SOME EFFECTS OF BLACK LOCUSTS AND BLACK WALNUTS ON SOUTHEASTERN OHIO PASTURES[1]

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"There is but one tree which will, to my knowledge, benefit the pasture land as pasture, and that is the black locust, which, being a legume, enriches the soil," wrote Joseph E. Wing[3] in 1912 (13). This opinion has been widely held, but it is not accepted by all observers. Some have claimed that trees of any type are detrimental to pastures, whereas others believe that black walnuts as well as black locusts lead to pasture improvement.

In addition to these opinions based upon observation alone, there is considerable information from investigations dealing with special phases of the problem. Chapman (2) attributed the superior growth of orchard grass that he remarked under black locusts to the nitrogen supplied by the trees. Gustafson (4) suggested, as a result of certain observations and litter measurements under black locusts on sandy areas, that the favorable effect of the trees upon the bluegrass could be explained by the nitrogen and other nutrients supplied, the moisture held, and the temperature reduction by the locust leaves. Graman and Merkle (3) found evidence of increases of mineral nutrients in the soil under locusts. In connection with observations of beneficial effects of black locusts and black walnuts upon West Virginia pastures, Broadfoot and Pierre (1) studied rates of leaf decomposition in the laboratory and correlated their results with certain chemical properties of the leaf samples. The leaves of these two species were found to decompose more rapidly and to contain more basic materials than most of the other leaf types studied.

An experiment to determine quantitatively whether black locusts and black walnuts actually do improve pasture herbage was established at the Middle Tennessee Agricultural Experiment Station in 1926. The results reported by Neel (6) indicate distinct improvement in the carrying capacity of both the

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[3] Joseph E. Wing is especially remembered as an early proponent of the value of alfalfa and alfalfa-grass mixtures in the eastern corn belt.

locust and the walnut plots compared to the open check plots. The greater advantage was from the locusts. Improvement was evident both in the amount of Kentucky bluegrass on the plots and in the pounds of beef produced.

The present study represents one phase of the Hillculture research program for Ohio. The purpose has been to measure some effects of black locusts and black walnuts and other trees upon the forage covers of southeastern Ohio pastures; and, through consideration of the various interrelated factors, to arrive at some basis for making predictions and practical suggestions for pasture improvement and for further research.

SITE SELECTION

In choosing tree-covered grass areas for study in comparison with open pastures, care was taken to eliminate insofar as possible all variables other than the presence of the trees. This necessitated the restriction of sites to relatively level areas where erosion was not active, for it was found that on sloping erodible land the greater depth of surface soil and the retarded runoff under the trees might be sufficient to account for great differences in the vegetation. For instance, on slopes ranging from 10 to 25 per cent, the average depth of surface soil under 23 isolated trees measured 11 inches as compared to $4\frac{1}{2}$ inches on the adjacent open areas. The maximum depth was 19 inches under the trees and 8 inches on the open slopes, and the minima were 6 and 0 inches, respectively. All of these sites were excluded.

Trees in fence rows, and those under which animals were likely to congregate were also eliminated, as were others where tillage differences were evident or seemed likely.

The sites selected were scattered but were all within a radius of approximately 15 miles of the Senecaville Dam in Guernsey County, Ohio.

The soils represented were derived from residual material: from limestone, from sandstone, and from shale. Limestone is more abundant in this area than throughout the Appalachian plateau region in general, but not all sites studied showed indications of limestone contributions, and at only a few was limestone the main source of the soil material. Most of the sites would be classified in the Westmoreland soil complex. Several belong in the Muskingum soil series.

HERBAGE YIELDS

Throughout the 1939 and 1940 seasons, yields of herbage were obtained from 4- by 4-foot plots under black locusts and black walnuts and from paired adjacent plots in the open pasture just beyond the influence of the tree. The plots not under the influence of trees are referred to in this paper as *check plots*.

Since each pair of plots was chosen to represent a particular situation, the logical procedure would be to consider each comparison individually as to species, density, yield, composition, and root development of the ground covers, and to relate these characteristics to the local conditions for growth. As, obviously, it is not practical to resort to such a detailed presentation, the yields are summarized (table 1) to give a general idea of the results, and some of the individual circumstances and relationships essential to a proper interpretation are brought out in the discussion and the additional information that follows.

