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flight exists, and (2). to use it as one means of pointing out that the research possibilities in Minnesota natural history are exceedingly great, and that it should be the aim of the Academy to promote and stimulate such research.

TREE PLANTING IN LOWER MICHIGAN SANDBLOWS

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A distressing feature of the landscape in northwestern Lower Michigan is the ever-present sandblow ranging from a few square feet to hundreds of acres in size. These sandblows are not the moving dunes of the Lake Michigan shore, but lie inland, and are the result chiefly of destructive agricultural practices.

One such sandblow covering some 600 acres is on the Manistee National Forest in Big Prairie Township, Newaygo County, Michigan. Unless controlled, this sandblow would continue to encroach further and further on productive land. Because this was the largest and most spectacular of the many sandblows in this locality, and because it was largely in Forest Service ownership, the Lake States Forest Experiment Station in cooperation with the Manistee National Forest, began studies in the spring of 1938 to determine the best means of controlling it.

THE BACKGROUND

When the first settlers came to Michigan, they found several natural prairies ranging from about 80 acres to nearly 25 square miles in size in the southwestern part of the State. These prairies occurred on glacial outwash and coarse valley fillings deposited during the Wisconsin stage of the Pleistocene Age. The fact that these natural prairies had developed relatively thick deposits of organic matter through the decomposition of countless generations of grasses and other herbaceous vegetation, and that they did not need to be cleared for agriculture, made them highly prized for such use.

History of Big Prairie. Big Prairie, which is the most northerly of the natural Michigan prairies, was the first area to be put into cultivation in Newaygo County. At first good crops were produced, but before many years the action of the wind had begun to cause shifting of the exposed sandy soil. In those early days, farmers did not know how to control wind erosion by cultural practices, so gradually they abandoned their fields and went elsewhere.

One farmer apparently realized the value of windbreaks, but too

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[1] Maintained at St. Paul 1, Minn. by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota.

late to save his holdings. In the northeast part of Big Prairie are several windbreaks composed of three or four rows of conifers, chiefly red pine, (*Pinus resinosa*), and eastern white pine, (*P. strobus*), but also including some ponderosa pine, (*P. ponderosa*), Austrian pine, (*P. nigra*), Norway spruce, (*Picea abies*), and a group of black locust, (*Robinia pseudoacacia*), behind which the soil is stable and covered with a good stand of grasses. Unprotected by the windbreak are some meager remains of an old dwelling and the top portion of an old rail fence, projecting above the enveloping sand. Had such planting been done earlier over the entire area, the land could have been saved and Big Prairie would not have become a raw expanse of barren sand.

Big Prairie in the 1930's. Quite different from the pleasing sight that met the eyes of the early settlers was the Big Prairie of the 1930's. Occasional hummocks of sod showed that soil had been scooped out by the wind until the level was two to five feet below what it had been. Instead of a large grass-covered field, some 600 acres of bare sand covered the area, much of it like a smooth gravel-covered pavement with fringes of soft, loose, blow sand piled up along the edges.

The bulk of Big Prairie was, of course, essentially devoid of vegetation, but around the edges of the big sandblow were about 300 acres of grassland and some patches of woodland. The more common tree species in the woodland area were eastern white pine (*Pinus strobus*),[2] white oak (*Quercus alba*), northern red oak (*Q. rubra*), and some northern pin oak (*Q. ellipsoidalis*). Scattered throughout the prairie were clumps of black cherry (*Prunus serotina*), willows (*Salix spp.*), and dewberry (*Rubus flagellaris*). The herbaceous vegetation within the area was distinctly that of the prairie. Predominant grasses were prairie beard grass (*Andropogon scoparius*), bluejoint turkey foot (*A. Gerardi*), Indian grass (*Sorghastrum nutans*), prairie three-awn (*Aristida oligantha*), and Canada blue grass (*Poa compressa*). There was also a number of typical herbaceous species such as pansy violet (*Viola pedata*), wild lupine (*Lupinus perennis*), spring vetch (*Vicia sativa*), asters (*Aster* spp.), blazing star (*Liatris aspera*), butterfly weed (*Asclepias tuberosa*), goldenrods (*Solidago spp.*), prickly pear (*Opuntia humifusa*), common milkweed (*Asclepias syriaca*), and horse weed (*Erigeron canadensis*).

During the late fall and early spring when winds are frequent and strong and the surface soil usually is dry, clouds of stinging, choking sand, often 40 or 50 feet high, were blown across Big Prairie very frequently. It was at these seasons that most of the soil movement took place.

