South Dakota State University
Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Bulletins

South Dakota State University Agricultural Experiment Station

4-1911

Alkali Soils

C. Willis

J.V. Bopp

Follow this and additional works at: http://openprairie.sdstate.edu/agexperimentsta_bulletins

Recommended Citation
Willis, C. and Bopp, J.V., "Alkali Soils" (1911). *Bulletins.* Paper 126.
http://openprairie.sdstate.edu/agexperimentsta_bulletins/126

This Bulletin is brought to you for free and open access by the South Dakota State University Agricultural Experiment Station at Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Bulletins by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.

BULLETIN NO. 126. APRIL, 1911

AGRICULTURAL EXPERIMENT STATION

SOUTH DAKOTA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

AGRONOMY DEPARTMENT

ALKALI SOILS

BROOKINGS, SOUTH DAKOTA

From the Press of the
Mitchell Publishing Company
Mitchell, S. D.

GOVERNING BOARD

Hon. A. E. Hitchcock, President.....Mitchell, S. D.
Hon. P. W. Dwight, Vice President....Sioux Falls, S. D.
Hon. A. M. Anderson.....Sturgis, S. D.
Hon. August Frieburg.....Beresford, S. D.
Hon. H. Reinhardt.....Eureka, S. D.

STATION STAFF

A. E. Hitchcock.....Regent Member
P. W. Dwight.....Regent Member
Robert L. Slagle.....President of College
James W. Wilson....Director and Animal Husbandman
N. E. Hansen.....Vice Director and Horticulturist
James H. Shepard.....Chemist
E. W. Olive.....Botanist
E. L. Moore.....Veterinarian
C. Larsen.....Dairy Husbandman
Clifford Willis.....Agronomist and Supt. of Substations
S. Garver.....Co-operative Assistant in Agronomy
C. M. Woodworth.....Eureka Substation
M. Champlin.....
(Co-operative) Asst. in Agronomy, Highmore Substation
J. V. Bopp.....Assistant Chief in Agronomy
W. L. Burlison,.....Chief Assistant in Agronomy
W. D. Griggs.....First Assistant in Agronomy
H. H. Biggar.....Assistant in Agronomy
O. E. White.....Assistant in Botany
J. H. Sarvis.....Assistant in Botany
William White.....Assistant in Dairying
D. E. Bailey.....Assistant in Dairying
Howard Loomis.....Assistant in Agronomy
R. A. Larson.....Secretary and Accountant
M. M. Johnson.....Bulletin Clerk and Stenographer

ALKALI SOILS

By Clifford Willis, Chief in Agronomy, and J. V. Bopp, Assistant Chief in Agronomy.

The continued demand for information concerning the distribution of alkali soils and proper methods of handling them have led this department to make these preliminary investigations.

In coming in contact with farmers in the eastern portion of South Dakota, where there is an abundant supply of rain-fall, the question was asked many times, "What shall we do with small areas wehere alkali is making its presence known by killing crops?" It seems that the system of cultivation of the soil has induced such excessive evaporation that the salts have been left on the surface. It has also been observed that in places where these spots are small in size that they are growing larger. The popular term designates alkali soils, with reference to poorly drained areas where there is usually an accumulation of white or brownish white salt on the surface. These salts usually make their appearance during the latter part of the growing season, being, of course, influenced by the distribution of rain-fall.

For convenience we may classify alkali salts under two groups, (1), soluble, (2), less soluble salts. The more common soluble salts consist of three chief ingredients, sodium chloride, (common salt); sulphate of soda, (Glauber's salt), and sodium carbonate. They are all detrimental to plant growth, the latter being known as "black alkali". The name, black alkali is very appropriate in that it produces black spots or puddles. This is because of the soluble effect of the sodium carbonate on humus. It hardly ever happens that only one of these salts is present but the three always seem to be associated. Commonly mag-

nesium sulphate, potassium sulphate, sodium phosphate, and sodium nitrate are also present.

There are other soluble salts of which the most common are two of mangnesium, the chloride and the sulphate, and calcium chloride. These are not as harmful as those first mentioned, in fact, they are at times quite beneficial.

The less readily soluble alkali salts are calcium sulphate, calcium carbonate, calcium bi-carbonate, and the carbonate and bi-carbonate of magnesium. If present in large amounts they are even beneficial and stimulate growth. They may be profitably added to those soils that contain a high percentage of soluble salts, preventing by a chemical reaction the caustic effect of sodium carbonate.

In experiments conducted by Kearney and Cameron, and given in report No. 71 of the United States department of agriculture, it was found that in a dilute solution of gypsum containing a considerable quantity of soluble salts in suspension, plants grew decidedly more vigorously than when grown in pure water. Practically the same results were obtained in using a solution of calcium carbonate.

HOW PLANTS ARE INJURED BY ALKALI?

On examining plants that have been injured by alkali it is found that the damage ordinarily occurs near the base of the trunk or at the root crown. Rarely does the injury occur at considerable depth in the soil. This effect in the case of green herbaceous stems, shows on the bark which turns to a brownish tinge for half an inch or more and can easily be peeled off. The salt will girdle the stem, which will in turn affect and poison the whole plant.

