CHAPTER XII

HUMUS

(Properties and Silvicultural Importance)

"So lie the dead leaves; but they and such as they nourish forever that great trunk ... which still sheds forth another crop and another, each as strong and as fair as the last."

Sir A. Conan Doyle

The term "forest humus", in its broadest sense, refers to the entire organic portion of the soil profile (Waksman). It includes undecomposed leaves, needles and twigs or litter, partly decomposed remains, or duff and the finely-divided decay-resistant residue often incorporated with the mineral soil and referred to as amorphous humus or "leaf mold".

Forest humus is an ecological factor of extensive significance. It is an important agent in the processes of soil development. The leaching of podzols, maintenance of the equilibrium of soluble salts in the melanized soils, and accumulation of sesquioxides in laterites are intimately related to the nature of humus decomposition. Different forms of humus modify the rate of natural reproduction of forest stands and thus influence the technique of selective logging. Forest humus plays an important part in the maintenance of the fertility of permanent forest nurseries, being a source of useful organisms, balanced nutrients, buffering colloids, growth hormones and other substances essential in tree growth.

The first classification of the organic layers of forest soils is accredited to the German forester Emeis who in 1875 described three types of forest humus; one consisting of well-decomposed organic matter largely incorporated with the mineral soil and containing nitrogen in the form of "nitric acid"; the other two being composed of "raw" organic remains. This subdivision has formed the basis for all subsequent schemes of classification.

P. E. Müller of Denmark was the first to look upon forest humus layers as naturally occurring biological units. In 1879 he subdivided the humus layers of forest soils into two types or groups, mull and mor.

The typical representative of Müller's mull group is the earthworm mull, consisting of an intimate mixture of humus and mineral soil. It has a friable, crumbly structure due to the presence of large earthworms, such as Lumbricus terrestris and supports a rich flora of nitrophilous geophytes. Müller's mor or raw humus group is characterized by a thick, matted layer of free organic matter, sharply delineated from the mineral soil. The vegetation includes acidophilous plants of saprophytic nature.

Since Müller published his original work, there have been numerous attempts to broaden the classification of humus and adapt it to the needs of silvicultural practice (Ramann, Ebermayer, Hesselman, Leiningen, Vater, Albert, Ekstrom, Frosterus.
and Tamm, Juncker, Tschermak, Bornebusch, Romell and Heiberg, and Heiberg and Bornebusch). Although these efforts have broadened the knowledge of humus forms, they have resulted in the introduction of several misconceptions and unnecessary complications. The following points summarize the chief discrepancies and omissions common to the existing classifications.

On the basis of observation of isolated cases, several authors declared that the rate of forest growth depends upon the type of humus. As more extensive studies showed, such a correlation does not hold true universally.

The degree of humification and development of mull or mor types was directly related to the reaction of the organic remains. "Sour" humus and "sweet" humus were used as synonymous for mor and mull humus in Russian, German and English literature. This relationship also proved to be unfounded, as strongly acid mulls with a reaction less than pH 5.0, as well as alkaline mors with a reaction as great as pH 8.0, were described.

Mull humus was presented as a material containing greater amounts of readily available nutrients than mor humus. Analysis of a large number of humus samples, as well as quartz sand culture experiments, proved the direct opposite of this supposition; pure mull types showed considerably less available nutrients per unit weight than the mor types.

The presence of an A₁ horizon with incorporated humus was assumed to be the distinguishing characteristic of mull humus. Actually, a number of varieties of the mor group with a pronounced A₁ horizon was observed.

Classificational schemes of different authors in various countries led to great terminological confusion. An examination of a glossary of the terms would show that almost every expression of international use has two or more meanings and the same material is known under several names.

None of the existing classifications gave sufficient consideration to the thickness and friability of the free organic matter, properties which are directly correlated with the rate of natural reproduction.

As a rule, classifications of humus completely disregarded the nature of the underlying mineral substratum. As recent investigations showed, chemically and to a great extent biologically, the humus layers are dependent upon the properties of the mineral soil.

Considering the outlined criticisms, and the information available at present, a general scheme of forest humus classification is outlined below. This classification recognizes two broad biological groups (mull and mor), eight well-defined and silviculturally important types (barren mull, earth mull, duff mull, podzol mull, crust mor, raw mor, infiltrated mor and rendzina mor), and a number of morphological varieties of secondary practical importance, (crumb mull, grain mull, firm mull, matted mor, fibrous mor, amorphous mor, etc.). The accompanying
drawings present schematically the important morphological features of humus types.

