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Subsoiling

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U. S.
EXPERIMENT STATION,
SOUTH DAKOTA.

IN CONNECTION WITH THE

SOUTH DAKOTA AGRICULTURAL COLLEGE.

SUBSOILING.

Departments of Horticulture and Agriculture.

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Subsoiling.

N. E. HANSEN.

In the past few years the question of irrigation has become a very important one in many parts of the West. By means of irrigation many thousands of acres of land have been brought under profitable cultivation, and the work has but barely commenced. Many sections of the West, however, have no available water supply, nor do they need irrigation every year. In other words, the climate is too moist for profitable irrigation every year, and yet crops often suffer from lack of sufficient rains when maturing. Hence, many farmers have felt the need of some method of increasing the drouth-resisting capacity of land, short of actual irrigation.

Subsoiling, by which is meant the stirring of the subsoil without bringing it to the surface, has been much discussed in this connection as being the best method of retaining moisture in the soil. Hence, subsoiling is now being thoroughly tested in many parts of Kansas and Nebraska. The general experience so far is rather favorable, yet further experience is needed. The question is a complicated one and several seasons are needed to determine the ultimate value of the method. The main question to determine is whether the increased yield will pay for the cost of subsoiling. Soils with a very hard subsoil are most benefitted, while soils with loose or gravelly subsoil are generally not benefitted by subsoiling, but, on the contrary, are sometimes injured. Subsoiling makes the soil very loose, and if not followed by rain sufficient to settle the soil before planting, a lessened yield generally results the first season. This is why subsoiling in the fall is regarded with the most favor, because the rain and snow firm the soil before planting time. In other words, subsoiling deepens the reservoir, but moisture is needed to fill it and to restore the capillarity between the stirred soil and the firm earth beneath, so that if

subsoiling is followed by a very dry winter, no benefit will be apparent, but rather the contrary.

Inventors of farm machinery are now earnestly called upon to devise some plow that will surface plow and subsoil in one operation. Where an ordinary plow must go ahead of the subsoil plow, it materially increases the expense of the work. Last year the Deere "Secretary" plow appeared and is now under trial in the Agricultural Department of this Station.

Some experimenters hold the opinion that it is best not to subsoil too deep the first year, but rather to loosen the subsoil two or three inches at a time until the full limit of the plow is reached. The "Secretary" plow is well adapted to this method.

In order to give the reader an idea of the recent extended discussion about subsoiling in the western states, it has been deemed best to bring together for convenient reference some extracts from published reports and from a few letters received in reply to inquiries. The extracts will serve to show that the subject of subsoiling is attracting considerable attention. Following these extracts from reports of experience in various parts of the West will be given the report of Professor E. A. Burnett on an experiment in subsoiling for various farm crops, and next the report by the writer on subsoiling for various garden crops. The past season was not a favorable one for testing subsoiling. The heavy rains of March and April settled the ground firmly, which favored the subsoiled plats. On the other hand, the abundant rains during the summer favored the surface plowed plats. Hence it was not a good season for testing the drouth-resisting capacity of the two series of plats.

It is plainly evident that there are some unsolved problems connected with subsoiling, and we are not prepared, with the present light on the subject, to make many definite statements. It is doubtless true that the broken capillarity between the stirred soil and the unstirred soil beneath must be restored before planting time. The method is evidently worthy of trial in many sections of the West, but each region must determine for itself the final value of subsoiling. The reports show that conflicting results have been obtained, but that the general experience is favorable where the operation has been properly conducted.

REPORTS ON SUBSOILING.

NEBRASKA AND KANSAS EXPERIENCE.

In Bulletin No. 43 of the Nebraska Agricultural Experiment Station on "The Conservation of Soil Moisture by means of Subsoil Plowing" (Sept. 5, 1895), Professor T. L. Lyon reports as follows:

"The ordinary methods of soil preparation and cultivation have, during the past two years, proved inadequate to bring the soil into a condition capable of retaining, through a prolonged dry spell, the moisture it received by precipitation. Experiments have shown that subsoil plowing, especially if done in the fall, and a thorough cultivation of the land during the growing season will do much towards conserving the soil moisture, thus enabling the crops grown thereon to withstand a drouth much better than those grown on land treated in the ordinary way.

"The good results of subsoiling on the Experiment Station farm have been very marked. No experiment was planned for testing the effect of subsoil plowing, but on land that had previously been subsoiled for sugar beets, and this year planted to corn, the effect of subsoiling was so strongly marked as to attract the attention of all who saw it. The subsoiled and surface plowed portions of land on which the corn is growing are in the same field on the east side of the farm. It is upland soil, with a gradual slope towards the east. In composition it is a fine loam with considerable organic matter. In the fall of 1891 a portion of this field was subsoil plowed for sugar beets, and this crop was raised the following year. It was not again subsoiled, but plowed in the same manner as was the remainder of the field. It is a very noteworthy fact that the position of this subsoiled land can now be determined almost to a row by the superiority of the corn growing on it. The stalks on the land not subsoiled are small, badly dried up, and have not made any grain, while those on the subsoiled land are of good size, having a fresh, green appearance, and will give a fair yield of grain. This, it must be remembered, is the effect in 1895 of subsoil plowing in the fall of 1891."

The four full page cuts, reproduced from photographs, show the very marked difference in the height of the corn in favor of the subsoiled corn.

Prof. Lyon writes further:

"Such results are encouraging in the extreme. They show that with very little extra expense crops can be raised with much less rainfall than is generally supposed. The subsoil plowing can be done with three horses, and does not require much more time than surface plowing. The subsoiler should

follow in the furrow of the surface plow. The operation doubles the expense of plowing, but as has been shown, its beneficial effects continue for several years. Probably once in three years would be often enough to subsoil, but that has not yet been determined definitely."