The plant may not die, but it will be quite certain to become unprofitable and not yield a crop. In cultivated land the injury is usually found to occur near the surface of the soil, concurrently with the well known fact, that the maximum amount of the salt is always found near the end of the dry season, indicates clearly that this accumulation is due to evaporation. The immediate surface is

even found covered with a crust consisting of earth cemented by the crystalized salts. Later in the season a layer of whitish dust, the result of the drying out of the crust, forms.

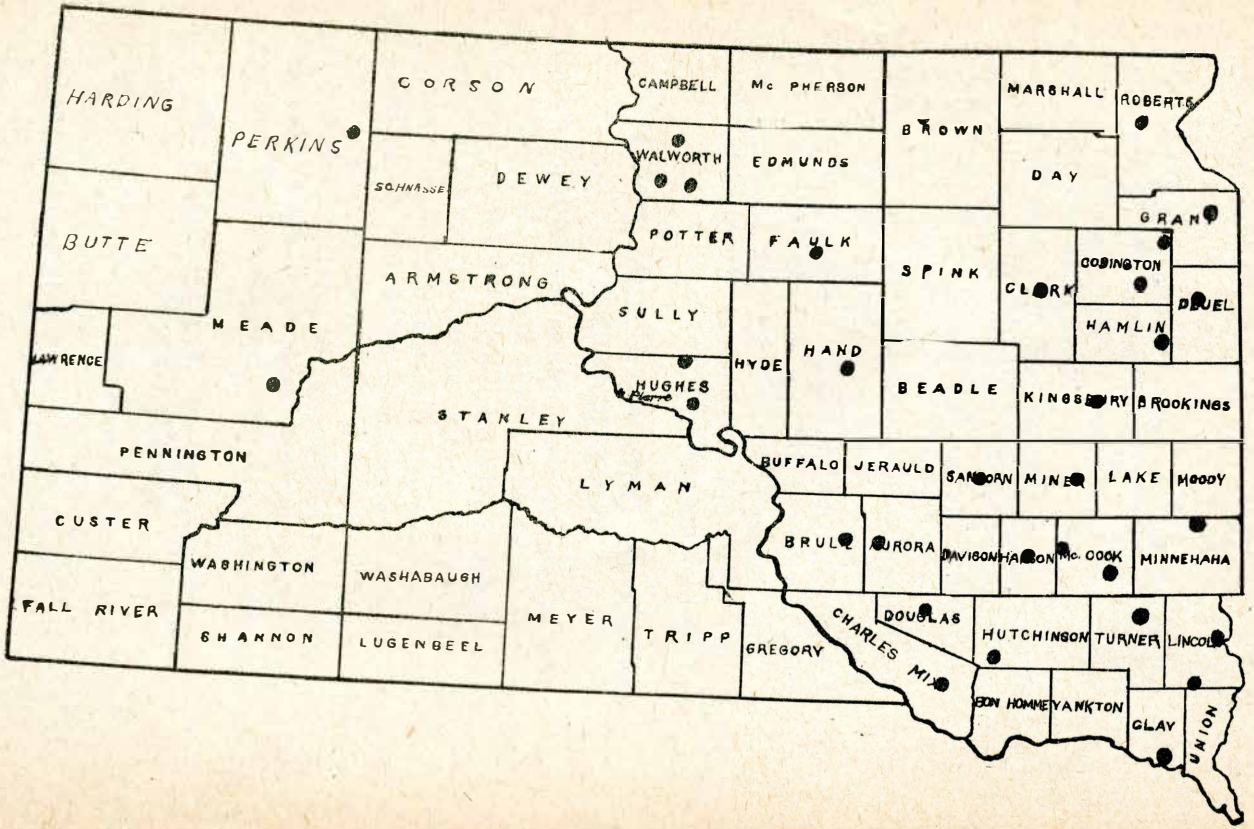
The physiological effect of the salt is to plasmolize the tissue of the plant so that the surface of the stem seems to be more or less corroded. The reason for this is that the concentration of the solution is so great that water is drawn out of the tissue of the plant destroying the cell structure. The plant will then wilt or die. This effect seems more apparent during the latter part of the growing season when the supply of rain-fall is limited and evaporation is increased leaving the salts to accumulate at the surface. Those plants on which the outer tissue is hard and woody are not so easily injured. Alfalfa when first starting has very tender rootlets and is easily killed, however, after it once becomes established, sending its feeding roots deep into the surface the crown becomes "corkified" and is then quite hardy.

MANNER OF OBTAINING SOILS FOR THE INVESTIGATIONS

Letters of inquiry were sent to several representative farmers of every county asking if they were willing to co-operate. From a total of nearly 100 farmers agreeing to send samples, 37 finally submitted complete reports. These soils were taken as directed from alkali spots. It was divided into two portions, the surface being taken to a depth of six inches and the sub-surface from 6 to 36 inches. Questions relating to the location, nature, drainage and handling of these soils were submitted and in many cases valuable practical experiences were obtained.

