INFLUENCE OF LIGNIN AND OTHER WASTE MATERIALS ON PLANT GROWTH

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RESUMEN

Se cultivan plantas en agua y arena, agregándose lignina finamente triturada y otras sustancias coloidales para modificar la textura. Ninguna de ellas tuvo efecto alguno sobre los cultivos en agua o grava, pero promovían el crecimiento en cultivos de arena.

Se cultivaron plantas en tierra, agregándose lignina y otros compuestos orgánicos, tanto para cultivos de cosecha única (no residuales) como para cultivos sucesivos, para observar los efectos residuales de estas substancias sobre cosechas consecutivas en el mismo suelo. En cada grupo, algunas cosechas aisladas demostraron haberse beneficiado con los tratameintos, al compararlos con cultivos en tierra sin tratar. Pero las diferencias medias resultaron carecer de importancia. De ahí se concluye que las ventajas que resultan de esos tratamientos, no pueden comprobarse o ponerse en evidencia en cultivos de invernáculo. Éstas se deberían a la capacidad aumentada de retener los elementos nutritivos en contra de los efectos del lavaje, etc. Los tratamientos citados son lejos más efectivos en cultivos realizados en campo abierto, y bajo estas condiciones deben mirarse sus posibles beneficios. El test preliminar de la velocidad con que se realiza el proceso de descomposición de un abono, en cambio, es preferible realizarlo en cultivos de invernáculo.

El agregado de lignina al suelo, no incrementaba el contenido de almidón en papas habiéndose utilizado plantas de la variedad Katahdin, que suele caracterizarse por su bajo porcentaje de almidón.

La adición de corteza finamente desmenuzada, parecía tener cierto valor en cuanto a la reducción de los efectos tóxicos que ejercen elevados porcentajes de sales nutritivas en el suelo, siendo por lo demás, dudosos sus efectos benéficos.

[1] Grateful acknowledgment is made of the aid and advise given during the course of these experiments by Dr. Joseph Seiberlich, of the University of New Hampshire Engineering Experiment Station. This work was carried out as a cooperative project. Funds granted by the New Hampshire State Legislature to the New Hampshire State Planning and Development Commission were used by the Engineering Experiment Station to initiate and implement the project.

El agregado de residuos de destilería no beneficia a los cultivos comparados con cultivos de control.

Cultivos en arena con aserrín en descomposición demostraron que este material puede aumentar el rendimiento, si el grado de descomposición es suficiente. Ésto se confirma comparativamente con cultivos en aserrín puro, en una mezcla de aserrín y tierra, y en tierra solamente. Estos aspectos necesitarán de estudios ulteriores, especialmente en lo que se refiere a métodos de fermentación u otros para descomponer con mayor rapidez el aserrín o materiales similares. Parece evidente que es un factor importante la mantención de una humedad adecuada en los productos en descomposición, ya que éstos tan sólo recibirán el agua proveniente de la precipitación natural.

INTRODUCTION

This is an account of a continuation of work reported previously, (2, 3). It was found that a relatively pure organic colloid, methocel, and an industrial waste product, lignin, showed some promise as aids to plant growth, when these were added to the medium in which the plants grew. Lignin is produced from many pulp mills as calcium lignin sulphonate. However, the staff of the Engineering Experiment Station of the University of New Hampshire has been interested in the uses for wood-hydrolysis lignin produced in the wood sugar process, since they have an extensive program for the study of the uses for the yeast grown on this sugar. Samples of this type of lignin have been supplied to us from the United States Forest Products Laboratory at Madison, Wisconsin. We have tried limited tests on calcium, ammonium, and magnesium lignin sulphonates, as well as shredded bark from the logs used in pulp mills. For comparison with the wood-hydrolysis lignin, peat has been added to some cultures, and a few plants have been tested with rotten wood or what amounts to naturally-produced lignin. Some composted sawdust has been tried.

Elsewhere, the trials made of lignin as a soil amendment have been comparatively few, although the literature is very extensive on the use of sawdust for such purposes. Alderfer, Gribbins, and Haley (1) have worked with a concentrated form of waste sulfite liquor containing a fairly high percentage of lignin sulphonate. They added this to soil primarily to study the effects on aggregation of soil particles, although some plants were grown in greenhouse tests. They concluded that the chief effect of this material was to improve soil structure. The results reported by Sowden and Atkinson (6) are

in general agreement with this. Spulnik et al. (7) have tried additions of waste sulphite liquor to soil. Sunflowers grown in this showed benefit from moderate amounts but showed toxic effects from heavier applications. Experiments by Phillips et al. (5) on ammoniated waste sulphite liquor showed that such material has some possibilities in improving plant growth when added to soil.

METHODS

The principal avenue of approach to this problem has been to add these materials to soil and grow plants in this soil and compare the growth and yield to plants grown in soil only. Plants used for these tests have been mostly potatoes and tomatoes, although a few other kinds of plants have been grown. In all cultures an appropriate amount of commercial fertilizer was added. These cultures were all grown in the greenhouse in various containers such as 14-quart galvanized pails and 1-gallon and 2-gallon glazed crocks. The interiors of the pails were first coated with melted beeswax or asphalt paint to prevent corrosion. In general, the amount of organic matter added varied from about onehalf liter per container to one-third of the volume of soil. Since the lignin was moist, measurement of it was done on a volume basis. As first received, 500 ml. of the lignin weighed about 325 grams. For some cultures the lignin or other organic material was placed in thin layers between layers of soil. In others it was mixed intimately with the soil.

