July 1952 Stromberg — Please Return

2.24

EXAMINATION OF SOILS FOR ALKALI - "FIRST-AID" METHODS *

By Warren R. Schoonover - Extension Soils Specialist

DEFINITION OF AN ALKALI SOIL:

An alkali soil may be defined as one which contains either or both of (a) soluble salts, usually sodium salts, sufficient to impair plant growth, or (b) adsorbed sodium sufficient to impair plant growth either through direct upset of plant nutrition or indirectly through deterioration of soil structure. Sometimes plant growth and/or soil structure may be impaired because of high magnesium rather than sodium. In the broadest sense, an alkali soil might include one containing boron compounds sufficient to impair plant growth. A soil containing only soluble salts is said to be saline and has commonly been called a "white alkali" soil. A soil containing a substantial percentage of adsorbed sodium in the so-called exchange complex, either with or without substantial amounts of soluble salts, is an alkali soil which is different chemically and physically from one which merely contains soluble salts. Soils of this kind often yield dark-colored extracts and may be called black alkali soils. In rare cases, the difficulty may be due to too much adsorbed potassium.

PRINCIPLES OF RECLAMATION:

Alkali soils may be reclaimed under conditions of good drainage by two processes: (1) mere leaching to remove the excess soluble salts, and
(2) supplying soluble calcium to replace undesirable amounts of adsorbed sodium, potassium, or magnesium, followed by a leaching of the salts of these replaced elements. In some cases, calcium may be rendered available from insoluble sources, usually carbonates, present in the soil.

MEANS OF CLASSIFYING ALKALI SOILS:

Alkali soils can be classified if a few simple facts are known, as follows:
(1) To what extent does the soil contain soluble salts?
(2) Is the soil dangerously low in available calcium? This characteristic is commonly expressed differently by saying a soil is bad if relatively high in adsorbed sodium. However, magnesium or potassium may be undesirable adsorbed ions. These other ions cannot be high unless calcium is low.
(3) Does the soil contain calcium carbonate?

If a soil is found to be low in available calcium, its so-called calcium requirement can be determined. This will serve as a guide to reclamation treatment.

HOW TO APPRAISE AN ALKALI PROBLEM:

Blocking out the problem - Soil Sampling:

Alkali soils are exceedingly variable. Samples should be taken to study the range of conditions rather than determine the average situation. Composite samples are not recommended. The most important portion of the profile to study is the top six inches or top foot, which will be the first soil occupied by the roots of plants in the alkali sensitive seedling stage. Occasionally samples should be taken with

* The system of analysis described here replaces and supersedes the system outlined for county laboratories in mimeograph dated March 16, 1949. These methods will be found easier, quicker, and more reliable. The results are more readily interpreted.

suitable subdivisions clear down through the soil profile to hardpan, water table, or probable end of the root zone. The range of conditions to be studied is often indicated by variations in the growth of plants.

The amount of soil collected from one hole with a 3" auger to a depth of 6" is usually sufficient to make first-aid analyses with reserves for further study if desired. Samples should be collected in waterproof containers. They should be thoroughly air dried and coarsely ground (2mm or 10 mesh) to prepare for analysis.

Limit Analytical Work to Essentials:

Complete analysis of the salts and of the exchange complex of alkali soils is a long and tedious procedure. Such analyses supply much information which is interesting but not useful for classifying soils or indicating treatment. Fortunately three simple determinations will enable one to understand the nature of most alkali soils. These are (1) estimating the soluble salt content by determining the specific electrical conductance of the extract from the saturated soil:
(2) determination of the soluble calcium and soluble magnesium in this extract;
(3) a semi-quantitative, effervesence test for calcium carbonate.

Much information is being developed on the tolerance of various plants for soluble salts. Less is known about the influences of low soluble calcium percentage which indicates an unfavorable situation in the exchange complex. Kelley's book and other data indicate that if calcium constitutes a substantial proportion, 30% or more, of the total soluble cations, the existence of an unfavorable situation in the exchange complex is unlikely. Unless calcium is quite low, magnesium may be considered an asset.

CLASSES OF ALKALI SOILS:

Soils may be classified on the basis of these simple tests, as follows:

(1) White Alkali Soils. These merely contain soluble salts, which should be reclaimable by leaching. Good soils would show a conductance of the saturation extract of less than 2 millimhos/cm., mildly saline soils 2 to 6 mmhos/cm., moderately saline soils 6 to 12, strongly saline 12 to 20. Above 20 mmhos/cm., soils would usually be devoid of vegetation except that, under favorable climatic conditions, a few salt-tolerant plants might grow. Calcium should constitute 30% or more of the estimated cations of soils in this class. Because the low solubility of gypsum confuses the situation, the soluble calcium percentage cannot be determined accurately in saturation extracts showing a conductance greater than about 8 millimhos/cm. In examining such soils, it is necessary to make extracts with a wider ratio of water to soil, a ratio which will yield an extract with a conductance around 1 to 2 mmhos/cm.

