Improving Nursery Soil by Addition of Organic Matter

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Typical farm crop management usually permits a certain amount of soil improvement every year or so through green manuring and addition of crop residues and animal manure. In contrast, most nursery crops remain on the land for a number of years, with practically no opportunity for green manure or cover crops. While the plants are growing in the cleanly cultivated nursery, only a small quantity of prunings are added to the soil. When finally the roots are balled and the crop is sold, most of the roots and a great quantity of topsoil leave the field. About one-tenth of the plowed horizon or tilled topsoil goes with the crop. Thus the customary practices in nurseries result in deterioration and loss of topsoil.

The obvious remedy would be the growing of soil-improving crops. Under this system the field would be planted to grass or legume and would not produce a nursery crop for a number of years. This would add organic matter and improve the physical condition of the soil. Most nurserymen, however, can ill afford the cost of idle land. They want a quick restoration of the topsoil.

The materials most likely to be used for this purpose are manure and peat in liberal quantities. Unfortunately, manure is expensive and not always available and, what is even more important, its effectiveness is brief in increasing the organic matter content and improving the physical condition of the soil. Peat lasts longer but it, too, may be expensive. Therefore the partial or whole substitution of cheaper waste products such as digested sewage sludge (Lunt, 1959) and woodchips (Lunt, 1955) needed to be investigated.

This bulletin reports a comparison of peat and manure, peat and sewage sludge, and sewage sludge and woodchips added to two depleted soils which had repeatedly grown nursery crops. The treatments were evaluated in terms of increased organic matter in the soil, improved soil conditions, and visibly improved growth of ornamental plants.

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Table 1. Initial acidity and organic matter content of soils

Nursery	pH		Organic carbon, per cent		Loss-on-ignition, per cent	
	0-6 in.	*6-12*	*0-6*	*6-12*	*0-6*	*6-12*
B	5.1	5.1	1.7	1.2	5.2	4.4
CI	5.4	5.2	1.9	1.2	5.4	4.4
CII	4.8	4.8	1.3	1.0	4.5	3.8

Table 2. Cubic yards of organic materials applied to the one-thirtieth acre plots

Treatment	Peat	Cow manure	Sludge	Chicken manure	Sawdust or chips
0					
M_3P_2	2	3	...	...	...
M_3P_4	4	3	...	...	...
M_3P_6	6	3	...	...	...
S_3P_2	2	...	3	...	...
S_3P_4	4	...	3	...	...
S_3P_6	6	...	3	...	...
S_6W_2	...	...	6	...	2
P_4C_1	4	...	...	1	...
P_4	4	...	...	...	...
M_6	...	6	...	...	...

MATERIALS AND METHODS

Soils. These studies were conducted at two nurseries in central Connecticut. Nursery B is in the low foothills just west of the Connecticut River Valley. The soil is Merrimac fine sandy loam to loam, and the field used for the plots had grown nursery stock for a number of years and was eroded.

Nursery C is in the Connecticut River Valley. The soil of field I is Hartford fine sandy loam, and of field II Hartford sandy loam. Both fields had been cropped to nursery stock for many years and much of the original topsoil had been removed through the balling of the roots when the plants were dug.

The fields were sampled prior to treatment, Table 1. The soils in all three fields were acid and were low in organic matter content.

Table 3. Composition of materials applied to the nursery plots

	Dry weight, lbs./yd.[a]		Composition as per cent of dry weight: Water		Organic matter		Nitrogen		pH	
	Nursery B	C	B	C	B	C	B	C	B	C
Peat	441	350	156	315	84	46	1.5	1.5	4.7	4.9
Sludge	749	667	68	108	43	43	1.8	2.6	4.9	5.1
Cow manure	452	272	193	268	55	77	2.0	1.4	7.8	7.0
Horse manure	418	...	118	...	51	...	1.5	...	7.1	...
Chicken manure	...	513	...	86	...	49	...	2.0	...	7.0
Sawdust	240	...	...	...	95	...	0.2[a]	...	...	...
Wood chips[b]	...	181	...	79	...	95	...	0.8	...	5.2

[a] Estimated from previous experience (Lunt, 1955).
[b] The chips at Nursery C included an appreciable amount of leaves.

The Treatments of 1954. At Nursery B eight organic matter treatments were applied in triplicate; at Nursery C eleven treatments were applied in duplicate to field I and in quadruplicate to field II. All plots were 1/30 A. in size. The treatments are listed in Table 2.

The peat used at Nursery B contained 83 per cent organic matter (dry basis), while that applied at Nursery C contained only 46 per cent organic matter. There were also some differences in the other materials used at the two nurseries. Sludge from the same sewage treatment plant was used at both nurseries, but the weight varied slightly due to variation in composition. The weight and composition of the materials are given in Table 3.

