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still remains to be investigated. It is hoped that in the future more protozoa will be grown in pure cultures and that their physiological reactions will be carefully investigated. When this is done protozoology may be said to be on an equal footing with bacteriology. It is the belief of the writer that most, if not all, of the protozoa may eventually be grown in pure cultures and that, in questionable cases of identification, physiological reactions will be relied upon just as in modern bacteriology. As to the practical application of such work it is difficult to predict anything. We are quite certain, however, that it is essential to understand the nutrition of any microorganism, particularly parasitic species, if we are to know the role played in the host. Perhaps such investigations as these with free living forms may add to the solution of problems in diseases caused by parasitic protozoa.

WILL PINE OR ASPEN DOMINATE MINNESOTA FORESTS?

HARDY L. SHIRLEY, PH.D.
Lake States Forest Experiment Station
United States Department of Agriculture

Aspen originally occupied only 3.5 per cent of the present forest land in Minnesota. It formed a dominant type only along the prairie-forest transition zone in the north, whence in association with oak it invaded the grassland in narrow fingers along the water courses, here and there establishing itself on the more favorable upland soils. In the forest land proper aspen and paper birch were confined chiefly to recent burns and the borders of lakes and streams. Early travelers and surveyors also described an aspen-birch-coniferous type and an aspen-birch hardwood type. These types may still be found today on pine or hardwood lands that have been subjected to frequent fires which resulted in killing their own reproduction as well as thinning out the older trees. Under such conditions aspen was able to invade original white and Norway pine forests. On burned over areas aspen and birch often seeded in contemporaneously with spruce and balsam giving rise to a mixed aspen-conifer type which if left undisturbed tends eventually to revert to conifers.

The advent of man has produced a profound change in the relative dominance of aspen and scrub oak. From an original area of 681,000 acres it has increased to 7,418,000 acres and now occupies 38 per cent of the forest land, an increase of over ten-fold. These figures are no longer a guess but are based upon field notes of the original surveyors and an accurate forest survey covering the entire State of Minnesota which was completed last year.

It is a matter of considerable concern to every citizen of Minnesota to know just what has happened to the forests of our state, what their present condition is, and what potential contribution the forest land can make to the general welfare of the commonwealth. The important economic considerations are — to what degree has this large-scale conversion of coniferous and hardwood forests to aspen reduced the realizeable income from the land and can man at reasonable cost arrest and reverse the process.

On good soils, aspen has produced valuable timber crops. The wood is light, relatively weak, decays readily under moist conditions, and has not as yet found its place in our general lumber markets. Aspen logs bring a good price if they can be used for veneer stock. For this use aspen has many of the valuable qualities of other veneer species. During the past few years when the market for pine had practically disappeared, aspen was still holding its own in the specialized field of food containers for which it is very well adapted. Aspen has also a limited market for pulp, but due to its short fibers does not command a high price.

The yield of aspen at 70 years of age is approximately 34,000 board feet per acre under very favorable conditions. This surpasses jack pine which produces only about 22,000 board feet per acre, but is less than good quality Norway pine and little more than half the yield of good quality white pine. Aspen has the further serious drawback of becoming defective rather early in life which often renders it useless as a merchantable product. A seventy-year old aspen stand on the Chippewa Forest, considered to be one of the best aspen stands in Northern Minnesota, has actually averaged only 6,000 board feet per acre of merchantable material. Over half of the standing trees are so defective that they cannot be sold. To off-set this serious defect, aspen grows rapidly, reproduces abundantly from root suckers and seed, and apparently requires very little attention up until the time it is ready for harvest.

On the lighter sandy soils the situation is entirely different. Here aspen is usually associated with jack pine and is of such poor quality that it rarely attains merchantable size. On such areas it is not aggressive and offers little obstacle to the production of conifers.

Ecologically, aspen has never been considered as a climax type except perhaps for the narrow strip of land lying along the transition zone between forest and prairie. The climax type on the better soils of Northern Minnesota is considered to be either hardwoods or a mixed type composed of basswood, sugar maple, and balsam.

