SPECIAL ARTICLES

SOME MUTUAL EFFECTS OF TREE-ROOTS AND GRASSES ON SOILS[1]

IT is commonly noticed that plants of the Gramineæ do not grow readily under certain species of trees, and while many reasons have been assigned, there does not seem to have been much systematic experimentation to determine the principal causes.

Shade thrown by the trees themselves has been commonly mentioned as an important factor. Considerable shade in itself will retard the growth of many grasses, but it is hardly probable this is important in the case of single trees; moreover, the shaded area varies with the time of day, and the grass receives light much of the time. Also, if shade is an important factor, why does not the grass live on the sunny side of the tree? Near the base of the trunk of low-branched trees this might become a controlling factor.

Another reason commonly assigned is the removal of 'plant food' by the tree, thus starving the grass. As the parts of the tree roots most active in removing soluble salts from the soil water are the newer root tips and branches, it hardly seems that these could be held responsible for the almost entire removal of plant food over the entire affected grass space. They would, at any rate, not usually be active for some distance from the tree trunk, and though roots may here be near the surface or even exposed, they play no active part in the removal of mineral constituents from the soil. As the soil solution is practically a constant as regards the amount of salts in solution, it would seem that were the removal of plant food by the tree very excessive, there would still be sufficient available for the grass owing to the nature of the solubility of soil minerals. As, however, it would be impossible to say in just what quantity and in what combination the plant food should be present for the best development of tree and grass, respectively, this factor of plant food removal is difficult definitely to rule out.

Another reason assigned, and perhaps the more logical, is the removal of water from the soil by the tree. The average sized tree during active growth transpires an enormous amount of water, especially if the season be hot and dry; but so does the grass, and it would be about as logical to blame the grass for removing so much water from the soil as to cut short the available supply for the tree. Here again, the root system for some distance from the tree does not play an important rôle in absorption of water. These possibilities of plant food and water removal would seem to be negatived by the experiments at Woburn to be mentioned later.

While all these factors working in conjunction may produce an effect on the growth of grass, there seems to be a much deeper underlying principle involved.

During some experiments carried out on a lawn in Takoma Park, Md., where a few scattered oak, chestnut and pine trees are growing, it was found almost impossible to obtain a stand of grass or clover. Beds were spaded up, stable manure applied and later artificial fertilizers added and the best of care given the plots. The grass and clover (the latter also inoculated with nitrogen bacteria) came up very well and for a time gave promise of a good stand, but in a month or two all died in spite of good care. When the plots were originally spaded up, many tree roots were encountered which were removed; the soil being shallow, these naturally live near the surface. The plots on which the grass had died were later spaded up again and found to be almost entirely filled up with young actively growing roots, the special preparation of the soil having been very favorable for their growth.

As the lawn is everywhere permeated with roots (though the trees are not close enough to form a dense shade) it was thought that these might have some malignant influence on the grass. It has been shown that washings from tree trunks and tree leaves are injurious[2] to plant growth, which might account for some of the trouble experienced in trying to obtain a stand of grass, but as the trees do

[1] Published by permission of the Secretary of Agriculture.

[2] Bull. 28, U. S. Department of Agriculture, Bureau of Soils.

not cover the entire lawn area, this cause could not be the only one. The converse effect, *i. e.*, a deleterious effect of grass on trees, was found by the Duke of Bedford and his co-workers.[3] In 1897 they began to notice the peculiar effect produced by grass upon their fruit trees, especially apple and pear trees. The soil on this farm is shallow, eighteen to twenty-four inches of soil overlying an impervious calcareous subsoil.

Their first supposition was the removal of plant food, and so they inaugurated experiments to determine if this assumption was correct, but all their experiments answered the question in the negative. They then tried if the removal of water by the grass was the cause, but here again they received a negative answer. They tried the effect of carbon dioxide on the tree roots, thinking this might be given off in such large quantities by the grass as to be harmful. This not proving to be the cause, they tried the effect of the exclusion of oxygen, and also of the effect of packing imitating the impervious sod, but in all cases they were baffled, finding no evident effect of any of these factors on the trees.

Having ruled out all the above-mentioned factors, they found by other experiments that only the most actively growing portions of the tree root system was affected by the grass. A circular sod of a few feet in diameter around the tree had no effect, but as the circle was increased, the tree began showing the detrimental effect, viz., premature falling of the leaves, and entire change of the normal ripe color of the fruit, from green to red, and a dwarfing of the tree. In very many instances the trees were killed outright. They also found by excavating the ground around the trees and by removing the root system, that the pernicious effect of the grass was strongly marked even when only one thousandth to two thousandths of the root system of the tree was exposed to the action of the grass.

