



Bulletin 231

October, 1917

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

"BLACK ALKALI" IN THE SAN LUIS
VALLEY

By
WM. P. HEADDEN



PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1917

The Colorado Agricultural College

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"BLACK ALKALI" IN THE SAN LUIS VALLEY

By

WM. P. HEADDEN

Bulletin No. 230 of this station, entitled "Rio Grande Waters", gives as full a statement of the water conditions peculiar to the San Luis Valley as we are able to present. The work on this feature of the valley has extended over a number of years. There are a great many features of the subject which are not of special interest to the general farmer or even to those interested in the lands of this valley, while there are others of vital importance to the ranchman, but of less interest from other points of view.

AGRICULTURE OF VALLEY RETARDED FOR A NUMBER OF YEARS

It is known to everyone acquainted with the irrigation of the valley since the early nineties, that at one time the section of the valley about Mosca and Hooper was a most remarkable wheat producing country. Mosca, for instance, was a thriving town with a large flouring mill, an elevator and a flourishing business. This prosperity passed a number of years ago; the elevator is unused, the mill was torn down, and, if I am rightly informed, a part of the machinery was taken out of the valley and the rest of it used in building the mills at Alamosa and La Jara. The mill at Hooper has only recently been dismantled as a flouring mill. As wheat growing was the biggest interest of this section, the milling industry may be assumed to present faithfully the course of the farming industry. Stock-raising, sheep, hogs and cattle, has enabled some to continue operations with some success, but as a general statement, the condition of this section of the valley has been deplorable for the past 10 or 15 years.

The towns of Mosca and Hooper are mentioned because they were the centers of this former prosperity, which was participated in by a large section of country.

The area now mostly unproductive is from 400,000 to 500,000 acres. The cause usually assigned for this condition is seepage.

SUB-IRRIGATION HAS CAUSED SEEPED LANDS

The system of irrigation used in the past was undoubtedly unfortunate and the practice of the people in applying it was in many cases unwise. I am credibly informed that, in some in-

stances, in the application of sub-irrigation, the water-plane is raised to within 12 inches of the surface, while in the most conservative cases the aim is to raise it within 22 inches. It is not our intention to consider the conditions under which these results may be obtained or to discuss methods of irrigation, but simply to present the facts. One result has been the seeping of that section of the valley lying to the north of the Rio Grande and east of Center. This fact has called into existence the Gibson and Sylvester ditches for the purpose of drainage. The conviction is very general that drainage will remedy conditions in this section of the valley. It does not matter whether this conviction is wholly or only partially correct, it establishes the prevalence of this seeped condition.

SOIL IS NOT EXHAUSTED

Another cause of failure might be exhaustion of the soil. This probably plays only a small part, if any, in the present unfavorable condition of this section. How unfavorable this general condition is, is not appreciated by any except those who have an intimate knowledge of the country. The practice of the ranchmen in farming this land may have been bad, but exhaustion of the soil is not at all a contributing factor.

An ordinary agricultural analysis of a soil from Hooper gave the following results:

ANALYSIS OF SOIL. HOOPER, COLORADO

| | Percent |
|------------------------------|---------|
| Sand* | 62.241 |
| Soluble silica | 15.229 |
| Sulfuric acid | 0.363 |
| Phosphoric acid | 0.320 |
| Carbonic acid | 2.629 |
| Chlorin | 0.081 |
| Lime (calcic oxid)..... | 4.295 |
| Magnesia | 1.595 |
| Potash | 1.383 |
| Soda | 1.326 |
| Ferric oxid | 3.930 |
| Aluminic oxid | 4.259 |
| Manganic oxid (br.)..... | 0.175 |
| Ignition | 2.260 |
| Sum | 100.085 |
| Oxygen equal to chlorin..... | 0.018 |
| Total | 100.067 |

* This sand consists of particles of igneous and other rocks rich in felspar and has, comparatively, a small amount of quartz particles.

This soil is quite typical of by far the larger part of the soils found in the valley and, so far as this kind of an analysis is reliable as an indication of the supply of plant food, the soil is excellent

in regard to its content of phosphoric acid and potash. The nitrogen is not given in this analysis, but judging from the amount of this element found in other samples, it is probably about 0.10 of 1 percent. The question of exhaustion of this soil, even if we assume that the addition of nitrogen would be advisable, can be dismissed as the cause of the unproductiveness of this large section of the country.