DISTRIBUTION OF ALKALI SOILS IN SOUTH DAKOTA

The dots on the accompanying map indicate the county and approximate location from which samples of soil were secured for this work. This does not necessarily


HARDING
PERKINS
CORSON
CAMPBELL
Mc PHERSON
MARSHALL
ROBERTS
BROWN
WALWORTH
EDMUNDS
DAY
SOHNASSE
DEWEY
GRANT
BUTTE
POTTER
FAULK
SPINK
CODINGTON
CLARK
ARMSTRONG
DUEL
HAMLIN
SULLY
MEADE
HYDE
HAND
LAWRENCE
BEADLE
KINGSBURY
BROOKINGS
HUGHES
STANLEY
PENNINGTON
BUFFALO
JERAULD
SANBORN
MINER
LAKE
MOODY
LYMAN
CUSTER
BRULE
AURORA
DAVISON
HANSON
Mc. COOK
MINNEHAHA
WASHINGTON
WASHABAUGH
FALL RIVER
MEYER
TRIPP
DOUGLAS
HUTCHINSON
TURNER
LINCOLN
SHANNON
LUGENBEEL
GREGORY
CHARLES MIX
BON HOMME
YANKTON
CLAY
UNION

mean that they are the only alkali soils in the state. They are only from such places where farmers were willing to co-operate. Alkali is found to a greater or less extent over the entire state, however, there are certain areas where the extent of the injury is greater than in others. Some of the soils did not contain a large amount of soluble salts. The injury to the growing crops in such case is due largely to excessive moisture or poor drainage. The investigations are indicative of the conditions in South Dakota, because the entire state is fairly well represented in this investigation. In those counties where no particular soil was analyzed conditions are similar to adjoining counties, and suggestive treatment can be recommended from them.

METHOD OF DETERMINING THE SOLUBLE SALTS

The method of making determinations of the soluble salts is that recommended by the Bureau of Soils in bulletin No. 8. The total soluable salts were found by using the electrolytic bridge. This is practical for a rapid determination of the total soluble mineral salts. "Measure 10 cubic centimeters of pure water from a burette into one of the hard rubber cells. The water for this, as for all such work with soils must be very pure, having a specific resistance of at least 150,000 ohms. Dry soil is then poured into the cell until there is just enough to absorb all the water. The resistance is then measured, the temperature of the soil taken with a thermometer, and the weight of the cell and contents determined. The cell is then thoroughly cleaned and dried and 10 cubic centimeters of a n-10 sodium chloride solution is measured into the cell from a burette. The cell is then put in the balance and soil is again poured in until the total weight of the cell and contents is the same as before. The resistance and temperature are again taken. This gives the resistance of a quantity of soil with the same water content, but with a known quantity of salt added to it. This quantity of salt lowers the resistance of the soil to a certain extent. From this a simple proportion will show how much sodium

chloride the original soil should have contained to have had the resistance, or rather the conductivity which it was observed to have. The quantity of salt in the soil is thus expressed in terms of sodium chloride."

SOLUBLE SALT IN ONE GRAM OF SOIL

"After the resistance has been corrected for temperature, as will be described later, the weight of soluble salt in milligrams in one gram of soil in sodium chlorid equivalents is found by the following formula:

$$S = \frac{10s\ R_1}{(R - R_1)\ W}$$

Where S : miligrams salt in one gram of soil; s : milligrams salt in 1 cc. salt solution; R_1 : resistence of soil saturated with distilled water; R : resistance of same quantity of soil saturated with same quantity of salt soultion; W : weight of soil in the cell in grams."

In addition to making the determinations of the soluble mineral salts a test was made to see whether any carbonates were present. This was done by testing the soil with a dilute solution of hydrochloric acid. Some of these soils analyzed were very strongly effervescent, while the sub-soil contained only a trace of carbonates, in other the reverse was true.

In addition to making these two chemical tests, the soil type was determined, because the texture of the soil will have some bearing on the treatment. Those soils which are more or less sandy can be more easily handled than those having impervious clay sub-soil, because of the ready percolation of water through the sandy soils. Next, the per cent of organic matter was estimated. Some of these soils ran very high in organic matter, while others were quite low.

TABLE I. Showing Complete Analyses of Soils

"a" is surface soil 0 to 6 inches deep; "b" is subsoil 6 to 36 inches deep.