Prof. Lyon's bulletin closes with the following:

SUGGESTIONS.

"Subsoil plowing, although a means of conserving moisture, does not produce it, and is, therefore, not a substitute for irrigation where the rainfall is too small to produce crops.

"Where there is a hard, dry subsoil, subsoil plowing is to be recommended.

"Where the subsoil is loose, gravelly, or sandy, subsoiling is probably unnecessary, or may even be injurious.

"Do not subsoil when the soil is very wet, either above or beneath, as there is great danger of puddling the soil, thus leaving it in worse condition than before. This is one of the reasons why it is better to subsoil in the fall than in the spring.

"If the ground be subsoiled in the fall the winter and spring rains have ample opportunity to soak in, that being the season of greatest rainfall and least evaporation.

"Subsoiling in the spring may be a positive detriment if the subsoil be extremely dry, as in that case the rainwater is partially removed from the young plant by the absorption of the bottom soil. If the spring rains were heavy this would not be a disadvantage.

"The effect of subsoiling land having a "gumbo" subsoil has not been ascertained, but if done at the proper time it would doubtless be beneficial. The "gumbo" subsoil, to a greater extent than any other found in this state, prevents the moisture from penetrating deeply into the soil, and as a consequence such lands are the first to suffer during a drouth. If the "gumbo" could be loosened it would obviate this to a great extent.

"Understand the nature and condition of the subsoil on your farm before subsoiling."

Scott Kelsey, of Topeka, Kansas, reports as follows:*

"I am well satisfied from my six years experience here that subsoiling is profitable on my farm, and in the Kaw valley. I also find that the good effects of subsoiling last about three years. I have, therefore, decided to subsoil, if possible, one-third of my farm each season. I run the surface plow eight inches deep and follow with the subsoiler, loosening it 8 to 12 inches deeper. This puts it in condition to readily receive all the water that falls during a heavy shower, and the surplus readily finds its way into the soil below the plowing, to be stored there

*Kansas State Board of Agriculture, Ninth Biennial Report, 1893-94, page 380.

for use of the growing crops in the dry weather and while the grain is maturing.

"I prefer subsoiling in the fall and early winter, as I have more time then. I get more out of the winter rains and snows, and I believe the soil is in better condition for spring planting. Where subsoiling is done in the spring, it needs good rains following to produce best results for that season.

"I am a strong believer in subsoiling, in deep plowing, in thorough cultivation, and in keeping the soil pulverized to the greatest depth possible, having found by experience that it pays."

Many reports of experience with subsoiling appear in the Tenth Biennial Report of the Kansas State Board of Agriculture, 1895-96.

H. R. Hilton, of Topeka, on pages 5-11, gives the results of his investigation of "Corn Roots and their Relation to the Soil." The article contains five cuts, showing comparative growth of corn roots in subsoiled and surface-plowed land. The roots on subsoiled land show much greater development.

"Figure 2 shows the root of a corn plant uncovered in 1895 on Scott Kelsey's farm, in the Kaw valley, just east of Topeka, grown in the track of a tree digger that, in taking up nursery stock in the fall of 1894, had pulverized the soil 18 inches deep and 20 inches wide. The track of the tree digger in its width and depth was a mass of fibrous roots. In the zone between the tree digger furrows, where the ground was hard, there were few fibrous roots, and a limited number of large smooth roots. This field yielded 84 bushels per acre in the season of 1895. The subsoil roots were followed 4½ feet down, but the ends were not found. By way of contrast see figure 3, on upland, four miles north of Topeka, never plowed over six inches deep. All the fibrous roots (food gatherers) were found in the lower two inches of the cultivated soil. A cultivator tooth running four inches deep would leave only two inches in depth of cultivated soil for the food gatherers to work in between the rows—entirely too limited an area to secure good results. The root development was small, and only two joints were covered sufficiently to send down subsoil roots. The yield was under 40 bushels per acre.

"Figure 4 shows root development on upland, on the farm of J. B. McAfee, 2½ miles west of Topeka, subsoiled 20 inches deep in the spring of 1895. This shows a large root development, and the yield was one-third greater than on adjoining field not subsoiled, with roots as shown in fig. 5."

On page 20 of the same report (the quarter ending March 31, 1896) Messrs. Youngers & Co., of Geneva, Fillmore county,

Nebraska, nurserymen, report on their extended experience with subsoiling. Mr. Peter Youngers, Jr., writes:

"We have practiced subsoiling on high prairie for the past nine years and the results have been most satisfactory, yet we learn that we can improve upon the methods of the past. We find it very essential to have the ground well firmed or packed after subsoiling, as the subsoil plow necessarily leaves many large crevices, which will cause it to dry out very rapidly in the spring if left in that condition. This packing process may be accomplished either by natural or mechanical means; that is, the subsoiling may be done early in the fall, which will give the ground ample time to settle before planting in the spring, or, if subsoiled in the spring, it may be packed by using a disk harrow heavily weighted, followed by a common smoothing harrow. In order to collect data on this subject to verify or disprove our own conclusions, we recently sent out a list of questions to 120 parties in Nebraska and Kansas who have been subsoiling. Answers have been received from 47, representing a total acreage subsoiled of 2,074 acres. Of these replies, 32 are favorable to subsoiling, 5 unfavorable, and 10 report no benefit derived. Those reporting unfavoraby, or no benefit, almost without exception subsoiled late in the spring and did not have a sufficient rainfall after to thoroughly saturate the ground loosened up. Most of these attribute their lack of success to the time at which the work was done, and say they expect much better results from the same land next year."