The species contributing to the yields at the different sites were very different. In no case were they distinctly more desirable on the check plot than on the plot under the trees; in most cases, in fact, the reverse was true. The main undesirable grass under trees was nimblewill (*Muhlenbergia shreberi*), which usually does not perist under heavy grazing. On all check plots that gave higher total yields than the walnut plots, the main grass was broomsedge (*Andropogon virginicus*).

There were more weeds, on the average, on the check plots; therefore the total yields would have been more favorable to the checks if weeds had not been discarded. The elimination of some weeds by clipping is, doubtless, a factor contributing to the increased yields on the check plots in 1940 over those in 1939.

TABLE 1

Comparison of herbage and protein yields under trees with yields from check plots

Average yields per acre

PLOTS	NUMBER OF PLOTS		TAME GRASS AND CLOVER*	DRY WEIGHT YIELD†		NUMBER OF DRY WEIGHT YIELDS FAVORING TREE PLOTS		PROTEIN IN HERBAGE		
	1939	1940		1939	1940	1939	1940	1939	1939	1940
			per cent	*lbs.*	*lbs.*			*per cent*	*lbs.*	*per cent‡*
Under walnuts	14	12	67	1,621	1,710	11	10	13.7	211	11.0
Checks	14	12	34	1,154	1,285	..	..	12.4	135	9.5
Under locusts	9	9	70	1,263	1,754	7	4	18.6	227	16.3
Checks	9	9	29	1,021	1,719	..	..	13.5	132	10.5

* From vegetation counts by the inclined "point quadrat" method.

† Note that these yields are low. This is due in part to the fact that the pastures are not highly productive; but it should be kept in mind that summer rainfall was below average in 1939, and rainfall was so distributed in 1940 that pasture yields were probably not above average.

‡ Incomplete analyses.

An important consideration in connection with these yields is their seasonal distribution. In the denser locust groves (fig. 1), almost all the growth had occurred by the first of June. Where the locust stands were thin and the trees were trimmed to a height of 10 to 12 feet (fig. 2), the seasonal distribution was similar to that of the open pasture, except that under all locusts, growth started a few days earlier in the spring. In some places, grass under black walnuts continued growth somewhat longer in midsummer than did grass in the open. Otherwise, the seasonal distribution was similar to that of the open pasture.

Grass that grows early in the season in dense locust groves remains green and immature throughout the summer. This is true also to some extent of grass under open stands of both locusts and walnuts.

FIG. 1. GRASS UNDER DENSE GROVE OF BLACK LOCUSTS STUDIED IN COMPARISON WITH OPEN PASTURE

This locust stand is too dense for much forage production except very early in the season. The grass under the trees is mainly Canada bluegrass. Dry weight yields were higher on the check plot (foreground). The grass under the locusts was much higher in protein.

FIG. 2. GRASS UNDER THIN STAND OF BLACK LOCUSTS STUDIED IN COMPARISON WITH OPEN PASTURE

Note the denser ground cover and the absence of broomsedge under the trees. The grass under the trees is mainly Kentucky bluegrass; that in the open, wild grasses and weeds. The yield of herbage under the trees was much superior to that in the open, both in 1939 and 1940.

FIG. 3

FIG. 4

FIG. 3. UNMISTAKABLE EVIDENCE OF GRAZING UNDER A BLACK WALNUT TREE

Note the height of the ungrazed grass outside the fence. Note also the density and uniformity of the Kentucky bluegrass cover under the tree and the characteristic scarcity of walnut litter.

FIG. 4. CLOSEUP OF BLACK WALNUT ROOT SYSTEM

Note the absence of walnut roots from the upper few inches of soil, the density of the Kentucky bluegrass, and the scarcity of walnut litter.

HERBAGE COMPOSITION

Nitrogen

The harvests of 1939 were analyzed for nitrogen by a modified Kjeldahl method. The results, calculated to protein, are summarized in table 2. All the plots under locusts yielded more protein than the corresponding check plots (see also table 1). The high protein values in the herbage under the locusts were very consistent, evidently reflecting the nitrogen supplied by the trees, for there was somewhat less clover under the trees than in the open. Only one check sample at one harvest was higher in protein than the corresponding locust sample. The small differences in favor of the grass under the walnuts would be expected as a result of shade.