Name		Soil. Type	Carbonates	Per cent organic matter	Per cent solub. salts	Lbs. per 7 acre inch
F. G. Darrow	a	Brown silt loam	yes	3.5	.71	14200
	b	Yellow clayey silt	yes	.5	.36	30600
J. B. Case	a	Grey clay loam	tr	1.5	.10	2000
	b	Grey clay	**yes**	.5	.05	4250
P. Muldea	a	Brown sandy loam	yes	3.0	.22	4400
	b	White clayey silt loam	yes	.3	.08	6800
C. M. Fonder	a	Brown sandy loam	yes	3.5	.13	2600
	b	Grey sandy loam	yes	.5	.05	4250
A. J. Wimple	a	Brown silt loam	none	3.5	2.10	42000
	b	Grey clayey silt loam	none	.5	.40	34000
G. B. Walter	a	Brown clay loam	none	2.5	.80	16000
	b	Grey clay	yes	.5	.76	64600
F. Bradley	a	Brown sandy loam	none	2.0	.46	9200
	b	Drab loam	none	1.5	.29	24650
J. E. Ludwig	a	Drab sandy loam	yes	2.0	.06	1200
	b	Brown sand	none	1.5	.0017	145
H. D. Sample	a	Brown sandy loam	yes	3.0	.19	3800
	b	Drab fine sandy loam	yes	1.0	.25	21250
S. S. Clark	a	Drab fine sandy loam	none	2.0	.03	600
	b	Yellow clayey silt	yes	.5	.22	18700
B. E. Parker	a	Drab silt loam	yes	2.5	.75	15000
	b	Yellow gravelly sand	yes	.5	2.11	179350
G. A. Morris	a	Grey clay loam	none	1.5	1.02	20400
	b	Grey clay	none	.5	2.11	179350
W. H. Montague	a	Grey clay loam	none	1.5	.85	17000
	b	Yellow sand	tr	.5	.28	23800
B. J. Hamburg	a	Drab silt loam	none	2.5	.04	800
	b	Drab clay loam	none	1.5	.05	4250
J. Martin	a	Drab clay loam	none	2.0	.50	10000
	b	Yellow clayey silt	tr	.5	.77	65450
T. Jane	a	Drab loam	none	2.0	.90	18000
	b	Grey clay loam	none	1.0	1.14	96900
W. B. Crisp	a	Brown sandy loam	tr	2.5	.08	1600
	b	Grey sandy loam	none	1.0	.05	4250
A. M. Pultz	a	Brown sandy loam	none	4.0	1.48	29600
	b	Drab clay	none	1.5	2.55	216760
J. W. Smith	a	Drab sandy loam	none	1.5	.15	3000
	b	Drab clay loam	none	1.0	.23	19550
J. H. Taylor	a	Brown sandy loam	yes	4.0	1.78	35600
	b	Grey sandy loam	yes	.	.02	1707
L. W. Robbins	a	Brown silt loam	none	3.5	?	?
	b	Drab loam	yes	1.5	.26	22100
R. W. Hipple	a	Drab sandy loam	none	2.0	.05	1000
	b	Grey sandy loam	none	1.0	.03	2550
R. D. Stove	a	Brown sandy loam	tr	2.0	2.17	43400
	b	Yellow sandy loam	yes	1.0	.66	56100
L. A. Swab	a	Drab loam	none	2.0	.04	800
	b	Drab clay loam	none	1.5	.05	4250
E. J. Ellis	a	Grey sandy loam	yes	1.0	2.61	52200
	b	Grey silt loam	tr	.5	.88	74800
T. N. Babcock	a	Brown silt loam	none	5.0	.03	600
	b	Drab clay	none	4.0	.003	255
O. E. Daniels	a	Grey clay loam	none	1.5	.11	2200
	b	Grey clay	tr	1.0	.99	84150
L. P. Chapman	a	Brown sandy loam	none	4.5	.02	400
	b	Grey sand	tr	1.5	.02	1700
O. S. Crawford	a	Drab sand	yes	1.5	.18	3600
	b	Very fine sand	yes	1.0	.06	5100
G. A. Morrison	a	Drab sandy loam	yes	1.5	.03	600
	b	Very grey sand	yes	.5	.02	1700
G. H. Bonney	a	Drab clay loam	none	2.0	.70	14000
	b	Drab clay loam	none	1.	1.01	85850
E. Skartvedt	a	Brown sandy loam	tr	2.5	.39	7800
	b	Drab fine sand	tr	1.	.46	39100
H. W. Simpson	a	Brown silt loam	tr	2.5	.12	2400
	b	Drab clayey silt	tr	1.5	.16	13600
Geo. Coleman	a	Grey silt loam	none	2.0	.02	400
	b	Yellow silt loam	none	1.0	.06	5100
W. G. Ackerman	a	Brown sand	yes	2.5	.43	8600
	b	Brown fine sand	yes	2.0	.39	33150

Note.—Weight of (a) 6 acre inches equal 2,000,000 pounds. Weight of (b) 6-36 acre inches, 8,500,000 pounds.

Many valuable facts were obtained from the questions submitted to the co-operators. One point brought out forcibly was the lack of sufficient drainage. This suggests at once a remedy to most farmers. No conclusions could be drawn nor any comparisons made which would lead to a single definite treatment as being successful. Some soils which had good drainage were badly affected, while manuring, from actual experience, cannot always be considered beneficial since conflicting results were obtained.

It was thought best to give in brief the experience of farmers as far as possible. Comment is made as warranted by the analysis, reports and soil type.