Figure 34

Schematic profiles of humus types (1) Barren mull; (2) Earth mull; (3) Duff mull; (4) Podzol mull; (5) Crust mor; (6) Raw mor; (7) Infiltrated mor.

Vertical lines indicate incorporated humus, whereas solid black indicates raw or free organic matter.

A. Mull Group or Active Humus

1. Barren Mull is formed under conditions promoting extremely rapid decomposition of organic remains. The litter is either entirely absent or is represented by a few scattered remnants of the last year's leaf fall. The mineral soil contains only a negligible amount of incorporated humus, which sometimes is difficult to detect by ocular examination. The humic layer does not exceed a depth of 2 inches. In spite of the rapid decomposition of organic remains, the upper layer of soil may be of very high acidity, approaching pH 4.

The type is confined chiefly to soils of lateritic nature, particularly the red and yellow forest soils. It also occurs in the brownearth region, and in areas adjacent to the prairie. This type is found under stands of both pines and hardwoods, oaks being the principal hardwood species.

The possibilities of natural reproduction are high due to exposed mineral soil. In spite of the low content of soil organic matter pine stands on barren mulls may be fairly productive. This is generally true of the lateritic zone where climatic conditions make satisfactory tree growth possible on soils with a minimum content of base exchange material and available nutrients.
Figure 35. Characteristic profiles of mull and raw humus types: 1. Crumb mull on a slightly podzolised loam; 2. Acid raw humus on a podzol sandy loam with orrstein horizon; 3. Alkaline raw humus underlain by limestone bedrock. The monoliths represent sections 20 inches deep.
3. Earth Mull is characterized by a dark A₁ layer with incorporated humus, usually varying in depth from 3 to 8 inches. In some instances the depth of humic layer is even greater. The layer of litter is thin and often interrupted. In many instances the litter is nearly absent. The reaction of the humic layer ranges from pH 5 to pH 8.

This type occurs in the region of brown earths, grey forest soils and podzolic soils, predominantly under hardwood stands. The rate of growth and quality of the stands are extremely variable. The ground cover association is composed of typical mesophytic "mull" plants, such as Mercurialis, Anemone, Hydrophyllum, Thalictrum, and Dicentra.

The conditions for natural reproduction in this type are very favorable. Because of the rapid decomposition of organic remains and the vigor of competing vegetation, thinnings and selective cuttings must be conducted in a very conservative manner. The value of earth mull as a natural fertilizer is low because of the high content of mineral soil. Its inoculating capacity is questionable since the earthworms and bacteria may not survive in the poorly aerated compost pile or in the acid nursery soil.

Depending upon the structure of the A₁ horizon, the earth mull may be divided into a number of morphological varieties, as follows:

(a) Crumb mull. The humic layer is of a coarse crumby structure resulting from the activity of large earthworms. The content of organic matter rarely exceeds 20 per cent. This variety occurs predominantly on heavy soils with a high ground water level. Forest stands are composed chiefly of hardwood species. A high percentage of culm material is common. The ground cover includes several species of ferns, and moisture-loving plants in addition to typical mull vegetation. The reaction of the humic layer varies from pH 5.5 to pH 3.0.

(b) Grain mull. This variety is characterized by a fine grained structure and the absence of large earthworms. The content of organic matter may be higher than in crumb mull. The ground cover consists of typical mull plants. Grain mull occurs on well drained soils of loam texture, often under stands of a high productivity. The reaction is about pH 6, or higher.

(c) Firm mull. The humic layer is structureless, of dense or firm nature and has a low content of organic matter, as a rule not exceeding 10 per cent. The reaction varies from pH 5.0 to 6.0. It is confined to heavy upland soils.

(d) Bor mull. The humic layer is of single-grained structure and reaches a depth of 8 inches. The content of organic matter usually does not exceed 6 per cent. The reaction varies from 5.0 to 6.5. The variety is confined to unleached sands, and occurs chiefly under pine and oak stands.