Selected samples of forage from the 1940 harvests were analyzed for nitrogen, which again was calculated to protein (table 1). The results were somewhat similar to those of the complete analyses for 1939.

TABLE 2

Protein, calcium, and phosphorus in oven-dried herbage under trees and from check plots

Averages for 1939

HARVEST	PROTEIN		CALCIUM		PHOSPHORUS	
	Under walnuts	Checks	Under walnuts	Checks	Under walnuts	Checks
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
First	12.3	11.6	0.34	0.31	0.18	0.16
Second	14.9	14.4	0.45	0.37	0.20	0.16
Third	14.1	11.2	0.42	0.35	0.21	0.18
	Under locusts	Checks	Under locusts	Checks	Under locusts	Checks
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
First	16.6	12.6	0.34	0.40	0.18	0.16
Second	20.0	15.6	0.50	0.61	0.20	0.19
Third	19.2	12.5	0.45	0.55	0.20	0.18

The fact that high protein percentages were found in the grass under the most widely spaced locusts suggests that a sufficient supply of nitrogen for the grass does not require a close spacing of the trees. The results even suggest that the check plots near locusts were receiving some benefit from the nitrogen from the trees. Otherwise the grass under the walnuts would be expected to be distinctly higher in protein than that on the check plots near locusts, because of the factors of shade, of more desirable species, and of better soil condition under the walnuts.

It is possible that the grass on some of the check plots was influenced by nitrogen from the locusts, because roots from the trees were found very close to several of these plots.

Calcium and phosphorus

The herbage harvested in 1939 was analyzed for calcium by the standard oxalate-permanganate method, and for phosphorus by the method of Zinzadze

(14). Samples were prepared by wet digestion with nitric and perchloric acid. The results are summarized in table 2.

Interpretation of these analyses is complicated by the fact that various grass and clover species were involved. Even so, the higher percentage of phosphorus under the trees was consistent in all but a few cases, as were the results with calcium under the walnuts. The exceptions seemed related to clover on the check plots. On the other hand, the calcium values involving locusts were not consistent, the higher averages on the check plots being due to a few very high values. These were obtained on plots with some clover, in comparison with plots of Canada bluegrass in the denser locust groves.

In general, the conclusion may be drawn that where grasses alone are considered, both calcium and phosphorus will be somewhat higher under thin stands of trees than in the open, but, if the trees eliminate clovers, they are likely to lead to lower contents of both these elements. The higher percentages and higher total yields of phosphorus in grasses under the trees raises the question as to whether better phosphorus nutrition may be involved in the beneficial effects of trees in some cases.

SPECIES AND DENSITY OF HERBAGE

The inclined "point quadrat" method of Tinney et al. (9) was used to study the distribution of ground cover plants and their density. Counts were made at most sites in the spring of 1939 and again in the late summer of 1940. The counts were used to compare the vegetation under certain tree species with that on adjacent check areas and with that under other tree species. The vegetation counts were continually supplemented by observations throughout the 2 years of the study. A detailed interpretation of the information obtained would require a consideration of the conditions of each individual site, but a generalized picture may be outlined as follows:

Trees of any type in southeastern Ohio pastures usually introduce differences in the ground cover species and density compared to the open pasture. The differences vary with the type and spacing of the trees.

Under thin stands of black walnuts and black locusts (fig. 2), the density of the forage covers is comparable to that of open bluegrass pastures. The dominant species in such situations is usually Kentucky bluegrass. Other grasses commonly found include nimblewill, timothy, redtop, and meadow fescue. Nimblewill usually occurs as a minor species in Kentucky bluegrass sods; meadow fescue is the dominant grass when it occurs; and timothy and redtop occur in mixtures.

Under black locusts in groves (fig. 1) and under many maples, beeches, oaks, and hickories, Canada bluegrass is the dominant forage species, but it rarely occurs under black walnuts, even in dense stands. The Canada bluegrass cover in the situation described is usually thin.

Poverty oat-grass (*Danthonia spicata*) and various "poverty" weeds frequently are found under maples, beeches, oaks, and hickories, but rarely under black walnuts or black locusts, even on poor sites.