The quantities of organic matter and nitrogen applied to the fields are given in Table 4.

Lime was applied to all plots. Fertilizer treatment was planned to provide sufficient available nutrients to avoid any serious deficiencies on any of the plots. Besides superphosphate, applications of 10-10-10 and muriate of potash were made as needed, based on soil tests and on observations of the cover crops. The approximate total nutrients supplied are shown in Table 4.

Table 4. The organic matter and nitrogen applied in the amendments and the nutrients supplied in commercial fertilizers. Expressed in lb./A.

Treatment	From amendments: Organic matter	N	From commercial fertilizer[a]: N	P_2O_5	K_2O
		Nursery B			
0	0	0	195	265	390
M_3P_2	43000	1080	15	205	30
M_3P_4	65100	1500	15	205	30
M_3P_6	87300	1890	15	205	30
S_3P_2	51500	1620	15	205	480
S_3P_4	73600	2040	15	205	480
S_3P_6	95800	2430	15	205	480
S_6W_2	72200	2490	15	205	480
		Nursery C[b]			
0	0	0	210	370	690
M_3P_2	28400	660	30	190	30
M_3P_4	38200	990	30	190	30
M_3P_6	47800	1290	30	190	30
S_3P_2	35600	1830	30	190	480
S_3P_4	45200	2130	30	190	480
S_3P_6	54900	2460	30	190	480
S_6W_2	62300	3090	30	190	480
P_4C_1	26800	930	90	220	410
P_4	19200	630	210	370	390
M_6	37700	690	30	340	30

[a] Most of the phosphorus and some of the nitrogen and potassium were applied at the start of the experiment in 1954. The balance was applied in 1955.
[b] The amounts of nutrients applied do not include a supplementary application of ammonium nitrate applied to half of each plot at Nursery C, amounting to 65 lbs. of N per A.

Tillage and Cropping. After applying the organic matter, the soil was disked and then plowed and left rough. Following the application of lime, superphosphate, and the other fertilizers, the plots were disked, then seeded to buckwheat. This crop was disked in early September and the following grass-clover mixture sown at the indicated rates in lb./A.: Timothy, 2; orchard grass, 3; Alsike clover, 2; mammoth red clover, 3; and ladino clover, 1.

At Nursery B the plots were plowed in May 1957 and several rows of Forsythia and Weigela planted. In the same summer both fields at Nursery C were plowed. In 1958, five varieties of Taxus were planted on field I. These were *T. baccata* var. *erecta*, *T. cuspidata* var. *Thayerae* and forma *densa*, and *T. media* var. *Hatfieldii* and var. *Browni*. On field II the entire area was planted to *T. cuspidata*.

Methods of Analysis. Quick tests were made by the Morgan[1] or Wolfe[2] method. Soil reaction was determined in a thin paste soil-water suspension by means of a glass electrode pH meter; total nitrogen by the Gunning method; organic carbon by the wet combustion method of Schollenberger[3], and cation exchange capacity according to Chandler's[4] barium acetate-electrometric titration method.

Moisture equivalent was determined by the centrifuge method of Veihmeyer.[5]

RESULTS

Organic Matter and Nitrogen Content of the Soil. The primary goal in treating the soils was to increase their organic matter content and improve their physical condition. The plow zone of all plots at Nursery B was sampled in November 1957, and at Nursery C in May 1958.

At Nursery B (Table 5) the organic carbon content was almost 1 per cent higher where organic materials had been applied 3 years before, than where they had not. This difference is highly significant. In two treatments, S_3P_6 and S_6W_2, the increase was 1.31 and 1.16 per cent respectively, and the increase for the other four treatments averaged 0.89 per cent, but these differences *among* the materials are not significant.

Total nitrogen in the soil was likewise increased significantly by the treatments. Treatments S_3P_6 and S_6W_2 averaged highest, but again the differences among the materials are not significant.

At Nursery C most of the treatments resulted in some increase in organic carbon, but none is significant. There were no significant differences in nitrogen content.

Moisture Equivalent and Cation Exchange Capacity. At both nurseries increases in moisture equivalent were slight and not significant, Table 6. Cation exchange capacity increased following all treatments save one, but only treatment S_3P_6 at Nursery B caused a significant increase.

Other Soil Characteristics. The mean pH was 5.4 in Nursery B and 5.8 in Nursery C. At the 1957 sampling at Nursery B the pH had been increased 0.1 to 0.2 pH unit by manure, but sludge tended to have the opposite effect.