"WHITE ALKALI" IS NOT INJURIOUS

Another cause often assigned for an unproductive condition of our lands is "white alkali". That there is alkali in this, as well as in other sections of the valley, is thoroughly well known. There is more evidence of this class of alkalis outside this section than within it.

It is natural that, when a section of country measured in square miles is covered by a white efflorescence, perhaps literally as white as snow, that it should make an impression upon one as an important factor in any unproductiveness of the land which may be observed. That this has been the case and has been passed on from one to another and from one section of country to another from the beginning of our agriculture till the present time is true, and it is unfortunate that it is true, for, whatever the results of laboratory experiments may be, I have yet to see the proof that these "white alkalis" constitute any seriously unfavorable factor in our field practice. When something is wrong, many of us, especially if we have not learned that it is no disgrace to acknowledge that we do not know everything, attempt to give a reason for the condition, whether it has anything to do with the question or not. In this way our ordinary "alkali" has been assigned as the cause of much evil.

I do not intend to go into this question here, but I may state that the alkali question is more complex than the average person imagines and includes much more than the white efflorescences so abundant, especially at times during the spring months, in some sections of the valley. This white efflorescence, our ordinary "white alkali", as it occurs west and south of Alamosa, or very generally throughout the valley, is essentially sodic sulfate, often mixed with calcic sulfate. I do not believe that these salts occur in these soils in sufficient quantities to cause any damage. The general reader should be reminded that these salts, as he sees them on the surface of the country, are what is left from the evaporation of large amounts of water which have brought them to the surface of the soil and left them there in the form of a very strikingly white powder whose quantity in the soil he greatly

over-estimates. More especially has he been led to over-estimate the injurious effects of these salts. I remember the impression made upon me by the whiteness of the country west of Alamosa during a trip in the spring of 1914. For more than two miles the surface of the ground on both sides of the road was perfectly white and this condition extended, especially to the southward, as far as one could see. I measured this efflorescence at some points and found it attaining a thickness of one-quarter of an inch or rather more. I took a sample of this, analyzed it, and found it to contain more than 91.0 percent of sodic sulfate. It is not a matter that should cause surprise that such a condition should impress one as very bad indeed, but I do not believe that it is a fact that it is very bad.

Some years ago I took some samples of soils at La Jara. Among them there were two from a field planted to peas; the stand was irregular but the peas were thrifty. These two samples represented 6 inches of soil, the top 2 inches and the succeeding 4 inches. The top 2 inches carried 3.0 percent of salts soluble in water; the next 4 inches 1.5 percent. Of these salts, 65 and 46 percent respectively were sodic sulfate, the rest, essentially, calcic sulfate. The peas undoubtedly had pushed their roots to a greater depth than 6 inches, but they had passed through this 6 inches and they were thrifty. I have seen just as marked instances in the eastern part of Alamosa, where a good lawn and garden were separated from land heavily charged with this "white alkali" by an ordinary picket fence. In this case the effloresced alkali contained 96 percent of sodic sulfate. These are only a few instances of this character that I have met with which lead me to believe that ordinary, so-called white alkalis are of themselves not sufficiently injurious to justify their consideration in this connection.

"BLACK ALKALI" POISONOUS TO PLANTS

There is a so-called "black alkali", which consists essentially of sodic carbonate, whereas the "white alkali" consists essentially of sulfates. The "white alkali" does not discolor the land; the "black alkali", when the soil contains much organic matter, gives rise to very dark, almost black, solutions and crusts, for which reason it is called "black alkali". The alkali itself is not black, it is white, just as white as the so-called white alkali, but it dissolves organic matter (humus) with a brown or black color. This alkali is so corrosive that it will destroy the tissues of young plants and even of older ones, and, of course, may kill them. Another effect of sodic carbonate, "black alkali", is to make the ground puddle and cake so

that when it is plowed it breaks up in hard cakes or lumps. This effect is so marked on some soils that the carbonate formed, due to the application of Chile saltpetre, cakes the ground so badly that anyone can tell just where the saltpetre was applied. This was so noticeable in a field in which I had made some fertilizer experiments that the plowman who was sent to do the fall plowing picked out of the 48 plots into which the field was divided, the 12 plots to which the Chile saltpetre had been added. The smallest amount added was 62.5 pounds to one million pounds of the soil. This would give rise to about 75 pounds of carbonate to each million pounds of soil, provided the largest possible amount of carbonate was formed, and yet this actually sufficed to puddle and cake the land to the extent that I have indicated. This amount expressed in percentage is seventy-five ten thousandths of 1 percent. This amount is very much less than is necessary to injure plants by directly eating off the roots or to poison them. The amount necessary to do this is from four to five one hundredths of 1 percent, or from 400 to 500 pounds in each million pounds of soil. This "black alkali" is really very poisonous to plants and its effect on the physical or mechanical condition of the soil is very bad.