Broomsedge rarely is found under trees of any type.

Pastures with poverty grass or other poor ground covers are almost certain to profit as to species and density from the presence of scattered black locusts or black walnuts.

Productive Kentucky bluegrass pastures are almost certain to suffer, both as to species and density, from the presence of maples, oaks, beeches, and hickories. There would be little effect from widely spaced black walnuts and probably no great effect from widely spaced black locusts.

ROOTS AND RHIZOMES OF HERBAGE

The most consistently evident characteristic of the underground grass parts in this study was the shallowness of roots and rhizomes under black locusts in groves. This seemed to be associated with increasing proportions of Canada bluegrass under the trees. The same characteristic of the rhizomes of Canada bluegrass was reported by Watkins et al. (11).

Although the most shallow roots and rhizomes observed have been from Canada bluegrass, it has seemed that Kentucky bluegrass, even in thin groves of black locusts (20-year-old trees spaced at 15 to 20 feet), lacks the root depth common to that grass in the open. But under individual locust trees or under black walnuts, the underground parts of the grass are apparently as deep as in the open pasture.

The total quantity of grass roots and rhizomes is evidently related to the depth of root development. Soil samples taken under black walnuts contained slightly more grass parts than samples taken in the open, and samples under locusts contained slightly less. The smallest quantities were obtained in the densest locust groves.

HERBAGE PALATABILITY

It has not been possible to establish any positive basis for measuring relative palatability in this study, but repeated observations have shown that grasses under black locusts and black walnuts are eaten readily by livestock, (fig. 3) and actually are preferred under some conditions.

The following factors seem to favor the apparent palatability of pasture under trees at certain seasons: more palatable grass species, shade protection for the animals, more moisture in grasses (during dry summer seasons), and delayed maturity of grasses.

There are also factors that may favor the apparent palatability of open pasture: more white clover, more sugar in herbage [mainly in contrast to dense shade (12)], and less moisture in grass (during moist spring seasons).

SOIL TESTS

Differences in the soil under black locusts and black walnuts have been found confined largely to the surface 3 inches. All comparisons were between carefully paired samples where the only basic difference was the presence of the tree. No surface litter was included in the samples. If proper precautions against differences in erosion, animal manure, and tillage are not taken in sampling, much more striking results are likely to be obtained. A general summary of the tests of 0- to 3-inch samples is given in table 3. Soluble phosphorus determinations also were made, but they showed no significant differences.

Organic matter was determined by a chromate oxidation method modified from Schollenberger (8); pH with the glass electrode; exchangeable bases by the

Kappen equilibrium method (5). Phosphorus was extracted by the method of Truog (10), and determined by that of Zinzadze (14).

The pH and exchangeable base differences under locusts are not consistent enough to be clearly significant. The other differences shown are significant, and, although not great, are sufficient to influence the growth of herbage. The

TABLE 3

Summary of soil tests under trees compared to check areas

0- to 3-inch soil samples

	UNDER TREE	CHECK	NUMBER OF COMPARISONS	NUMBER FAVORING TREE SAMPLES
Black walnut comparisons				
Organic carbon . . . *per cent*	3.0	2.2	37	34 (1 even)
pH	6.2	5.9	40	36
Exchangeable bases . . . *m.e./100 gm.*	16.1	11.5	32	29
Volume weight	0.95	1.09	16	15 lower
Black locust comparisons				
Organic carbon . . . *per cent*	2.1	1.6	18	16
pH	5.5	5.3	18	9 (5 even)
Exchangeable bases . . . *m.e./100 gm.*	9.9	7.9	13	8
Volume weight	1.13	1.19	10	6 lower (1 even)

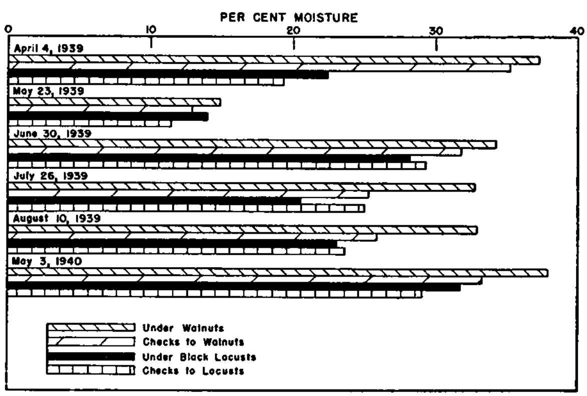

FIG. 5. MOISTURE IN SOIL UNDER TREES COMPARED WITH THAT IN SOIL ON ADJACENT CHECK PLOTS

Averages of 0- to 3-inch samples on several dates

organic matter content of soil under trees undoubtedly reflects to some extent the cooler microclimate, as well as the supplies of organic materials (table 3).