Mr. Youngers here quotes a number of reports, both favorable and unfavorable, from various parts of the State, and continues:

"The above are characteristic replies, and corroborate our own views on this subject exactly, viz: That where the work is done in the fall or very early in the spring, or where sufficient moisture falls to thoroughly wet the ground loosened before the growing season commences, the results will be all that could be desired; otherwise subsoiling will prove a failure the first year. The past season (1895) we met with another almost total failure of crops, yet the subsoiled ground produced corn enough to feed us through the year, while all of our corn on land not subsoiled was cut for fodder only. We noticed a very marked difference in the time of germination of the corn on land subsoiled and that on land not subsoiled. We finished planting a subsoiled field containing 20 acres on the afternoon of May 13; on the morning of May 14 we commenced planting a field of eight acres not subsoiled. The same seed was used, the same planter, the depth of planting was the same, and yet the corn on the subsoiled ground was large enough to cultivate fully one week before that on land not subsoiled. The plants started off with more vigor and the difference continued in favor of the subsoiled field throughout the season. This can readily be accounted for when we consider the fact that corn roots have been traced to the depth of six feet, and frequently have a spread of five or six feet a few inches below the surface, and with the subsoil loosened

up to the depth of 16 to 20 inches it is but reasonable to suppose that the roots will penetrate the soil more readily, and thus enable the plant to make a more vigorous growth. This supposition is borne out by the facts in the case.

"The potato crop was also a failure in our neighborhood the past season; yet our potatoes on subsoiled land yielded 130 bushels per acre, and as we realized 40 and 50 cents per bushel for our entire crop, we consider ourselves amply repaid for the extra labor put upon the preparation of the ground. Prof. Milton Whitney, chief of the division of agricultural soils, department of agriculture, while in Nebraska in the fall of 1894, visited our grounds for the purpose of obtaining samples of soil and subsoil for analysis. The analyses show the soil and subsoil to be composed very largely of silt, which renders it very refractory and much improved by deep plowing. They also show the soil to be very rich in plant food, containing one-half of 1 per cent. of potash, and the subsoil a fraction more than that. Through arrangement with Professor Whitney, we sent three samples of soil to the department daily during the summer of 1895 from May 2 to September 13, for the purpose of determining the moisture contained in the soil under various conditions. These samples were taken in brass tubes 16 inches long and three-fourths of an inch in diameter, which were driven into the ground to the depth of 12 inches, then taken up, tightly sealed, and forwarded to Washington. There each sample was carefully weighed, and, after all the moisture had been taken out, weighed again, the difference in weight giving the exact quantity of moisture in each. Sample No. 1 was taken from prairie sod, No. 2 from land plowed in the ordinary manner eight inches deep, and No. 3 from land subsoiled 16 inches deep in the fall of 1894. The average percentage of moisture in each sample for each month of the summer is shown by the following table:

Month.	No. 1.	No. 2.	No. 3.
May	12.41	14.09	16.41
June	15.80	16.10	20.41
July	14.46	12.98	17.45
August	11.29	11.19	17.24
September (First 13 days)	10.82	12.35	14.37

"Using ordinary plowed land as a basis, this gives an increased percentage of the moisture in the subsoiled land for the several months as follows: May, 16.18 per cent.; June, 26.77 per cent.; July, 34.43 per cent.; August, 54.06 per cent.; being for the month of August more than half as much again moisture in the subsoiled ground as in that not subsoiled.

"I do not wish to convey the idea that all that is necessary in order to raise a large crop every year is to subsoil to the depth of 16 or 18 inches; but by subsoiling we loosen up the hard ground so it can be penetrated by the air and water, thus rendering available a vast amount of plant food, which would otherwise be lost."

In the Ninth Biennial Report, page 382, Mr. Peter Youngers, Jr., reports as follows, which includes observations to the close of 1894:

"Several years ago our nursery firm observed that whenever we planted grain, corn or potatoes following a crop of trees, we invariably had much better results than where ordinary plowing and cultivation had been followed. This led us to experiment on field as well as nursery crops, and we find that the same deep plowing and thorough preparation of the soil for field crops will pay as well as for any other high-priced crop. The main expense is in the subsoiling. This, in fact, is only an extra plowing. We prepare the soil by first plowing eight inches deep with an ordinary stirring plow, which is followed by the subsoil plow, stirring the soil eight inches below this. The subsoil plow does not throw the soil to the surface, but merely loosens it in the bottom of the furrow. We use three horses on each plow.

"By this method of plowing we have a bed of 16 inches of mellow soil ready to act as a reservoir to hold any surplus moisture that falls during the season. About August 15, 1894, when the earth was so dry on the ordinary plowed land, the subsoiled land retained moisture enough to ball in the hand under slight pressure, and three weeks after the hot winds had destroyed the surrounding cornfields, the field that was subsoiled stood uninjured—scarcely any of the tassels killed. This field was planted entirely too thick to obtain good results. Wherever a hill was not crowded the stalks had well-developed and well matured ears, though the continued dry weather caused a failure of the corn crop on account of thick planting, some hills having as many as seven stalks. This thick planting was caused by an error in not changing the plate in the planter after being used to drill corn for fodder.

"But the results in other crops fully satisfy us that subsoiling is no longer an experiment. For instance, rye land subsoiled yielded 30½ bushels per acre; land not subsoiled, 2½ bushels. One field of 20 acres was planted to oats. Part of this had raised two crops of corn since subsoiling, the oats being the third crop, and the yield was 39¼ bushels per acre. Another portion of the field has raised but one crop of corn since subsoiling, the oats being the second crop, and the yield was 44⅓ bushels per acre, while oats in an adjoining field, not subsoiled, yielded 17 bushels per acre. Potatoes planted in May yielded 96 bushels per acre of good, average size.

"Last year, 1893, on subsoiled land, a yield of 75 bushels of corn per acre was obtained; on land not subsoiled the yield was 36 bushels per acre.

"The land on which the experiments were conducted is high prairie, our well being 114 feet deep."

