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Laurence C. Walker

Stephen F. Austin State University

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Foliage Symptoms as Indicators of Potassium-Deficient Soils

BY
LAURENCE C. WALKER

THE FORESTER who is going to plant trees on abandoned farm land needs to know what species are suitable to a given area. For this purpose, an analysis of the leaves of native vegetation, including (1) the determination of the chemical composition of the leaves, and (2) the observation of symptoms of nutrient deficiencies, has been found useful. A previous paper (Walker, 1955) reported chemical analyses relating the amount of potassium (K) in the foliage of various plants to the availability of potassium in the soil. The present paper discusses visible symptoms of nutrient deficiency attributed to a shortage of potassium. The ultimate aim of these studies is the development of a method for recognizing potassium deficiency in abandoned farm land so that the forester may avoid planting species that require substantial amounts of potassium.

Experimental Areas

Sand plains of glacial outwash origin occur extensively within the Adirondack Mountains of New York. Under the native vegetation, these coarse-textured acid soils develop weak to medium podzolic characteristics. Basic nutrients, particularly potassium, except for the portion retained by the organic component, are leached from the solum as rapidly as they are released by mineral decomposition.

Conifers were planted on abandoned farmlands on many of these plains in the 1930's. In a few years it was noted that

the growth of white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), Norway spruce (*Picea abies* (L.) Karst.), and white spruce (*Picea glauca* (Moench) Voss) was severely retarded. These species developed small, chlorotic needles which did not last the usual time. Heiberg and White (1951) found these abnormalities indicative of K deficiency.

Exchangeable potassium in the plow horizon (upper 6 to 8 inches) in the plains ranges from 4.9 to 20.8 ppm. and averages 9 ppm. The potassium content diminishes to 2 ppm. in the upper B horizon and remains constant to the B₃ at about 4 feet. Only a trace of acid-soluble phosphorus occurs in the plow layer and upper B horizons. At lower depths, the phosphorus content is as much as 12 ppm. The pH increases with depth from 5.3 in the surface soil to 5.7 in the B₃. Nitrogen averages 0.13 percent in plow zones, while organic matter averages 4 percent. As expected, organic matter is closely related to nitrogen in these soils. It is also related to exchangeable potassium: the amount of

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mineral colloidal matter in coarse sands is too meager to have much effect on the supply of potash in ionic form. Hence, most of the available element is held on organic colloids.

Textural analysis of the plow zone showed that this material consisted of 89 percent sand, 6.4 percent silt, 0.8 percent coarse clay, and 3.8 percent fine clay (Heiberg and White, 1951). These sands belong to the Hinckley series. Other non-deficient brown podzolic soils belonging to the Gloucester, Cornwall, Hinckley and Essex series were studied for comparison.

Previous Investigations

Eckstein, Bruno, and Turrentine (1937), Wallace (1951), Bear *et al.* (1949), and McMurtry (1948) have presented reviews of what was known about the foliar symptoms of nutrient deficiencies, chiefly in field and orchard crops. A monograph by Becker-Dillingen (1939) outlines some deficiency symptoms of forest trees in Europe.

Recently Heiberg and White (1951) found that potassium deficiency in red pine, white pine, Norway spruce, and white spruce produced short chlorotic needles which turned brown and died prematurely. Stone (1953) found that deficiencies of magnesium in sandy soils in which young red pine, white pine, and jack pine were planted resulted in a bright yellow discoloration of the tips of the needles in the fall.¹ Lafond observed similar magnesium deficiency symptoms for red pine in Quebec. It was suggested that this symptom is often accompanied by low levels of potassium.²

In some instances it was not until the third year after Stone applied magnesium fertilizer that the apical yellowing disappeared. A few trees then exhibited potassium deficiency symptoms. Conversely,

¹Both Heiberg and White's and Stone's work was carried out in the vicinity of the present research.

²Personal communication from E. L. Stone, Cornell University.

magnesium deficiency symptoms were intensified by fertilizing with potassium. Kidson, Askew, and Chittenden (1940) observed a high percentage of potassium in leaves of trees severely affected by magnesium shortage. This suggests the importance of the K/Mg ratio in determining the severity of the magnesium deficiency. Deficiencies of potassium may also be accentuated by the presence of large amounts of nitrogen in available form in the soil (Worswick, 1950), as stimulated growth results in increased requirements for potassium.

Chlorotic needles of white pine seedlings grown under low potassium conditions in sand media have been observed (Mitchell, 1939; Hobbs, 1944).