Volume-weight determinations have indicated a less dense soil under black walnuts and under widely spaced black locusts than in open pastures, and observational studies have indicated better granulation. Earthworms have seemed especially active under walnuts, where their effect upon stable aggregation has been very marked.

Soil-moisture determinations were made by oven-drying samples from a number of sites on various dates. Not all of the comparisons gave consistent results, but certain general relationships seem clear (fig. 5). The dates included are those on which the largest numbers of samples were taken. Not all of the same sites were represented on every date.

The surface 3 inches of soil under the trees averaged higher in moisture, except under locusts in the summer (fig. 5). The driest sites in summer were in the dense locust groves. Soil-moisture equivalents determined were not sufficiently higher under the trees to indicate that the relationships would be different in terms of available moisture. Samples below 3 inches have indicated generally less moisture under trees in summer. Samples under maples and other shallow-

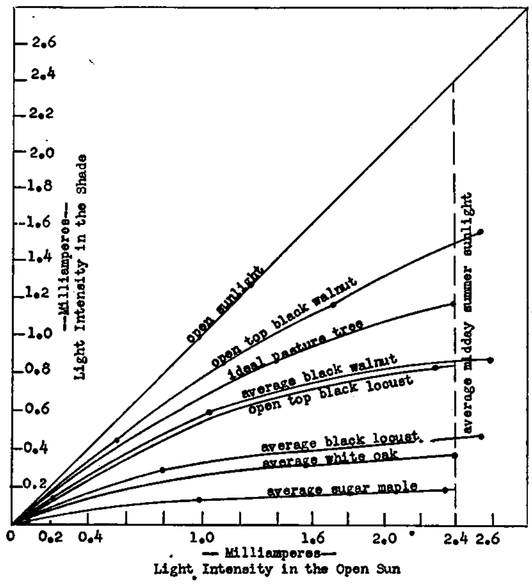

FIG. 6. RELATIVE LIGHT INTENSITIES UNDER DIFFERENT TREE SPECIES

Individual trees, except *average black locust,* which refers to pastured groves as they occur

feeding trees have indicated that the surface 3 inches is frequently very dry in summer.

LIGHT INTENSITY

The most marked vegetation differences under trees in some places are extended north or east, suggesting shade as their primary cause. Such is the case in the occurrence of Kentucky bluegrass under many trees farther south. In Ohio this extension north or east is sometimes evident, but more frequently it is not. This is not an indication that shade is an unimportant factor in Ohio; it merely serves to emphasize the importance of other factors as well.

The light intensity under various trees was measured with a Photronic cell and milliameter in the early summer of 1940. Some of the relationships determined are summarized in figure 6.

Black walnuts on the average cast less shade than any other common tree of the area. Isolated black locusts cast less shade than many other common trees, including most oaks and hickories. Individual walnuts cast denser shade than some locusts. Sugar maples cast the densest shade measured.

TREE LITTER

Because of the rapid rate of disintegration and decomposition of the tree litter very little accumulates under black walnuts or widely scattered black locusts. In locust groves several tons of litter may accumulate per acre, but the amount is not so great as under most forest trees. Black-walnut litter breaks down somewhat more rapidly than that of black locust. This rapid breakdown probably accounts for the belief that walnut litter usually blows away; actually, more of it remains than under most other trees, for it works into the grass and is held in spite of the wind.

Amounts of certain nutrients equivalent to the following may be added annually to the surface soil in the litter from isolated walnuts and locusts: $CaCO_3$, 100 to 150 pounds per acre; P_2O_5, 5 to 7 pounds; nitrogen, 20 to 35 pounds. These values are based upon an estimated annual litter fall of 1,500 pounds of dry matter per acre, and a number of analyses of litter collected immediately after it had fallen from the trees in 1939.