They finally, after about seven years' work, concluded the pernicious effect of the grass could be due only to some poisonous substance formed in the soil around the tree roots, leaving the question open as to whether these substances were due to direct excretions from the grass or to a changed bacterial action in the soil induced by the presence of the grass.

Jones and Morse[4] have described a similar relation existing between the shrubby cinquefoil (*Potentilla fructicosa*) and the butternut tree (*Juglans cinerea*), the latter killing the former for an area equal to and often much greater than that of the tree top. Excavations showed in every case of the dead or dying cinquefoil that the butternut tree roots were in close physical relation with those of the shrub. Young birch, beech, maple, cherry, apple and pine trees growing among the cinquefoil in the same field had no such influence on the latter. More recently an antagonism between peach trees and several herbaceous plants, commonly used as cover crops in orchards, has been reported by Hedrick.[5]

In work done in these laboratories, Reed found unquestionable evidence that plants do produce toxic conditions in the medium in which they grow. Agar in which wheat had grown was decidedly toxic to a second crop of wheat. Agar in which corn or cowpeas had grown was scarcely, if at all, toxic to wheat, Agar in which oats had grown was quite toxic to wheat, but not as toxic as that in which wheat itself had previously grown. Apparently excretions from the roots of a given plant, or its near relatives, are more toxic to that species than the excretions from plants belonging to more distantly related species.

It was decided to try the effect of tree seedlings on the growth of wheat under control of external factors, and accordingly a number of tree seedlings were dug up in the forest in the early part of June, 1906. The species gathered were pine, tulip, maple, dogwood, and cherry, and varied in height from about 15 to 40 cm., care being taken to get the entire root system. These were planted in paraffined wire pots,[6] using soil already made

[3] Woburn Experimental Fruit Farm, 3d Rept., 1903, and 4th Rept., 1904.

[4] Rept. Vt. Expt. Sta., 16 (1903), 173–190.

[5] *Proc. Soc. Hort. Sci.*, 1905, 72.

[6] This method of pot culture is fully described in Cir. No. 18, Bureau of Soils, U. S. Dept. of Agriculture.

up to optimum moisture condition. The water content was kept up subsequently by frequent watering. These pots, along with two controls, were put into the greenhouse and left standing for about two weeks before planting to wheat in order to enable the tree roots to become established in the soil. At the end of this time, all pots were planted to wheat, putting the same number of germinated wheat seeds in each pot.

The first crop of wheat was cut down at the end of about three weeks and weighed and the pots immediately replanted without disturbing the soil. The wheat was similarly planted and harvested every two or three weeks until the middle of December, by which time nine crops had been removed. In each crop the average green weight of the plants in the controls was considered 100, and the relative weights of the others calculated on this basis. The accompanying table shows the tabulated results of the successive crops. There is plainly a decrease in the green weight of the plants grown in the pots with the trees. This can not be due in any way to shade, as the seedling trees were not large enough to interfere in this way, and the pots were all arranged in a row, so all had an equal amount of light. The water content can not be a factor, either, as all were watered every day or two during the hot summer and every three or four days during the cooler autumn. The 'plant food' removed can hardly be considered a serious factor in the case of such small seedlings, especially as the crops increase again, as will be pointed out below, and there were of course no leaf washings from the trees to affect the wheat.

It seems, therefore, that the presence of the roots must have had some other effect on the growth of the wheat, as the size of the pots made it necessary for the two kinds of roots to be in close physical relation. That the retarding effect is due to substances excreted by the tree roots seems probable, and a closer inspection of the table shows an evident increase in yield toward autumn when the physiological activities of the trees were diminished by their entering upon their seasonal rest. It was also noticed that the tree pots that produced as much wheat growth in November as the controls were the ones in which the trees showed the earliest signs of winter rest. Attention should be called to the fact that if the tree seedlings removed sufficient plant food to starve the wheat plants in the summer period, the increase in yields toward autumn would hardly be looked for.

The increase in wheat growth in the various pots toward autumn is more clearly brought out in the last two columns. The first shows the average of the preceding six crops, which brings the time up to the middle of October, about the time the physiological activities of the trees would be decreasing, as the crop harvested October 13 was not planted until about September 20. The second of these columns shows the average of the last three crops.