H. R. Hilton writes on page 24, same report:

"WHAT SUBSOILING IS.—A plow is an implement used to completely overturn or invert the furrow slice it cuts out, bringing the under part of the soil slice to the surface and placing the top soil at the bottom

of the furrow. A subsoiler has been unfortunately misnamed a subsoil plow, giving the impression that in its operation the surface soil is buried 12 to 18 inches below the surface and the subsoil from a corresponding depth brought to the surface—in other words, that subsoiling is very deep plowing. The subsoiler, whether run 10 or 20 inches deep, does not invert or disturb the relative position of the surface and subsoils. Its operation resembles harrowing more than plowing; it is in effect a one-tooth harrow mounted on a plow frame, its long tine with forward curve loosening the soil to a depth of 15 to 20 inches, just as the ordinary harrow tooth loosens it two or three inches.

"THE OBJECT OF SUBSOILING.—When the subsoil is hard or compacted so that water percolates through it more slowly than through the surface soil, and especially when the rate of drainage is less than two inches of water per hour, subsoiling becomes necessary to loosen the compact substratum and relieve the surface soil of its surface water during a heavy rain. This accomplishes two desirable objects. By preventing supersaturation of the surface soil surface washing and baking are prevented, and by draining the water to a lower level in the soil a larger percentage is secure against evaporation immediately after the shower and preserved for the service of the plant.

"When the subsoil is porous and the surface soil very fine, subsoiling has been made beneficial by sifting some of the fine surface soil into the subsoil, thus reducing the size of the spaces between the soil grains and increasing the amount of surface in the substratum reached by the subsoiler. The end desired is, to make the fine top soil more porous and the coarser or jointed subsoil less porous; the means, a subsoiler operated when the top soil is dry.

IOWA EXPERIENCE.

Prof. J. L. Budd, of the State Agricultural College, Ames, Iowa, writes:*

"Our ordinary prairie and bluff soil, as plowed year after year to a depth of four or five inches, becomes impacted just below the shallow, mellow surface by the treading of the horses in the furrow and the pressure of the plow in rolling the furrows until it becomes almost as impervious as hardpan. Subsoiling to a depth of from 12 to 15 inches gives a deep seed bed, that holds moisture even during such a trying season as the past one. During the past 25 years we have practiced a method of subsoiling in garden, potato field and nursery which has given remarkable results with little increased cost. We subsoil deeply under the rows only, just prior to planting. With this plan, the summer rains run under the rows, and, if the fall is considerable, it percolates from the softened trenches under the intervening spaces and softens the whole surface. As an instance, in planting potatoes in garden or field, we mark out the rows with the subsoil lifter, running it under each row to a depth of from 12 to 15 inches. On this deep,

*Kansas State Board of Agriculture, Ninth Biennial Report, 1893-94, page 385.

mellow seed bed the seed is dropped, and pressed down by stepping on the pieces. The pressure of the foot sinks the seed down in the mellow furrow four or five inches, permitting perfect covering with a harrow. Over these trenches we have grown 300 bushels per acre, when on untrenched soil the yield was less than 100 bushels. But the gain is not so apparent in very wet seasons. In the nursery, we run the subsoil lifter under every row. The rows for setting grafts of cherry, plum and pear, we mellow up to a depth of 15 inches by running two or three times in each row. During the past dry summer, all visitors have been surprised at the growthy expression and perfect health of our nursery trees standing over these deeply mellowed trenches."

One of these subsoil lifters, made according to Professor Budd's directions, has been used with excellent results for several years on the horticultural grounds of this Station. From experience and observations at Ames and Brookings, the writer regards it as a very valuable implement for nursery and garden work. The implement is not patented and is not as yet manufactured in a commercial way. It illustrates in a marked way the benefit of stirring the soil deeply previous to planting root-grafts, seedling stocks for budding and grafting, shrubs, trees, etc. After planting the soil is always firmed by tramping to restore capillarity.

MINNESOTA EXPERIENCE.

Prof. Willet M. Hays, of the Minnesota Experiment Station, reports* the following results on subsoiling in the spring of 1895 for wheat and oats on the Coteau sub-station farm at Lynd, Lyon county, Minnesota, about 40 miles east of Brookings, South Dakota. All the land was plowed 5½ inches deep; in addition to this, the subsoiled plats were subsoiled 6 inches deeper.

Wheat sown with press drill produced 18.9 bushels per acre on subsoiled land, and 23.1 bushels per acre on land not subsoiled. Sown with chain drill the yields were 20.4 bushels on subsoiled land and 21.1 bushels on land not subsoiled. Sown broadcast the yields were 18 bushels on subsoiled land, and 17.1 bushels on land not subsoiled. The average yields were 19.1 bushels per acre on subsoiled land, and 20.4 bushels per acre on land not subsoiled.

The yields of oats were 33.3 bushels per acre on subsoiled land, and 42.8 bushels per acre on land not subsoiled.

*Minn. Agr. Exper. Station, Bulletin No. 46, page 386, Dec., 1895.

AT FARM NEAR MORGAN, MINN., Feb 8, 1897.

PROF. N. E. HANSEN,

Brookings, South Dakota,

DEAR SIR:—Yours of 29th ult. I found awaiting my return yesterday.

In the fall of 1895 I subsoiled about one hundred acres of land which had been cultivated about twenty years; first going with common plow to depth of about six inches, then following in same furrow with a Deere "Iron King" subsoiler, which stirred the soil to the depth of some ten or twelve inches below bottom of first furrow. The land was of the common prairie loam, with a brownish colored subsoil at a depth of ten to sixteen inches from the surface. The subsoiler brought some of this to the surface, and a good deal of it to within two to four inches of surface. The land was planted to corn. The season up to about July 1st had an abundance of rain, and so no results, so far, could be determined. July and August was dry, and about Aug. 1st my corn and that of my neighbors commenced to suffer for want of moisture, but that on the subsoiled land remained green and vigorous, showing no signs of thirst, and so continued until it was cut up from the 5th to the 10th of September.