The fact that there is an appreciable build-up of bases in the surface soil under walnuts from the relatively small annual contribution of the litter indicates that the combination of walnuts and grass is a very efficient system. The minerals used by the trees are probably derived mainly from soil horizons below the layer occupied by grass roots. Leaching losses probably are slight.

It is probable that the difference in favor of the soil under walnuts compared to checks is less in heavily grazed than in lightly grazed areas. This does not detract from the desirability of the walnut-grass combination, for it probably means that the annual removal of forage and of bases has been higher under the trees than in the open pasture. Many of the comparisons made were in lightly grazed areas.

The nuts produced by walnut trees are undoubtedly a factor in the nutrition of the grass in some places, but since only a few of the trees in this area produce nuts regularly and many of them produce no nuts at all, this possible contribution need not be given primary consideration. Observations have indicated that the nuts under walnut trees have essentially the same effect upon grass as does the litter. The discussion of the effects of litter may be considered to include nuts, when these are present.

The effect of tree litter upon grass growth seems worthy of more consideration than it commonly receives, but evaluation of its importance is difficult. Certainly its effects are both physical and chemical, and may be either detrimental or beneficial, depending upon the type of litter and the type of ground cover. Black-walnut litter apparently approaches the ideal for Kentucky bluegrass. It forms a very fine light mulch without smothering the grass. Then it readily works into the soil and undergoes rapid decomposition with resultant release of its nutrient content.

But even so, observations in the early spring have suggested strongly that the grass under black walnuts may be severely stunted by lack of nitrogen. This would result from the incomplete decomposition of the carbonaceous litter to a favorable C-N ratio (7). The same type of stunting has been noted under other trees with more resistant leaf types but has never been seen under black locusts, even though more carbonaceous litter was present than under walnuts. Further evidence is supplied by the observed vigor of grass growth around dead trees, where decomposition of the carbonaceous matter has been more complete.

Accordingly, it is suggested that nitrogen starvation may be responsible in part for the poor grass growth under many trees and may play an important role in the elimination of certain species, such as Kentucky bluegrass. Under many black walnuts the relatively low yields made by pure stands of Kentucky bluegrass probably result from a lack of available nitrogen.

Winter grazing favors the rapid decomposition of leaf litter, and observations have suggested that this favors the next year's growth of grass. Thus, it seems that management may be an important factor in tree-covered pastures.

TREE ROOTS

The natural distribution of tree roots in the soil was given considerable attention in this study. No common tree species in the area seemed to have fewer feeding roots in the shallow surface soil than the black walnut, and most species had many more. A characteristic walnut root system is shown in figure 4. The large branch roots, in some instances, are closer to the surface, but in such cases most of the smaller branches turn downward into the soil rather than upward into the zone of the grass roots.

Black locusts have more surface feeding roots than walnuts, but not so many as beeches or maples. There are more shallow tree roots in black locust groves than under isolated trees.

PERIOD OF TREE ACTIVITY

Observations both in 1939 and 1940 have revealed that black-walnut leaves start to develop later in the spring and more of them are lost during the summer and early fall than is characteristic of other common trees. The leaves do not reach full development until nearly the first of June. This may be an important factor in the superior growth of grass under walnuts, for there is extra opportunity for the grass to grow in the spring before the leaves develop, and in the fall after they have been shed.

GENERAL DISCUSSION AND CONCLUSIONS

Interpretation of the results obtained depends to some extent upon the individual point of view and the criteria used for the measurement of pasture improvement; but from any point of view it seems clear that under certain circumstances there is a beneficial effect upon pastures from the presence of widely spaced black walnuts and black locusts, in addition to the influence of these trees through prevention of erosion.

In extremely poor pastures of southeastern Ohio, trees of almost any species are likely to be of some benefit. On the other hand, in highly productive white-clover-Kentucky-bluegrass pastures there is little reason to believe that improvement could ever be accomplished by trees of any type, and there is abundant evidence that most trees would cause considerable injury.