3. Duff Mull. This type is characterized by the presence of a substantial layer of friable litter and duff, varying in thickness from 1 to 2½ inches. The infiltrated horizon may be structur-
ed or structureless. The depth of the humic layer seldom exceeds 8 inches. The reaction of the organic portion usually varies from pH 5.0 to 7.0.

Duff mull occurs predominantly on well drained podzolic and grey forest soils supporting either pure hardwoods or mixed hardwood-coniferous stands. The conditions for natural regeneration of the stand are somewhat less favorable than are found on the true mull type and selective logging may be carried on with a somewhat greater intensity. The duff portion as a rule has a high content of nutrients, and can be advantageously used as a fertilizer or inoculating medium.

Duff crumb mull, duff grain mull, duff bor mull and duff firm mull are morphological varieties of this type separated on the basis of the nature of the A1 horizon. With the exception of the duff layer, these varieties are essentially similar to those of the earth mull type.

4. Podzol Mull. This type is a peculiar transition between mull and mor forms. The entire absence or slight development of the infiltrated A1 layer as encountered in podzol soils, is the outstanding characteristic. The litter and duff layers are of a distinctly friable structure and their thickness does not exceed 2½ inches. The reaction of organic horizons varies from about pH 5.0 to 6.0. This type occurs on podzolized soils supporting hardwood-coniferous or pure coniferous stands. The ground cover is largely composed of raw humus plants and several species of Liliaceae.

The duff layer has, as a rule, a very high content of available nutrients, and is characterized by the presence of very active organisms, both fungi and bacteria. It is an ideal fertilizer and inoculating medium for most species.

This type is very favorable for natural reproduction of conifers, particularly spruce, fir, hemlock and white pine. Selective logging should be carried on in a very conservative manner, as the rapid decomposition of the duff layer will result in a drastic reduction of soil fertility. The danger of soil deterioration is due to the absence of incorporated humus and the exposure of the sterile podzolic layer following the rapid decomposition of the free organic remains. The silvicultural importance of this type has been overlooked and the type itself usually confused with "raw humus."

B. Mor Group or Inert Humus

1. Crust Mor. This type is primarily confined to the boreal region of the North American and Eurasian continents, particularly to barren sandy soils, too poor to support heath shrubs. The organic remains assume the form of a thin, but firm, crust-like layer of lichens, xerophytic mosses and needles. This crust has an extremely acid reaction, approaching pH 3.0. Crust mor and its adverse influences upon forest growth are well known from the descriptions of the "Yağ" type of the Russians and the "Cladina" type of the Finnish foresters.
2. Raw Mor. Duff layer consists of partly decomposed remains of vegetation, particularly wood, interwoven by the mycelia of fungi and often by the roots. It is of a compact or tough consistency, ordinarily varying in thickness from 3 to 5 inches, but in places reaching a depth of 1 foot. It rests directly upon leached mineral soil. The reaction varies from pH 3.5 to 5.5.

This type is confined to true podzols and occurs predominantly under the dense stands of conifers. The ground cover is composed exclusively of acidophilous raw humus plants of saprophytic nature, such as Vaccinium, Lycopodium, Maianthemum, Cornus canadensis, and Linneas.

The raw mor is noted for its unfavorable influence upon natural regeneration. In order to promote the decomposition of the thick mat of organic remains, stands must be opened by heavy selective logging. Sometimes the duff layer is broken up mechanically. As fertilizing and inoculating material it is considerably more valuable than earth mull, but is inferior to podzol mull and some varieties of duff mull.

A description of the main morphological varieties follows:

(a) Matted mor: Duff layer appears as a tough, compacted brown mat of leaves, needles and wood remains approximately 4 inches in thickness. It is the most common variety found on podzol soils of America and Europe.

(b) Amorphous mor: Duff layer is compacted but not tough, composed chiefly of dark brown, nearly black wood remains. The lower portion is highly dispersed and has a greasy feel when wet. The thickness of duff layer may be as great as 12 inches. This variety occurs in cool regions of high humidity, and is associated with very strongly podzolized soils.

(c) Fibrous mor: Duff layer is of a considerable thickness, firmly bound by interwoven roots of heath plants, but not compact. Occurs on soils with a ground cover of Hypnum and Vaccinium spp. Widely distributed in Scandinavia, and northern Russia, chiefly on soils of sandy texture.

