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The Effect of Lime and Organic Matter on the So-Called Hardpan Subsoils

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Numerous investigations have been conducted regarding the growth of plants above ground, but relatively few in regard to the production of the part of the plant below the surface of the ground which gathers the mineral food for the plant.

Root development may be affected by two principal external factors (1) stimulating agents such as moisture, or fertilizers on the root itself; and (2) the physical characteristics of the soil. Sir John Dawes (1) states that superphosphate causes a much enhanced development of the underground collective apparatus of the plant, especially of lateral and fibrous roots. Sachs (2) showed that the more concentrated the nutrient solution the shorter the roots. Miller-Turgau (3) studied the effect nitrogen and mixed salts had on root growth. The presence of nitrogen in a nutrient solution caused a very vigorous growth of secondary roots; also a concentrated solution of mixed salts retarded root growth. The greatest growth was in weak solutions. Watt (4) as a conclusion of some field experiments, says, "One of the beneficial effects of superphosphate on wheat under semi-arid conditions is that it caused the young plant to send its roots quickly into the subsoil." It is a well known fact that lime and organic matter tend to better the physical condition of soils but their effect on soils when studied in connection with root penetration on tight lands has not been so extensively looked into, especially when the subsoil is taken into consideration.

Throughout the United States, there are many soils which have a rather impervious subsoil of a hardpan nature. This structure has been known to be the cause of crop failures very often because it does not allow for the movement of water and aeration so necessary for the plant nor does it permit the roots of common plants to have a sufficient range of soil to get their necesary plant food. This means that in a few years the plant food available will be very limited if the subsoil cannot be used to any extent as such a source. In view of these facts, and the fact that Oklahoma has a considerable area so affected, the Oklahoma Station started some experiments with the main object in view of studying methods of breaking up this subsoil so that plant roots could penetrate it, thus releasing plant food that would not otherwise be of benefit and bringing about better moisture and air circulation.

The first experiment was started in 1916 on the Kirkland soil series on the Station at Stillwater. This upland series is characterized by its tough, clayey hardpan subsoil upon which crop production is not the best, because of the hindrances already mentioned. In this experiment was included a tract which had been planted to alfalfa in 1913 .

Alfalfa is a good plant to work with; first, because of the nature of the plant itself in that it has a deep root system and tries to pass through the hardpan. Thus the root development, as affected by such a condition, could be better observed than it could with shallower rooted plants. Second, it being an important crop both for hay production and for the building up of the fertility of the soil the results would be of great benefit to the farmers whose land is of this character.

The tract of land was originally divided into four plots, viz:

Manure 2	Check 1
Check 3	Manure 4

Each plot contained .6 acres. Plots 2 and 3 received an application of 12 tons of manure per acre in 1913, but in 1916 the resurvey was made of the Experiment Station farm and plots 2 and 4 were dropped. Plots 1 and 3 were further divided each into 2 plots, viz:

Check
Lime
Manure
Manure and Lime

Each plot is now 146ft.x89ft. Limestone was applied to the newly made plots 2 and 4 at the rate of 2 1-2 tons per acre May 27, 1916, after the first cutting of alfalfa. Since that time the plots have received no further treatment. Careful data have been recorded regarding root development, growth of alfalfa plants, and crop yields.

For studying the root development two plants were extracted from each of the four plots in 1920, because at this time it was observed that the alfalfa was gradually dying out on the check plot.

The roots of the plants on Plot 1 failed to penetrate the plastic clay hardpan. On plot 2, which received lime in 1916, the roots extend about 13 inches deeper than in the check plot. On plot 3 where barnyard manure was applied in 1913 the tap root penetrated the clay hardpan extending into the open porous lower subsoil. On plot

4, which received manure in 1913, and lime in 1916, the root development is greatest. The roots extend through the hardpan and deeper into the lower subsoil by about 10 inches than on the plot treated with manure only. This development may be due to the stimulating effect of the lime and manure on the plant or to their action on the hardpan. The following analyses and determinations were made to ascertain whether or not the hardpan had been affected.