On the ordinary pasture, which is not very productive in this area, the introduction of widely spaced black walnuts or black locusts certainly would cause no injury, and in many cases, would improve the forage, whether measured in species, yields, composition, palatability, or seasonal distribution.

It is not possible to say how high the level of production under trees could be raised by the use of fertilizer and other means. Wide spacing of the trees and trimming of the lower branches certainly would be required as other limiting factors were corrected, but there is no indication that yields could not be increased with fertilizers, as long as the trees were spaced to prevent overlapping of their branches.

The most serious detrimental effect likely to be encountered in actual practice is the elimination of white clover by the trees. There was not enough clover involved in the studies made to indicate how completely this would occur, but there was an indication that the tendency would be in that direction, especially with black locusts. Nitrogen supplied through the locusts, however, might offset the loss. In the only case where a check plot with a high proportion of white clover was compared to a pure stand of Kentucky bluegrass under locusts, the pure Kentucky bluegrass was higher in nitrogen and gave a higher total yield of nitrogen than the mixture of bluegrass and white clover in the open. The locusts in this comparison were spaced near the optimum for pasture. It would be interesting to know what would have been the result if both plots had received liberal applications of phosphate and potash fertilizers.

The effect of trees upon pasture grasses cannot be considered as a simple phenomenon with a single cause. Rather, it represents the net effect of the alterations introduced by the tree, that is, the reduced light, the tree leaf fall, the tree root competition with the grass and with weeds, and the many indirect reactions of these factors through soil condition, soil moisture, soil temperature, and soil organisms. Whether this net effect is beneficial or detrimental depends upon the type of pasture, the type of soil, the climate, and the season, as well as upon the type of tree. A clearer understanding of the factors involved is essential to accuracy in the prediction of results.

The importance of this concept of the net effect is well illustrated by the black locust. The need of poor pastures for nitrogen seems readily satisfied by this tree, but there are many questions concerning the extent to which this nitrogen can be utilized without serious limitations to growth from the tree root competition or from too much shade.

Black walnuts provide no source of nitrogen for the grass, but from all indications they are less likely to introduce other limitations to growth. Thus, the net effect of the tree is to be traced to the moderating influence of the light shade, the remineralization of the surface soil through the leaf fall, the more constant soil moisture supply, the better physical condition of the soil, the tree root competition with deep-rooted weeds but not with the grass, and the absence of any condition that severely limits grass growth.

In many cases there is no obvious reason for the yield being as low as it is. This suggests that the grass lacks nutrients which could be supplied by fertilizers or through legumes. From this it would follow that a combination of walnuts with locusts might improve poor pastures more than either species alone, especially if phosphates were supplied. The locusts would supply the nitrogen without being spaced so closely as to introduce the limitations associated with them, and the walnuts would create other favorable conditions.

For every region there should be a theoretical "ideal pasture tree" that would provide a maximum net benefit to the pastures. The studies in southeastern Ohio indicate that such a tree for this region should possess approximately the following characteristics:

Its period of leaf activity should extend only from about June 15 to September 15.

Its canopy should admit approximately 50 per cent of the bright open sunlight to the grass during its period of leaf activity.

Its leaves should be small, fragile, and very high in minerals and nitrogen.

Its root system should extend to a great depth and be highly developed but should feed mainly below the surface 4 inches of soil.

It should be a nitrogen-fixer.

It should be capable of establishment on poor upland sites.

It should possess high commercial value.

With these seven requirements as a standard it is relatively easy to indicate the ways in which trees fall short in their characteristics. The black walnut approaches the ideal in more ways than any other common species. Its greatest weakness is its inability to fix atmospheric nitrogen. The black locust approaches the ideal in more ways than most other common trees, foremost among its desirable characteristics being its ability to fix atmospheric nitrogen.

SUMMARY

Information is presented which indicates that many of the prevailing pastures of southeastern Ohio are improved by the presence of widely spaced black locusts and black walnuts.

The investigation provides evidence that the effect of trees upon pastures is a complex phenomenon that cannot be explained on the basis of any single factor. An evaluation of the more important factors is attempted.

On the basis of the evaluated factors, it seems possible to make reasonably accurate predictions as to the net effect that will follow the introduction of trees into a pasture. The effect will be beneficial or detrimental depending upon the condition of the pasture and the type of tree introduced.

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