NITRATES DESTRUCTIVE IF PRESENT IN SUFFICIENT QUANTITIES

There are still other salts that occur in our soils of which we must take some note, for they may easily become so abundant as to be injurious, or even to be fatal, to all vegetation. In bulletins Nos. 155, 160, 178, 183 and 186 of this Station I have described in some detail, the occurrence of these salts, nitrates, in some of our Colorado soils in such quantities as to kill vegetation, even old, well established apple trees. One of the very first occurrences of this sort that I recognized was in the San Luis Valley. The occurrence of these salts may have two effects. A small amount of them, 10 to 20 parts to a million parts of the soil, may produce big crops of oats or other farm products, whereas, too much of them will burn and kill the crop. At this time I wish only to call attention to the fact that this question exists in the agriculture of the San Luis Valley. I may state that I saw in Rio Grande County in the season of 1916, a quarter section that had been planted to peas, on which no peas were grown. The grasshoppers were blamed for the destruction of the crop, but no grasshoppers were to be found on the quarter section. Nitrates, however, were present in this soil in fatal quantities. These statements are made simply to impress upon the minds of interested parties that there

are real, serious questions pertaining to the agriculture of the San Luis Valley besides the question of seepage.

There are still other salts whose occurrence is most remarkable, but they need not be so much as mentioned in this place.

HIGH WATER-PLANE NOT THE CAUSE OF CROP TROUBLES

The people of this valley themselves are not all satisfied that the benefits claimed for drainage have been realized or are attainable. That the presence of a high water-plane alone has, in fact, done the harm to the 400,000 or 500,000 acres of land included in the Moffat-Hooper-Mosca section is claimed by some. The view that I take is that this is not so. The water-plane is certainly too high in many places in this section, but in others, it is low enough for the production, under other conditions, of good crops, whereas this land produces nothing. In the practice of sub-irrigation, the water-plane is intentionally raised to within 22 inches, and even as near as 12 inches, of the surface, with no detrimental results; at least, this is the information that I have received. Doubting some of the information, I have made inquiry concerning the parties giving it, and concerning the facts; they seem to be reliable.

Agronomists may doubt that good crops of alfalfa may be grown year after year on land in which the water-plane is held within 12 inches of the surface throughout the growing season. It seemed to me remarkable but, after what I have seen and learned from some of these people, I feel compelled to accept their statements. I have presented these facts of farm practice because of their suggestiveness in connection with the claims made—that it is because of the waterlogged condition of the Hooper-Mosca section that it will not only not produce as in former years, but almost not at all. I have refrained from writing of these facts for ten years or more, but the bad condition of this section is now so well known to everyone that there is no good reason why one should not write frankly about it.

There is no question but that water has been used unwisely and that sub-irrigation is not the best practice for this valley, nor is there any question but that there should be drainage enough to take the water off the surface of the ground. There is, further, no question but that some bad results would be experienced in changing from the system of sub-irrigation to irrigating by furrows and flooding, but we have the following facts:

Good crops, even excellent crops, are raised by sub-irrigating, whereby a higher water-plane is maintained than exists in parts of the valley which are now practically wholly unproductive. If

in the same country a high water-plane during the cropping season produces good results, why should we attribute the unproductiveness of other parts of the same country to a water-plane no higher, or to one that is even lower? So far as the variability in the height of this water-plane is concerned, there is not much room for movement, in the case stated, from 42 inches below the surface in the winter to 12 inches in the cropping season. The permanent water-plane in the unproductive section lies within these limits, at about 36 or 37 inches, according to my personal observations.

I do not think that any practical farmer will deny that the practical results obtained by the expenditure of considerable sums of money on drainage ditches have been disappointingly small. These experiments with drainage ditches have been made on a sufficient scale and length of time to justify a very good judgment of how much is to be hoped for from these alone and, as said, the results are disappointingly small.

ABUNDANT "WHITE ALKALI" OF VALLEY NOT A SERIOUS PROBLEM

Another fact is that the ordinary "white alkali" which occurs abundantly in the valley is not a serious problem, though it has been made to appear such. I am not alone in this view of the question and know that many practical men are fully convinced of this.