The earlier foresters assumed that the aspen which followed logging in Minnesota forests marked only a transition stage, which would be followed soon by a return to valuable stands of pine, spruce and hardwoods. There was considerable evidence to support this view. Seedlings of white pine, white spruce and balsam could be found growing in the shade of aspen wherever coniferous seed trees were available. Furthermore, even today one can find nu-

merous stands of mixed pine and aspen, which would seem to indicate that aspen has served as a nurse crop for the conifers. Critical examination of these stands, however, has usually revealed that the pine is just as old as the aspen, and instead of tending to gain ascendency is actually losing ground, particularly on the more favorable soils.

In order to determine just what does happen to the pine seedlings which make their appearance among the under-vegetation of an aspen forest, an intensive experiment was started in 1929. Three different plots were laid out. On one plot all the trees were removed, on the second 35% of the trees were cut, while the third remained uncut. Conifers were planted on definite 10 ft. sq. quadrats on each plot. In addition, seed were sown in prepared spots on all plots. The quadrats were treated so as to determine the relative importance of the under-story of shrubs and herbaceous plants, the overstory of aspen, and the competition of the roots of the trees from the overstory. The conifers were protected from browsing by deer or rabbits by enclosing the plots within rabbit-proof fences. These plots have been very carefully tended during the past six years and have yielded exceedingly interesting results.

For Norway, white and jack pine, and also for white spruce, the most rapid rate of growth occurred where competition from both the aspen overstory and the under-growth was entirely removed. Among the factors involved in determining the growth of the planting conifers are light, root competition and both root and shoot competition of the under-vegetation. The aspen canopy on the uncut plot reduced the light intensity to approximately 23% of that prevailing in the open, while on the partially cut plot 35% light was available. The shrubs, herbaceous under-growth, and aspen suckers, reduced the light intensity to 14% of that in the open. The light factor was investigated in a special supplementary study conducted in the nursery at Cass Lake, where plants were cultivated in artificial shades. This study indicates that for optimum growth a light intensity of approximately 50% is necessary. Under the less favorable conditions prevailing in the forest optimum growth occurred in 100% light. Hence we may conclude that in all except the weeded quadrats on the clear cut plot light was below optimum for growth.

Root competition has also been shown to be an important factor in the growth of plants in an understory. To study this factor the roots of all aspen trees entering four of the quadrats on each plot were severed by digging a trench two feet deep around them. The trench was filled after all roots had been cut. Trenching was repeated at two-year intervals to maintain the quadrats almost free from the roots of the overstory. The young conifers made more rapid growth on the trenched quadrats than on the untrenched quadrats in both of the plots having an overstory. This greater rate of growth was probably due to more favorable moisture supply par-

ticularly during periods of stress. Samples of soil taken at weekly intervals during the growing seasons showed that the moisture content fell below the wilting percentage on the untrenched quadrats at least once annually during three of the five years, a condition which did not occur on the trenched quadrats. Eliminating root competition in no way compensated for insufficient light. Increasing light, of necessity, also reduced root competition at the same time and gave a double stimulus to growth.

The competition of understory was in every case disastrous, regardless of whether the overstory was removed or not. Some of the white spruce seedlings were able to survive for the six-year period, but made very slow growth. It is extremely unlikely whether as many as one out of ten thousand of them would ever reach maturity unaided. Both light and root competition approached limiting conditions in these quadrats.

The results from sowing seed directly in the forests were in general accord with those obtained from the planted trees. Where competition of the under-vegetation was allowed to proceed unmolested, practically all seed spots failed. When competition of both understory and overstory was removed, the seedlings made even more rapid growth than when cultivated in the regular Forest Service nursery.

In this paper I have described the results from only one experiment, but many others on a less intensive scale have been conducted and have yielded exactly the same type of results. Since the advent of the Emergency Conservation programs we have undertaken to apply the results of these intensive experiments over considerable areas. Naturally, less intensive work is done but the results are in complete agreement. The requirements then for successful conversion of the very aggressive types of aspen to conifers include elimination of competition from the under-vegetation, and removal of sufficient of the overstory to allow the plants to obtain full sunlight for approximately two hours during each day. Under ordinary conditions this is an expensive procedure, and can only be justified where definite provisions can be made for continued care of the coniferous planting.

Returning to the question set forth in the title, we can say that pines will dominate aspen on the very poor, sandy soils, but on the heavier upland soils, aspen will continue to dominate pine in Minnesota, probably for several tree generations, unless the essential features of the expensive procedure for conversion outlined above are followed out.