REVEGETATION STUDIES

In attempting to restore vegetation to the barren areas of Big Prairie, it was necessary to learn whether or not trees could be established

[2] Scientific names of trees are in accord with E. L. Little, "Check List of Native and Naturalized Trees of the United States" (1953); scientific names of other plants conform to the 8th edition of "Gray's Manual of Botany," (1950) by M. L. Fernald.

immediately, with or without the aid of mechanical barriers, or if it would be necessary to follow more closely in the steps of natural succession and begin with grasses and herbs before establishing shrubs and finally, trees.

To attain this objective it was necessary to consider such factors as the poor water-holding ability of the soil, the low nutrient and organic content of the soil, the high evaporation rate, the high surface soil temperatures to be expected in midsummer, and the abrasive action of the blowing sand.

Some conception of the poor, droughty soil may be afforded by a mechanical analysis of the surface 12 inches of soil, by the Bouyoucos method, which disclosed a silt plus clay content of 4 percent and a combined sand percent of 96. The computed wilting coefficient was 2.53 percent. Frequently during the summer the soil moisture content was but little above the wilting coefficient.

Treatments Tested. Two 10-acre blocks along the south edge of the big sandblow were selected for the study. These were laid out into long narrow plots approximately 66 x 660 feet (1 acre) with their long axes in the north-south direction. Windrows of brush 2 to 3 feet high were placed along the east and west edges of the south half of each plot. At the center of the area, one acre, including one-tenth of an acre in each plot, was broadcast with brush. The remainder of the north half of each plot was left unprotected. Snow fence was placed along the west edge (the prevailing winds were from the southwest) of the 10-acre blocks to provide some protection from moving sand. In one block additional staggered rows of snow fence were established along the edges of the four western plots. One block was planted in the spring of 1938 and one in the spring of 1939. Some fail plots were replanted with other species in 1940 and 1942.

Within these plots the following tree species were planted: jack pine (*Pinus banksiana*), red pine (*P. resinosa*), pitch pine, (*P. rigida*), eastern white pine (*P. strobus*), Scotch pine (*P. sylvestris*), Austrian pine (*P. nigra*), northern red oak (*Quercus rubra*), bur oak (*Q. macrocarpa*), white ash (*Fraxinus americana*), Russian-olive (*Elaeagnus angustifolia*), black locust (*Robinia pseudoacacia*), eastern cottonwood (*Populus deltoides*), hybrid poplars (*X Populus spp.*), Siberian elm (*Ulmus pumila*), and basket willow (*Salix viminalis*). Each species was planted partly in the area protected by broadcast brush, partly in the area protected by windrow brush, and partly in the unprotected area. In addition, root cuttings of common lilac (*Syringa vulgaris*), obtained from nearby abandoned farms, were planted in several rows across each treatment. The following grasses and herbs also were planted: Winter rye, quack grass (rhizomes covered in furrows), grain screenings, soy beans, Sudan grass, and an alfalfa-brome grass mixture. The winter rye was planted under three conditions: (1) no treatment, (2) soil given dressing of well-rotted manure during previous year, and (3) under cotton mesh cloth.

Brush was broadcast on a small sandblow, about 1½ acres in extent just south of the main prairie and the area was then planted to Scotch pine.

Observations made. To provide some factual basis for analyzing causes of mortality due to physical factors, measurements were made for the first four years of soil moisture, rainfall, air temperatures (in a weather shelter), and soil surface temperatures at weekly intervals. Soil moisture was determined during the growing season (May to October) only. For two years wind velocities at the 1-foot level were recorded from May to December for each treatment.

Records of survival and growth of the planting, were made at the end of the first, second, fourth, and tenth years (for a few species which had not undergone 10 growing seasons, growth was adjusted to a 10-year basis).

RESULTS AND CONCLUSIONS

Plantings of winter rye, cottonwood cuttings, black cherry, black locust, Russian-olive, Siberian elm, white ash, and basket willow cuttings, all failed within two years and were replanted to jack pine, Scotch pine, or Austrian pine. On one portion of one plot, well-rotted manure had been applied to the soil and on this area, winter rye did establish a good stand, and jack pine planted subsequently showed improved growth. The quack grass rhizomes gave a good stand the first year, but declined rapidly thereafter and had almost disappeared after 4 years.

The hybrid poplars failed completely except for two rooted clones of the following parentage: *Populus nigra* X *P. trichocarpa* and *P. maximowiczi* X *P. trichocarpa.* Since then, even these latter two clones have almost completely failed and the survivors have made less satisfactory growth than the better pines.