3. Infiltrated Mor. The thick duff layer is quite similar to the duff layer of the matted mor. However, it is underlain by an infiltrated A1 horizon with incorporated or rather "washed in" humus, which is the distinguishing characteristic of this type. The tongues of the infiltrated horizon extend to a depth of one foot or more, and often occurs as dark spots.

Infiltrated mor is confined chiefly to podzol soils with impeded drainage. The forest cover is composed predominantly of mixed hardwood-coniferous stands. The ground cover includes mosses, ferns, sedges and other water-loving plants. The understory includes a considerably higher amount of tall shrub species than is found on the raw mor type. Natural reproduction proceeds rapidly, but may be easily suppressed by weed species if the stand is cut too heavily.
On wet gley soils of heavy texture, the A1 horizon is black, or nearly black, plastic, and of muck-like or sapropel nature (Stebutt). This variety may be referred to as sapropel mor. The plastic sapropel layer has a tendency to cement the soil and, therefore, is undesirable as fertilizer.

4. Rendzina Mor. This type is found on exposed limestone outcrops and calcareous deposits in the podzol region. The dark brown duff layer is approximately 4 inches thick and consists of partly decomposed wood remains. It grades into a nearly black, finely divided humic layer, varying in thickness from 2 to 4 inches. The reaction of the duff and humic horizons varies from pH 6.5 to pH 8.0. The forest stands are inferior and composed chiefly of conifers. Northern white cedar is the predominant species in the United States. The ground cover includes typical saprophytic plants occurring on strongly acid soils.

As the organic layers rest upon highly calcareous strata, their destruction through fire, logging, or erosion converts the land into unproductive barrens. The use of the duff layer as fertilizer is objectionable because of its high content of calcium and magnesium carbonates.

The lime-bearing substrata of high mountains develop so-called "Alpine humus" which is closely related to rendzina mor.

Figure 36 shows characteristic profiles of mull and raw humus types.

**Chemical and Biological Properties of Humus in Relation to Its Morphology or Degree of Decomposition**

![Graph showing chemical and biological properties of humus](image)

Because of differences in degree of decomposition, humus types are characterized by the specific proportions of lignin, carbohydrates, proteins, fats, resins, and similar groups of constituents. The most significant fractions of these groups may be isolated by extraction with water, ether, alcohol, strong acids and other reagents, and determined quantitatively. The relative distribution of these fractions brings out not only the differences between the types of humus, but also the differences between a certain humus type and the original residue from which it was derived. Table 2 illustrates proximate chemical composition of the three types of forest humus occurring in the podzol belt of the Lake States.

The rate of organic matter decomposition is broadly correlated with the activity of microorganisms as manifested by the liberation of
carbon dioxide, the consumption of oxygen, the heat of fermentation, or release of soluble nitrogen. A quantitative recording of these processes may serve to indicate the general nature of organic remains. Diagram 36 shows the differences in the evolution of carbon dioxide by mull and mor types of humus (Galloway). Table 26 presents the amounts of ammonia and nitrates released during incubation of old beech leaves from mull and raw humus types (Bornebusch).

It should be noted that natural environment is an extremely important factor in the activity of organisms and, hence, the results of biological investigations of humus under optimum laboratory conditions have but relative significance. In particular, it is difficult to judge on the basis of laboratory trials the inoculating value of different humus deposits; the organisms which are very active in a fertile natural soil or in laboratory environment may rapidly degenerate upon the transplanting into composting medium or nursery soil.

Table 25. Proximate Chemical Composition of Different Types of Forest Humus
(After H. M. Galloway and W. E. Patzer)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Acid raw</th>
<th>Alkaline raw</th>
<th>Crumb humus</th>
<th>Per cent of dry material on ash-free basis*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other soluble fraction</td>
<td>3.42</td>
<td>0.26</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>Hot water soluble fraction</td>
<td>5.22</td>
<td>2.42</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>Alcohol soluble fraction</td>
<td>4.65</td>
<td>2.12</td>
<td>3.17</td>
<td></td>
</tr>
<tr>
<td>Hemicelluloses</td>
<td>6.84</td>
<td>7.82</td>
<td>2.94</td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td>6.08</td>
<td>2.21</td>
<td>1.69</td>
<td></td>
</tr>
<tr>
<td>Lignin</td>
<td>41.51</td>
<td>32.72</td>
<td>31.16</td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>11.11</td>
<td>12.41</td>
<td>19.02</td>
<td></td>
</tr>
<tr>
<td>Total accounted for</td>
<td>78.83</td>
<td>59.96</td>
<td>60.27</td>
<td></td>
</tr>
</tbody>
</table>

* Ash contents: Acid raw humus-4.55; alkaline raw humus-14.46%; crumb mull-90.12%.