The subsoiled land, however, appears to be colder [later? N. E. H.], and the corn was from a week to ten days behind that not subsoiled.

My conclusions are these:

1st. That subsoiled land holds and furnishes more moisture to the plants than that not subsoiled.

2nd. That subsoiled land is at first colder [later, N. E. H.] than that not subsoiled.

3rd. That I believe that upon land having a compact subsoil it will be profitable to subsoil.

Yours respectfully,

C. D. GILFILLAN.

SOUTH DAKOTA EXPERIENCE.

MANCHESTER, KINGSBURY CO., S. D., Feb. 8th, 1897.

PROF. E. A. BURNETT,

Brookings, South Dakota,

DEAR SIR:—Your favor of January 29th relative to subsoiling is at hand. In reply would say:

In the fall of 1895 I used a subsoil plow on a few acres of ground part of which had previously been fall plowed. I ran my subsoil furrows about 14 inches apart, and from 12 to 18 inches deep.

A part of this ground was planted to corn, part to potatoes, part sown to wheat, and part to millet. I gave it a thorough cultivation and in connection with some of my neighbors watched the outcome with a great deal of interest. But when harvest came the closest observer could not detect a particle of difference in the crop on ground that was subsoiled and that which was merely fall plowed with a gang

plow and about 6 or 7 inches deep. Straw on subsoiled ground was no longer, heads were no longer and no better filled, and so far I fail to see any benefit from my extra work, but I feel that the theory is correct and we may find an improvement in the succeeding crop.

I think perhaps if we should have dry seasons again we could see an improvement on subsoiled ground, but when ground is thoroughly wet, as it was last season, I think it labor wasted to subsoil.

I am very truly yours,

A. M. ASPINWALL.

CLARK, CLARK CO., SOUTH DAKOTA, Jan. 6th, '97.

PROF. E. A. BURNETT,

Brookings, South Dakota.

DEAR SIR:—Your favor 3rd inst. at hand asking for my experience in subsoiling. In the fall of 1895 I subsoiled about 80 acres, using the Perrine subsoiler and running it to a depth of 15 to 18 inches and making the furrows or trenches about two feet apart. It took four good horses to do it.

This method of subsoiling, without going ahead with another plow, has only been practiced a few years and has many advantages over the old system of following in the furrow of a common plow, the principal one being that the wind cannot blow the dirt around. It breaks and loosens the ground nearly from one furrow to another and leaves it in fine shape to take in moisture. It seems to raise the whole surface of the ground from three to five inches, and the loosening up and tearing to pieces which one of these plows with four big horses hitched to it will accomplish must be seen to be appreciated. I think this work should be done in the fall so the ground can settle some before being seeded. The good results of subsoiling like this must last for several years. Last season was a poor year for a trial test as there was plenty of moisture during the growing season.

Thirty acres was sowed to rye in the spring, using a spring tooth cultivator, which worked admirably, as the stubble was light. In heavy stubble it might clog badly. Thirty acres was planted to corn after cultivating with a spring tooth.

The winter beginning so early, I did not get threshing or corn husking done, so I am not able to give the yield, but am sure they were the very best crops of rye and corn I have ever raised here. A narrow strip through a wheat field was a considerable better than at either side. I raised about fifteen acres of potatoes, part of which was subsoiled and part was not. This was a good test, and I think the subsoiled ground yielded about one-third more, of better quality and more even size. Before this I have always considered it necessary to use four horses on the potato digger, but when the subsoiling was reached we found two horses could do it with ease. When it came to fall plow-

ing the advantages were very evident, as the plow could be run any depth.

I feel sure that great and permanent good will result from this system of subsoiling and an intelligent surface cultivation, and that many good crops might be raised during some of our dry seasons that would be a failure within the ordinary methods of farming.

Yours, &c.,

H. C. BOCKOVEN.

CLARK, SOUTH DAKOTA, May 26, 1897.

DEAR SIR:—I regret I am not able to give more reliable information in regard to my subsoiling experiments. I raised corn and rye on my subsoiling last season and they were the best crops I ever raised here. Corn was fed mostly from the shock, and the rye is not yet threshed. I did not raise any corn or rye on surface plowed land and so cannot make a comparison. My potatoes were part on surface plowed land and part on subsoiling. We estimated the crop was at least one-third better on subsoiling.

Yours, &c.,

H. C. BOCKOVEN.

SUBSOILING.

E. C. CHILCOTT.

Experiments in subsoiling are now under way on the Station farm. It is the intention of this department to make a thorough test, not only of the effect of subsoiling, to various depths and at different times of year—both spring and fall—upon the crop production for the ensuing year, but also to determine by accurate laboratory tests the percentage of moisture in the soils thus variously treated, for each week during the growing season. In this way it is believed that some valuable information can be obtained concerning the effects of subsoiling. Several experiments, depending for results upon crop yields alone, have been carried on during the last four years, but the results have been so indefinite and conflicting as to throw but little light upon the subject. With our present limited knowledge on this subject we can do but little more than to theorize.

Simply as a theory, based upon the above mentioned experiments, and from general observations and experience during fifteen years residence in this state, I offer the following:

1st. Unless the disturbed soil becomes thoroughly saturated with water after the subsoiling is done and before the crop is sown, the effects of subsoiling are almost certain to be injurious. Subsoiling should therefore be done in the fall, if at all, and to not too great a depth.

2nd. Subsoiling to the depth of from 12 to 20 inches in the drier portions of our State, where the precipitation during the winter is often insufficient to saturate the soil to that depth, is likely to be injurious to the crop-producing powers of the soil for one or two years after subsoiling.