I shall not discuss the question of the occurrence of some chlorides in this valley at this time. The nitrate question is really of some importance and the occurrence of certain chlorides in this fresh water valley is an interesting problem, but they do not constitute the big important fact that I want to present in this bulletin.

"BLACK ALKALI" PRESENT IN DETRIMENTAL QUANTITIES

This fact is that, while the total amount of alkali in the soil of the Hooper-Mosca section is comparatively moderate, the character of this alkali is very bad. There is present, in most of the land, sodic carbonate, "black alkali", enough to be detrimental, if not fatal, to any crop that may be planted. The best information at my disposal indicates that the presence of 400 parts of sodic carbonate to the million parts of soil is injurious, or possibly fatal, while it is probable that few, if any, crops can survive in the presence of as much as 500 parts to the million. The amount of alkali in this land is generally taken at something like 1,000 to 1,200 parts to the million. This amount of "white alkali" would not be in the least dangerous, but if one-half of it were "black alkali", very serious trouble would ensue. In fact, the land would be ruined for all practical purposes.

In order to ascertain how generally the carbonate of soda may be distributed throughout this district, I took two sets of samples, beginning in the first case a little south of McGinty and continuing to Hooper, and in the second case a little east of Center and continuing to Hooper, but to make the two series continuous, I shall give the results from Hooper to Center.

| SODIC CARBONATE IN SOME SAN LUIS VALLEY SOILS IN PARTS PER MILLION | |
|--|--------------------------------------|
| | Black Alkali in Parts Per Million |
| An old, gone-back ranch..... | 865.0 |
| Land in bad condition, crops failed..... | 375.0 |
| Land barren for some years..... | 722.0 |
| Land barren..... | 925.0 |
| Land barren, soil sandy..... | 5103.0 |
| Alfalfa field, stand good..... | 144.0 |
| Alfalfa field, stand medium, old..... | 200.0 |
| Alfalfa field, stand good..... | 259.0 |
| Sandy soil, alkali grass, some sweet clover..... | 121.0 |
| Diked and flooded soil..... | 109.0 |
| Sandy loam, uncultivated..... | 253.0 |
| Oats, a failure..... | 609.0 |
| Deserted land..... | 200.0 |
| Wholly unproductive land, treatment excellent..... | 510.0 |
| Wholly unproductive for many years..... | 3222.0 |
| Land just surfaced..... | 200.0 |
| Land flooded 1916 rye poor..... | 398.0 |
| Land flooded 1916, rye, only a little living..... | 410.0 |
| Land planted to peas; peas did not live..... | 633.0 |

These samples represent flooded, cultivated and uncultivated lands and there is not one of them that does not contain notable quantities of this very objectionable salt. We see that flooded land planted to rye and containing 398 and 410 parts of "black alkali" to the million of the soil produced nothing. Further, that no single sample taken was free from this salt, even though some of it had just been flooded in the manner that is now frequently practiced in this section. The people, at least some of them, realize that this method, as practiced, is not a perfect success (see the two fields of rye), but they know that it is the best way yet adopted to handle this land.

If we can discover the source and supply of this carbonate, it will help us to form some clear notion of our chances of correcting the evil. It will help us to form an idea of how much we may hope to accomplish.

"Black Alkali" Comes from Waters of Valley

The source of this carbonate is the water of the valley. The artesian water at La Jara, obtained at 65 to 70 feet, is good water, and that obtained at Alamosa, at a depth of 923 feet, is also good water. This is not the case with the town well or the mill well at

Mosca, nor with the mill well or the railroad well, or the town well at Hooper. These waters are brown, strongly alkaline and contain sulfur; they even smell of it. The older residents of the section well remember that there was a well near the present railroad station of McGinty that was called the soda well, because, so it was said, they could use this water instead of baking powder for making light bread. I never believed this story, but it shows that the water was remarkable and that the citizens were resourceful in presenting the advantages of the country. This well is now closed.

The presence of gas in this district is, in some instances, abundant enough to furnish light and fuel for the houses of the owners.

The conditions that cause the waters to be brown and to carry sodic carbonate in such easily recognizable quantities have produced the difficulties that threatened the district from the beginning and which the practice of sub-irrigation has made real.