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1 The Conn. Agr. Expt. Sta. Bul. 541, 1950.
2 Ind. Eng. Chem. (Anal. Ed.) 15:248-51, 1943.
3 Soil Science 40:311-320, 1935.
4 Jour. Agr. Res. 59:491-506, 1939.
5 Proc. First Internatl. Cong. Soil Sci., Washington 1:512-534, 1927.

Table 5. Organic carbon and total nitrogen content of the soil as a per cent of dry weight

Treatments	Organic carbon		Total nitrogen	
	Nursery B Nov. 1957	Nursery C May 1958	Nursery B Nov. 1957	Nursery C May 1958
0	1.35	1.48[a]	1.32	1.08[a]
M_3P_2	2.22	1.80	1.84	1.02
M_3P_4	2.29	1.48	1.71	1.08
M_3P_6	2.20	1.72	1.61	1.12
S_3P_2	2.24	1.55	1.64	1.00
S_3P_4	2.27	1.65	1.84	1.08
S_3P_6	2.66	2.00	2.08	1.18
S_6W_2	2.51	1.75	2.05	1.15
P_4C_1	....	1.52	....	1.00
P_4	....	1.18	....	1.02
M_6	....	1.55	....	1.05
L.S.D. (P = .05)	0.75	0.55	0.64	0.37

a Average of fields I and II.

Nitrates were two to three times higher in the treated than in the untreated soils, and calcium and magnesium were increased in the manured soil.

At Nursery C, sludge did not have any acidifying effect. Tests for nutrients were made only by the spot plate technic and no differences of consequence could be detected. There were no other differences in chemical composition.

PLANT GROWTH

Buckwheat. Buckwheat was seeded about August 1, 1954. In September, before disking the crop, these observations were made: (1) At Nursery B the buckwheat plants on the check plots were considerably larger and greener than those on the other treatments; this indicated a response to the more readily available nutrients from the commercial fertilizer applied to the check plots. (2) At Nursery C the growth on the manured plots was poorer than on the sludge plots.

Table 6. Moisture equivalent and cation exchange capacity of the soil

Treatments	Moisture equivalent, per cent		Cation exchange capacity m.e. per 100 g. soil	
	Nursery B Nov. 1957	Nursery C[a] May 1958	Nursery B Nov. 1957	Nursery C[a] May 1958
0	11.7	11.6	7.7	4.8
M_3P_2	11.8	12.9	9.1	5.5
M_3P_4	11.8	12.8	8.8	5.2
M_3P_6	11.8	12.5	9.3	5.4
S_3P_2	11.8	12.2	8.9	5.1
S_3P_4	11.9	12.4	8.8	5.0
S_3P_6	11.9	12.3	10.1	6.1
S_6W_2	11.8	12.6	8.6	5.6
P_4C_1	....	11.8	...	4.7
P_4	....	11.0	...	5.1
M_6	....	11.9	...	5.4
L.S.D.	3.5	2.3	2.4	2.2

a Average of fields I and II.

Grass-clover. At Nursery B the color and density of the stand on the check plots was poor in 1955 and worse in 1956. Differences in growth between manure and sludge treatments were small and inconsistent.

At Nursery C growth was slow in the spring of 1955, apparently due to a shortage of available nitrogen. Therefore, ammonium nitrate was applied to half of all plots at the rate of 195 lb./A. In June observations revealed a response to the extra nitrogen on both fields, although on field II the treated areas were brownish due to necrotic tips which were likely caused by a potassium deficiency aggravated by the extra nitrogen.

On June 22, 1955 the grass was cut from 8 sq. ft. on each plot, dried and weighed. Regardless of organic material added, the extra nitrogen increased growth about one-half. The addition of organic matter had not increased growth materially.

Table 7. Ranking of Forsythia and Weigela plants, June 1958, Nursery B; sum of rank assigned by two observers (the lower the number the smaller the plants)

Plant	0	M_3P_2	M_3P_4	M_3P_6	S_3P_2	S_3P_4	S_3P_6	S_6W_2
Forsythia	32.5	25	36	38	29.5	25	23	7
Weigela	28	26	33	42.5	31.5	15	23	17
Both species	60.5	51	69	80.5	61	40	46	24

Forsythia and Weigela. Comparative growth of the nursery stock was determined visually.

Rankings of the plants in Nursery B were made by two independent observers in June 1958, in April and October 1959, and in September 1960.

The results of the 1958 ranking are given in Table 7. At that time, treatment S_6W_2, sludge and chips, was significantly poorer ($P = .05$) than the others. This was likely due to toxicity of the sludge. Insufficient lime had been used to precipitate such metals as copper and zinc which are present in sludge and toxic under acid conditions (Lunt, 1959). Soil tests showed no evidence of lower nitrates due to the presence of the sawdust.

Manure plus 4 or 6 cu. yd. of peat, treatments M_3P_4 and M_3P_6, promoted growth, especially of Weigela. This effect is significant at about $P = .16$. No other treatments were significant.

