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Plant Migration Studies

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II.—*Plant Migration Studies*

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I. FOREST TREES.

It is a familiar fact that new species appear from time to time among the native plants of a region. Such newcomers turn out on examination to be new only in the sense that they have not previously lived in the region, and in every instance these new plants are found to have come from other regions where they had existed for a longer or shorter period of time. In some cases the new species remain for a time and then disappear, or at least become inconspicuous, but more commonly they crowd in among the former plants and become permanent members of the plant community. Whenever such an addition is made to the flora of a region there is a readjustment of the former species, with a necessary change in the relative numbers of the individuals, and the particular habitat of each. In the case of annual plants these adjustments are made rapidly, so that in a short time the prominent features of the plant community may be entirely changed. On the other hand, in the case of perennial plants there is greater stability, new species finding greater difficulty in entering, and the old species giving away, if at all, only after the lapse of a much longer time. A vegetation which is well rooted in the ground is much less easily disturbed than one whose roots live for but a single season and then abandon the particular plot of ground where they grow. Forests are therefore conservative plant communities, into which new species gain entrance with difficulty, and which change very slowly after such entrance has been effected. There is only one other plant community whose stability approaches that of the forest, namely, the grassy vegetation of the prairies and plains, which is com-

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posed of perennial-rooted grasses, sedges, and rushes. Where these form a close sod new species are almost wholly excluded, and but little change takes place in the character of the vegetation. It is only where the surface is not closely covered that the grassy vegetation is more easily modified by the incoming of new species. Where accident, or disease, or some other cause has destroyed the grassy covering new species promptly take possession. A fine example of this is to be seen in the growth of *Helianthus annuus* on the mounds made on the prairies by such burrowing animals as gophers and prairie dogs. Where the tough sod was broken by the freight-wagons which crossed Nebraska by various "trails" many years ago botanists find many newcomers, which could not have gained a foothold in the unbroken sod.

FACTORS IN MIGRATION

The means of migration are physical and biological, the former including all the factors which are external to the plant, and which involve the mechanical movement of the plant or some of its parts, while the latter includes the devices on the part of the plant by means of which it takes advantage of physical agencies. In this paper only those means which have to do with the migration of forest trees will be considered, thus limiting the discussion by excluding a multitude of devices of all degrees of complexity which pertain to other plants.

The most general physical agent in the dissemination of plants is the movement of the air in the currents of wind. These sweep over the earth's surface with all degrees of rapidity, and with a carrying power which increases as the squares of the velocities. The fact that winds shift their direction at short intervals, rarely maintaining the same direction for more than a few hours, or at most a few days, makes them especially useful agents in the movement and transportation of such seeds and fruits as can be blown from place to place. It is probably true that to some extent the distribution of all of the species of trees which grow naturally in Nebraska is affected by the winds. The violent and long continued winds of high velocity transport seeds and fruits

of all kinds, whether or not they show any special adaptations for wind carriage.

A second general agent in dissemination is moving water, upon which seeds and fruits may float from place to place. Every brook, every creek, every river carries thousands of seeds, many of which ultimately float to the banks, or are lodged upon sandbars and islands. In the aggregate the number of seeds carried in this manner is large, but the number of trees resulting from their growth is by no means as great, since many seeds are injured by prolonged soaking in water, and in addition many do not find favorable conditions for growth when cast ashore.

Animals of various kinds are active agents in the dissemination of seeds and fruits, especially of trees. Here the means of transportation are much more efficient, since they may result in the dispersal of seeds in all directions, and often for much greater distances. Squirrels, rats, mice, and other rodents which carry and secrete stores of food, and many herbivorous mammals which feed more or less commonly upon seeds and fruits, are efficient means for distributing the seeds of trees and other plants. To these must be added the birds of nearly all species, excepting those that subsist wholly upon animal food. Their power of swift flight enables them to transport seeds long distances in every direction, across barriers which are practically impassable for quadrupeds. The number of different species which take part in seed dissemination is not less than two hundred in the portion of the central plains included within the boundaries of Nebraska, and of these probably one-third carry the seeds of trees.

Nebraska occupies a central position in the United States, and is somewhat south of the centre of the North American continent. It lies between latitude 40° to 43° north of the equator, and longitude 95°30′ to 104° west of Greenwich. It lies almost wholly in the Great Plains region, or the "Prairie Province" as denominated by Pound and Clements in the "Phytogeography of Nebraska." In the valley of the Missouri River along its eastern border its elevation above sea-level is 268 metres (880 feet) at the southeast, and about 335 metres (1100 feet) at the northeast,

while westward and northwestward the elevation is much greater, reaching 1500 metres (4900 feet) in the northwest, and fully 1616 metres (5300 feet) towards its southwest boundary, near the Wyoming line.

The river system is a very simple one. Along the eastern border is the turbid Missouri River, which receives the Nemaha and Weeping Water (both short streams) south of the mouth of the Platte River. The Platte River flows from the Rocky Mountains as two streams, which unite in western Nebraska, and is, like the Missouri River, a rapid and turbid stream. It receives one tributary, Lodgepole River, in the western part of the state, the much-branched Loup River (which drains the Sandhills) in the centre, and the Elkhorn River toward the northeasterly part. On the north is the Niobrara River which comes from the Wyoming foothills, and in the extreme northwest are branches of the White River, rising in the mountainous country of Pine Ridge. On the south the Republican River comes from the elevated plateau of eastern Colorado, traverses the southern counties, and then passes into Kansas where it joins the Kansas River, and finally reaches the Missouri River. In the southeast, the Blue River drains a triangular area closely adjacent to the Platte River, and flowing south empties into the Kansas River.

The surface features of the state are considerably varied, including the wet and marshy "bottoms" of the Missouri River valley, the steep "bluffs" which limit them on the westerly side, the hilly and broken country still further inland, the rolling surface of the prairies of the eastern portion of the state, the more pronounced hills adjacent to the bluffs of the Platte valley, the broad and nearly level valley of the Platte River, the steep and irregular hills of the Sandhill country, the high plains, "bad lands," buttes, and mountainous ridges of the extreme west.