Some information is available regarding nutrient deficiency symptoms in herbs (Goodall and Gregory, 1947; Kitchen, 1948; Bear *et al.*, 1949). Generally, browning and curling of leaf margins, chlorosis, and premature leaf-fall are evident.

Certain precautions must be taken when deficiency symptoms alone are used for the diagnosis. Thomas (1945) warns that a color abnormality usually attributed to a particular deficiency may vary with temperature, light and moisture. Earlier, Moller had also stressed that seasonal variations in the mineral absorption of plants affect the time the symptoms appear. Drought, continuous strong winds, low temperature, and frost are known to produce marginal leaf scorch similar to that caused by a lack of potassium. Deficiencies of copper and manganese are also said to be difficult to distinguish from potassium deficiency (Worswick, 1950).

Wallace (1951) has presented the following general foliar symptoms of potassium deficiency:

1. dull bluish-green color
2. chlorotic, especially in interveinal areas
3. browning of tips and marginal scorching
4. brown spots first occurring on older leaves

Worswick also noted necrosis along

TABLE 1. Potassium in foliage (dry-weight basis) and soil plow-layers.

Species	Deficient specimens			Normal specimens			Fertilized specimens	
	July percent	August percent	Soil ppm	July percent	August percent	Soil ppm	August percent	Soil ppm
<i>Pinus strobus</i>	0.44	0.27	10.1	0.67	0.46	26.4	0.57	33.7
<i>Prunus serotina</i>	.65	.55	9.8	1.07	1.26	26.4	1.64	33.7
<i>Betula populifolia</i>	.77	.71	10.1	.90	1.16	9.8	1.25	35.2
<i>Acer rubrum</i>	.59	.45	10.0	.66	.68	36.5	.96	46.5
Rubus subgenus <i>Eubatus</i>	.73	.65	12.4	1.21	1.11	38.7	1.57	48.9
<i>Spartium scoparium</i>	-----	.30	8.9	-----	-----	-----	1.31	49.9

midribs and veins and the presence of creamy-yellow coloration shading into yellow-green prior to scorching as symptoms of potassium deficiency.

Field Procedures

Four replicated sampling plots were established in each of 19 locales. In addition, plots fertilized with 200 pounds per acre of 60 percent potassium chloride were also installed.

Sampling varied for the several vegetative forms. Tree leaves were taken from east-facing branches at the crown middle of nine species. Leaves, including petioles, and needles were removed from branches in the field. Collections were made in early July and mid-August. Leaves of *Rubus* subgenus *Eubatus* spp. and *Fragaria virginiana* Duchesne were randomly collected. In addition to native vegetation, cultivated *Lupinus perennis* L., *Trifolium pratense* L., and *Spartium scoparium* W. were studied. Leaves of *Lupinus* and leaves and stems of *Trifolium* and *Spartium* were sampled in August. Soil samples were taken from the plow and B horizons.

Laboratory Procedures

Tissue samples were dried at 70° C. in an electric oven for 3 hours shortly after collection, then ground in a Wiley mill and dried at 70° C. in a circulating-air oven for 24 hours (White, 1954). Samples of dry tissue weighing 1.000 gm. were ashed

at 500° C. for 3 hours, the ash dissolved with 2N nitric acid, diluted to volume, and the aqueous solution analyzed for potassium content with a Beckman flame spectrophotometer.

Soil samples were air-dried and passed through a 2mm. mesh sieve. Analyses were made in duplicate on air-dried soils. For exchangeable potassium determinations, a 50-gm. sample was leached with N NH₄Ac as outlined by Peech *et al.* (1947). The leachate was evaporated to dryness, treated with sufficient H₂O₂ to oxidize organic matter, acidified with 2N HNO₃, and subjected to flame spectrophotometric analysis. Total nitrogen was determined by a modified Kjeldahl method (Jackson, 1949). Analysis for acid-soluble phosphorus was by the SnCl₂-reduction method on an extract leached with 0.002N H₂SO₄. Oxidizable organic matter was measured by wet combustion using H₂Cr₂O₇ and H₂SO₄ with heat applied (Jackson, 1949). Hydrogen-ion concentrations were determined with a Beckman glass electrode pH meter using a soil-water "paste" (Peech *et al.*, 1947).

Results and Discussion

Symptoms of potassium deficiency varied with the species studied.³ Table 1 shows the amounts of potassium found in deficient

³Kodachrome slides illustrating these symptoms may be borrowed or copies procured at cost from the author.

and normal specimens.