In the two 1959 rankings, the toxicity of the S_6W_2 treatment began to lessen, and in the final ranking in September 1960 (Table 8) the plants on this treatment were approximately equal to those on the check plots. All of the other treatments resulted in visibly and significantly ($P = .05$) better growth with no definite differences between the manure-peat and the sludge-peat treatments.

Table 8. Ranking of Forsythia[a] plants, September 1960, Nursery B; sum of ranks assigned by two observers (the lower the numbers the smaller the plants)

Plant	0	M_3P_2	M_3P_4	M_3P_6	S_3P_2	S_3P_4	S_3P_6	S_6W_2
Forsythia	12	30	39	24	27	31	34	19

[a] Includes some Weigela plants in treatments M_3P_2, M_3P_4, and M_3P_6 of one replicate.

Table 9. Estimated new growth in inches of *Taxus cuspidata* in 4 replicates, Field II, Nursery C

	0	M_3P_2	M_3P_4	M_3P_6	S_3P_2	S_3P_4	S_3P_6	S_6W_2	P_4C_1	P_4	M_6
1959	9.5[a]	9.7	9.6	8.7	9.8	10.2	10.6	10.2	9.0	8.8	9.0
1960	5.5[b]	5.8	5.3	5.7	6.3	6.4	6.0	6.8	5.2	5.0	5.7

[a] Mean of 3 independent estimates in 4 replicates.
[b] " " 2 " " " 4 " .

Taxus. In October 1959, the length of the 1959 growth or stem elongation of the plants in Nursery C was estimated independently by three observers, and the process was repeated in September 1960 by two observers.

In 1959 observations of the five Taxus varieties in field I indicated that growth was greater on the sludge-treated plots in five cases, and equal to the others in three cases. Because more than one variety was involved, none of which had received all of the treatments, and since there were only two replicates, no further information could be obtained from field I.

For field II, estimated growth in inches is reported in Table 9. Differences were small but the analysis of variance shows an easily discerned and significant increase ($P = .01$) from the sludge treatments in comparison with all other treatments.

The 1960 estimates of two observers are also presented in Table 9. Here the beneficial effect of sludge on growth was again significant ($P = .01$). None of the other treatments produced any significant differences.

DISCUSSION AND SUMMARY

The analysis of the soil 3 or 4 years after treatment showed that most amendments increased carbon and nitrogen and that there was surprisingly little difference among materials and amounts. Evidently these soils have an equilibrium level which can easily be attained but cannot easily be exceeded. The other characteristics of the soil, moisture equivalent and cation exchange capacity, were not so easily changed because they depend upon more than organic matter.

A greater increase in organic matter and nitrogen was produced at Nursery B than at Nursery C. This was undoubtedly due, in part, to the better quality peat and manure used at Nursery B. Assuming 2 million pounds of soil 6⅔ inches deep, we estimated that 4 cu. yd. of the peat applied to a plot at Nursery B would increase the organic matter 44,400 lb./A. or 2.22 per cent. At Nursery C the estimated increase from 4 cu. yd. of the peat used there would be 19,260 lb./A. or 0.96 per cent.

On the other hand, in treatment S_6W_2, Nursery C received the same kind and amount of sludge as did Nursery B, yet it increased soil carbon and nitrogen significantly less at Nursery C than at Nursery B. More rapid decomposition of the organic matter at Nursery C due to the coarser texture of the soil may have been a contributing factor. Also because the chips used at Nursery C included leaves, less lignin was added to the soil per unit of dry weight applied.

In conclusion, it is evident that, from the standpoint of measurable improvement in soil properties, the choice of organic matter can reasonably be governed more by cost than by any other consideration. The study shows that the application of organic matter can result in significantly improved growth of nursery stock. However, the evidence from Nursery C suggests that sludge is more effective than manure in promoting growth of Taxus. As pointed out earlier, it is essential that the soil pH be high enough to inactivate toxic metals in the sludge lest the sludge suppress growth as it did in Nursery B. Our analyses of the soil do not provide a ready explanation for the superiority of sludge in Nursery C because the changes in carbon and nitrogen, exchange capacity, pH, or available nutrients were not outstanding. Nevertheless the Taxus indicates that the soil is improved more by sludge than by the other materials.

REFERENCES

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The Author

Herbert A. Lunt retired from the active staff of the Station in 1955 as soil scientist, Department of Soils. Before his retirement he had begun an extensive field trial of the improvement of nursery soil by the addition of organic matter. During the ensuing years he has returned periodically and joined Paul E. Waggoner in observations of the plots. Thus Dr. Lunt has made possible the completion of this worthwhile task which he so well began.

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