The soils of Nebraska show much of uniformity. Most of the eastern portion is overlaid with loess, which becomes more sandy westward toward the Sandhills, while still further west it becomes more clayey. These three general types of soil are more or less modified locally, as by the increase of humus in the marshy

borders of some streams, the increase of organic matter in the drainless valleys of the Sandhills, and the alkali soils surrounding many ponds in regions still further west.

The climate of Nebraska is of the "continental" type. The rainfall which reaches 88 centimetres (35 inches) a year in the southeastern part gradually decreases westward to 35 centimetres (14 inches). It is very unequally distributed throughout the year. About 30 per cent falls in the spring, 39 per cent in the summer, 23 per cent in the autumn, and 8 per cent in the winter. The humidity of the air is generally low, and is especially so in the winter. The insolation is high, the days with sunshine being more than three times as many as those without. The temperature ranges are from about 38°C. (100°F.) as the maximum heat of summer, to —36°C. (—30°F.) as the minimum of winter, the former for the southern counties, and the latter for the northern. The prevailing winds are from the southeast in spring and summer, and from the northwest in the autumn and winter. The average for ten years of the number of miles of wind for each season in eastern Nebraska (Lincoln) is, 28,111 in spring, 21,016 in summer, 23,586 in autumn, and 23,460 in winter.

The native trees of Nebraska have developed many devices, for the distribution of their seeds, adapted to the physical factors just described. These may be reduced to five general classes, viz.: wings, hairs, fleshy fruits, rolling balls, edible nuts.

WINGS

Rock pine (*Pinus scopulorum* (Engelm.) Lemmon). Each seed is provided with a delicate membranous wing, a centimetre long and five to seven millimetres wide. When the seed drops from the cone it is given a whirling motion by a slight twist and bend in the plane of the wing, and if caught by the wind is carried a considerable distance from the parent tree. This tree occurs in the Rocky Mountains from Montana to Wyoming and Colorado, and in Nebraska (1[1]) has pushed out upon the foothills

[1] The figures in parentheses refer to the maps showing the distribution of the different species of trees.

(Pine Ridge, and Wild Cat Mountains), and from these to the bluffs of the Niobrara, and North Platte rivers. From the latter it spread to scattered stations along the eastern edge of the Great Sandhill region (Holt, Greeley, Valley, Custer, Lincoln and Franklin counties).

Basswood or Linden (*Tilia americana* L.). The wing is an extension and enlargement of the bract of the peduncle of the inflorescence. The several spherical, dry fruits at maturity are attached nearly at right angles to this wing, which is slightly bent and twisted. At maturity the bract carrying the fruits separates at its base from the tree, and when caught by the wind whirls horizontally, carrying its freight of seed-bearing fruits often to a distance of many metres from the parent tree. The linden occurs abundantly in the forests bordering the Missouri River southeast of Nebraska, and it now extends up that river along the eastern edge of the state (16) and along the Niobrara River to Cherry County. It has also extended up the valley of the Blue and Republican rivers on the south to Jefferson County, and the Platte River in the central portion of the state, to Nance County.

The Elm (*Ulmus* spp.). The flat seed-pods are winged on their margins so that the surface is increased several times. When ripe they are very light, and are easily carried by the wind to a distance of ten to twenty or more metres from the parent tree. While great numbers fall to the ground under the tree, many are carried to a distance equal to or more than that of the height of the tree.

The White Elm (*Ulmus americana* L.) is very abundant in the valley of the Missouri River southeast of Nebraska, and thence eastward to the Atlantic Ocean. From the southeastern forest body of this species it has extended up the several river valleys into all portions of the state (17) to the western counties.

Rock Elm (*Ulmus racemosa* Thomas) occurs commonly in the forest belt bordering the Missouri River southeastward, and from this region it has moved upward along the eastern border of the state (18) and up the Niobrara River near the northern boundary. While it has been recorded from but two stations (Cass

and Keya Paha counties) it is highly probable that it occurs somewhat sparingly and perhaps intermittently along the eastern and northeastern border.

Red Elm (*Ulmus fulva* Michx.) is abundant in the Missouri River forest area, from which it has spread westward up the river valleys nearly or quite half way across the state (19). Beyond this area a single station is reported in Frontier County.

The Ashes (*Fraxinus* spp.). Each cylindrical seed pod is prolonged upward into a flat oar-shaped, slightly bent and twisted wing. Where the fruit separates from its pedicel it drops with the heavier seed-end down, and is given a whirling motion by the wing, and when caught by the wind is carried many metres before it reaches the ground.

White Ash (*Fraxinus americana* L.) is common in the Missouri forest area, from which it has extended up along the eastern border of the state (22) to Sarpy County.

Green Ash (*Fraxinus lanceolata* Bork.) is also common in the Missouri forest area, from which it has spread westward and northward along the river valleys, across the state (24) to the western counties.

Red Ash (*Fraxinus pennsylvanica* Marsh.) is found with the preceding (23) and apparently has been disseminated with it.

Red Bud (*Cercis canadensis* L.). The bean-like pods are very flat and thin, and are well adapted to be carried in the wind a few metres. It is common in the Missouri forests and has extended northwestward into Nebraska (36) as far as Lancaster and Douglas counties.

The Maples (*Acer* spp.). The bicarpellary fruit develops two thin membranous curved and slightly twisted wings, one on the back of each carpel. At maturity the carpels split apart, and each falls slowly with a whirling motion, while the wind carries it to a greater or less distance from the parent tree. In a high wind this distance may be twenty to thirty metres, or even more.

Mountain Maple (*Acer glabrum* Torrey) is abundant in the Rocky Mountains of Wyoming and southward, from which it has extended eastward into the extreme western part of the state (42) at two stations (Sioux and Scott's Bluff counties).