Prunus serotima. Striking and unusual discolorations in the foliage of black cherry were observed in the middle of August. Bright red margins extending almost to tip of the leaf and about one-half the distance to the midrib were produced. The line of demarcation between the pigmentation and normal coloration is well defined (Fig. 1). Trees so affected were limited to unfertilized plots, while those growing under fertilized conditions appeared normal. Almost all leaves on the trees were similarly discolored. By late September, the anthocyanin margins had widened and extended to the leaf tip; red color intensity also increased, and blue and violet hues were produced. The effect of autumnal coloration is quite distinct from this malformation.

None of the species of *Prunus* studied exhibited curling of the edges of leaves, an established symptom of potassium deficiency for orchard-grown varieties of *Prunus cerasus* L. (Wallace, 1951). Boynton

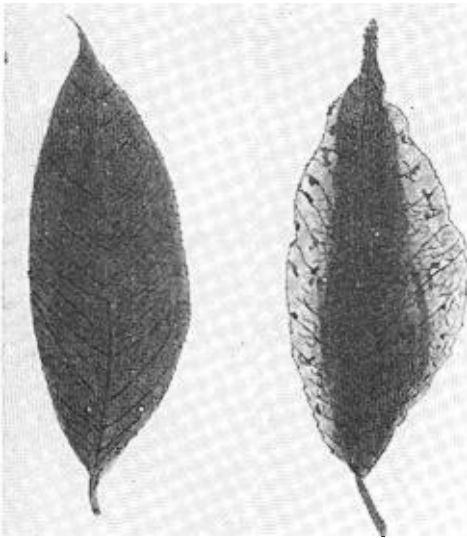


FIGURE 1. *Abnormal coloration (red) at margins of potassium-deficient Prunus serotina leaf (right) and normal leaf (left).*

and Compton (1945) found the critical value of potassium for *P. cerasus* in midsummer shoot leaves to be between 0.75 and 1.00 percent. Below this point, deficiency symptoms occurred.

The abnormalities observed seem to result from potassium deficiency, but it is quite possible they are tied in with magnesium deficiency. While Wallace describes magnesium-deficient *Prunus cerasus* as containing pigmentation similar to that reported here, he states that in some cases it is difficult to distinguish between marginal necrosis resulting from magnesium deficiency and a similar condition resulting from a low supply of potassium. Boynton stated that in his experience this abnormal coloration more closely resembles potassium deficiency than magnesium but then followed his comment on the likelihood of either appearing on such soils.⁴ Since magnesium deficiency may be induced by applying potassic fertilizers (Boynton and Compton, 1945; Lilleland and Brown, 1938), the fact that fertilization did not accentuate deficiency symptoms also substantiates the hypothesis. Similarly, according to Blank (1947), potassium deficiency accelerates anthocyanin formation.

Pinus strobus. Chemical analyses of needle tissue collected in July show that trees with deficiency symptoms as described by previous workers contained from 0.32 to 0.59 percent potassium and non-deficient trees from 0.53 to 0.84 percent. This decreased in August to between 0.19 and 0.38 percent for deficient and 0.40 and 0.55 percent for normal trees exclusive of fertilized individuals which had between 0.41 and 0.76 percent potassium in August foliage. Heiberg and White (1951) found from 0.45 to 0.74 percent potassium in mid-September collected needle tissue from healthy trees. At that time, they found a maximum of 0.34 percent potassium in current year's needle tissue for pines displaying deficiency symptoms. In

⁴Personal communication, *ibid.*

the present study, it was difficult to detect appreciable improvement in the foliage of fertilized trees noted to be potassium-deficient prior to fertilization in May. Elongation of new branches and needles as the season progresses tends to mask foliar symptoms of deficiency, particularly late in the season. Early spring seems to be the most appropriate time for ocular determination of low potassium levels for white pine. For this species, the diminution of potassium in needle tissue as the season progresses is quite clear-cut (Walker, 1955).

Betula populifolia. Chlorosis of the leaves of gray birch, beginning at the margins and proceeding inward, was noted in mid-August (Fig. 2).

The transition from yellowish-white chlorotic coloration to normal-appearing green tissue in leaves exhibiting deficiency symptoms is sharp in contrast to the gradual transition of colors in autumn foliage. In either case the yellowing probably results from the breakdown of chlorophyll and limitation of its production to expose yellow carotinoids.