Great care was taken at all times and with all cultures to have the experimental plants as uniform as possible and to minimize the errors of random sampling. When tomato seedlings were used, they were started in sand in advance and only the most vigorous and uniform specimens were chosen from a large population to transplant to the cultures. With potatoes, only high-quality, certified seed was used. They were allowed to green or bud out in diffuse light in the laboratory for a few weeks before planting and then only those with the most uniform and vigorous sprouts were chosen for planting.

The location of the individual containers was shifted, usually at weekly intervals, to avoid the effects that would be produced if the positions of these containers were not changed.

Besides soil cultures, a small number of plants were grown in water and sand. The nutrient solution for there cultures had lignin added to it, and these cultures were compared with cultures containing no lignin and with cultures containing other colloidal materials. In the first group of cultures only sifted lignin with a particle size below 200 mesh was used.

Because of the variation in some of these treatments, it will make the presentation clearer to take up some of the more specific details of methods along with experimental results.

EXPERIMENTALS RESULTS

A. *Water and Sand Cultures*

1. *Water cultures with* (a) *nutrient solution alone,* (*control*) (b) *colloidal clay,* (c) *methocel,* (d) *colloidal lignin (wood hydrolysis).*

Corn seedlings were grown in 1-gallon size crocks with two plants per crock and seven crocks per treatment. The amounts of nutrient salts used for all of the twenty eight crocks were : NaNO-- 32 gms., NH_4NO_3—10 gms., KCl—24 gms., $MgSO_4$—40 gms., $CaCl_2$—12 gms., Na tetraphosphate—20 gms., plus iron as $FeSO_4$ and trace elements. These were dissolved and distributed equally among the crocks. To one-fourth of the culture crocks a water suspension of dialyzed colloidal clay was added at the rate of 0.142 gms. of clay on a dry basis. Another group of seven crocks had a solution of methocel added at the rate of 2 gms. per 1-gallon crock. For preparation of the lignin cultures, sifted dry lignin below 200 mesh size was agitated thoroughly in water with a few drops of wetting agent, « Tergitol » Penetrant 4. This was added at the rate of 0.4 gms. of dry lignin per crock to another group of seven crocks. The solutions were changed as originally mixed in all cultures at weekly intervals, occasionally adding small amounts of dilute sulphuric acid to prevent chlorosis. The seedlings were placed in holes in wooden supports, each being held in place with a little cotton. The supports rested on the tops of the crocks. The plants grew fairly uniformly and vigorously and there was no particular visible difference in the plants growing in any of the cultures, except that there was a marked brownish coloration of the roots of the plants in the lignin medium, which was probably due to the adherence of lignin particles to the roots by adsorption. By the time they were forty eight days old, the plants were mostly over two feet tall and rather large and unweildy

for further growth in these containers. They were harvested at this time and a summary of the dry weights appears in Table 1.

Discussion of these results will be reserved for consideration along with that of the next two sets of cultures.

TABLE 1

Effect of Colloidal Materials Added to the Nutrient Media in Water Culture on Growth of Corn Plants 48 days old

Treatments	Shoots		Roots	
	Dry wt- totals ob 14 plants (grams)	Average of 7 pairs	Dry wt. totals of 14 plants	Average of 7 pairs
Control, nutrients only......	23.4	3.4	7.6	1.1
Colloidal clay, 0.14 gms. per 1 gal. culture jar plus nutrients......................	27.5	3.9	9.1	1.3
Methocel, 2.0 gms. per 1 gal. culture jar plus nutrients...	22.7	3.2	7.8	1.1
Colloidal lignin, 0.4 gms. per 1 gal. culture jar plus nutrients......................	16.8	2.4	7.1	1.0

2. *Water cultures with* (a) *nutrient solution alone, (control),* (b) *colloidal lignin (wood hydrolysis),* (c) *neutral calcium lignin sulphonate.*

Tomato plants were grown in these cultures which were prepared in much the same way as given above, except for some slight variations in the amounts of nutrients alts. The calcium lignin sulphonate was obtained as a dry powder but it dissolved completely in the nutrient solution. The plants grew vigorously to maturity and a considerable crop of ripe fruit was harvested. A summary of results is presented in Table 2.

3. *Sand cultures with* (a) *nutrient solution alone, (control),* (b) *methocel,* (c) *colloidal lignin (wood hydrolysis).*

Sunflower plants were grown in materials of two different textures which were the same as described previously (2), i. e., coarse gravel, and relatively fine sand. Since some benefit had been found for methocel in improving growth of plants in sand, it seemed desirable to compare it with lignin as a modifier of texture.

TABLE 2

Effect of Colloidal Materials Added to the Nutrient Media on Growth of Tomato Plants, Valient Variety

Treatments	Yields of ripe fruit per 7 plants, grams	
	Total Yields	Average
Control, nutrients only	1172.5	167.5
Colloidal lignin 0.2 grams per 1 gal. jar plus nutrients	1023.6	146.2
Neutral calcium lignin sulphonate 0.2 grams per 1 gal. jar plus nutrients	1068.1	152.6

The plants were grown in 1-gallon-size glazed crocks, forty-two in all. One half of this number contained sand, the other half gravel. One third of each group, or seven crocks, received nutrient solution only, another third received nutrient solution plus methocel at a rate of 4 gms. per 14 crocks of both sand and gravel, while the last third received sifted lignin at a rate of 2.8 gms. for the same number. The nutrient solutions were made up in a similar way as described above and were added in amounts of 500 ml. per crock. Stoppers were placed in the holes in the bottoms of the crocks with inverted porous saucers above them and the levels of the solutions kept to the top of the sand or gravel at all times with additional water. At weekly intervals the solutions were drained, the sand or gravel was flushed thoroughly with water, and the solutions were renewed.