Silver Maple (*Acer saccharinum* L.) occurs abundantly in the Missouri forest area from which it has extended up the Missouri River nearly to the mouth of the Niobrara River (43) and westward fifty to sixty miles, in the moist lands along the streams.

Box Elder or Ash-leaved Maple (*Acer negundo* L.) grows abundantly in the Missouri forests, from which it has extended across the state (44). As this species occurs in the Rocky Mountains from New Mexico northward it is possible that some of the trees in western Nebraska have come down from the mountains and met those disseminated directly from the eastern forest areas.

Ironwood (*Ostrya virginica* (Miller) Willd.). The small nut is enclosed in a bladdery bag, which is so much larger that it serves the purpose of a wing. A dozen or more of these are aggregated into a loose strobilus. The obvious purpose of this structure is the easy transportation of the seed by the wind either in the whole strobilus, or the separate seed-bearing bags. The tree is abundant in the Missouri forests, from which it has extended up through the eastern and northern counties to Brown, Cherry and Sioux counties (63)..

Water Beech (*Carpinus caroliniana* Walter.). The small nut is attached to a foliaceous, somewhat three-lobed bract, which serves as a wing. These bracts are not crowded into a strobilus, but constitute a loose raceme. On falling from the tree the bracts serve to float the seed in the wind for some distance from the parent tree. This species occurs in the Missouri forests, and has been reported from eastern (Sarpy County) and northern stations (Brown County) in Nebraska (64) to which it has apparently extended its range.

The Birches (*Betula* spp.). The little nut is winged on its margins. These grow in small cones, from which when mature they are shaken out by the wind, and carried away some distance before reaching the ground.

Canoe Birch (*Betula papyrifera* Marshall). This tree occurs in Minnesota and Montana, the Black Hills of North Dakota, and at a single station on the Iowa River in central Iowa (Hardin County). In Nebraska it is found only on the bluffs and in the

ravines along the Niobrara River in Keya Paha, Brown, and Cherry counties (65). The occurrence of this tree in Nebraska is a puzzle to the botanical geographers, for it is difficult to conceive of any means by which the seeds could be carried from the nearest known stations. Even should we consider the possibility of its dissemination from the Black Hills the difficulty is nearly as great, for the distance is fully one hundred and fifty miles, a part of it across the very rough country known as the "Bad Lands."

Black Birch (*Betula occidentalis* Hook.) occurs abundantly in the Rocky Mountains west of Nebraska (66) and has extended from thence eastward into the state in Sioux County.

River Birch (*Betula nigra* L.) is found in the Missouri forests southeastward, and has extended its range northward along the eastern border of the state, being reported from Cass County (67).

HAIRS

The Willows (*Salix* spp.). The bicarpellary seed-pods contain two rows of inverted seeds (anatropous), each of which develops a circular tuft of long straight ascending hairs on its funicle. Upon the dehiscence of the mature fruit the seeds are released, when the hairs spread out almost spherically, and are caught by the winds and floated away for long distances, often a mile or more, or in high winds, many miles.

Black Willow (*Salix nigra* Marsh.) is common in the Missouri forests, from which it has spread up the streams, apparently across the state (5).

Almond Willow (*Salix amygdaloides* And.) is found abundantly in the Missouri forests, and has followed the river valleys across the Plains to the Rocky Mountains (6) and even to Oregon.

Shining Willow (*Salix lucida* Muehl.) occurs in the Missouri forests and has moved up the river to Cass County (7).

Sand-bar Willow (*Salix fluviatilis* Nutt.) is abundant in the Missouri forests, from which it has extended up the river valleys, across the Plains to the Rocky Mountains (8), California, and Oregon.

Bebb's Willow (*Salix bebbiana* Sarg.) is found in the Black Hills of South Dakota, and the Rocky Mountains from Montana to Colorado, from which it has extended eastward (9) so as to enter the northwest corner of the state (Dawes and Sioux counties).

Diamond Willow (*Salix missouriensis* Bebb) is common along the Missouri River in Western Missouri from which region it has extended its range northward along the river, and westward in the Republican, Platte and Niobrara river valleys to the western border (10).

The Poplars (*Populus* spp.). The bi- and tricarpellary seed-pods develop two or three rows of seeds having the same general structure as those of the Willows. On the escape of the seeds they are buoyed up by the attached mass of fluffy hairs, and carried away by the winds, sometimes for several miles.

Quaking Aspen (*Populus tremuloides* Michx.) is a Rocky Mountain tree which has extended eastward into Nebraska but a few miles in the western counties (11) from Banner to Sioux, Dawes and Sheridan counties.

Balsam Poplar (*Populus balsamifera* L.) occurs in the Rocky Mountains of Wyoming from which it has extended eastward into Nebraska in Sioux County (12).

Narrow-leaf Cottonwood (*Populus angustifolia* James) is also a member of the forests of the Rocky Mountains, from which it has come eastward into Nebraska (13) in Sioux and Scott's Bluff counties.

Rydberg's Cottonwood (*Populus acuminata* Ryd.) occurs here and there in the Rocky Mountains of Colorado and Wyoming, from which it has invaded western Nebraska (14) at one point (Scott's Bluff County).

Common Cottonwood (*Populus deltoides* Marsh.) is very abundant in the Missouri forests, from which it has passed up the rivers across the state (15) to the western border and beyond.

FLESHY FRUITS

Red Cedar (*Juniperus* spp.). The small few-scaled cones increase their parenchymatous tissue and become fleshy, and berry-

like. They are eaten by some birds, and in this way the seeds are scattered.

Eastern Red Cedar (*Juniperus virginiana* L.) is found scattered over the eastern United States, and occurs in the various bodies of forests eastward of Nebraska. From these it has moved westward up the river valleys fully two-thirds of the distance across the state (2).

Western Red Cedar (*Juniperus scopulorum* Sarg.) occurs in the Rocky Mountains, from which it appears to have moved eastward into the western third of the state (3).

