3. The influence of rootstock on the uptake of boron is pointed out.

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LEACHING OF POTASH FROM A SANDY CITRUS SOIL OF FLORIDA

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Potash has long been regarded as accumulating in clay soils in forms that are neither water-soluble nor exchangeable. The "fixation" of added potash in non-exchangeable forms merely augments the supply of similarly combined potash already present in ordinary clay soils. The amounts of non-exchangeable potash in these soils are considerable although widely variable. For example, a good productive grassland soil from Illinois was found to contain 6,360 pounds per acre or 18 percent of the total potash fixed as non-exchangeable while a non-productive soil contained about 3,360 pounds per acre which represented 11 percent of the total potash of the soil.

The above idea of "fixation" or accumulation of added potash into a non-exchangeable form has been borrowed and applied to the sandy citrus soils of Florida. However, when the characteristics of sandy citrus soils were considered, it was found that they were inherently different from clay soils and that potash might be expected to leach rather easily. Preliminary work by Peech on the Citrus Experiment Station potash experiments indicated that potash leached instead of accumulated since he found little more total potash in the plots which had received 10 percent applications than in those which had received 3 percent applications of potash. The source and rate of application of nitrogen and phosphoric acid were held constant while potash was varied. Thus, the indications are that the potash supply is a "hand to mouth" matter, or in other words potash must be supplied frequently to sandy citrus soils in order to maintain an adequate supply.

Since 1921 the Citrus, Experiment Station has been carrying on an experimental potash block which was divided into plots with varying rates of application of potash.
Figure 1.—Relative rates of leaching of potassium (K), calcium (Ca), and magnesium (Mg) following the application of muriate of potash (KCl) as a straight fertilizer material. A.—represents the amount of potassium (K) added to the sample as a component of muriate of potash. A'—represents the total exchangeable potassium present in the sample following the addition of muriate of potash at the start of the first leaching experiment.
These rates were 3, 5, and 10 percent potash applied 3 times per year at an average of 20 pounds per tree. Over a period of about 15 years the 3 percent plot had received 1,530 pounds of potash per acre, and at the end of that period an analysis for total potash* conducted by Peech indicated that a total of only 107 pounds or 7 percent of the potash applied could be found. The 10 percent plot had received 4,500 pounds of potash over the same period of time, and a total of only 130 pounds or 3 percent of the potash could be recovered. Since the removal of potash is relatively small, it is obvious that there has been considerable loss of potash, evidently through leaching.

Sandy soils, in contrast to clay soils, are considered to be organic as far as their chemistry is concerned. Since the organic matter content of sandy soils is very low the most significant loss of applied potash is through leaching. However, a relatively small amount of the applied potash may be fixed by the organic matter of these soils. Consequently, there are 3 ways in which this fixed potash may be released from a sandy soil: (1) By replacement of slowly exchangeable potash, (2) by decomposition of organic matter, and (3) by dispersion of soil humates**. Following any one of these 3 activities in the soil, potash may be either taken up by the crop or lost by leaching.

Of the various factors which affect the loss of potash, the most active ones are rainfall, pH and the manner in which potash is applied, either as a straight fertilizer material or in a mixed fertilizer. With these facts in mind, both laboratory and field experiments were set up to determine the rate of leaching of potash from a sandy citrus soil (a Norfolk fine sand). The laboratory experiments consisted of controlled leaching of large soil samples following the application of potash as straight muriate of potash (KC\(_1\)) and as a component of a mixed citrus fertilizer. These experiments were followed by a field experiment.

The laboratory studies were made on soil from plots which had been used to determine the effects of different basic materials and magnesium sulfate on citrus. These materials were dolomite and calcium carbonate applied at rates varying from 0 to 6,400 pounds per acre, and magnesium sulfate and magnesium carbonate applied at rates of from 0 to 1,600 pounds per acre. Sixteen samples having an initial range in pH from 5.15 to 6.05 were selected, placed in 5-gallon glazed crocks and leached with distilled water which was applied at the equivalent rate of one-half inch of rain per acre every other day. Surface evaporation and weed growth were reduced by keeping the crocks covered with heavy wrapping paper. At the end of every 2½ inches of rain the volume of the accumulated leachate was measured, samples taken and analyzed.