TABLE 3

Effect of Colloidal Materials as Modifications of Texture in Sand Culture with Sunflower Plants

Treatments	Sand		Gravel	
	Dry wt. totals of 7 plants (gms.)	Average of 7 plants (gms.)	Dry wt. totals of 7 plants	Average of 7 plants
Control, nutrients only	29.9	4.3	25.3	3.6
Methocel	51.9	7.4	21.5	3.1
Lignin	48.5	6.9	23.5	3.3

The plants grew uniformly and vigorously within each treatment. The size of the plants in the sand was quite visibly greater than those in the gravel, as may be seen from Figure 1. The plants were harvested just previous to blossom formation, and the dry weights of tops were taken. These are summarized in Table 3.

There are several conclusions to be drawn from a comparison of the results of the separate treatments within this experiment, as well as a comparison of them with the results from the more fluid media reported above in parts 1 and 2. Considering the first set of comparisons, one of the evident conclusions is that both lignin and methocel are quite effective in increasing growth in and in contrast to controls of sand with nutrients only, but in gravel they are not effective. The results when using methocel alone with sand and gravel were similar (2). The reasons for this would be rather speculative but it might be a fair assumption that both methocel and lignin act in causing greater surface contact of the root hairs with the sand particles and a consequent greater ease in absorption of nutrients. This sort of action could not be nearly as effective with the coarser particles of the gravel. It should be noted in this connection that the plants shown in Figure 1 as typical of size of the plants grown in sand and gravel were both supplied with lignin. However, this general size relationship of the plants would hold quite closely in comparing the two textures with methocel in both of them. It would also hold for plants grown in sand with either colloidal material compared to those in sand with nutrients only.

In contrast to the beneficial effects of added colloids in sand, we find from the yield figures on water cultures in Tables 1 and 2, values for the colloids that are fairly close to the controls. Some small increasse in yield is given with colloidal clay. These same general results have been often observed with tomatoes grown in water culture with and without lignin added to the nutrient media. Thus, it is evident that the modifying effect of added colloids does not act in a beneficial way to the same extent in water cultures as it does in sand cultures.

B. *Soil Cultures*

In the beginning of this experimental work several isolated sets of cultures were grown with various crops, each with its own group of control plants in soil to which no organic matter was added. The soil from each of these was discarded at the harvest of a single crop. Later on it became apparent that it would be desirable to study the residual effects of some of these organic materials on growth, i. e., to grow successive crops in these same lots of soil. This was done for several sets of experiments. For convenience, these two types of tests will be called: 1. single crop (non-residual) cultures and 2. successive (residual) cultures.

1. *Single crop (non-residual) cultures.*

The general methods of growing these plants already has been described. No attempt was made to keep the soil at a uniform or constant moisture content because of the large amount of labor involved. Sufficient water was applied by a hose as often as the appearance of the soil indicated a need for it. Potato plants were grown until they were completely mature, and then the tubers were weighed. In the case of the tomatoes, the fruits were gathered and weighed as they ripened until nearly all were harvested. Usually the last few small ones were harvested all on one day, whether fully ripe or not Then the yield weights for any one plant were added for the total yield.

The results for several separate experiments are summarized in Table 4. The material most frequently used for comparison with controls was wood hydrolysis lignin with a scattering of trials with peat, lignin plus sulfur, and rotten wood. The lignin carrying a small amount of sulfur was tried because of the interest in its effect on starch quality. It afterwards proved to have no effect on this. The trial of lignin and sulfur with onions was made because of the known relation of sulfur to the aromatic constituents of that plant. The sulfur was toxic at the concentrations used, however. It should be noted that the results for Experiment N° 1 in the table were published before (4), but are repeated here to make the data more complete.

The salient features of this table may be sought best by consulting the totals at the bottom. The first series of totals is for controls compared to lignin as far as these were tested simultaneously. The second set summarizes those plants grown in controls, lignin, and peat simultaneously, etc. In general, the lignin shows some slight advantage over the controls; in individual experiments, as in No. 1 and 6, it shows considerable advantage. The difference in total yield is not significant as shown by calculation of the standard error. However, the use of these materials in greenhouse cultures probably

TABLE 4

Effects of Various Organic Materials on Yields of Single Crops (non-residual) in Different Soils

Expt. N°	Kind of crop	Type of Soil	Size and kind of container	N° of plants per treatments	Basis of yield figures	Amt. of organic matter per container	Average yield in grams: Control	Lignin (wood hydrolysis)	Peat (acid)	Lignin (w. h) s	Rotten Wood
1	Potato	Fine Sandy Loam	14-qt. pails	7	wt. of tubers	500 ml.	319	451		411	
2	Potato	Fine Sandy Loam	13-qt. pails	7	wt. of tubers	600 ml.	424	459	391	203	
3	Tomato	Clay Loam	1-gal. crocks	7	wt. of ripe fruits	400 ml.	709	568			
4	Tomato	Fine Sandy Loam	1-gal. crocks	7	wt. of ripe fruits	400 ml.	637	627			676
5	Potato	Clay Loam	14-qt. pails	10	wt. of tubers	500 ml.					
6	Tomato	Clay Loam	14-qt. pails	10	wt. of ripe fruits	500 ml.	492	653	222		
7	Onion	Fine Sandy Loam	1-gal. bulb pans	32	fresh wt. of tops and bulbs	100 ml.	27	39		2	
8	Tomato	Loamy Fine Sand	14-qt. pails	7	wt. of ripe fruits	1000 ml.	619				607
Totals of expts. 1, 2, 3, 4, 5, 6, and 7							3029	3263			
Totals of expts. 2, 5, and 6							1337	1578	1064		
Totals of expts. 1, 2, and 7							770	949		616	
Totals of expts. 4 and 8							1286				1283

does not tell the whole story as regards possible advantages, as will be discussed later.