From this limited study the critical potassium level for gray birch foliage may be tentatively set at about 1.00 percent. No deficiency-exhibiting leaves were found

with more than 0.83 percent potassium and normal appearing foliage did not contain less than 1.00 percent when symptoms appeared.

With the data at hand and the knowledge that magnesium deficiency is prevalent in soils of these areas, it is difficult to conclude that this symptom is solely that of potassium deficiency. The evidence does point in that direction, however, particularly since it has been shown that fertilization with potassium in sites low in available magnesium accentuates magnesium-deficiency symptoms. This did not occur in the present study.

Acer rubrum. Leaves on red maple trees in low-potassium soils were chlorotic throughout the summer. In fertilized plots, the foliage was notably greener than elsewhere. Chlorosis occurs throughout the leaf, but is slightly more pronounced at the margins. About 0.60 percent may be considered as the point below which potassium is in short supply and deficiency symptoms may be expected to appear. The range in August for leaf potassium in deficient-appearing trees was from 0.29 percent to 0.66 percent and in healthy-appearing trees from 0.56 percent to 1.11 percent. Bard (1945) found potassium ranging from 1.02 percent to 1.16 percent potassium in leaves sampled in late summer from trees grown in soils fertilized with over 200 pounds per acre (100 ppm) exchangeable potassium.

Rubus subgenus Eubatus spp. Coloration was observed on leaves of these plants similar to that noted by Wallace (1951) for *Rubus occidentalis* L. Marginal browning extended between veins, practically to the midrib, and growth appeared poor. This midsummer abnormality resembles very closely the natural coloration of foliage in autumn. In fact the resemblance makes visual distinction late in the season virtually impossible. It is quite probable that under both conditions the leaves are in similar

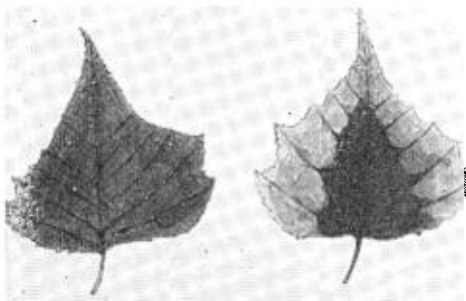


FIGURE 2. Chlorotic margins of *Betula populifolia* leaf (right) with normal leaf (left).

states physiologically, anthocyanin pigmentation having been exposed as a result of destruction of chlorophyll molecules. It is suggested that, for this species, the critical potassium level below which deficiencies may be expected is 0.80 percent.

Wood (1947), working with cultivated *Rubus occidentalis*, discovered potassium deficiency symptoms in older leaves. They turned brown at edges and tips, then curled, and finally turned black. He, as well as the present writer, found no relationship between the amount of exchangeable potassium in the soil and the concentration of the element in leaves of this species.

Spartium scoparium. This European legume exhibited symptoms of potassium deficiency which were substantiated by fertilization and quantitative analyses of that element in the plant. General yellowing and chlorosis of leaves beginning at the base of the plant and the bases of leaves and leaflets, stunting of plants, and reduction in size of leaves were characteristics of plants seeded a year prior to sampling in an abandoned field (Fig. 3). Fertilizing with 200 pounds per acre of KCl in May following the year of planting had, by mid-August, resulted in normal-appearing plants. The foliar potassium level increased four-fold.

Miscellaneous. Analyses of *Pinus banksiana* foliage support Stone's (1953) conclusion that needle-tip chlorosis of this species in the Adirondack area is due to low

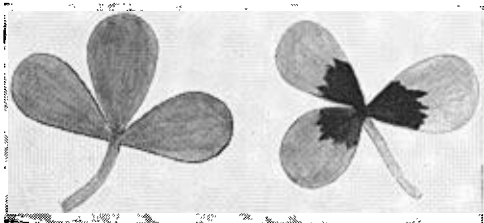


FIGURE 3. Chlorosis of *Spartium scoparium* leaf (right) and leaf from K-fertilized plant (left).

magnesium levels rather than to potassium deficiency. The amount of potassium in deficient-appearing and healthy needles sampled did not differ significantly. The average was 0.38 percent.

Fertilized and unfertilized *Fragaria virginiana*, *Lupinus perennis*, and *Trifolium pratense* exhibited leaves similar to those which, when produced by cultivated plants, are described in the literature as being potassium deficient (Eckstein, Bruno, and Turrentine, 1937; Kitchen, 1948; and Morgan, 1948). But there is no evidence that these abnormal coloration symptoms are reliable as indicators of potassium deficiency in reforestation sites.