The species showing the best survival and development after ten years were jack pine, red pine, Scotch pine, white pine, pitch pine (table 1). Bur oak and Austrian pine had survived well, but had grown rather slowly. Lilac had poor survival and development, although it was not a complete failure. The effects on survival of treatment with broadcast brush in many cases were very slight, but were uniformly marked on height development. The principal exception was white ash, in which survival was zero in the untreated area and 77 percent in the broadcast brush. However, white pine and red oak also had much improved survival in the broadcast brush areas. The effects of the windrowed brush were less noticeable. Trees adjacent to the windrows grew about as well as those in the broadcast brush zone. However, a few rows away, growth was about the same as it was in the unprotected area.

Of interest is the marked effect of one application of well-rotted manure on the height growth of jack pine planted a year after treatment.

It was interesting to observe that for the first 10 years the trees planted in Big Prairie were largely free of injury from such common insect pests as the white pine weevil, the pitch nodule maker, and the root collar weevil. This probably resulted from the relative isolation of these plantations from other stands of these trees. That this freedom from injury

Table 1.—TEN YEAR SURVIVAL AND HEIGHT GROWTH (ADJUSTED) OF TREES PLANTED ON BIG PRAIRIE

Species	Class of	Treatment	Ave. survival	10th Year Ave. Height Total	Compared to Control
			Percent	*Feet*	*Percent*
Jack pine	2-0	None	94	10.4	100
		Broadcast Brush	95	14.3	138
Jack pine	1-1	None	87	4.7	100
		Broadcast Brush	94	11.0	234
		Well-rotted manure	86	12.0	255
Red pine	2-1	None	93	3.5	100
		Broadcast Brush	99	7.0	200
White pine	2-1	None	79	1.9	100
		Broadcast Brush	90	7.5	395
Pitch pine	2-0	None	72	4.5	100
		Broadcast Brush	76	6.1	136
Scotch pine	2-0	None	99	5.5	100
		Broadcast Brush	86	7.9	144
Scotch pine	2-1	None	93	4.3	100
		Broadcast Brush	93	7.5	174
Austrian pine	2-1	None	93	2.3	100
		Broadcast Brush	97	3.0	130
Red oak	1-0	None	87	.8	100
		Broadcast Brush	100	1.4	175
Bur oak	1-0	None	91	1.3	100
		Broadcast Brush	96	2.4	185
White ash	2-0	None	0	0	
		Broadcast Brush	77*	2.5	

*This represents the most striking effect of the broadcast brush treatment.

may not long continue is indicated by the appearance of the root collar weevil in Scotch pine plantations along the north side of the large sandblow.

The most serious causes of loss and injury during the first four years were nutrient deficiency, heat, sand covering, and drought. Very little loss or injury was attributed to the abrasive action of blowing sand.

The treatments did have some effect on wind velocities as measured by anemometers placed 12 inches above ground in the zones which were unprotected, protected by windrowed brush, protected by broadcast brush. Wind velocity was retarded the most in the broadcast brush area and least in the unprotected area.

The effectiveness of the broadcast brush in promoting better growth appears to have resulted largely from reduction in rapid soil moisture evaporation and retarding surface soil movement.

Ten years after treatment a few natural seedlings of quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), and jack pine had become established in some of the broadcast brush areas. None were noted in the unprotected areas.

These studies indicate that it is feasible to reclaim Big Prairie and similar sandblows directly by planting trees, especially if brush is broadcast between the rows of trees. Since these studies were established, a large part of the open sand area has been planted with trees, chiefly red pine, Scotch pine and jack pine. The blowing of the soil has been essentially stopped with the result that this area no longer is a menace to surrounding lands. These methods have been applied successfully on sand dune and sandblow plantings made to the west of this area. Similar methods have also proved successful in Vermont (Kelly et al., 1948).

LITERATURE CITED

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SOME RELATIONSHIPS BETWEEN THE DEVELOPMENT OF THE FIRST GENERATION LARVAE OF THE EUROPEAN CORN BORER (PYRAUSTA NUBILALIS HUBNER) AND TEMPERATURE UNDER FIELD CONDITIONS

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ABSTRACT

A study was made in 1950 and 1951 on the development of first generation corn borer larvae on eight different lines of field corn. The cumulative effective temperatures required for the larvae to reach different instars were calculated by using two thresholds as the base temperature: 50° F, a threshold extrapolated from the linear portion of the temperature-rate of development curve, and 36° F, a threshold extrapolated from the curved portion of the same curve. Both of these temperatures were used by Caffrey and Worthley (1927).

It was found that the development of borer larvae in relation to the cumulative effective temperature was, in general, very consistent in the two years, in spite of the fact that the eggs hatched and the larval populations were examined on different dates in the two years. This was true whether 50° or 36° F was used as the base temperature in calculating the effective cumulative temperature. Furthermore, the configuration of