Papaw (*Asimina triloba* (L.) Dunal). The large fleshy fruits which contain about eight large hard seeds are edible, and are picked up and carried off, or eaten directly by various quadrupeds. In either case it happens that some of the seeds are carried some distance from the parent trees. This species is very common in the Missouri forests, from which it has moved up the river valleys (4) in southeastern Nebraska (Richardson to Pawnee, Nemaha, Otoe, and Saunders counties).

Hackberry (*Celtis occidentalis* L.). The globose one-seeded fruits are fleshy, and are in fact small drupes, much like thin-fleshed cherries. They are freely eaten by birds, and thus the seeds may be carried to considerable distances (even to many miles) from the parent trees. This species occurs abundantly in the Missouri forests, from which it has extended its range up the Missouri, Republican, Platte and Niobrara river valleys, across the plains (20) to the Rocky Mountains.

Red Mulberry (*Morus rubra* L.). The compound fleshy fruit (sorosis) consists of an aggregation of small one-seeded drupes, each surrounded by the fleshy calyx-lobes. They are eaten by many birds, and the hard seeds are voided uninjured, and thus carried far away from the parent trees. The Mulberry is found abundantly in the Missouri forests, from which it has extended northwestward along the eastern border of the state to Cedar County (21).

Prairie Apple or Western Crab-Apple (*Malus iowensis* (Wood) Britt.). The fleshy fruit contains five two-seeded carpels, and is eaten by swine, cattle, sheep, horses, and probably by

deer, rabbits, woodchucks and a few other quadrupeds. Such fruits as are carried short distances and then dropped whole, or partially eaten, may supply seeds from which new trees may spring. This species is abundant in the Missouri forests, from which it has extended its range into Nebraska along the Missouri River and up the Niobrara River to Brown County (25). It has been distributed up the Nemaha River valley to Gage County, and the Platte River valley to Butler County.

The Hawthorns (*Crataegus* spp.). The fleshy fruits are in fact little apples with bony instead of papery carpels. The flesh is palatable and the fruits are eaten by many quadrupeds (as swine, cattle, sheep, horses, deer, rabbits, etc.) and by some birds which are attracted by the bright colors in most of the species.

Blackthorn (*Crataegus tomentosa* L.) occurs in the Missouri forests, from which it has moved up the river into the southeastern counties, from Richardson to Lancaster and Douglas (26).

Downy Haw (*Crataegus mollis* (T. & G.) Scheele) occurs in the Missouri forests, and has extended its range apparently with the preceding species to Lancaster and Douglas counties (27).

Red Haw (*Crataegus colorado* Ashe) is probably a western species which has moved down into the Sandhill region, where it occurs along the banks of the Dismal and Middle Loup rivers in Thomas County (28).

Thorny Haw (*Crataegus occidentalis Britt.*) is a native of Colorado, Wyoming and Montana from which it has moved down the Niobrara River to Cherry, Brown, Rock, Holt, Keya Paha, Boyd and Knox counties. It occurs also on the Middle Loup River in Thomas County (29).

Juneberry (*Amelanchier canadensis* (L.) Med.). The little hard-seeded apples have a soft edible flesh which is greedily eaten by birds. Many of the seeds pass through the alimentary canal uninjured and are thus distributed over considerable distances. This species occurs in the Missouri forests, from which it has moved up the valley of the Missouri River as far as Sarpy County (30).

Cherries and Plums (*Prunus* spp.). The monocarpellary, two-ovuled ovary becomes a fleshy one-seeded drupe. The hard shell of the stone protects the seed from crushing when the fruit is eaten by birds or quadrupeds, and preserves many of the embryos while the seeds are passing through the alimentary canal. The smaller fruits (cherries) are greedily eaten by many birds, while the larger (plums) are eaten by quadrupeds, and occasionally carried away by birds.

Choke Cherry (*Prunus virginiana* L.) is found in the Missouri forests, from which it has been carried northward along the Missouri River as far as Sarpy County, and westward in the Nemaha, Blue and Republican river valleys to Franklin County (31).

Wild Black Cherry (*Prunus serotina* Ehrh.) occurs in the forests of Missouri, from which it has spread into southern and eastern Nebraska, to Sarpy County along the Missouri River, and Franklin County in the valley of the Republican River (32).

Wild Plum (*Prunus americana* Marsh.) is common in the country East of the Plains, into and across which it appears to have been carried, so that it is now found in the Rocky Mountain region. It is found in all parts of Nebraska (33), even in the "pockets" in the Sandhills into which it must have been carried by birds.

Kentucky Coffee Tree (*Gymnocladus dioica* (L.) Koch). The large monocarpellary fruits (15–18 centimetres long, 4–5 wide, and nearly 2 centimetres thick) contain about half a dozen large, spherical, very hard seeds, imbedded in a sweet pulp. The ripened pods hang on the trees for a part of the winter, and when they fall are picked up by quadrupeds which are attracted by their sweet odor. The hardness of the seeds prevents their being crushed. The tree occurs in the Missouri forests, and has followed the Missouri and Niobrara rivers northwestward to Rock county (34). In the southeastern part of the state it has followed the smaller streams westward fifty to sixty miles from the Missouri River.

Honey Locust (*Gleditsia triacanthos* L.). The large twisted and bent monocarpellary fruits (20–30 centimetres long, 2–2.5

wide, and 0.5 thick), contain ten or more very hard, flat seeds, bedded in a sweet pulp. The pods fall from the tree during the winter and are picked up and partly eaten by the larger quadrupeds, as swine, cattle, etc., and doubtless were also by deer, buffaloes, and other wild animals before the advent of white men. The hardness of the seeds preserves them from injury. The tree is common in the forests of Missouri, and has been carried up the Missouri River and its tributaries so that now it occurs as far west as Franklin County in the Republican valley, and Holt County along the Niobrara River (35). It has also passed up the Nemaha and the Blue rivers to Gage and Lancaster counties.