Table 26. Liberation of Soluble Nitrogen in Mull and Raw Humus Types after Six Weeks Incubation
(After C. H. Bornebusch)

<table>
<thead>
<tr>
<th>Nature of humus</th>
<th>Reaction pH</th>
<th>Total N percent</th>
<th>Nitrogen liberated from 1 kg. of dry humus</th>
<th>NH₃ grams</th>
<th>NO₃ grams</th>
<th>Total grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beech mull; old leaves</td>
<td>6.1</td>
<td>1.70</td>
<td>0.034</td>
<td>1.200</td>
<td>1.234</td>
<td></td>
</tr>
<tr>
<td>Beech raw humus; old leaves</td>
<td>5.6</td>
<td>1.97</td>
<td>0.252</td>
<td>0.020</td>
<td>0.272</td>
<td></td>
</tr>
</tbody>
</table>
Nutrient Content and Exchange Properties of Humus

The nutrient content of humus is a function of three variables: type of humus, nature of underlying stratum, and composition of forest stand. Mull types having a high volume weight show considerably lower concentration of nutrients than mor or raw humus types. Heavy soils derived from parent materials rich in minerals, as a rule produce humus with a high content of nutrients, whereas sandy or siliceous soils, produce humus poor in nutrients. Light demanding species, particularly pines, tend to accumulate less nutrients in their litter than do tolerant trees, such as spruce, maple and basswood. Table 27 includes average values of different fertility factors for a number of humus types found on granitic deposits of the Lake States region. Diagram 37 facilitates a comparison of the nutrient contents present in various types of humus. Although humus is a factor of great complexity, involving physico-chemical, biological and catalytic aspects, a close correlation was shown to exist between the nutrient content of humus and the growth of forest seedlings under controlled conditions (Fig. 38).

Base exchange capacity is closely related to the content of lignin-like substances, and may serve as an indicator of the degree of humus decomposition. The base exchange capacity of raw humus ranges between 40 and 100 m.e. per 100 g. The base exchange capacity of mull humus is seldom greater than 30 m.e. per 100 g. because of the high content of mineral matter; however, the exchange capacity of the organic fraction itself may exceed 200 m.e. per 100 g.

![Diagram of nutrient content](image)

Figure 37. Contents of Nitrogen, Calcium, Phosphorus, and Potash in Different Types of Organic Remains from Upland Forest. JP--jack pine duff; NP--Norway pine duff; WP--white pine duff; AB--aspen-birch duff; HM--hemlock duff; HH--hardwood-hemlock duff; HS--hardwood-spruce fir duff; H--hardwood duff; HG--hardwood grain mull humus; HC--hardwood crumb mull humus.
Table 27. Fertilizing Value of Organic Remains of Upland Forest Vegetation, as Determined by Chemical Analysis