3rd. The use of some plow having a subsoiling attachment, such for instance as the John Deere "Secretary" plow, whereby three or four inches of subsoiling can be done each year, gradually increasing until the desired depth is reached, is likely to be safer and more efficient than the ordinary subsoil plow, which will not "hold to the ground" unless run to a depth of from 12 to 20 inches.

4th. Go slow.

SUBSOILING FOR FARM CROPS.

EDGAR A. BURNETT.

In the spring of 1896, through the courtesy of Prof. N. E. Hansen, certain plats of land on the horticultural grounds came under my supervision to test the value of subsoiling for ordinary farm crops, as against fall plowed land not subsoiled, and treated by ordinary farm methods. The land selected was divided into strips lying adjacent to each other and as nearly alike in texture and composition as it was possible to secure. Early in November, 1895, one half was plowed and subsoiled in the bottom of the furrow to the depth of eighteen or twenty inches. The other half was plowed, at the same time, eight inches deep and left rough in the furrow. No manure was used. The plats were cultivated and otherwise treated exactly alike throughout the season of 1896.

The abundant rains during the early part of the growing season furnished an excess of moisture. During April, May and June 11.78 inches of water fell at the College. Up to the middle of June the question of drainage was of greater importance than that of conservation of moisture. These heavy rains firmed and saturated the soil of the subsoiled plats and put it in excellent condition to produce a crop, but they also filled the soil of the unsubsoiled ground so full of water that no severe effect of drouth was noticed at any time. The crop on the subsoiled land was ranker and heavier than on the unsubsoiled land, owing, as I believe, to a greater extension of root surface and a consequent increased feeding ground which, during the hot, dry weather of August enabled the corn more effectually to withstand these conditions.

The wheat and the oats sown on the subsoiled plats withstood the hot winds of May 5th and 6th with less injury than the unsubsoiled plats, but during the hot, sultry weather of June the grain on the subsoiled plats was the first to lodge. Both plats suffered equally from rust, which finally destroyed them.

POTATO EXPERIMENT.—On May 9th, '96, two plats of ground, each one-tenth acre, were planted to potatoes, Saltzer's Lightning Express being used for the experiment. Plat 1 was subsoiled and Plat 2 was fall plowed. Each had been thoroughly

fitted. The Aspinwall planter was used in planting. The plats were harrowed once after planting and were then given level and shallow cultivation at intervals of one week after June 13. Cultivation stopped July 7, when the vines covered the ground where the stand was good. They were rankest and greenest on the subsoiled plat, but they also made a heavy growth on the other plat. About one-third of the seed had been killed by the heavy rains, or from other causes, but the percent of loss was nearly the same on each plat, being very slightly less on the unsubsoiled plat.

Each plat was dug Sept. 26, with the following yield:

	Yield in pounds.	Marketable lbs.	Small Pounds.	Per c. Marketable.
Plat 1, subsoiled	1,063	940	123	88
Plat 2, unsubsoiled	847	650	197	76

Increased yield on subsoiled land, 25 per cent.

Yield per acre, subsoiled, 177 bushels.

Yield per acre, unsubsoiled, 141 bushels.

CORN EXPERIMENT.—On May 21, '96, two plats, each one-tenth acre, were planted to Dakota dent corn. Plat 1 was subsoiled and Plat 2 was fall plowed only. The ground was thoroughly fitted and planted with a check rower 3 feet 8 inches apart each way. There was an average of three stalks in each hill with a good, even stand.

Each plat received shallow cultivation, beginning with a Breed's weeder June 14 and continuing with a Planet Jr. horse hoe at intervals of one week until July 14, when the corn was laid by, having received five cultivations.

On July 7 the corn on the subsoiled plat was taller and ranker than on the unsubsoiled. This difference continued to increase during July. On July 20th the corn on the subsoiled plat stood 6 feet 6 inches high on an average, while the corn on the unsubsoiled plat had an average height of 5 feet 3 inches. The subsoiled plat was nearly one week in advance of the other plat in tasseling, but both plats were fairly, though not fully matured on Sept. 5th, when they were cut, in anticipation of frost. They stood in the shock until husked on Sept. 26th. The stalks were weighed from the field and the corn stored and

dried before weighing. The following yields were obtained from the plats:

	lbs Stalks.	lbs Corn.	Pounds Matured.	lbs Soft.	Per Cent. Matured.
Plat 1, subsoiled	650	360	200	160	55
Plat 2, unsubsoiled	600	322	171	151	53

Increased yield of corn on subsoiled land, 11 per cent.
Increased yield of stalks on subsoiled land, 8 per cent.
The rainfall for the growing season was as follows:

March	2.84 in.
April	5.55 in.
May	3.45 in.
June	2.78 in.
July	2.00 in.
August	.44 in.
Total for 6 months	17.06 in.

SOME CONCLUSIONS.

1st. Owing to the abundance and distribution of moisture, none of the plats suffered greatly from drouth. I am convinced that the increased vigor and yield noticeable on the subsoiled plats was due to the loosening of the hard boulder clay subsoil, which permitted a freer development of roots and extended the feeding area of the crop. This loosening of the subsoil also increased the water-holding capacity of the soil, which was beneficial through August and permitted the roots to extend themselves into the deeper and moister soil where they would be less affected by hot and dry weather.

2nd. This experiment was too limited in extent to determine the exact benefit to be derived from subsoiling. This benefit must always depend on the character of the subsoil, the amount of moisture received after subsoiling, up to and during the growing season, and the kind of crop to be grown.

3rd. In this experiment, the yields of corn and potatoes were plainly in favor of the subsoiled plats.

SUBSOILING FOR GARDEN CROPS.