Buckthorns (*Rhamnus* spp.). The small drupe contains two to four very hard one-seeded stones, surrounded by a thin flesh. When these drupes are eaten by birds the seeds are preserved from injury by their hard covering.

Buckthorn (*Rhamnus lanceolata* Pursh) is common in the Missouri forests, from which it has moved up along the eastern border of the state to Cherry County on the Niobrara River. It has followed the tributaries of the Missouri River (Nemaha and Blue rivers) to Gage, and (Platte River) Saunders counties (38).

Indian Cherry (*Rhamnus caroliniana* Walt.) occurs somewhat sparingly in the Missouri forests, from which it has advanced into eastern Nebraska (39) having been noticed at two stations (Cass and Saunders counties).

Buffalo Berry (*Lepargyraea argentea* (Pursh) Greene). The small red or amber one-seeded drupes are edible, and are eaten by birds and thus carried away. The seed is protected from injury in the alimentary canal by its hard covering. This small tree is a native of the Rocky Mountain region and westward, from which it has been carried eastward across the state (40) to the banks of the Missouri River (Nemaha County).

Sumach (*Rhus copallina* L.). The small one-seeded drupes are crimson in color and have an acid flavor. They are eaten by birds, and their seeds are protected from injury by the bony seed coat. This species occurs in the Missouri forests, and has been carried northward (45) to the extreme southeastern corner of the state (Richardson County).

ROLLING BALLS

Sycamore (*Platanus occidentalis* L.). The flowers grow in spherical heads, and produce compact, spherical clusters of oblong nutlets, which hang from long peduncles. When they fall from the tree (in the winter) they roll over the ground in the wind, carrying their seeds with them. These trees are common in the forests of Missouri, from which they have moved up along the eastern edge of the state to Douglas County (37).

EDIBLE SEEDS AND NUTS

Buckeye (*Aesculus glabra* Willd.). The large brown shiny seeds drop to the ground as soon as mature, where they are quite conspicuous. Here they are picked up by large animals and sometimes swallowed. They are too hard to be easily masticated, and many must be rejected after trial. In the meantime they have usually been carried some distance from the parent tree. This species occurs in the Missouri forests, from which it has moved into Nebraska (41) as far as Richardson, Pawnee, and Nemaha counties.

Walnuts (*Juglans* spp.). The large drupaceous fruits contain a bony shell (the nut) enclosing a four-lobed, edible seed. At maturity the bitter flesh rots away, leaving the nut, which is picked up by squirrels and related rodents, and carried away to be eaten at once, or hidden for future eating. Many of these are dropped on the way, or those hidden are forgotten or overlooked, so that much effective distribution of seeds has taken place.

Butternut (*Juglans cinerea* L.) is common in the Missouri forests, from which it has been carried into the southeastern part of Nebraska, as far as Gage, Johnson, Otoe and Cass counties (46).

Walnut (*Juglans nigra* L.) is found in abundance in the forests in the Missouri River valley southeast of Nebraska, and from here it has moved up that river and up the Niobrara valley to Cherry County. It has occupied the southeastern corner of the state, and the Republican valley to Harlan County (47).

The Hickories (*Hicoria* spp.). The fruits are drupes, with a hard flesh which splits at maturity into four segments and separates from the hard, smooth, but usually angled nuts, each enclosing a two- to four-lobed, edible seed. These nuts constitute the favorite food of squirrels, and are carried away and secreted in great quantities. Many of these eventually germinate and spring up into young trees.

Shellbark Hickory (*Hicoria ovata* (Mill.) Britt.) is common in the Missouri forests, from which it has been carried into the southeastern counties of Nebraska, from Gage to Cass (48).

Big Hickory Nut (*Hicoria laciniosa* (Michx.) Sarg.) occurs in the Missouri forests, from which it has been carried northward along the Missouri River from Richardson to Sarpy counties (49).

Mocker-Nut (*Hicoria alba* (L.) Britt.) occurs in the Missouri forests, from which it is reported to have moved northward (50) into eastern Nebraska (*Sargent*).

Pig-Nut (*Hicoria glabra* (Mill.) Britt.) is common in the Missouri forests, from which it has been carried along the Missouri River into eastern Nebraska from Richardson to Cass counties (51).

Bitter Hickory (*Hicoria minima* (Marsh.) Britt.) is common in the forests of the Missouri River valley, from which it has been carried northward into the southeastern counties of Nebraska (52) from Richardson to Pawnee, Lancaster and Cass.

Oaks (*Quercus* spp.). The fruits (known as "acorns") are thin- and tough-shelled nuts, each containing a single, large, edible seed. They are relished by squirrels and other rodents, as well as by swine, cattle and sheep, and also by deer and buffaloes. All of these no doubt have contributed in some degree to their dissemination, but the squirrels have been the most active agents in this work, gathering and hiding them in many places, usually at some distance from the parent tree.

White Oak (*Quercus alba* L.) is common in the Missouri forests, from which it has been carried into southeastern Nebraska (53) as far north as Cass County.

Post Oak (*Quercus minor* (Marsh.) Sarg.) is found in the Missouri forests, from which it is reported to have moved northward (54) into southeastern Nebraska (*Sargent*).

Bur-Oak (*Quercus macrocarpa* Michx.) is abundant in the Missouri River valley forests, from which it has migrated along the river valleys fully half way across the state (55), reaching Harlan County on the south, Custer County in the centre and Cherry County on the north. It occurs, also, in the Black Hills of South Dakota, to which it was probably brought from the same Missouri forest area.

Yellow Oak (*Quercus acuminata* (Michx.) Sarg.) found in the Missouri forests, has barely reached Nebraska (56) in Richardson County.

Low Yellow Oak (*Quercus prinoides* Willd.) of the Missouri forests has barely reached southeastern Nebraska (57) in Richardson County.

Red Oak (*Quercus rubra* L.) is common in the Missouri forests, from which it has been carried northward along the Missouri River to Dixon County (58) and westward fifty or sixty miles.