The few tests on both peat and rotten wood show no total increase over the controls, although one individual trial in each gave better yields.

Experiment No. 4 of Table 4 also included some tests with neutral peat, neutral lignin and calcium lignin sulphonate. All gave yields lower than the controls, and the lignin sulphonate was poorest of all. In fact, in soil to which this was added it was very difficult to get plants started. It was necessary to replant many times.

At the close of each experiment samples of soil were taken for pH and nutrient analysis. Usually there was some slight difference between the controls and the treated soils. The pH values were nearly always close to 5.0 and the nutrients present in moderate amounts except the nitrate nitrogen and the ammonium nitrogen which were often nearly exhausted.

2. *Successive (residual) Cultures.*

As indicated above, these were grown to determine the effects of organic materials on crops grown in the same soil in succession. One series was grown in fine, sandy Newmarket loam, the results of which are summarized in Table 5. Crop No. 1 consisting of potatoes, was grown in galvanized pails, ten per treatment. The treatments consisted of the addition of 900 ml. of lignin per pail of soil and the addition of the same amount of peat to another ten pails of soil. The controls contained soil only. After the harvest of this crop the soil was removed from the pails and placed in three separate piles according to their respective treatments. Each piles was thoroughly mixed and to each of those previously treated was added enough lignin or peat to equal one-third of the total volume when returned to the containers. The containers were two-gallon crocks which were used for all of the remaining crops. Each crock of soil received 35 gms. of 8-16-16 fertilizer which was placed in a thin layer in the soil halfway between the top and the bottom. These three sets of crocks were then allowed to stand in the greenhouse for 75 days without vegetation before the next crop was planted. During this composting period the soil in each was kept thoroughly moist.

The second crop consisted of tomatoes, and as the figures for the average yields do not give the full picture, some statements about it are in order. Tomato seed of the Rutgers variety was started in sand,

and about three weeks later, when the plants were two to three inches tall, they were transplanted to the crocks of soil. From the beginning, great difficulty was experienced in getting the control plants to grow, and in fact, many were replanted two or three times. Since the plants were started in October, additional artificial light was given from the time of planting for six hours each evening. By the middle of February the healthy plants were in the fruiting stage and the following observations were made:

a) Controls

5 plants entirely dead from early in the start of the experiment.
3 plants of fair size, but yellow and in poor condition.
2 plants in good condition, producing fruit.

b) Lignin

1 plant totally dead.
2 plants of fair size, but yellow and in poor condition.
7 plants in good condition and producing fruit.

c) Peat

1 plant yellowing and in poor condition.
9 plants in good condition and producing fruit.

The average yields for this crop, then, given in Table 5, are based upon two plants for controls, seven plants for lignin, and nine plants for peat.

TABLE 5

Residual Effects of Lignin and Peat in Soil Mixtures on Plant Growth in Newmarket Fine Sandy Loam

Crop Nº	Date Planted	Date Harvested	King of Crop	Amount of Organic Matter Added	Average Yield in Grams		
					Control	Lignin	Preat
1....	3/15/46	7/2/46	Potatoes	900 ml.	636	621	660
2....	10/12/46	4/20/47	Tomatoes	1/3 of soil volume	576	630	733
3....	5/1/47	8/27/47	Tomatoes	»	947	718	503
4....	9/5/47	3/1/48	Tomatoes	»	63	447	689
5....	4/22/48	7/27/48	String Beans	»	135	142	147
			Totals..................		2357	2558	2732
			Average..................		471	511	546

The explanation of this effect is probably to be found in too high a concentration of some nutrient element or group of elements. A consideration of the analyses of the soil given in Table 6 indicates

TABLE 6

Soil pH and Nutrient Analyses After Crops Given in Table 5

Analysis taken after Crop Nº	Soil Treatment	pH	NO_3N	NH_4N	P	Mg	K	Ca
1...........	Control	4.90	low	very low	medium	very low	trace	very low
	Lignin	4.89	trace	very low	medium	very low	trace	very low
	Peat	4.51	low	very low	medium	very low	trace	very low
(pH at start of Expt. 2).	Control	6.80	This soil had stood in the moist state with no vegetation and 35 gms of 8-16-16 fertilizer per crock for 2 ½ months before planting to Crop Nº 2.					
	Lignin	6.50						
	Peat	6.30						
2...........	Control	4.20	very high	very low	low	low	very high	very low
	Lignin	4.22	high	very low	low-medium	low	very high	very low
	Peat	4.02	medium	medium	medium	low	medium	very low
3...........	Control	4.89	trace	very low	medium	very low	very low	low-medium
	Lignin	4.56	none	very low	medium	very low	trace	medium
	Peat	4.40	none	very low	medium-high	low	trace	medium-high
4...........	Control	5.1	low-medium	very low	medium	low	medium-high	high
	Lignin	5.0	medium	very low-low	medium-high	low	high	very high
	Peat	4.6	medium	very low-low	medium-high	low	medium	very high

nitrogen and possibly potassium toxicity as a cause. These analyses are of samples taken shortly after the harvest of each crop. While the amount of nitrate nitrogen in the control soil is shown to be in excess of very high, it should be noted that the amount of nitrogen before adding fertilizer was low, and this soil received no more than the other treatments. No other element seems to be high enough to be injurious. Another explanation that might be advanced is that there may be a toxic effect from the activities of the roots of the previous crop or from the activities of microorganisms. The fact that either of these effects did not appear in the other two soils might be attributed to the adsorption qualities of the organic matter, and the use of nitrogen in the decomposition of organic matter by microorganisms.