Table 1. Adjoining soil of the same soil series in 1916 showed the following calcium content:

	% Ca.
Surface	.22
Subsurface	.33
Subsoil	.44

Table 2. In 1920 the plots showed the following:

	% Ca.	% Total Carbon
Plot 1—Check		
Surface	.305	......
Subsurface	.281	.381
Subsoil	.534	......
Plot 2—Lime		
Surface	.421	......
Subsurface	.602	.275
Subsoil	.387	......
Plot 3—Manure		
Surface	.160	......
Subsurface	.261	.695
Subsoil	.321	......
Plot 4—Manure and Lime		
Surface	.200	......
Subsurface	.337	.495
Subsoil	.152	......

Table 3. Showing yields of hay in pounds per acre:

Plot No.	Treatment	1915	1916	1917	1918	1919	1920	
1	Check	5533	3489	1919	2020	1618	2097	2774
2	2½ T. Limestone, 1916	5533	4121	2755	3210	2364	4221	3701
3	12 T. Manure	11124	9913	6829	6817	6785	8256	8287
4	12 T. Manure, 1913, 2½ T. Lime, 1916	11124	9862	7030	7652	6783	9956	8735

From tables 2 and 3 it can be observed that the increased yields on plots 3 and 4 have removed much of the calcium. The calcium content is lower in plot 3 than in plot 1 evidently due to this cause. Although plot 4 received an application of limestone the calcium content is lower than plot 1. This also is evidently due to the increased yield of alfalfa over plot 1. Plot 2 shows more calcium than plot 1. The increased yield on plot 2 over plot 1 has not been large enough to reduce the calcium below that found in plot 1, the average increase being but 922 pounds per acre above plot 1 yield, while plot 3 gave 5513 pounds average increase over plot 1; and plot 4, 5961 pounds average increase over plot 1. By comparing the first and second foot of plot 1 with the respective sections of plot 2, and the first and second foot of plot 2 with the respective sections of plot 3, it will be observed that the lime content has been increased.

Table 4. Showing maximum moisture holding capacity, 1920:

Treatment Depth	Check Plot 1	Lime Plot 2	Manure Plot 3	Manure and Lime Plot 4
1st foot	40.93%	41.88%	43.93%	47.73%
2nd foot	39.92	42.27	39.64	43.89
3rd foot	40.13	41.91	35.80	38.91

Table 4 shows that the organic matter in the first foot has increased the moisture holding capacity. Lime has increased the moisture holding capacity as is observed by comparing the second foot of plots 2 and 4 with that of plots 1 and 3. No conclusions can be made from the results of moisture holding capacity of the third foot on any of the plots.

Table 5. Showing the results of penetration tests on these plots. These are averages of 3 tests made during the summer of 1920 on each plot, when the moisture content was between 18 and 21%.

	Check*	Plot 2 Lime	Plot 3 Manure	Plot 4 Manure and Lime
1st foot	242	226	154	150
2nd foot	390	304	384	329

*Figures are relative representing the number of times a given weight falls a given distance.

These results show that the organic matter present in the surface foot greatly lowers the resistance to penetration. It also shows that lime in the second foot reduces the power necessary to penetrate, as can be noted by comparing the second foot in each of plots 2 and 4 with the second foot on plots 1 and 3.

Other methods, namely, dynamiting and deep tillage were tried but in each case they proved of no permanent value because the subsoil ran together soon after the first large rain.

SUMMARY

1. Organic matter increased water holding capacity of the soil most in the first foot section.

2. Lime increased the water holding capacity not only in the first foot section, but in the second foot section as well.

3. Manure had the greatest effect in lessening penetration in the first foot.

4. Lime decreased the resistance to penetration in the second foot section.

5. Lime increased the yield of alfalfa, but manure caused a greater increase.

6. The greatest beneficial returns both as to the physical condition of the soil and increases in yields came through the use of both lime and manure.

7. With no treatment the roots development was limited mostly to the soil above the stiff clay hardpan.

8. Where lime was applied the roots entered the hardpan but did not pass through.

9. Where manure alone was used the roots extended through the hardpan.

10. The greatest depth of root penetration and greatest root development was where both lime and manure were applied. The tap-roots in this case extended below the hardpan subsoil into the more porous lower subsoil.

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