J. B. Case, Belle Fourche.—"There were some alkali spots on my farm with nothing growing on them. After a rain the ground would become white as snow. I manured it heavily, then irrigated and seeded it to alfalfa and now it seems to be all right."

The soil is a gray clay loam with a gray clay subsoil. It has natural drainage. The surface has only a trace and the subsoil a considerable amount of carbonates. The soil is low in organic matter. The analysis shows 2,000 pounds of soluble salt in the surface and 4,250 in the subsoil. Under drainage will be difficult because of the impervious nature of the subsoil.

P. Muldea, Altamont.—"There are some alkali spots near a slough. It lies about one foot higher than the branch and has surface drainage. Eight years ago it was seeded to flax, but the flax did not grow well. Since then it has been quite wet, and has not even grown weeds."

The soil is a brown, sandy loam with a white, clayey silt loam subsoil. The analysis shows that this soil is rich in organic matter, and contains 4,400 pounds of salt in the surface, and 6,800 in the subsoil. Both surface and subsoil contain large quantities of carbonates.

A. J. Wimple, Beresford.—"I have a spot on my farm about 12 feet wide and 100 feet long. This field has been in pasture for many years, and was this year planted to

corn. The corn is about knee high, with no ears. I have applied manure at the rate of 12 tons per acre, but the crop did not do well. It is fairly well drained, and corn near it will yield 80 bushels per acre. The crop on the strip seems to be sickly."

Mr. Wimple's soil is a brown silt loam with gray clayey silt loam subsoil. The surface contains 3 1-2 per cent of organic matter, and shows no effervescence, hence there are little if any carbonates present. The analysis shows most of the soluble salts on the surface instead of in the subsoil. Because of poor drainage salts have accumlated there on account of evaporation. There are 42,000 pounds of salt in the surface and 34,000 in the subsoil.

G. B. Walter, Selby.—"For the past 21 years I have lived in sight of this spot. At first it was not bare, but gradually it got to be so sheep would go and eat the soil, and finally came to be the bare spot it now is. It is about six by 14 paces and has good natural drainage. No applications of manure have been given at any time."

The soil is a brown clay loam, underlaid by gray clay. The surface contains about 2 1-2 per cent of organic matter, and is strongly effervescent. The analysis shows 16,000 pounds of salts in the surface and 64,600 in the sub-soil.

Frank Bradley, Tripp.—"There are a few alkali spots on my farm which seem to be increasing in size. I have not tried to improve them by manuring. The soil is what is known here as a swale, but it can be drained. Crops make only a poor growth and die as the salts come to the surface."

The soil is a brown sandy loam, with a drab loam subsoil. There are no carbonates present. The surface is quite strongly alkaline, containing 9,200 pounds, while the subsoil has 24,650 pounds.

J. E. Ludwig, Dempster.—"I have some soil which is very poorly drained. Oats and barley grew fairly well this year, but last year flax died while in blossom."

The surface of drab, sandy loam is underlaid by brown sand. Carbonates are present but decrease as depth

increases. The analysis shows that the surface contains only 1200 pounds of salts, and subsoil only 145 pounds. The texture of the soils permits readily of underdrainage, carrying soluble salts away. Evaporation brought most of what remained to the surface. It seems that the evaporation of water from the soil brought the salts to the surface which killed the flax. Surface drainage is in this case of first importance.

H. D. Sample, Altamont.—"I have some soil areas such as you describe. It is not very wet, but can be fairly easily drained. Crops grow very little."

The surface six inches is a brown sandy loam underlaid by a drab sandy loam subsoil, containing a considerable amount of carbonates. The soil is fairly rich in organic matter.

Dr. S. S. Clark, Canastota.—"I have kept an accurate record of the crops and conditions for each week, in book form for 15 years. On some spots of my farm crops did not seem to do well. On one particular acre the records show no crops for the years 1892 to 1898, when I applied about 20 loads of manure per acre. The following year there was a crop of about 10 bushels of corn per acre. The field averaged 35 bushels, and this spot was very noticeable. In 1900 I planted it on May 10, to potatoes and it yielded about 180 bushels of nice, smooth tubers. It is now seeded down to clover and timothy and looks good, but I again dressed it with 10 loads of manure in 1908."

The soil on Mr. Clark's farm is a drab, fine sandy loam surface underlaid with the characteristics glacial boulder clay. The surface shows only a small quantity of salts, but the sub-soil has 18,700 pounds. The method of handling has no doubt improved this soil.

B. E. Parker, Canastota.—"I have some land on my farm on which I have applied about 10 loads of manure per acre, but it does not seem to help the crops. It is fairly well drained but inclined to be wet. It could easily be ditched."

This soil is a drab silt loam on yellow, gravelly, sand subsoil. It contains a large quantity of carbonates and a very large amount of salts. The analysis shows 15,000 pounds in the surface and 179,350 in the sub-soil.