For crop number three, which was again tomatoes, the soil was again emptied from the crocks and re-mixed, adding fertilizer elements to make up for the shortages revealed by the analyses of the soil. For example, the controls received no further application of nitrogen, but did receive moderate amounts of superphosphate, magnesium sulphate, and calcium carbonate.

No difficulty was encountered with this crop in getting the plants started or in their growth thereafter. The control plants grew more vigorously than the others.

Crop number four gave somewhat of a repetition of the performance of crop number two, except that none of the plants died outright. However, many of the control plants were stunted. In this case there was even less of any outstanding differences in either pH or nutrient analyses to account for the effect.

It is obvious from the foregoing descriptions of the behavior of these crops that the numerical yield data do not indicate the full effects of these treatments. Although the totals and averages of the yields of the three treatments indicate a slight advantage for the soils treated with organic matter, a calculation of the standard error reveals that the differences are not significant.

Some observations on the appearances and physical character of these soils made during the growth of the last crop may be of interest at this point. The color of both soils with organic matter was much darker than the controls, and it was much easier to sink a trowel into them. There was no evidence of separate particles of either peat or lignin, which showed that probably the peat and the lignin were now thoroughly incorporated into the soil. Casual observation showed that it required much less time for water to sink into the soils to which peat or lignin had been added. This would be an important factor in aiding the penetration of rainfall and in avoiding rapid run-off. These soils are being saved for further growth tests.

Two other types of soils, heavy clay loam and a loamy, fine sand, were tested for residual effects of lignin only and for a fewer number of crops. The results of these tests are summarized in Tables 7 and 8. It is evident from these results that lignin does not benefit the growth of crops in these soil types, at least under these conditions. With clay, in particular, it seems difficult to secure any response from added organic matter, at least under greenhouse conditions.

TABLE 7

Residual Effects of Lignin in Soil Mixtures on Plant Growth in Clay Loam

Date Planted	Date Harvested	Kind of Crop	Amount of Lignin per Plant	Average Yield in Grams	
				Control	Lignin
2/15/47..	6/21/47	Potatoes	1000 ml.	705.9	665.5*
				tubers	
7/14/47..	4/15/48	Tomatoes	same	59.0	68.0
				fruits	
			(fresh wt. of tops)	79.0	115.0
11/14/47..	4/15/48	Tomatoes	1/3 of volume	531.9	573.4
				fruits	
5/8/48..	9/20/48	Tomatoes	same	574.5	507.5
			Totals..................	1950.3	1929.4

TABLE 8

Residual Effects of Lignin in Soil Mixtures on Plant Growth in Loamy Sand

(10 plants per treatment)

Date Planted	Date Harvested	Kind of Crop	Amount of Lignin per Plant	Average Yield in Grams	
				Control	Lignin
2/15/47..	6/10/47	Potatoes	1000 ml.	545	357
8/20/47..	1/29/48	Tomatoes	1000 ml.	1024	882
			Totals........	1569	1239

SOIL CULTURES WITH LIGNIN TO SHOW EFFECT ON STARCH OF POTATO TUBERS

These cultures were grown because previous published results (4) had shown some indication that lignin in the soil might influence starch content of potato tubers. All of the previous potato cultures mentioned here were the Green Mountain variety, which agronomists know to be one of the higher producers of starch. This quality makes it desirable for the manufacture of certain food products, but the Green Mountain is more subject to net necrosis and other virus diseases than certain other varieties which are not as high in starch production. It seemed of interest to test this point further, i. e., whether another variety, desirable in other respects, could have the starch content of its tubers increased by such soil treatment. The Katahdin potato was chosen as a representative of this group and plants of this variety were grown in two types of soil, a heavy clay loam and loamy, fine sand. Twenty plants were grown in each, in pails, and half of each group received additions of lignin at one-third volume rate. The results as shown in Table 9 show that the lignin treatments were not effective in increasing the yield or the starch content of this variety. The analyses of starch were made by Dr. Joseph Seiberlich, of the Engineering Experiment Station, and were made upon all of the tubers above 50 grams in weight per individual tuber.

TABLE 9

Effect of Lignin Mixed with Soil on Yield and Starch Content of Potato Tubers, Katahdin Variety

(Planted February 23, 1948)

Type of Soil Treatment	Loamy Fine Sand		Clay Loam	
	Lignin 1/3 volume	Control	Lignin 1/3 volume	Control
Total yield in grams.......	2572	2992	3978	4013
Per cent starch in tubers...	13.29	14.28	11.52	13.25

SOIL CULTURES WITH SHREDDED BARK

Bark from the logs used in the paper pulp mills is a by-product produced in large volumes, and so far, very little use has been found for it. A sample of coniferous bark, largely spruce and hemlock, was obtained from the Brown Co., of Berlin, New Hampshire, shredded in a hammer mill, and mixed with soil in which tomatoes were grown.