N. E. HANSEN.

In the fall of 1895 a tract of land, very uniform throughout in all respects, was selected on the horticultural grounds to test the value of subsoiling as compared with ordinary fall plowing. No manure was used. Early in November, 1895, one-half was plowed eight inches deep and left rough in the furrow. The other half was plowed eight inches deep, and immediately following the ordinary plow came the subsoiler, which deepened the furrow to the further depth of ten to twelve inches The land was thus stirred to the total depth of eighteen to twenty inches. The Deere "Iron King" subsoil plow, furnished to the Station by the courtesy of the John Deere Co., Moline, Ill., was used for the work. The land is a rich black loam, underlaid with a very hard boulder clay subsoil. The subsoiler encountered a number of large boulders in the course of the work, which had never been removed, as they were below the depth of ordinary plowing. The subsoiling work was found too hard for three heavy horses, so four horses were used. The "Iron King" stood up remarkably well under the very severe strain put upon it by the heavy boulders, but we do not regard subsoiling as at all practicable on any extended scale on land with a stony subsoil. As it was, the point of the plow was finally twisted slightly out of true, but this could not be regarded in any way as the fault of the implement, which has strength amply sufficient to withstand any legitimate strain put upon it.

In the spring of 1896 part of the land was planted to garden crops, and throughout the season the two series of plats received exactly the same treatment.

TOMATOES.

The tomato seed was sown in flats in the greenhouse March 16; the plants transplanted into thumb pots April 8; into 4-inch pots April 25; put in cold frame May 16; and set in the field May 29. The same cultivation was given the two plats throughout the season. Lots Nos. 98, 96, 99 and 97 were started in hotbed and transplanted direct into the field May 29. In the field all the plants were set four feet apart each way.

Several varieties were duplicated to serve as checks. It was both a variety test of early varieties, and a subsoiling test. As a variety test it will be noticed that the Early Ruby was the most productive, both on fall plowed and subsoiled land. On fall plowed land (No. 99) the yield in round numbers was at the rate of 491 bushels per acre; and on subsoiled land (No. 97) at the rate of 558 bushels per acre. This superiority of the Early Ruby is a general experience with cultivators in various parts of the state, even in the extreme northern part* and hence it will be a safe variety to plant for the main crop.

For first early the best is probably the Earliest of All, although it is too rough to hold the market when the smoother sorts come in. Hubbard's Early and Bond's Early Minnesota are also good, very early varieties.

The first requisite for a tomato in this section is earliness. None of the very large and late varieties are recommended.

The question of commercial tomato seed as compared with home-grown seed was also part of the experiment in the case of the Earliest of All, Dwarf Champion, Bond's Early Minnesota, Early Advance and Early Ruby. The results appear in the table of yields. There were ten groups; five on surface plowed and five on subsoiled land. On the surface plowed land four of the groups resulted in favor of the homegrown seed, and one in favor of the commercial seed. On the subsoiled land all five of the groups resulted in favor of the commercial seed. Hence no very definite deductions can be made. Nos. 6 and 78 give the yield of an early variety, the result of twelve years' selection in this State, as (in round numbers) 386 bushels per acre on surface plowed land, and 397 bushels per acre on subsoiled land.

Nos. 18 and 90 give the yield of a variety originated in South Dakota; in round numbers the yield was at the rate of 394 bushels per acre on surface plowed and 323 bushels on subsoiled land.

*Mr. Dudley Staats, of Milbank, S. D., has raised the Early Ruby with great success for the past eight or ten years.

DATES OF FIRST RIPE TOMATOES.

No.	Name.	Seedsman.	Surface plow'd.	No.	Sub-soiled.	Remarks.
1	Red Cherry	A. W. Livingston Sons	July 25	73	Aug. 8	14 days later on subsoiled.
2	Yellow Cherry	A. W. Livingston Sons	" 17	74	July 17	No difference.
4	Earliest of All	Gregory & Sons	" 17	76	" 25	8 days later on subsoiled.
5	Earliest of All	Homegrown	Aug. 8	77	Aug. 8	No difference.
6	Twelve years selection in South Dakota	Rev. T. H. Youngman	" 17	78	" 10	7 days earlier on subsoiled.
7	Hubbard's Early	Geo. W. P. Jerrard	" 15	79	" 8	7 " " " "
8	Bond's Early Minnesota	Homegrown	" 8	80	" 8	No difference.
10	Dwarf Champion	Homegrown	" 15	82	" 17	2 days later on subsoiled.
11	Dwarf Champion	A. W. Livingston Sons	" 8	83	" 17	9 " " " "
12	Early Advance	A. W. Livingston Sons	" 8	84	" 10	2 " " " "
13	Early Advance	Homegrown	" 8	85	" 11	3 " " " "
14	Early Ruby	(D. Staats' strain) Homegrown	" 8	86	" 15	7 " " " "
15	Early Ruby	Homegrown	" 15	87	" 20	5 " " " "
16	Early Ruby	A. W. Livingston Sons	" 15	88	" 10	5 " earlier " "
17	May's First of All	Homegrown	" 17	89	" 17	No difference.
18	Dakota (Warner's seedling)	H. C. Warner	" 28	90	" 17	11 days earlier on subsoiled.
21	Bond's Early Minnesota	Gregory & Sons	" 8	92	" 10	2 " later " "
22	Early Ruby	Gregory & Sons	" 17	93	" 15	2 " earlier " "
23	Earliest of All	Gregory & Sons	" 8	94	" 8	No difference.
24	Bond's Early Minnesota	Iowa Seed Company	" 15	95	" 10	5 days earlier on subsoiled.
98	Dwarf Champion	A. W. Livingston Sons	" 8	96	Aug. 8	No difference.
99	Early Ruby	A. W. Livingston Sons	" 8	97	" 8	No difference.

The foregoing table shows that in nine cases the tomatoes on subsoiled land were later than those on surface plowed land; earlier in six cases; and in seven cases no difference was perceptible.