Scarlet Oak (*Quercus coccinea* Muench.) occurs in the Missouri forests, and has entered the southeastern counties of Nebraska (59) from Richardson to Cass.

Black Oak (*Quercus velutina* Lam.) is found in the Missouri forests, from which it has moved northward along the eastern border of Nebraska (60) to the Platte River.

Black Jack Oak (*Quercus marilandica* Muench.) of the Missouri forests, has moved into the southeastern counties of Nebraska (61), Richardson to Pawnee and Nemaha.

Laurel Oak (*Quercus imbricaria* Michx.) is found in the Missouri forests, from which it has moved northwestward nearly or quite to the southeastern corner of Nebraska (62). Although this species has repeatedly been reported from this part of the state, I have seen no specimens which were collected within our borders. I have specimens collected in Missouri but a short distance from the southeastern extremity of Nebraska.

DISCUSSION

From the foregoing statistics it appears that of the seventeen trees whose fruits or seeds are winged thirteen came into Nebraska from the southeast and four from the west. Of the eleven species with hairy seeds six came from the southeast and five from the west. Of the twenty species with fleshy fruits sixteen came from the southeast, and four from the west. The single species whose seeds are in rolling balls came from the southeast, and all of the species with edible nuts (eighteen) came from the southeast. The significance of these facts is not at once very obvious. They do not directly indicate the relative value of the several devices for dissemination, nor do they plainly decide the question of the efficiency of winds, waters, birds, and quadrupeds as carrying agents. Thus the fact that thirteen trees with winged fruits or seeds came from the southeast, and only four from the west, does not indicate the greater efficiency of the south-east winds over those from the west. The fact that there is a much more compact forest area, containing a greater number of species of trees of this kind a short distance southeast of the state, is of far greater importance. The nearness of a vigorous vegetation representing many species makes that vegetation more efficient in invading a territory. The Missouri forests dominate the forests of Nebraska, because they are near by, and contain many species. This is shown more emphatically in the case of the species with edible nuts, all of which have come from the Missouri forests, where they are abundant. In Wyoming and northern Colorado there are no species of this kind in the sparse forests within a hundred miles of the western border of Nebraska. There are no oaks, hickories, walnuts, or buckeyes in this portion of the Rocky Mountain foothills to move eastward. On the other hand, there are species of trees having hairy seeds not only in the Missouri forests, but also in the canyons of Wyoming, and here we find that almost one-half of our trees of this kind came from the west. It is to be remarked, however, that while five of the six southeastern species have crossed the state, the five western species have moved eastward only a few miles from the Wyoming line.

Of the thirteen southeastern species with winged seeds or fruits three barely enter the state, one has advanced one-fourth of the way across the state; three, one-half; one, two-thirds, and five to or beyond the western border. Of the four western species, two have barely entered; one has advanced half way, and one, two-thirds of the way across the state.

Of the sixteen species with fleshy fruits, seven have barely entered the state; six have advanced half way across the state; one, three-fourths, and two to the western border and beyond. Of the four western species two have advanced about one-fourth of the way across the state; one, three-fourths, and one has reached the Missouri River.

Lastly if we examine the eighteen species with edible nuts, all of which have entered from the southeast, we find that fifteen have barely entered the state; one has advanced nearly one-fourth of the way across the state, one, two-thirds, and one, three-fourths.

Summarizing what we have found, by assigning a definite value to the distance covered by each species and taking the aggregate of these for all the species, we find that the average of those with winged seeds and fruits is fifty-three per cent of the whole distance; for those with hairy seeds, fifty-two per cent; with fleshy fruits, forty-five per cent; with edible nuts, sixteen per cent; and with rolling balls, ten per cent. We can thus express the efficiency of each device in these per cents, as follows:

Wings on seeds or fruits	53	per cent
Hairs on seeds	52	" "
Fleshy fruits	45	" "
Edible nuts	16	" "
Rolling balls	10	" "

That the migrating movement of the trees in Nebraska is still going on is attested by many observers, especially in the southeastern part of the state. The conditions under which such movement occurs are usually the following:— (1) Cessation of prairie fires, (2) protection from domestic animals, (3) a forest border in a moist valley. Under such conditions the forest bor-

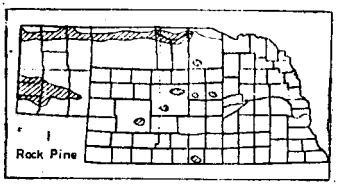
der becomes margined with tall-growing weeds which kill the tenacious prairie grasses, at the same time affording a lodgment for seeds of shrubs and trees. These grow, and gradually the shrubs and trees retain possession of the belt of ground, at first to the partial exclusion of the weeds, and later to their total suppression. Still later the trees overtop the shrubs, and eventually the latter may be suppressed also. While this is happening, a new weed belt is forming in advance of the belt of shrubs and young trees, and thus the forest margin is continually advanced.

There are many such advancing forest borders in Nebraska. In fact wherever the fires and domestic animals are kept out such an advance is commonly taking place. The rate of advance varies from a few feet a year to a hundred feet under favorable conditions, and in exceptional cases to several hundred feet. When it is remembered that an advance of but ten feet a year along a forest border a mile long adds a little more than an acre of woodland, even such a slow advance is seen to accomplish much. In this way in the course of a century the actual forest area may be greatly enlarged. While such a steady advance of the forest margins is now actually going on, there is another mode of distribution which is even more rapid. A seed is carried by a bird or other means to a considerable distance from the body of trees of its kind. It springs up in its new station and eventually produces seeds, and becomes a centre from which further distribution takes place. A case of this kind has been brought to my attention in the recent appearance of the Linden tree (*Tilia americana*) in the vicinity of Lincoln.

In the western part of Nebraska the present spreading of the Rock Pine (*Pinus scopulorum*) is quite noticeable. It is not uncommon to find young trees considerably in advance of the older trees of the sparse forest, around which are many small trees which have sprung up from the young parent trees.