The soil happened to be a loamy fine sand that had been freshly sterilized with steam. The plants were grown in one-gallon size glazed crocks with one liter of bark mixed thoroughly with the soil in each of the ten crocks. Another ten crocks received soil only as controls. Half-way from the bottom of each crock a layer of 10 grams of 5-10-10 fertilizer was placed, i. e., half-way between the top and the bottom of the soil mass.

TABLE 10

Effect of Shredded Bark on Growth and Yields of Tomatoes in Soil with and without Steam Sterilization

Date Planted	Date Harvested	Kind of Crop	Amt. of shredded bark per plant	Other soil treatment	Average Yield in Gms.	
					Control	Shredded Bark
					A	B
3/7/47..	8/29/47	Tomatoes	1000 ml	steam-sterilized	195	358
					C	D
3/4/47..	8/29/47	Tomatoes	1000 ml	non-sterilized	306	273
7/18/47..	11/10/47	Tomatoes	1400 ml	non-sterilized	123	108

RESULTS OF PH AND NUTRIENT ANALYSIS OF SOILS IN WHICH THE ABOVE CROPS WERE GROWN

Yields Indicated	Kind of Growth	Soil Treatment	pH	$NO_3.N$	$NH_4.N$	P	Mg	K	Ca
A	very poor	sterilized soil only	5.50	very high ++	very high ++	low	very high	very high ++	very high
B	very good	sterilized soil & bark	5.73	high	med.	low	med.-high	very high +	high
C	good	non-sterilized soil only	5.38	very high +	low	very low-low	very high	very high	very low
D	good	non-sterilized soil & bark	5.64	high	low	very low-low	very high	very high +	low-med.

The plants were transplanted to these crocks when they had reached a size about two inches tall. Almost from the first the plants in the bark cultures grew vigorously, but great difficulty was experienced in getting the control plants to grow. Many of them weakened and died, and to these cultures new plants were transplanted. Careful tests of the steam showed no toxic substances from it. The yields which appear in Table 10 were taken from the surviving plants. Later, two crops of tomatoes were grown in non-sterilized soil and show no advantage from the bark treatment. The first crop of tomatoes in non-sterilized soil was grown in crocks and the second crop was grown in pails. Soil samples were taken and analysis revealed that the soil alone, before any fertilizer had been added, contained quite large amounts of some nutrient elements. An analysis at the harvest of the crops as given also in Table 10 shows that apparently the steaming made the nutrient elements available to an extent to make them toxic, which was further aggravated by the addition of the fertilizer. It may also be assumed that the shredded bark either absorbed, or in some other way minimized this toxic effect and increased the uttilization of nitrogen by microorganisms This is further borne out by the fact that the other cultures without sterilization grew fairly well with or without bark and with no increase in yield from the bark treatment.

It thus appears that shredded bark has some possibilities as a conditioner for very fertile soils, or for use as acarrier for fertilizer elements.

SOIL CULTURES WITH DISTILLERY WASTE

Distillery waste in fresh condition was obtained from a plant in Newmarket, New Hampshire, and an analysis of it revealed 6 per cent dry matter, 4 per cent of which was nitrogen. Therefore, 2000 grams of the fresh waste would contain nearly 5 grams of nitrogen. Since it had such a high water content in the fresh state it was discovered early that when it was added to the soil a large mold growth was fostered, and plants too close to the waste did not grow well. This was true of lettuce and radish plants which were first grown in mixtures of the waste with soil. It was better practice to apply the waste to the soil a considerable time in advance of starting the crop in order to allow this abnormally large fungus activity to pass. It was also found that in pot cultures in the greenhouse about the easiest way to handle and apply it was in layers placed between layers of soil. Because of its pasty consistency it would be difficult to mix intimately with the soil.

Data on yields for three crops are given in Table 11 together with the soil treatment. It should be noted that an equivalent amount of nitrogen was furnished to the controls as that contained in the distillery waste. Whether this is a fair comparison is not certain. For potatoes, the distillery waste was distinctly adverse, but for one crop of tomatoes it was slightly beneficial. Work with this material was ended at this point due to the closing of the distillery.

TABLE 11

Effect of Distillery Waste on Yields of Potatoes and Tomatoes

Date Planted	Date Harvested	Kind of Crop	Amt. Per Plant of Distillery Waste	Average Yield in Grams	
				Control	Distillery Waste
3/5/47	7/7/47	Potatoes	200 gms.	427	284
7/11/47	10/23/47	Tomatoes (same soil as above, remixed)		120	80
4/11/47	8/27/47	Tomatoes		1013	1222

SAND CULTURES WITH COMPOSTED SAWDUST

Sawdust and rotten wood had composted for one year before the cultures were started. The composting materials were placed in outdoor wooden bins or cribs with one side made of boards in a louvred fashion for aeration. The bins were or cubical shape, four feet in each direction, with a perforated hollow wooden cylinder in the center to aid aeration. In November, 1946, the following materials were placed in the bins in approximate proportions by volume:

Serial Nº	Kind of Material	Tested December 15, 1947	
		pH	Aldehyde Test
1b.......	2/3 sawdust + 1/3 manure	6.13	slight
2b.......	2/3 sawdust + 1/3 manure + 5 lb. urea	6.16	slight
3b.......	2/3 sawdust + 1/3 soil	6.37	medium
4b.......	Rotten wood + 5 lb. urea	6.32	large

A little over a year later some material was taken from three of these bins to test in cultures of growing plants in the greenhouse. Material from bin *2b* was omitted because it was very similar to the material in bin 1*b*. At the same time samples of each tested for sugar and for pH as is given above to gain some information about the progress of decay.