<table>
<thead>
<tr>
<th>Type of organic remains</th>
<th>:Base:</th>
<th>:Repl.:</th>
<th>:Repl.:</th>
<th>:Avail.:</th>
<th>:Avail.:</th>
<th>:Ca:</th>
<th>:Mg:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>:pH:</td>
<td>:m.e.:</td>
<td>:percent:</td>
<td>:p.p.m.:</td>
<td>:p.p.m.:</td>
<td>:m.e.:</td>
<td></td>
</tr>
<tr>
<td>Jack pine duff</td>
<td>5.6</td>
<td>13.3</td>
<td>0.372</td>
<td>24</td>
<td>186</td>
<td>7.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Norway pine duff</td>
<td>5.4</td>
<td>29.3</td>
<td>0.653</td>
<td>38</td>
<td>287</td>
<td>12.9</td>
<td>3.2</td>
</tr>
<tr>
<td>White pine duff</td>
<td>5.4</td>
<td>47.1</td>
<td>0.976</td>
<td>60</td>
<td>433</td>
<td>28.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Aspen-birch duff</td>
<td>5.7</td>
<td>39.3</td>
<td>0.775</td>
<td>69</td>
<td>471</td>
<td>27.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Hemlock duff</td>
<td>4.8</td>
<td>73.2</td>
<td>1.490</td>
<td>57</td>
<td>432</td>
<td>29.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Hardwood-hemlock duff</td>
<td>5.4</td>
<td>72.5</td>
<td>1.430</td>
<td>148</td>
<td>741</td>
<td>44.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Hardwood-spruce-fir duff</td>
<td>5.5</td>
<td>65.8</td>
<td>1.290</td>
<td>66</td>
<td>545</td>
<td>38.6</td>
<td>8.0</td>
</tr>
<tr>
<td>Hardwood leaf mul</td>
<td>6.5</td>
<td>90.5</td>
<td>1.460</td>
<td>115</td>
<td>660</td>
<td>66.6</td>
<td>9.5</td>
</tr>
<tr>
<td>Hardwood grain mul</td>
<td>6.4</td>
<td>15.5</td>
<td>0.227</td>
<td>35</td>
<td>282</td>
<td>11.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Hardwood crumb mul</td>
<td>5.3</td>
<td>27.6</td>
<td>0.610</td>
<td>37</td>
<td>296</td>
<td>16.5</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Average standard errors: pH 4.02; B.Ex. 44.4; Tot. N 0.07; Avail. P +6.7; Avail. K₂O +25.1; Rep1. Ca +0.4; Rep1. Mg +1.0.

Figure 38. Relation of the Base Exchange Capacity and of the Nitrogen, Calcium, Potassium, and Phosphorus Contents of Different Organic Materials to the Growth of Norway Spruce Seedlings.

Each unit of the ordinate represents the following values: 100 mg. of the dry weight of seedlings; 10 m.e. per 100 gm. of base exchange capacity; 0.2 per cent of total nitrogen; 0.1 per cent of replaceable calcium; 0.01 per cent of available potash; and 0.002 per cent of available phosphorus.
significance of Humus in Nursery Practice and Reforestation

Regardless of the origin or morphological form, humus fulfills in the soil four important functions; it improves physical properties of the soil, provides nitrogen and other plant food, absorbs mineral salts, and increases the availability of nutrients through its exchange and catalytic effects.

In no other branch of plant production is a deficiency of humus manifested with such sharpness as it is in forest nurseries. Forest trees, especially conifers, develop in their youth on a purely organic layer of forest debris, and thus acquire more or less pronounced saprophytic tendencies. No crop residues are left in the soil of the nursery because even the root systems of seedlings are removed. Continuous weeding and cultivation, artificial irrigation, and additions of commercial fertilizers promote biological activity and rapid decomposition of organic matter. Under these conditions, the maintenance of an adequate supply of humus may require regular additions of organic remains to the soil.

If fertilizers are applied to a nursery soil having a low content of humus, mineral colloids are likely to be insufficient to prevent the loss of salts by leaching. In times of drought, the moisture content of humus-deficient soils rapidly decreases through evaporation, and fertilizers tend to accumulate on the soil surface in injuriously high concentrations.

The statement that "Humus is the spirit of the soil" (Knox), may be an exaggeration; yet, it is to a great extent applicable to nursery soils.

Until recently research and reforestation practice have been neglecting the role which organic matter plays in the survival and growth of plantations. The indifference may be attributed to comparatively limited experience in the reforestation of old cut-over areas, the complicating co-influence of mineral colloids, occurrence of organic matter as incorporated humus as well as surface litter, and certain analytical difficulties in the determination of organic matter, which only lately have been removed.

At the present time reforestation in this country is, in the main, practiced on cut-over or burned-over lands depleted of organic matter and therefore greatly reduced in absorbing capacity and nutrient content. Under such conditions, organic matter content of soil is of particular importance in the selection of planting sites or tree species to be planted.

According to the agronomist's saying, "Nitrogen spells organic matter." In leached or sandy forest soils, with their revolving fertility renewed through the annual leaf fall, the organic matter appears to be nearly synonymous with the content of all nutrients. Diagrams 39 and 40 illustrate the relationships found in cut-over sandy soils of Wisconsin granitic outwash (7-inch surface layer).

Organic matter retains considerable amounts of water and soils rich in humus are likely to be less subject to drought injury than humus-deficient soils.
A study of plantations in podzol region has indicated a pronounced increase in the rate of initial growth of trees due to the higher content of organic matter (Table 23). A general tendency for the increased survival of seedlings was also observed on soils rich in organic matter.