George A. Morris, Coal Springs.—"The land from which the samples of soils were taken has never been broken. The soil is found in patches ranging in size from perhaps 12 to 50 feet in diameter and are generally six to 12 inches lower than the land around them. The bottoms of these places are level and smooth, and when not plowed will hold water almost like a basin. But when once cultivated readily absorb more water. The land surrounding these spots is dark and grows grass. The soil is very hard to plow, being a gray clay loam with a gray clay subsoil. We were only able to plow a few inches deep by using steam power. Corn was killed when about a foot tall, and after the weather had become very dry. I have observed that after this soil has been cultivated it improves, and will take up water quite readily."

The surface soils contain 20,400 pounds of salts and subsoil 179,300. These areas approach the character of bad lands.

W. H. Montague, Vermillion.—"There is only one so-called alkali spot that I know of in this neighborhood. It is not well drained, and has never been treated, being in pasture. There are no weeds nor grass growing on it."

The soil is a gray clay loam on a yellow sand subsoil. The analysis shows 17,000 pounds of salts in the surface and 23,800 in the subsoil. From the texture of the subsoil good drainage should carry away a large portion of these salts.

B. J. Hamburg, Corsica.—"I have given so-called alkali spots on my farm heavy coatings of manure, and it seems to help crops. The soil is very poorly drained, and it will be practically impossible to drain some at all."

The soil is a drab silt loam on drab clay loam subsoil, and contains no carbonates. The analysis shows 800

pounds of salts in the surface, and 4,250 in the subsoil. From the character of the soil and the analysis, it seems that the poor drainage affects crops more than salts.

John Martin, White Lake.—"On some portions of my land the alkali seems to work to the surface, more and more every year. If the season is just right it produces fair crops, but if there is too much rain, or it is too dry the yield is very poor."

The soil is a drab clay loam on yellow clayey silt. The analysis shows 10,000 pounds o fsalts in the surface and 65.450 in the subsoil. This shows a large amount of alkali in the sub-soil, and by poor handling this is coming to the surface.

T. Jane, Blunt.—The soil is a drab loam, with a gray clay loam subsoil. The analysis shows 18,000 pounds of salts in the surface, and 96,900 in the subsoil.

A. M. Pultz, Lake Preston.—"There are a number of small alkali spots on my farm. They are not increasing in size. Wheat, oats and barley seem to be the best crops. I have manured some at the rate of eight loads per acre, and the crops seem to do better where the ground was not too wet. The soil is poorly drained, and it will be practically impossible to help carry away surplus water. Some spots do not grow any crop at all. As soon as the plants are up, they look yellow and stunted. It grows very short, but fills up with plump grain."

The soil is a brown, sandy loam, rich in organic matter, on a drab clay loam sub-soil. The analysis shows that this soil is very high in mineral salts.

J. W. Smith, Kimball.—"There are some alkali spots on my farm, which have not yet been cultivated. The spots have been quite heavily manured, but the grass did not seem to do any better, possibly because of the poor drainage. It is, however, possible to drain them. The plants seemed stunted in size."

The soil is a drab, sandy loam, on drab clay loam

subsoil. The analysis shows this soil to be heavily loaded with mineral salts.

J. H. Taylor, Alaska.—"Alkali spots are occasionally found on my farm, but they seem to be decreasing in size. I have no preference for any particular crop for these spots. No manure has ever been applied to them, and they are well drained."

The soil is a very dark, sandy loam, on a gray medium fine, sandy loam subsoil. Both the surface and the subsoil contain a large per cent of carbonates. The surface is rich in organic matter, containing as high as 4 per cent. The analysis shows that the surface contains a large quantity of salts, while the subsoil is comparatively free.

L. W. Robbins, Spencer.—"I have a small alkali spot on my farm, and it seems to be increasing in size during wet weather. The soil is a brown silt loam on drab loam subsoil. Last fall I manured at the rate of nine loads per acre. The soil is near a pond and is poorly drained, but I intend to drain it soon. There was a growth of grass early in the spring, but the land is now bare."

The sub-soil is strongly impregnated with carbonates, while the surface is comparatively free.

R. W. Hipple, Wagner.—"There are no alkali spots in this neighborhood as far as I know. However, some low, poorly drained soils become whitish when the water evaporates, and the crop seems to be injured in some way. A few loads of barn-yard manure has made them fertile."

The soil is a drab, very fine, sandy loam, on a gray very fine sandy loam subsoil. The texture of the soil indicates that it should be easily drained if there were an outlet. The analysis shows that it is not high in mineral salts.

R. D. Stove, Howard.—"There are no typical alkali spots on my farm. There are small areas where the crops only do well during an average year. The spots are very poorly drained, and it would cost a great deal to drain

them. After giving an application of manure the crops seemed to grow better."

The soil is a brown sandy loam, underlaid by a yellow saidy loam subsoil. A test with hydrochloric acid shows the soil only slightly effervescent, but the subsoil very strongly indicating the presence of a large quantity of carbonates. The analysis shows over 43,000 pounds of mineral salts in the first six inches of soil.