Most of the work thus far on the utilization of wood waste had been with soil cultures, but because of some of the variable results obtained, which in turn might be attributed to the variable character of the soil, it seemed advisable to try some cultures in sand.

The compost materials were each mixed thoroughly and sampled for nutrient analysis, and guided by this, appropriate nutrient salts were added to make up for deficiencies. Arbitrarily, about one-third of each kind by volume was mixed with two-thirds of sand and each placed in ten pails. A set of control cultures was set up with nutrients and sand only, and on November 29, 1947, these cultures were planted with seed of the long Tendergreen variety of string beans, five per pail, which were later thinned to two of the most vigorous plants.

OBSERVATIONS ON CULTURES

By January 5, 1948, or earlier, there were quite marked evidences of chlorosis and other adverse effects on some of the plants. However, the *control* plants were conspicuous for their good dark-green color and freedom from injury of any kind. The *remaining cultures* all had the same type of symptoms, i. e., mottled chlorosis and necrotic borders of older leaves. Slight differences could be generalized: *rotten wood*, mottled chlorosis of upper leaves, dead edges on older leaves; *sawdust and manure*, pale green-yellow of young leaves, dead borderand mottled chlorosis of older leaves; *sawdust and soil*, necrotic edge and mottled chlorosis in all but youngest leaves.

The next day a complete nutrient solution was given to all the cultures. They were flushed out thoroughly with tap water and the solutions were added at weekly intervals thereafter. By January 15, the appearance of the newer foliage had markedly improved.

On January 20, the harvest and weighing of fresh pods was begun. These were picked at marketable size, and the harvest continued until March 3, 1948. At this time the tops were harvested and recorded along with the summary for the pod harvest in Table 12. The weights for the tops may not be very reliable as considerable dropping of leaves occurred before this. It is interesting to note that in general they follow the order of magnitude of the weights of the pods.

TABLE 12

Effects of Composted Sawdust on Total Yields of String Beans and Potatoes in Sand Cultures

Date Planted	Date Harvested	Kind of Crop	Control-sand only	Sand + composted rotten wood	Sand + composted sawdust and manure	Sand + composted sawdust and soil
11/29/47	3/3/48	String beans, fresh pods	448.3	336.5	300.4	130.6
		String beans, fresh tops	855.0	690.0	630.0	440.0
3/18/48	7/22/48	Potatoes	1107.1	901.3	363.4	1854.8

As shown there, the best yield was from the control plants as would be expected from the better appearance of the plants all through their growth, followed by the rotten wood yields, sawdust and manure yields, sawdust and soil yields, in that order. To obtain some idea as to whether the differences in yields could be attributed to any differences in nutrients, samples of the culture media were taken for analysis soon after harvest, the results of which showed no distinct diferences. All were rather low except phosphorus. The pH varied between 5.0 and 6.0. It seems safe to conclude that the adverse effects from the composted material may have been due to a lack of nitrogen or perhaps toxic substances from the sawdust. In other words, the composting process had not proceeded far enough

to make these good media for growth. This is further substantiated by the results from a potato crop grown in these same culture materials. In this case the yield with the poorest material for the beans is the best for the potatoes.

These potatoes were grown in pails after emptying, remixing, and adding fertilizer, but omitting phosphorus which was high already.

SOIL AND SAWDUST CULTURES

A test was made of the growth of tomato plants in three media, (*a*) soil only, (*b*) sawdust only, and (*c*) soil $^1/_2$, sawdust $^1/_2$, mixed thoroughly. Because of several interesting developments in this experiment, the procedure will be described in some detail.

The literature contains many accounts of experiments of the addition of sawdust to soil. Nearly all are agreed that fresh sawdust is bad in its effects because of the large amount of cellulose which it contains and which causes a depletion of nitrogen in the soil by the action of the bacteria needed to decompose it. Nevertheless, some first-hand information was sought, especially on the growth of plants in pure sawdust.

As a preliminary trial, seven potato plants were grown in each of the three combinations mentioned above. The seed pieces were sprouted in sand in November for about a month and then were transplanted to the culture jars, which were one-gallon containers. To the top of the medium in each crock five grams of 8-16-16 fertilizer and one gram of pure urea were added. Contrary to what might be expected, the plants all grew and thrived about equally well in the three materials, probably because the nitrogen and other nutrients were entirely adequate. No yield data are available because the crocks were too small to grown potato plants to maturity. After the plants were pulled up, the contents of the crocks were emptied into three separate piles according to their respective identity, thoroughly mixed and samples taken for nutrient analysis as given below:

Nutrients in Growth Media After a Crop of Potatoes

Material	pH	NO_3N	NH_4N	P	Mg	K	Ca
Soil only	4.04	high	very low	very low	very low	very low	very low
Soil + Sawdust	4.13	none	very low	low-medium	very low	trace	very low
Sawdust Only	4.11	low	low	very high	low	very low-low	very low

One or two things about this deserve comment. The pH is quite uniform throughout. The sawdust in both cases has lowered the nitrogen markedly. Other elements have been depleted to quite an extent in all three materials.