(2) Soils low in salinity but low in soluble calcium percentage. Such a condition indicates high exchangeable sodium or other undesirable cation. Such soils include so-called black alkali soils. The further the soluble calcium percentage falls below 30%, the worse the problem.

(3) Soils having the undesirable characteristics of both classes 1. and 2. Soils in classes 2. and 3. usually need a corrective treatment in addition to leaching. In fact, the treatment may be necessary in order to make the soils sufficiently permeable to be leached. When a soil of class 2. is treated with an amendment such as gypsum, it may shift to class 1. or to class 3. because of the change of adsorbed sodium to a soluble sodium salt such as sodium sulfate.

(4) Normal soils. (Soils which are acid but normal in their cations other than hydrogen would fall in this group). Conductance of saturation extracts will be below 2 mmhos/cm. and often less than 0.5 mmhos/cm. Ca or Ca + Mg will constitute more than 30% of the estimated soluble cations. Ca should equal or exceed Mg.

ANALYTICAL PROCEDURE:

1. Prepare a Saturated Soil Paste:

Fill an 8 oz. tumbler or other suitable container two-thirds full of soil. Slant surface of soil so that water can be added to low side and air escape at the high point. Add distilled water slowly until soil appears to be nearly wet. Stir with a spatula or a teaspoon. Add water, while continuing the stirring, until the soil paste shows the following characteristics:

(a) Will glisten as it reflects light.
(b) Will flow slightly when the container is tipped.
(c) Will slide freely from the spatula or spoon except in the case of heavy clay soil.
(d) Free water will not collect in surface depressions upon standing.

When the saturation point has apparently been reached, the sample should be allowed to stand a half hour or longer and then rechecked according to the four criteria mentioned above. This is a convenient stopping place and the paste may, if necessary, stand over night. Cover the tumbler with a watch glass, jelly glass lid, or disk of heavy paraffined paper. Sometimes a knowledge of the amount of water required to saturate a soil, the saturation percentage, is of interest but, for these first-aid methods, is not essential. In order to save time, do not weigh soil nor measure water. If soils should be wet a little beyond the saturation point, no harm will result. Estimating over-all salinity within 10% is sufficiently accurate. It is better to have soil slightly over-wet than under-saturated.

2. Make a Saturation Extract of the Soil.

Set up a suction filtering assembly consisting of a funnel over container connected to a vacuum line or water pump with suitable trap. Size 1-A or 2 Buchner funnels are convenient. They take 7 cm. filter paper.

Place a dry 7 cm. Whatman #50 filter paper (or other suitable grade) in the clean, dry funnel and fill with the saturated soil paste. Apply suction and continue until enough filtrate is obtained to determine conductance, soluble calcium, and soluble magnesium. These determinations will usually require 10 to 15 ml. of extract. Do not continue suction after the soil drys and cracks, and air starts passing through. Store the extract in a small vial.

3. Test for $CaCO_3$:

Wash the sides of the tumbler in which the paste was made with a little distilled water, collecting some thin mud in the bottom of the tumbler. Add a few drops of dilute hydrochloric acid (1 to 4) to the mud and shake or stir with a rod. Note effervescence. If there is no visible effervescence, hold your ear to mouth of the container. Effervescence too slight to be seen can be heard. Score as follows:

Violent bubbling	++++
Moderate bubbling	+++
Slight bubbling	++
No visible bubbling but audible effervescence	+
No evidence visible or audible	0

Make note of rate of filtration and color extract. Black alkali soils will yield extract very slowly and the extract will be dark colored. If a soil filters rapidly and gives a clear extract, it is unlikely to present a difficult reclamation problem.

4. Determine Electrical Conductivity of the Saturation Extract:

The conductivity measurement will be made with Solubridge MD-26 using the

small conductivity CEL Go5x2, or with Solubridge RD-15 using CEL G-2. Model RD-26 reads electrical conductivity in millimhos/cm. on the outer scale which covers a range of from 1 to 15 millimhos/cm. Model RD-15 reads in mhos/cm. x 10^5 over a range of from 10 to 1000 K x 10^5. The reading must be divided by 100 (i.e. pointed off two decimal places) to read in millimhos/cm.