The soil samples were leached until the rates of leaching of potash were about comparable. Following this leaching, muriate of potash was applied at the rate of 82 pounds per acre. Leaching was then continued until the equivalent of 8 acre-inches of rain had been applied following the application of the muriate of potash.

A resume of the data is presented here for the dolomite series which was selected as being representative of the results obtained from the other 3 materials. Representative curves of the rates of leaching of the various "bases" are presented in Figure 1. The accumulated total chemical equivalents of potassium (K), calcium (Ca), and magnesium (Mg) lost by leaching are plotted against equivalent "acre inches" of rain applied to Sample 3 of the dolomite series. This sample had been treated in the field with dolomite at the rate of 400 pounds per acre. The data obtained, as shown by

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* Total potash includes exchangeable and fixed (or non-exchangeable) potash.

** "Humates," the term used to designate those complex soil organic compounds having base exchange properties.
Figure 2.—Relative rates of leaching of potassium (K), calcium (Ca), and magnesium (Mg) following the application of a mixed citrus fertilizer. A represents the amount of potassium (K) added to the sample as a component of the mixed fertilizer. A' represents the total exchangeable and soluble potassium (K) present in the sample at the start of the second leaching experiment. D represents the total exchangeable and soluble potassium (K) added to the sample as a component of the mixed fertilizer.

Equivalent Acre Inches Of Rain Applied

Total Milliequivalents Leached

Magnesium (Mg)
Calcium (Ca)
Potassium (K)

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the potassium curve of Figure 1, indicate
that the easily leachable potash had been
lost by the end of the application of the
equivalent of 4-acre inches of rain. The
rate of loss covered a range of approxi-
mately 3 to 8 percent of the total soil pot-
ash per acre inch of rain applied. The re-
maining potash leached at a lower rate, 1
to 3 percent per acre inch of rain applied.
In other words, there are 2 rates of leach-
ing of potash; the first and more rapid rate
can be attributed to the solution of potash
salts, and the latter rate to the replace-
ment of exchangeable potash, decomposi-
tion of organic matter and dispersion of
the humates as mentioned earlier in this paper.
The gradation of the more rapid rate into
the lower rates of loss is gradual; however,
for convenience of discussion the change in
rate is discussed as if it occurred in steps.
It is interesting that following the applica-
tion of 8-acre inches of rain the check (no
dolomite) had lost a total of approximately
18 percent while the other dolomite plots
had lost from 8 to 10 percent of the total
amount of potash applied. While consider-
able potash was retained at the end of 8
inches of rain, it should be noted (Figure
1) that this retention was at the expense of
calcium and magnesium which had been
replaced and leached. If the leaching were
continued, the pH would have a tendency
to drop since the adsorbed potash is more
easily lost than either calcium or magne-
sium. A citrus fertilizer mixture was then
applied to the same samples at a rate of
1,000 pounds per acre and leached as before.
The formula of the mixed fertilizer was as
follows with 40 percent of the nitrogen be-
ing organic and sand being used as filler:
N—3; P2O5—6; K2O—8; MgO—2 (Wat-
er soluble); MnO—1; CuO—1.
Leaching was carried out until the equiva-
 lent of 16 acre-inches of rain had been
applied. Again in order to omit considerable
detail a resume of the results for the dolomite
series is presented since the results from
the other treatments were similar. The data
of Figure 2 are presented in the same man-
ner and for the same sample as were the
data of Figure 1. Although the amount of
potash was greater at the start of this ex-
periment, the equivalent of the additional
application of potash from the mixed fer-
tilizer was lost with the application of the
equivalent of 6-acre inches of rain; addi-
tional amounts of potash were thereafter
lost from the reserve arising from the pre-
vious application of muriate of potash. Each
inch of rain removed approximately 5 per-
cent of the total potash in the soil at the
time, and this rate had not fallen off greatly
even at the end of the leaching period. This
rate continued for about twice as long as
the first and more rapid rate of loss from
the application of straight muriate of potash
and accounts roughly for the loss of 30 per-
cent of the potash applied in the mixed fer-
tilizer. Here, as in the first experiment, the
rates of loss of potash are divided into steps
for convenience of discussion even though
it is realized that the change is gradual.
The first rate of loss was doubtless due to
the solution of potash salts and to the re-
placement effect of the soluble fertilizer
salts and the soil acids. As soon as the ex-
cess fertilizer salts were washed out the
remaining potash was lost at a lower rate of
leaching during the remaining 10-acre inch-
es of rain applied. The rate was approxi-
mately 3 percent of the total potash pres-
cent in the soil per acre-inch of rain applied
which indicates a loss of approximately 30
percent of the potash present in the soil
for the remaining 10-acre inches of rain ap-
plied and a total loss of around 60 percent
of the total potash present in the soil im-
mediately following the application of the
mixed fertilizer and 170 percent of the ap-
plied mixed fertilizer. The continued leach-
ing at a lower rate is probably due to the
combination of factors mentioned in the
introduction of this paper.
A further comparison of the rates of loss
of potash from the application of straight
muriate of potash and from the complete
citrus fertilizer, Figures 1 and 2, indicates
that the rate following the application of the complete fertilizer was roughly 2 or 3 times that following straight muriate of potash. Again, this is probably due to the displacement of the exchangeable potash by the soluble fertilizer salts and soil acids and to the fact that the total amount of potash in the soil at the start of the experiment was high. In other words, potash is lost fairly slowly as long as the concentration of soluble fertilizer salts, including potash, is low, however, as soon as these salts, particularly those of calcium and magnesium, are added the loss of potash is again greatly accelerated (Figures 1 and 2). Thus, there is little, if any, advantage, as far as conservation of potash by the soil is concerned, in applying it as straight muriate of potash, especially when the loss of exchangeable calcium and magnesium is considered.