MAPS SHOWING DISTRIBUTION OF NEBRASKA TREES

(Compiled from specimens and available data in the Herbarium of the Botanical Survey of Nebraska. The lines are drawn so as to show the general distribution of each species, it being impossible to show details on maps drawn to such a small scale. In some cases isolated stations have been connected where there is good reason for believing that the species extends from one to the other, while in others no such attempt has been made, although further investigation will probably show intermediate stations, if not an actual continuity.)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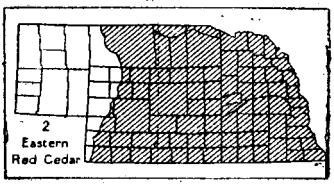
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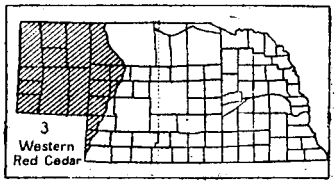
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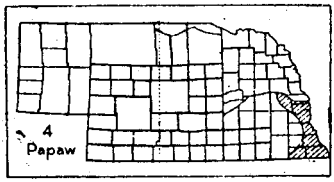
Red Cedar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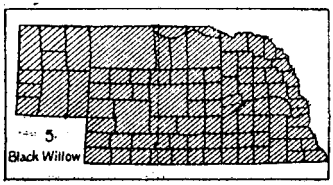
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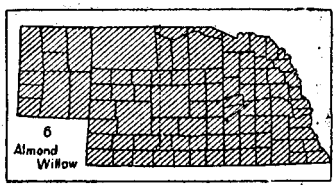
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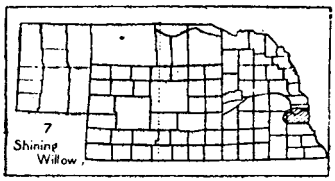
Willow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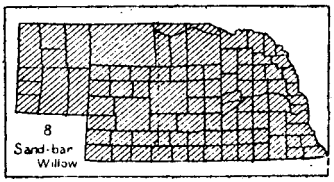
Shining
Willow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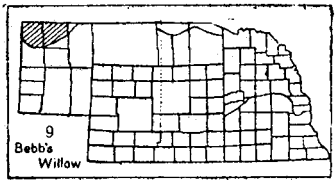
Sand-bar
Willow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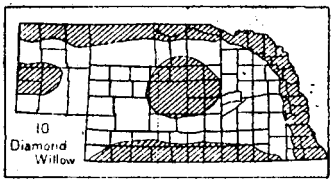
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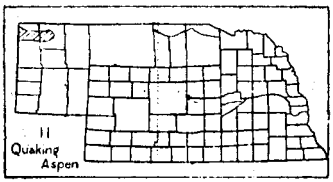
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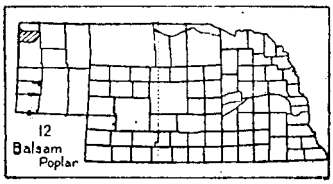
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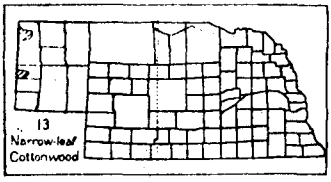
Poplar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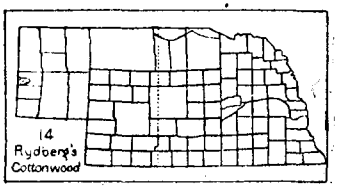
Narrow-leaf
Cottonwood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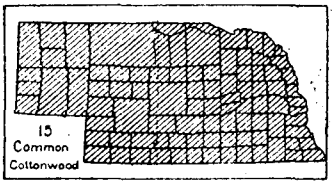
Cottonwood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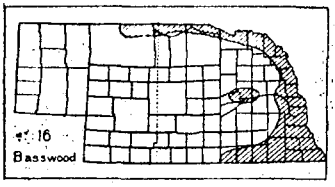
Cottonwood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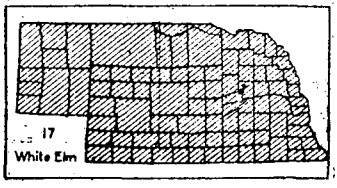
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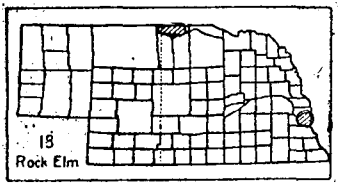
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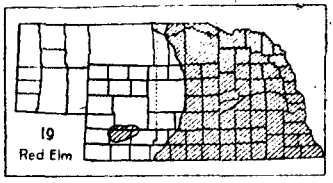
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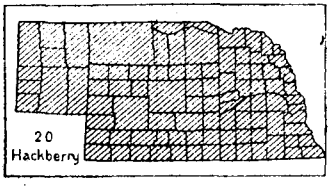
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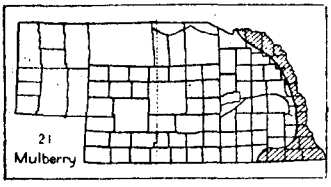
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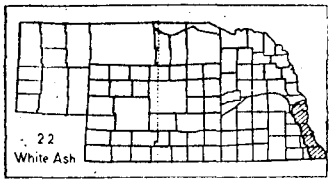