L. A. Swab, St. Lawrence.—"There are a few so-called alkali spot on my farm. They are very poorly drained, but can be easily improved. Crops have done fairly well, excepting when there was too much rain. Wheat seems to be the best crop."

The soil is a drab loam on drab clay loam subsoil. The analysis shows only a small amount of mineral salts in the surface. A similar spot which has been heavily manured will take up water readily, and small grains do exceptionally well.

E. J. Ellis, Clark.—"There is some soil such as you describe on my farm. Wheat is the best crop to grow on this land as it yields the best. The spots do not appear to be growing larger. It has been in pasture for years, and is not very well drained. This soil was broken once, and seeded to flax. It grew waist high, but did not ripen."

The soil is a gray sandy loam on a gray silt loam subsoil. The surface contains a large amount of carbonates. Analysis shows the soil to be very high in mineral salts.

T. N. Babcock, Watertown.—The soil on Mr. Babcock's farm is a brown silt loam on a drab clay subsoil. This soil is very rich in organic matter, the surface containing 5 per cent, and the sub-soil approximately 4 per cent. The analysis shows a very low content of soluble mineral salts. The soil from which the sample was taken is well drained. From the analysis and report this seems to be a low, wet spot, entirely free from alkali.

O. E. Daniels, Giddings.—Mr. Daniels says that these spots are referred to as "buffalo wallows," and when cul-

tivated gradually become smaller, and smaller and disappear. The land is quite level, and it would be quite expensive to drain it. The best crop for this soil seems to be speltz. The soil after it dries becomes very hard.

The soil sent by Mr. Daniels is a gray clay loam, underlaid by a gray clay subsoil, and contains only a small amount of carbonates. he analysis shows 2,200 pounds of soluble salts in the surface, and 84,150 pounds in the subsoil.

L. P. Chapman, Alexandria.—The soil is a brown, sandy loam on gray sand. The surface contains about 4 1-2 per cent of organic matter. It is well drained, and contains only a small amount of carbonates. The analysis shows only 400 pounds of soluble mineral salts in the surface. Crops should do well on this soil after it is well drained.

O. S. Crawford, Lowry.—"There are a few alkali spots on the bottom land, however, I know of none on the upland. I believe that speltz would be the best crop for these spots."

The soil is a drab sand, on sand subsoil, and contains a large amount of carbonates. The analysis shows that both surface and subsoil contain only a reasonable amount of soluble salts.

G. A. Morrison, South Shore.—"There were some spots on my farm, but they seem to be decreasing in size. They are well drained and what drainage I have done has seemed to benefit them very much."

The analysis shows that there is only a small amount of salt present. The character of the soil being a sandy loam on sand subsoil would make it easily possible that natural under-drainage has leached out the alkali.

G. H. Bonney, Forestburg.—"There is only a small spot where the surface becomes white as snow during summer when there is much evaporation. The area is of such small size, being only a roadway, so it is impossible to say what crops would grow. Grass does not grow on it."

The soil is a drab clay loam and contains only a small amount of carbonates. The analysis shows it to be rather

high in soluble mineral salts, the surface containing 14,000 and the subsoil 85,850 pounds.

E. Skartvedt, Canton.—"There is a spot on my farm which is very white every spring. It is in pasture so I cannot say what crops would grow best. Neither grass nor weeds will grow on this spot to any extent. It has been given heavy applications of manure, and is well drained naturally."

This soil is a brown, sandy loam, on drab fine sand, and contains only a very small amount of carbonates. The analysis shows the surface to contain 7800 pounds of mineral salts, and the subsoil 39,100 pounds.

H. W. Simpson, Faulkton.—"There are a great many of these spots ranging in size from two to three rods across each way, in this part of the state. Many of them can be tiled. The soil seems to be so impervious that water will not percolate through and it is possible to drain such spots which now are very wet. Plants made only a very poor growth. They looked very sickly."

The analysis shows only 2,400 pounds of soluble mineral salts in the surface, and 13,000 pounds in the subsoil. The soil is a brown silt loam containing 2 1-2 per cent of organic matter, and is only slightly effervescent. The subsoil is a drab clayey silt and contains a very high per cent of carbonates. Good drainage would help this soil very much.

George Coleman, Elm Springs.—"There are no alkali spots in this neighborhood."

The soil is a gray silt loam on yellow silt loam subsoil. An analysis shows it to be low in soluble mineral salts. Deep plowing, and turning under manure and organic matter will improve this soil, because it is low in humus.

W. G. Ackerman, Milbank.—"I am not sure whether these are alkali spots, but there seems to be something wrong with the soil, as it seldom grows anything. It is fairly well drained and makes about a half a crop. About the middle of the season plants stop growing and will ripen considerably later than the rest of the field."

The type of soil on this farm is brown sand, and contains a very large amount of carbonates. The analysis shows the surface to contain 8,600 pounds of soluble salts on the surface and 33,150 in the subsoil. From the character of the soil good drainage should improve it.

C. M. Fonder, Sisseton.—"There are a few alkali spots on my farm. These small areas seem to be more injurious during wet seasons."