It was observed that the loss of potash was accentuated at a pH below 5.3 or above 6.0. Laboratory work here at the Station supports this observation for sandy soils. Apparently the soil acids displace potash when the pH is below 5.3, while the excess of soluble salts and carbonate residues displace potash at a pH above 6.0. Recently Peech and Bradfield* have shown this to be true for clay soils.

Since laboratory leaching studies at best are only a close approximation of actual grove conditions, field studies were set up in an effort to supplement the potash data already obtained in the laboratory. The dolomite row of the previously mentioned plots was selected since it most nearly approximated present commercial grove practices. Following the usual application of a mixed citrus fertilizer, sets of soil samples were taken periodically whenever approximately 3 inches of rain had fallen. All samples were taken from the same series of trees and as closely as possible from the same position around each tree. This procedure was continued until the next application of fertilizer was made. During this time a total volume of 20 inches of rain had fallen, thus giving ample opportunity for the leaching of potash to take place. Total and exchangeable potash were determined for each sample.

An analysis of the data from the field experiment confirms the results of the laboratory experiments. About 30 to 50 percent of the potash was lost from the total in the soil during the first 8 to 10 inches of rain while by the end of 20 inches of rain about 75 percent had been lost. If there had been a greater volume of rainfall, a great deal of the remaining potash would also have leached. Analyses made on samples from the above mentioned field experiments show that both total and exchangeable potash approximate each other within 15 to 20 pounds. This indicates that there is very little non-exchangeable potash in the light sandy citrus soil studied. Thus, the rate of loss of potash is very closely correlated with the rainfall.

**Conclusion**

Both laboratory and field experiments indicate that the potash added to a sandy citrus soil of Florida does leach. The rate of loss is greater below and above than within the pH range of 5.3 to 6.0. Although proper control of pH will slow down the rate of loss, it is clear that potash does not accumulate in soils similar to the one studied.

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