All of the ground waters that I have examined from Center east to Hooper and from Hooper, I may add from Moffat, south to below McGinty, carry sodic carbonate in solution. In the case of the brown waters, there is present in the strata from which the waters come, enough humus which is soluble in sodic carbonate, to impart the brown color. Some of the wells near the edge of this area, especially shallow wells, carry sodic carbonate, though they are only slightly or not at all colored. The characteristic of our mountain waters is that they carry only a small amount of substances in solution, and these substances are silicic acid, the carbonate of lime, and the carbonate of soda. The silicic acid and the carbonate of lime can be removed easily, but not the carbonate of soda. This salt is not removed to any great extent when its solution passes through the soil, nor is it thrown out of solution by any agent or by the evaporation of its solution as the lime may be by the escape of carbonic acid on exposure to the air.

The artesian waters along and south of the Rio Grande are excellent waters for all domestic purposes; they carry carbonate of soda with the carbonate of lime and silica just as the waters of the mountain streams do and in only slightly greater quantities. This is not true of the brown waters, for they carry almost nothing besides the sodic carbonate and they carry a great deal of this salt. The mill well at Mosca, for instance, carries $1\frac{1}{2}$ pounds of sodic carbonate in every 1,000 pounds of water and only 1-10 of a pound of all other solids taken together. A barrel of this water weighs a trifle over 300 pounds and this well will furnish a great many barrels in an hour.

A few results stated in parts to the million will serve to show how generally and abundantly this salt occurs in these brown artesian waters.

SODIC CARBONATE IN SOME ARTESIAN WATERS

| | Parts Per Million |
|--|-------------------|
| Rio Grande water..... | 14.1 |
| Bucher Well, 923 feet deep Alamosa..... | 68.0 |
| Well near McGinty, shallow..... | 371.0 |
| Well north of McGinty, deep..... | 1229.0 |
| Well at Mosca, shallow, 1st flow..... | 318.0 |
| Well at Mosca, 780 feet deep..... | 1388.0 |
| Well between Hooper and Center, 375 feet deep..... | 79.2 |
| Well between Hooper and Center, 739 feet deep..... | 477.0 |
| Well at Hooper, 1st flow..... | 371.0 |
| Well at Hooper, 780 feet deep..... | 1446.9 |
| Well near McGinty, 15 feet deep..... | 236.0 |
| Sylvester drainage ditch..... | 228.0 |

The water of the Gibson drainage ditch is not rich in total solids and carries but little sodic carbonate. Alkali from a claim, Harper I think was the claimant's name, was rich in sodic carbonate, as was also an incrustation taken from near the ditch.

These data are enough to show how rich these brown waters and all others in this section are in sodic carbonate compared with the Rio Grande water or with the deep artesian water at Alamosa.

Brown Water Kills Vegetation Because It Contains "Black Alkali"

These results show that even the drain-water and that of shallow wells is rich in sodic carbonate. This sodic carbonate does not make the water unpleasant to drink, on the contrary, waters carrying only a moderate amount of it are pleasant waters; for instance, the waters from the first flow at either Mosca or Hooper which carry less than 400 parts per million are agreeable, though they taste slightly of sulfur. The water from the 15-foot well near McGinty is very pleasant to drink, though it carries 236 parts of sodic carbonate to the million. It is a very different matter when these waters are applied to the surface of the ground or to crops and allowed to evaporate to dryness or the solution to become concentrated. When this happens, the crops will not grow and the land becomes hard and difficult to handle. Such land does not necessarily show any other signs of its bad condition. This is the explanation for the fact that this brown water is not good for irrigating purposes. This is the reason for its killing vegetation.

I saw a meadow north of Blanca, and about east of McGinty, to which some of this brown water had been applied. The vegetation had been killed, whether it was blue-stem or sedges. The

water was not good for it. This explains, too, the statements made to me by a party who had taken up a desert claim, that, "the more water I used, the worse I was off". He claimed to have raised good crops the first year or so, but that subsequently he could raise nothing. I gathered two samples of alkali at this man's place and found that one of them carried 40 percent and the other 15 percent of sodic carbonate, or "black alkali". This man had come to the conclusion that he could raise nothing on this land. He hoped only to use it for grazing purposes. His judgment was good, for it was based on experience; he had tried to grow grain and alfalfa and they would not grow. The land contained enough sodic carbonate to kill these plants. Some of the artesian water that he obtained on this place was good for domestic purposes.

The presence of sodic carbonate explains the experience of another man who stated that water flowing from a well had spread out over a strip of ground and continued to do so for several months, and after this nothing would grow on this land. This took place several years ago and the land has not yet recovered.