Conclusions

From this exploratory study, practical application is evident. The use of demanding species (white pine, red pine, white spruce, red spruce) for plantation establishment on sites where potassium-deficiency symptoms are observed or where exchangeable potassium in soil plow layers is less than 20 ppm would be poor silviculture unless fertilization was anticipated. A somewhat lower value may be inferred from the data presented by Heiberg and White (1951).

Sites presently occupied by species with deficiency malformations have responded favorably to 200 pounds per acre of 60 percent KCl. Subsequent treatments may be necessary, but the economics of that procedure is beyond the scope of this paper. Yet, Galoux (1954) considers it both practical and economical to fertilize impoverished soils with potassium prior to establishment of scotch pine and spruce plantations in France. In the low potash areas of the present study, however, less demanding conifers such as Scotch and jack pines are recommended for infertile fields to aid the restoration of site potential for later succession by more demanding and more valuable species.

Summary

Abnormal colorations indicative of potassium-deficient soils were observed in foliage

of *Prunus serotina*, *Betula populifolia*, *Acer rubrum*, *Pinus strobus*, and *Rubus* subgenus *Eubatus* spp. For the first species, a strikingly bright-red pigmentation occurred at leaf margins. *Betula populifolia*, when potassium-deficient, exhibited leaves with chlorotic margins sharply delineated from normal-appearing green tissues. *Acer rubrum* foliage was uniformly chlorotic. Needles of *Pinus strobus* were short, chlorotic, and often brown at tips. Leaflets of *Rubus* subgenus *Eubatus* spp. displayed marginal browning which extended between veins practically to the midrib. Foliage of cultivated plants (*Lupinus perennis*, *Trifolium pratense*, and *Spartium scoparium*) exhibited abnormal coloration, but except for *S. scoparium* the leaves of which were chlorotic, this could not be attributed to potassium nutrition alone. On sites where these deficiency symptoms are exhibited, stunted growth of the more demanding conifers is also likely to occur. Critical values for potassium concentration in mid-August collected leaf tissue below which deficiency symptoms may be expected are as follows:

<i>Prunus serotina</i>	0.8 percent
<i>Betula populifolia</i>	1.0 percent
<i>Acer rubrum</i>	0.6 percent
<i>Pinus strobus</i>	0.4 percent
<i>Rubus</i> subgenus <i>Eubatus</i> spp.	0.8 percent
<i>Spartium scoparium</i>	0.3 percent

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Colchicine

Colchicine—in agriculture, medicine, biology, and chemistry. By O. J. Eigsti and Pierre Dustin, Jr. 1955. 470 pp. Iowa State College Press, Ames, Iowa.

Review by Roland E. Schoenike

Southern Forest Experiment Station, U. S. Forest Service.

Many workers in plant genetics have wished for a comprehensive synopsis of what is known about colchicine. This is such a book.

The authors are well qualified. Albert Pierre Dustin, father of the junior author, initiated the modern era in colchicine research by showing that the drug arrests mitotic division in animal cells. This was followed by hundreds of experiments to demonstrate that the phenomenon occurs in almost all biological material. Pierre Dustin, Jr., continued the work after his father's death. In 1937 the senior author discovered the most striking and important effect of colchicine, the induction of polyploid cells, by treating onion root tips with the drug. The next five years saw a tremendous increase in polyploid research. For a while, such research became what the authors describe as a colchicine fad.

The book can be understood, in the most part, by persons with only a smattering of genetics. Terminology is handled well, particularly in dealing with the polyploid problem. Subjects are arranged logically and treated clearly. Chief objections are an unevenness in style, a tendency toward repeti-

tion, especially in the earlier chapters, and possibly the overstressing of some experimental work such as the 1934 experiments of A. P. Dustin. Documentation is exceptionally thorough; each chapter contains 50 to 300 references, including many personal communications. The illustrations are carefully chosen and printed on high-quality paper.

The book reviews all aspects of the subject. Three chapters are devoted to the pharmacology and pharmacognosy of the drug, three to its effects on plant and animal cells, and one to its chemistry. Several chapters deal with its effects on animals and humans. Five valuable chapters are concerned with polyploidy. A short chapter on techniques for handling the drug is followed by a longer one discussing the specific effect of colchicine on cells.

The book is essential for persons engaged in colchicine research, and perhaps also for geneticists and cytologists generally. It should be of interest to plant and animal physiologists, pathologists, and histologists. Biochemists can profit from several chapters. In short, it touches on many major areas of research.