The cells are tested at intervals by rinsing twice with and then testing when filled with N/100 K Cl solution. The temperature of this solution should be taken at the time of filling the cell and the temperature adjustment on the bridge set accordingly. The N/100 K Cl should give a reading of 1.41 millimhos/cm. (141.2 on the dial of Solubridge RD-15). The cells sometimes change a little bit with use or with the thickness of deposit of platinum black on the electrodes. Therefore, the reading may depart from 1.41. To correct for this error, shift the temperature adjustment until the correct reading is obtained. Note the number of degrees F and direction (+ or -) it was necessary to shift the dial pointer. Apply this shift as a standard correction. For example, if the temperature is 70° F and the reading obtained with N/100 K Cl is 1.50, instead of 1.41, it will be found necessary to shift the pointer to a reading of 76°F to bring the conductivity reading to 1.41, or a shift of +6°F. Then when testing a soil extract with a temperature of X°F apply the correction by setting the dial at(X+6)°F. The Berkeley office will supply N/100 K Cl solution for testing cells.

Proceed as follows to test the electrical conductivity (specific-electrical-conductance) of the saturation extracts you have prepared. Take the temperatures of the extract and set the temperature dial of the brid e accordingly, taking the correction into consideration. Rinse the cell with distilled water. Since slight dilution is unimportant and extract often is scarce, fill the cell with extract, discharge into the extract container, mix by swirling, repeat with a second rinsing. In this way, all of the extract will be saved and it will only be diluted with the small amount of water which adhered to the walls of the cell. Now fill the cell and make and record the conductivity reading. If the conductivity is beyond the scale of the bridge, dilute with a known ratio of water to extract and read again. Since conductivity will be used to estimate total soluble cations it is best to dilute all extracts with conductivity exceeding four or five millimhos/cm. to get into the range of fairly complete ionization. To estimate soluble cations in ME/L, multiply conductivity in mmhos/cm. by 10.

5. Determine Calcium in Saturation Extract:

Take a 5 ml. or 10 ml. aliquot (not more than half of your extract) and determine calcium by versenate titration with the Ca++ indicator. Calculate and record as ME/L. Calculate the percentage that Ca is of estimated total cations. If the extract is as dark as coffee, call the Ca zero.

6. Determine Magnesium in Saturation Extract:

Take a 5 ml. or 10 ml. aliquot and determine Ca+Mg by versenate titration, using the proper buffer, indicator, and sodium cyanide. If extract is plentiful so that the titration could be repeated in the case of a poor end point, the cyanide may be omitted. Subtract Ca from Ca+Mg to give Mg and calculate the percentage that Mg is of total estimated cations. If the extract is as dark as coffee, call the Mg zero.

APPRAISE RESULTS AND DECIDE ON NEXT STEP:

The data developed to this point will enable you to classify the soil. After classifying, proceed to the next phase if necessary.

Class 1. Soils with conductivity of saturation extract above 2 mmhos/cm. and calcium 30% or more of estimated cations can be called white alkali or saline soils and

be reclaimable by leaching. No further laboratory work is required on such soils. However, if conductivity is above 9 mmhos/cm. and Ca is 27 ME/L (about the solubility of gypsum) or more, you cannot be sure of the classification or what would happen on leaching.

Start again with a wider ratio of water to soil. Suggested Soil:Water ratios are as follows:

Cond.Sat.Ext.Mmhos/cm.	Soil:Water
9 to 15	1 to 2
15 to 30	1 to 4
30 to 60	1 to 10
60 to 100	1 to 20

If conductivity of saturation extract is above 100 mmhos/cm. use enough water to secure an extract with a conductivity of 1 to 2 mmhos/cm. Filter the extract you have prepared using an ordinary funnel and folded filter. Determine conductivity as before and soluble calcium as percent of estimated cations. Reclassify the soil.

Class 2. Soils with conductivity below 2 mmhos/cm. and with calcium less than 30% of estimated cations. Such soils will be problem soils. The lower the calcium, the greater the problem. Determine calcium or gypsum requirement as described later.

Class 3. Soils in this class combine the characteristics of classes 1 and 2. If permeable at the start of leaching, they will probably become less permeable as leaching progresses. For soils in this class, determine calcium or gypsum requirement.

Class 4. Non-alkali soils. No further examination required.

CALCIUM REQUIREMENT TEST:

Prepare a saturated solution of gypsum by shaking C.P. gypsum with water. Let settle until clear or filter. Determine Ca+Mg in ME/L using versenate titration and Ca+Mg indicator. The concentration should be about 29 to 30 ME/L.