The brown artesian water is bad and the testimony of users of water in the valley is that they prefer river-water to artesian for irrigating their crops. The brown artesian waters have not been used for irrigating but they, as well as the water from the shallow well and that from the drainage ditch, show that this "black alkali" is in the soil and, more than this, that it is in all of this section of the valley down to a depth of 780 feet at least. The greater the depth from which the water comes the richer it is in "black alkali". (See preceding analyses.)

SUB-IRRIGATION, EVEN WITH RIVER-WATER, BRINGS "BLACK ALKALI" TO THE SURFACE BY CAPILLARITY AND EVAPORATION

The system of irrigation generally practiced is sub-irrigation, in which the water-plane is brought within a few inches of the surface, from 22 to 12 inches. River-water is used for this purpose but it effects the bringing of this "black alkali" to the surface by capillarity and evaporation. The fact that it is possible to maintain the level of the water so near the surface shows that for some reason or other the water does not run down through the soil to any great depth, but is held near the surface, either because the lower part of the soil is so full of water that the irrigating water applied simply lies on top of the previous water-table, or that the lower portion of the soil won't let the water run through. The fact is that, in this portion of the valley, the water-plane is generally high; I found it 36 or 37 inches below the surface, but it can be

found at a less depth in other places. This ground-water carries about 260 parts of "black alkali" to the million parts of water. It mixes with the river-water added in sub-irrigating the land and brings the "black alkali" with it. This went on for a number of years till the land became so rich in "black alkali" that crops were no longer successfully raised and this is the condition today throughout this section of some 400,000 or 500,000 acres. Most of the people of the valley still think that sub-irrigation is a good system. A few are convinced that it is not.

CONDITIONS CAN BE CORRECTED

The important questions for the valley are, Can this condition be corrected? and, Is it feasible to correct it?

I answer "Yes" to both questions, but there are difficulties in the way.

The conditions are very bad. There is no hope of removing, in any way, the great reserve supply of sodic carbonate as indicated by the richness of the artesian waters in this "black alkali". This section of the valley is full of this water, and the deeper we go the richer is the water in "black alkali". The more of this water we bring to the surface or allow to leak into the upper strata out of uncased wells, the worse we are off. No man can tell how long it has taken to bring about these conditions, but they have already existed from the very early history of the valley and, so far as we are concerned, they are as permanent as the mountains inclosing the valley. The water has probably never run out of this section of the valley and the deep artesian waters never will, if we measure time in terms of human lives.

We do not care how these conditions have come into existence, the question is, To what extent can we modify them? Can we modify the surface portion of this land so that we can raise crops?

GYP SUM WILL CONVERT "BLACK ALKALI" INTO HARMLESS "WHITE ALKALI"

It is well known that gypsum, sulfate of lime, will convert this "black alkali" into "white alkali", which is so good as harmless compared with the black. By the application of this gypsum we can mitigate the evil, but this will be a difficult problem if we continue the practice of sub-irrigation which brings the "black alkali" up; it will be necessary to change the system and wash the "black alkali" with the gypsum down. The people have found out that, at the present time, about the only thing they can do to make any headway against the present conditions is to dike and flood the land. There is usually space enough between the permanent water-plane and the surface to permit them to better the

conditions in this way by carrying the "black alkali" into the deeper portions of the land, but they do not destroy it or even permanently remove it. The addition of a sufficient amount of gypsum, theoretically, $1\frac{3}{4}$ pounds for every pound of "black alkali" in the soil, practically about 9 pounds of gypsum to one of "black alkali", will change it into "white alkali" and then the land will not get hard for 4 inches on the surface and the crops will grow again. The application of the water must be to the surface by means of furrows or by flooding.

A very important consideration is, How can the gypsum be obtained? It would have to be brought in, as this mineral does not occur in the valley. At the present time, freight rates are prohibitive. The net cost to me of 6 tons of ground gypsum at Portland was \$24.00, the freight to Center was \$48.00. The cost of this gypsum was too high and the freight was much worse.

While gypsum does not occur in the valley, it is usually very abundant between the first line of hogbacks, the Dakota sandstones, and the east flank of the Front Range. It usually outcrops and its quarrying is easy. The quarrying, transportation and grinding ought to be a community matter if this section of the valley is to be reclaimed. These things must be done on small profits.

Some drainage is necessary to reclaim portions of this land, but how much benefit is to be expected from large systems, aiming to drain the whole section is an open question.

