly concerned with three elements, namely nitrogen, phosphorus and potassium. If a special need for other elements is suspected they also should be added. However, excess addition will cause toxicity problems, spraying with too high a concentration will result in severe leaf burning. Therefore, one has to be careful that the proper amount is applied.

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