In an effort to correct some of the deficiences, the following treatments vere given, mixed intimately with the soil and sawdust:

Amounts Per 1-Gallon Crock

1. Soil only	2. Soil and Sawdust	3. Sawdust only
4 gm. urea	9 gm. NH_4NO_3	4.5 gm. NH_4NO_3
10 gm. Ca superphosphate	10 gm. Ca superphosphate	4.0 gm. urea
4 gm. $MgSO_4$	4 gm. $MgSO_4$	4 gm. $MgSO_4$
4 gm. KCl	8 gm. KCl	4 gm. KCl
15 gm. $CaCO_3$	15 gm. $CaCO_3$	15 gm. $CaCO_3$

On July 30, 1947 uniform tomato seedlings were planted, one per crock, which grew fairly uniformly for some time. On September 9, four grams of urea was added to each crock.

By October 22, the differences in effects of these materials were quite striking. The plants in *sawdust only* were the largest, and had larger and riper fruits than the others, but the foliage was more mature with a purplish and brownish tinge on it. This was probably due to a low phosphorus supply, as further brought out by subsequent soil analysis. All of the plants in this group were alive, and all had fruits on them. The plants in *soil only,* although smaller and with smaller fruit, had a good green color. One of these plants was dead and the other one had blossoms but no fruit. The plants in soil and sawdust were all dead but two and these two were very stunted.

As the fruit ripened, records were taken of the yields. This was

completed by November 1, 1947. Total yields in grams were as follows:

Sawdust Only	Soil Only	Soil + Sawdust
1228	429	0

Shortly after the harvest samples were taken of each medium with the results given below:

Nutrients in Growth Media After a Crop of Tomatoes

Material	pH	$NO_3.N$	$NH_4.N$	P	Mg	K	Ca
soil only	4.49	very high +	very low	low-med.	low-med.	very high +	very high
soil + sawdust	3.91	very high ++	very high	high	med.-high	very high +++	very high
sawdust only	7.40	none	very low	low	very low	trace	very high

The one outstanding thin about this is the high level of nearly all nutrients in the mixture of soil and sawdust, especially nitrogen. The contrast between this and the sawdust only is rather striking. The high level of nutrients probably caused the stunting of the plants in the mixture. The supply of all these nutrients was low before the fertilizers were added and very similar amounts caused no bad effect on the other cultures. This indicates that there is a very troublesome problem in growing plants in cultures of this sort, i. e., the proper balance and fair method of comparing fertilizer effects. Admittedly this study is of a preliminary nature, but it raises some questions for verification and further study, probably best performed in outdoor plots.

SUMMARY

Water and sand cultures of plants were grown to which finely divided lignin and other colloidal materials were added as texture modifiers. They were without effect in water cultures and they aided growth in sand but not in gravel. The effect is probably one of increased surface contact between root hairs and sand particles.

Plants were grown in soil cultures to which lignin and other organic materials were added, both as single crop cultures (non-residual) and as successive cultures for the residual effects of these substances on several crops in the same soil. In each group some individual crops showed benefit from the treatments in comparison to crops grown in soil only, but the average differences were not great enough to be significant. It appears from this that there are certain benefits from such treatments which cannot be realized or made evident in greenhouse cultures. These would come from increased speed of penetration of rainfall, improved structure, increased ability to hold nutrients against leaching, etc. All these are far more effective on crops grown in outdoor plots, and that is where the possible benefits of such organic additions to the soil should be measured. A possible exception to this would be the preliminary testing of the speed of a given composting process. This might well be done in greenhouse cultures.

Additions of lignin to soil were without effect in increasing the starch content of potato tubers in comparison to those in soil without lignin. The plants were of the Katahdin variety which is known to be ordinarily low in starch.

Shredded bark appeared to have some value in minimizing the toxic effects of high amounts of nutrient salts in the soil, and other than that, its beneficial effects are doubtful.

Applications of distillery waste to soil gave no benefit to crops grown in such soil in comparison to the controls.

Sand cultures with composted sawdust showed that this material may be valuable in increasing yields if the composting has progressed long enough. This is further substantiated by experiments on crops grown in pure sawdust in comparison to a mixture of sawdust and soil, and soil only. Further study is needed on these points, especially on methods of composting or other methods of breaking down sawdust and like materials more rapidly. It seems evident that one important factor may be the maintenance of proper moisture contents of the composts since these received none other than that from natural precipitation.

LITERATURE CITED

1. ALDERFER, R. B., GRIBBINS, M. F. and HALEY, D. E. *Effect of waste sulfite liquor on aggregation of soil particles. — Ind. Eng. Chem.* **36** : 272-274, 1944.
2. DUNN, STUART and LYFORD, W. H., JR. *Influence of soil texture upon growth of plants. — N. H. Agr. Exp. Sta. Tech. Bull.* **90**, 1946.
3. DUNN, STUART and SEIBERLICH, JOSEPH. *Uses of lignin in agriculture. — Mech. Eng.* **69** : 197-198, 212, 1947.
4. DUNN, STUART, SEIBERLICH, JOSEPH and EPPELSHEIMER, D. S. *The use of lignin in potato fertilizer. — Northeastern Wood Utilization Council Bul.* No. **7** : 21-26, 1945.
5. PHILLIPS, M., GOSS, M. J., BROWN, B. E. and REID, F. R. *The ammoniation of waste sulphite liquor and its possible utilization as a fertilizer material. — Journ. Agr. Res.* **53** : 209-224, 1936.
6. SOWDEN, F. J. and ATKINSON, H. J. *Waste sulphite liquor as a soil treatment. — Sci. Agr.* **28** : 175-182, 1948.
7. SPULNIK, J. B., STEPHENSON, R. E., CLADWELL, W. E. and BOLLEN, W. E. *Effect of waste sulfite liquor on soil properties and plant growth. — Soil Sci.* **49** : 37-49, 1940.