Place 5 grams (or 10) of the soil to be tested in a flask or bottle. Add 100 ml. (or 200 for 10g.) of the saturated gypsum solution. Stopper and shake at intervals for 10 minutes. Filter through a folded paper. Determine Ca+Mg in a 5 ml aliquot. The soil will adsorb calcium and exchange other cations for it, largely sodium and magnesium. Since the magnesium added to the extract from the soil is accounted for in the titration, the difference between the Ca+Mg (really just Ca) in the original gypsum solution and the Ca+Mg found in the extract represents calcium which would be adsorbed, under conditions of a plentiful gypsum supply and excess water, to replace sodium. If it seems desirable to know how much Ca was adsorbed to replace Mg, titrate Ca only in another 5 ml aliquot of the extract. The difference between Ca adsorbed to replace Na and total Ca adsorbed is Ca adsorbed to replace Mg. All titrations are calculated to ME/L of extract. These values are converted to ME/100 g. of soil as follows: Since 1 tenth of a liter of solution was used to extract 5 grams of soil or 1/20 of 100 grams, just multiply the ME/L values by 2 to convert to ME/100 g.

CALCULATE GYPSUM REQUIREMENT:

Saturated gypsum solution is not concentrated enough to replace all of the exchangeable sodium but appears to replace a large proportion of it. ME/100 grams equals equivalents per 100,000. The equivalent weight of pure gypsum, $CaSO_4 \cdot 2H_2O$, is 86. 1 ME/100g = 86# per 100,000 # of soil or 1720# per 2,000,000 #. 2,000,000# is about the weight of the top 6" of an acre of soil, 1720# is 86% of a ton, therefore to get the estimated gypsum requirement in tons per acre 6", multiply the ME/100g of Ca adsorbed to replace sodium by .86. Any value determined in this

manner would seem to be a minimum value. It could serve as a starting point for test plots or field scale reclamation. If a soil corrective such as gypsum is applied to a soil and water applied, many reactions will take place. Some of the calcium will be adsorbed to replace magnesium rather than sodium. There is no way to prevent this but the magnesium may in turn replace sodium on other soil particles. The lower layers of soil are being treated with a constantly changing solution. The gypsum requirement as determined above is based on the assumption that in the end nearly all the calcium, plus the magnesium released, will replace sodium. We know this is not the case in some of our soils high in magnesium. Much more gypsum or other soil corrective may be needed for such soils. The Ca needed to replace magnesium may, of course, be calculated if the suitable titration and calculations are made.

One important question which must be answered by field trials and by observation on plant response to alkali conditions is how deep a layer must be reclaimed to be successful with a given crop. Data developed so far indicate that while 6" is enough for some grasses, 1 foot is required for alfalfa.

SUMMARY:

Alkali soils can be classified and treatment indicated on the basis of a few simple tests:

1. Presence of $CaCO_3$
2. Conductivity of a saturation extract
3. Soluble Ca ME/L + % Sol.Ca
4. Soluble Mg ME/L + % Sol.Mg
5. Net gypsum requirement, tons/A 6"

The attached data sheet will serve both as a work sheet and a report sheet.

COUNTY _____ Laboratory No. _____
Date _____

EXAMINATION OF ALKALI SOILS - SUMMARY AND CONCLUSIONS

SUB-SAMPLE IDENTIFICATION:

A. $CaCO_3$						
B. Cond. Sat. Ext.						
C. Ca in Sat. Ext. ME/L						
D. Sol. Ca % = 10 x "C" ÷ "B"						
E. Mg in Sat. Ext.						
F. Sol. Mg % = 10 x "E" ÷ "B"						
G. Ca Requirement - net ME/100 g.						
H. Min. net gypsum req. Tons/A 6"						
Conclusions Class 1, 2, 3, or 4						
Leach "L"						
Treat and Leach "T L"						

Laboratory No. _____
Date _____

SUB-SAMPLE IDENTIFICATION:

A. $CaCO_3$						
B. Cond. Sat. Ext.						
C. Ca in Sat. Ext. ME/L						
D. Sol. Ca % = 10 x "C" ÷ "B"						
E. Mg in Sat. Ext.						
F. Sol. Mg % = 10 x "E" ÷ "B"						
G. Ca requirement - net ME/100g						
H. Min. net gypsum req. Tons/A 6"						
Conclusions Class 1, 2, 3, or 4						
Leach "L"						
Treat and Leach "T L"						