The soil is a brown, sandy loam, quite rich in organic matter, on a gray sandy loam sub-soil. The laboratory test shows quite a large amount of carbonates. The analysis shows 2600 pounds of salts in the surface six inches, and 4250 in the subsoil. Mr. Fonder has given these spots no treatment at any time. He says the soil is poorly drained, which accounts for the accumlation of the alkali, but it will be possible to drain it. From the appearance of the crop it seems that the injury is due to excessive moisture rather than to alkali. Good drainage would help them very much.

METHODS OF RECLAIMING ALKALI SOILS

Counteracting Evaporation.

Noting that the injury is due to the translocation and accumulation of salts in the upper soils will suggest one of the best, and first methods of treatment. The alkali is carried to the surface in solution in water, and as the water evaporates is left on the surface. The greater the evaporation, the more rapidly will the salts accumlate, so that the best treatment will be to prevent this as much as possible. Good surface cultivation will do much in keeping it in the sub-soil, and lower down, where little harm results. Tillage should begin early in the season because at that time a considerable amount of the salts have been carried into the sub-soil by the spring rains. If the crop has been started early, and good cultivation is practiced it may be brought to maturity before harm or injury is wrought.

Mulching has been recognized in irrigated sections as a very effective remedy. In orchards where alkali is apt to be brought to the surface, shading the ground even may be sufficient to prevent great injury. Litter of all kinds has been successfully used. However, it involves more or less expense and trouble than the simple tillage of the surface to prevent evaporation throughout the season. We should remember that the deep preparation and thorough surface cultivation must be regarded as the prime factor in maintaining and improving our alkali soils.

APPLYING GYPSUM OR CALCIUM SULPHATE

Since there is very little sodium carbonate present in any of the soils submitted for chemical analysis, an application of gypsum will not be of especial benefit in changing the small amount of sodium carbonate to sodium sulphate. We know that sodium sulphate is the least injurious of the sodium salts and that plants are able to withstand a large amount of it. According to Hilgard and Loughridge, barley is capable of resisting about five times more of the sulphate than of the carbonate, and at least twice as much as of common salt.

DRAINAGE VERY BENEFICIAL

The remedial measures so far proposed are only temporary and do not remove the excess of salts. Mulching or cultivation prevents the evaporation of water and the accumulation near the surface while the reversion of the harmful carbonate to the sulphate of sodium also does not afford permanent relief. However, since many of these soils are found in depressions where there is an excess of water in certain periods of the year, and since the salts are very soluble it necessarily follows that they may easily be carried away in solution. Tile drainage will, therefore, afford permanent relief. Flooding an irrigated section will wash the salts deeper into the subsoil where it loses its harmful effects. Analysis of drainage waters in various

sections have shown that they carried large quantities of salts in solution. Of course surface drainage will also greatly aid, yet it is not as immediate as tiling.

With the data at hand it seems feasible that where alkali salts have accumulated it is due in a measure to incomplete drainage and poor cultural methods. Crop yields in nearly every instance mentioned by farmers with whom this co-operation was carried on shows that excessive moisture was the major cause of injury.

LIST OF AVAILABLE BULLETINS

89. Preliminary Experiments with Vapor Treatments for the Prevention of Stinking Smut in Wheat.

90. Tankage and other By-Products for Pigs; Shrunken Wheat for Swine.

91. Co-operative Vegetable Tests in 1904; Peas, Beans, Sweet Corn. Cabbage.

92. The Milling Qualities of Macaroni Wheat.

94. Alfalfa and Red Clover.

95. The Treatment of Nail Pricks of Horse's Foot.

96. Forage Plants and Cereals at Highmore Sub-Station.

97. Speltz and Millet for the Production of Baby Beef.

98. Crop Rotation.

99. Macaroni and Durum Wheats. A continuation of Bulletin 92.

100. The Value of Speltz for the Production of Beef and Pork

101. Forage Plants at the Highmore Sub-Station, 1906.

102. Evergreens for South Dakota.

103. Breeding Hardy Strawberries.

104. Breeding Hardy Raspberries.

105. Stock Food for Pigs,

106. Sugar Beets in South Dakota.

107. Sheep Scab.

108. New Hybrid Fruits.

109. Rusts of Cereals and other Plants.

110. Progress in Variety Tests of Oats.

111. A Study of South Dakota Butter with Suggestions for Improvements.

112. The Killing of Mustard and other Noxious Weeds in Grain Fields by the use of Iron Sulphate.

113. Progress in Variety Tests of Barley.

114. Digestion Coefficients of Grains and Fodders for South Dakota.

115. Report of Work for 1907 and 1908 at Highmore Sub-Station.

116. Acidity of Creamery Butter and its Relation to Quality.

117. Sugar Beets in South Dakota.

118. Corn.

120. Progress in Variety Tests of Alfalfa.

121. Sugar Beets in South Dakota.

122. Creamery Butter.

123. Milk Powder Starters in Creameries.

124. Progress of Grain Investigations.

125. Fattening Steers of Different Ages.