It will be seen that there is a decided increase in the average yield of these three crops over the average of the preceding summer crops, except in the case of the dogwoods, and they were, excepting the pine, the last to drop their leaves, having only dropped them

RELATIVE GREEN WEIGHTS OF WHEAT CROPS, GROWN IN ASSOCIATION WITH TREE SEEDLINGS

Date of Harvesting.	6/29	7/12	8/1	8/22	9/6	10/13	10/29	11/19	12/8	Average of First 6 Crops (Summer)		Average of Last 3 Crops (Autumn)	
Control	100	100	100	100	100	100	100	100	100	100		100	
Maple 1	76	65	86	68	67	86	92	91	96	74		93	
Maple 2	44	86	75	59	71	89	90	75	109	71	72	91	92
Maple 3	21	83	72	72	79	84	81	103	92	70		92	
Dogwood 1	92	96	76	84	71	65	83	68	115	81	79	89	91
Dogwood 2	86	79	63	86	75	73	84	107	88	78		93	
Cherry	81	91	102	91	71	94	88	102	93	88		94	
Tulip	21	106	82	77	68	100	77	109	103	76		96	
Pine	55	69	68	52	54	80	62	83	60	63		68	
Pine (dead)	62	96	85	91	80	89	97	96	67	84		87	

when the last crop of wheat was removed on December 8.

An interesting case is that of the two pine seedlings. During the growth of the first crop one of these died, and the pot with the dead seedling left intact was carried on in the set and treated in the same way as the other cultures. The greater yield in this pot over that in the pot containing the live pine is clearly evident.

Another feature is the variation in yield obtained in the pots with different species of trees. It would appear that the cherry was least active in checking growth of wheat, the dogwood next, followed by the tulip, then maple, and most of all, live pine, although it would not be safe to assume this same order would obtain in the field.

It should be mentioned that in replanting the wheat, the soil was disturbed only enough to accomplish this, so the organic matter left by the wheat roots would act as a light application of green manure, although it is well known that wheat is not very effective as green manure. This would perhaps help slightly to counteract the deleterious effect of the tree roots on the wheat, but the aim was to leave the soil undisturbed.

Summarizing the foregoing, we find that seedling trees of tulip, dogwood, maple, cherry, and pine retard growth of wheat when the latter is grown under conditions making it necessary for the wheat roots to be in close physical relation with the tree roots. That this retarding effect differs with different species of tree seedlings, that the checking of wheat growth is greatest during the season when the tree seedlings are most active physiologically, and this checking effect becomes less as the season of physiological inactivity of the trees is approached. That in the case of pine, at least, the live pine is much more detrimental to wheat growth than the dead pine.

This injurious effect of trees on wheat appears to be due to the excretion of substances by the trees, toxic to wheat growth.

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NOTES ON ORGANIC CHEMISTRY

FORMATION OF FUSEL OIL

The production of fusel oil during the course of the ordinary alcoholic fermentation involves grave practical difficulties to the manufacturer of distilled spirituous beverages, because the removal of this constituent entails a considerable expense. To the pure chemist also, this formation of fusel oil is of importance because it, apparently, complicates the chemical changes involved in the course of fermentation. The conversion of grape sugar, $C_6H_{12}O_6$, into alcohol, $2C_2H_6O$, and carbon dioxide, $2CO_2$, is very simple, but to account for the production of small, variable amounts of amyl alcohol and similar substances compels the use of quite complicated equations. The difficulties of both the brewer and the chemist will be lessened, or wholly removed by some highly interesting work which Felix Ehrlich[1] has carried out in the Berlin Institution of Sugar Industry. He has fermented pure sugar solutions with pure yeast cultures and obtained, on an average, about 0.4 per cent. of fusel oil. The addition of *l*-leucine,

$$\genfrac{}{}{0pt}{}{CH_3}{CH_3}{>}CHCH_2CH(NH_2)CO_2H,$$

or of *d*-isoleucine,

$$\genfrac{}{}{0pt}{}{CH_3}{C_2H_5}{>}CHCH(NH_2)CO_2H,$$

to the fermenting material immediately raised the content of fusel oil to 3 per cent. The former compound gave inactive amyl alcohol,

$$\genfrac{}{}{0pt}{}{CH_3}{CH_3}{>}CHCH_2CH_2OH,$$

and the latter, optically active, dextro-rotatory amyl alcohol,

$$\genfrac{}{}{0pt}{}{CH_3}{C_2H_5}{>}CHCH_2OH.$$

On comparing the formulæ it will be observed that the alcohols can be formed from the leucines by the addition of the elements of water and the elimination of ammonia and carbon dioxide.

The latter substance is, of course, evolved, and the question arises as to the fate of the ammonia. Special experiments showed that the fermenting liquid and the gases issuing from it were free from ammonia and nitrogen,

[1] *Ber. d. chem. Ges.*, **40**, 1027 (1907).