COMPARATIVE HEIGHT OF VINES on subsoiled and surface plowed land: Several hundred measurements were made the latter part of August by Mr. Fred K. Luke, assistant horticulturist, who carried out the details of the tomato experiment, but no deductions could be made, as was also the case in the above table.

TOMATOES ON SURFACE PLOWED AND SUBSOILED LAND.

Number.	Name.	Seedsman.	Surface Plowed. Number plants.	Surface Plowed. Yield per plant in ounces.	Surface Plowed. Yield per acre in bushels of 60 lbs	Subsoiled. Number.	Subsoiled. Number plants.	Subsoiled. Yield per plant in ounces.	Subsoiled. Yield per acre in bushels of 60 lbs.	Comparative yields on subsoiled land.
1	Red Cherry	A. W. Livingston Sons	19	*84.86	240.657	73	14	129.75	367.962	52 per cent increase
2	Yellow Cherry	A. W. Livingston Sons	20	*61.28	173.807	74	13	89.96	255.120	46 " " "
4	Earliest of All	Gregory & Son	20	133.47	379.568	76	14	183.82	*521.301	37 " " "
5	Earliest of All	Homegrown	19	138.97	394.108	77	12	125.83	356.846	9 " " decrease
6	12 years selection in South Dakota	Rev. T. H. Youngman	20	136.15	386.112	78	15	140.33	397.967	3 " " increase
7	Hubbard's Early	Geo. W. P. Jerrard	19	143.47	406.871	79	16	162.09	459.677	12 " " "
8	Bond's Early Minnesota	Homegrown	19	168.65	478.280	80	11	151.36	429.247	10 " " decrease
10	Dwarf Champion	Homegrown	20	99.05	280.889	82	8	91.37	289.133	7 " " increase
11	Dwarf Champion	A. W. Livingston Sons	20	87.95	249.420	83	10	108.4	307.415	23 " " "
12	Early Advance	A. W. Livingston Sons	20	151.82	430.566	84	17	138.76	393.514	8 " " decrease
13	Early Advance	Homegrown	17	133.6	378.055	85	13	110.61	313.683	17 " " "
14	Early Ruby	(D. Staats' strain) homegrown	20	118.6	336.342	86	17	155.58	441.215	31 " " increase
15	Early Ruby	Homegrown	19	165.63	469.716	87	16	160.75	445.876	2 " " decrease
16	Early Ruby	A. W. Livingston Sons	20	139.2	394.762	88	16	187.56	531.908	34 " " increase
17	May's First of All	Homegrown	20	156.55	443.966	89	13	158.07	448.276	9 " " "
18	Dakota (Warner's Seedling)	H. C. Warner	20	139.2	394.762	90	14	114.07	323.495	18 " " decrease
21	Bond's Early Minnesota	Gregory & Sons	20	143.45	406.815	92	13	176.84	501.507	23 " " increase
22	Early Ruby	Gregory & Sons	20	124.8	353.926	93	16	167.12	473.941	33 " " "
23	Earliest of All	Gregory & Sons	19	128.1	363.283	94	15	153.73	435.968	20 " " "
24	Bond's Early Minnesota	Iowa Seed Company	20	141.55	401.426	95	17	65.11	184.647	54 " " decrease
98	Dwarf Champion	A. W. Livingston Sons	107	83.75	237.509	96	109	107.93	306.827	28 " " increase
99	Early Ruby	A. W. Livingston Sons	77	173.41	491.779	97	65	196.89	558.367	13 " " "

The foregoing table shows that in fifteen cases the yield was in favor of subsoiling; while in seven cases the crop was larger on the surface plowed land. The average yield on the subsoiled land was 11.13 per cent greater than on the surface plowed land.

*Plus.

BEANS.

Several varieties of beans were planted May 29 and given good cultivation. No variety test was made, and so varying quantities of seed were planted. But of each variety exactly the same quantity of seed was planted on the subsoiled as on the surface plowed land. The yields were as follows:

	Surface Plowed.		Subsoiled.		Comparative Yield.
	Pounds.	Oz.	Pounds.	Oz.	
Yellow Eyed Field	40	14	37	3	9 per cent. decrease
Landreth's Scarlet	3	8	4	10	32 " " increase
Jackson's Won.Dwf.Lima	2	10	3	4	23 " " "
Burpee's Bush Lima	5	13	5		13 " " decrease
Henderson's Bush Lima	1	2	1	13	62 " " increase

YIELD OF RUTABAGAS.

Bloomsdale Swede, planted June 27	92		93	12	1 per cent increase
Large White Rutabaga planted June 27	66	13	84		25 " " "

CARROTS.

Variety, Danvers, or Half Long. Date planted, May 15. Yields: Surface plowed, 2,700 lbs. Subsoiled, 2,133 lbs. Decrease in yield on subsoiled land, 21 per cent.

The heavy rains washed out more of the seed on the subsoiled than on the surface plowed plats, as the soil was looser; in a dry season the results would probably be different.

CABBAGE.

	Surface Plowed.			Subsoiled.		
	No. heads.	Total weight pounds.	Av. weight pounds.	No. heads.	Total weight pounds.	Av. weight pounds.
Early Jersey Wakefield	53	162.71	3.07	53	192.	3.62
Marblehead	39	194.	4.97	31	204.75	6.60
Late Flat Dutch	55	249.25	4.53	35	207.5	5.92

The foregoing table shows that the Wakefield averaged 18 per c. larger, Late Flat Dutch 30 per c. larger, and Marblehead 33 per c. larger on the subsoiled than on the surface plowed land.

The same care and cultivation was given to the plants on the subsoiled land as to those on surface plowed land.

SUMMARY.

Further experiments will be needed to settle the question, as the general experience shows that the effects of subsoiling continue several years. These experiments will be carried on during the coming season, and will also include studies in the effects of subsoiling on tree seeds and cuttings.