Since it is evident that conservation requirements, either for grassland or forest land, have the same objective, a coordinated program based on the use of manure and urine would give a wider application to the management of soils on this basis, would give more assurance of a heavy output per acre and be more economical.

Several results indicate that the absorbing or base exchange capacity of the soil is related to the content of fine soil material, i.e., material less than 0.02 mm in diameter. As regards these effects, it may be a matter of practical purpose that one per cent of organic matter is a suitable basis to plan for fine soil material. This basis is in line with the usual content of organic matter in soils high in organic matter.

Figure 39. Relation of total nitrogen to organic matter in cut-over sandy soils of Wisconsin (Plainfield and Vilas series)

Figure 40. Relation of available phosphoric acid and available potash to organic matter in cut-over sandy soils of Wisconsin (Plainfield and Vilas series)
A study of plantations in podzol region has indicated a pronounced increase in the rate of height growth of trees due to the higher content of organic matter (Diag. 41). A general tendency for the increased survival of seedlings was also observed on soils high in humus (Diag. 42).

Since the influence of organic matter supplements, within certain limits, the effect of mineral colloids, a coordinated consideration of both of these factors should provide a wider selection of planting sites, and, at the same time, would give more assurance of success.

General observations indicate that the absorbing or base exchange effects of soil organic matter are at least two and one-half times as great as those of fine soil material, i.e., material less than 0.05 mm. in diameter. Hence, as regards these effects, it may be estimated for practical purposes that one per cent of organic matter is equivalent to 2.5% of fine soil material. This implies that a considerably lower content of mineral colloids is adequate for successful planting on soils high in organic matter. Figure 43 presents an example of a scheme of planting possibilities for four coniferous species under Wisconsin climatic conditions and for soils not influenced by ground water. The slanted lines re-

![Diagram](image-url)
Figure 41. Relation of height growth of jack pine and red pine plantations to the content of organic matter in podzolic sandy soils of northern Wisconsin. The general trend is indicated by free-hand curves.

Figure 42. Relation of survival of jack pine and red pine plantations to the content of organic matter in podzolic sandy soils of northern Wisconsin. The general trend is indicated by free-hand curves.
present the minimum acceptable ranges of fine soil material and
organic matter for each species. The ordinate and abscissa values
for any point on a species line give the minimum acceptable values
of each constituent for that species. Therefore, the lines of
species which touch the intersection of perpendiculars erected from
the coordinates, or fall within the area enclosed by the perpendi-
culars, indicate that these species are suitable for planting on the
soil in question. A transparent right triangle will be found
helpful in using the diagram.

For example, if the soil analyzes 20% of silt and clay
and 2.7% of organic matter, then the site is suitable to jack pine, 
red pine, and white pine, but not white spruce. The graphs may
also be used in a somewhat different manner. Suppose the soil of
a large outwash tract is known to contain about 10% of silt and
clay particles; then the sites suitable to red pine should have
at least 3% of organic matter.

A study of local plantations is a prerequisite for the
establishment of standards suitable for other species and climatic
conditions.

Observations in hilly regions have indicated that the
organic matter content of cut-over soils is usually greater on
northern than on southern exposures. Thus, the data from soil
organic matter determinations tend to express the influence of
temperature, moisture, and other site factors common to various
topographical aspects.

The determination of organic matter content may serve
as an index of soil depletion resulting from grazing, burning,
removal of litter, or erosion, and may be very useful in the
management of woodlot soils.

Because soil organic matter occurs in the form of surface
debris as well as humus incorporated to various depths with the
soil, the samples for analysis should be collected by means of a
tube which removes a representative cross-section of the entire
surface soil layer to a definite depth, usually 7 inches.

Figure 44 presents a few illustrations of the effect of
humus upon the growth of trees.

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Figure 44. Effect of humus upon the growth of trees. Top: Fourteen-year old red pine on sand deficient in organic matter; average height 6 feet. Plantations of the same age ordinarily attain an average height of 15 ft. Bottom: Two-year old Norway spruce raised in quartz sand cultures with addition of various organic remains: 1. Check; 2. Sedge peat; 3. Hardwood crumb mulch; 4. Hardwood-hemlock duff.