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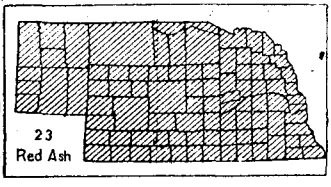
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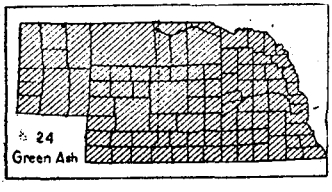
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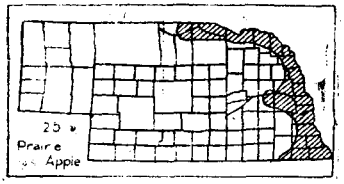
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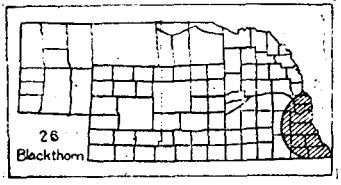
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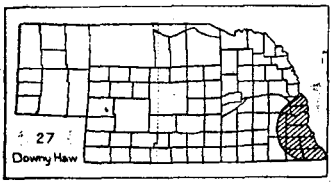
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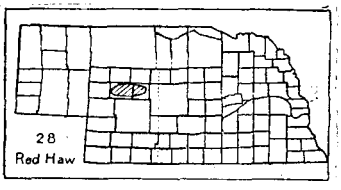
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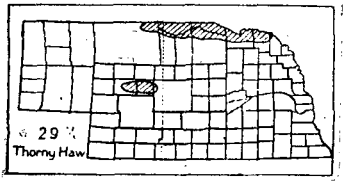
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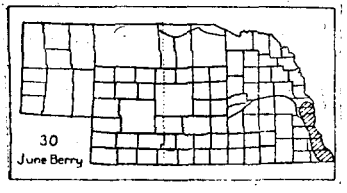
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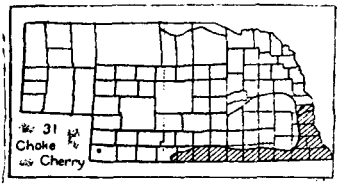
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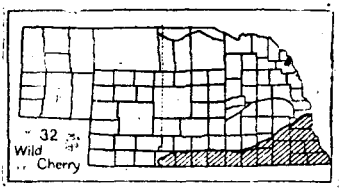
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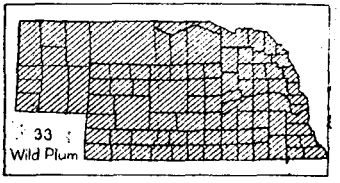
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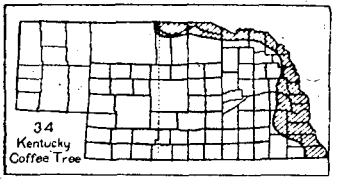
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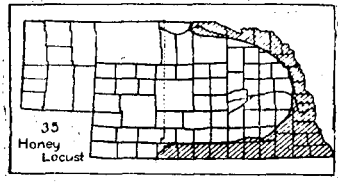
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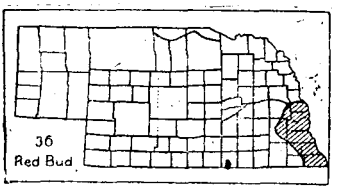
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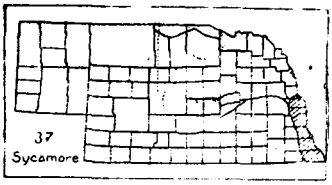
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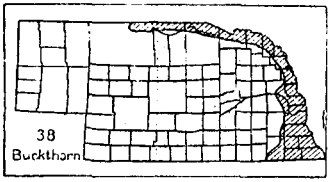
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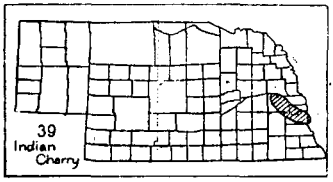
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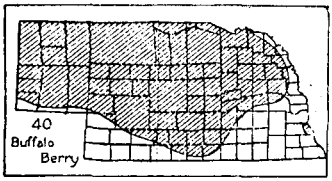
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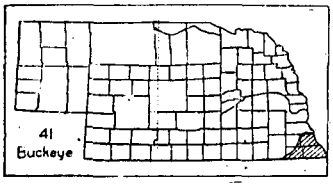
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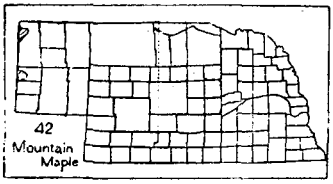
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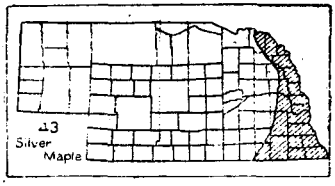
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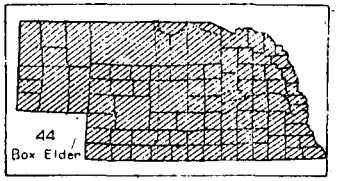
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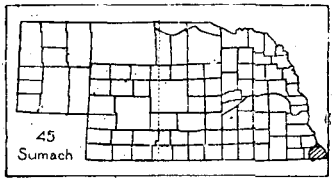
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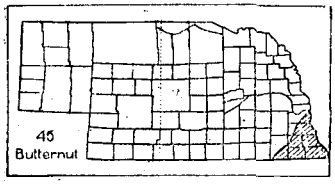
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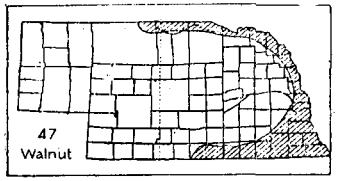
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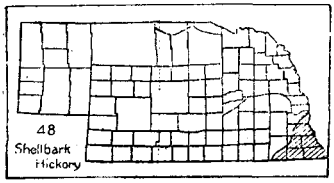
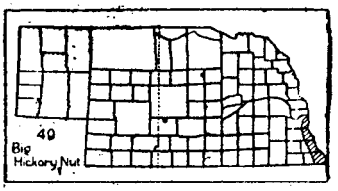
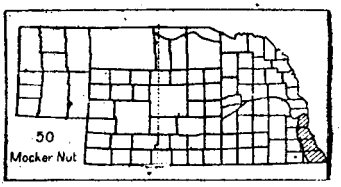
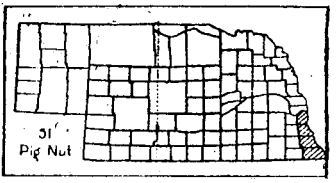
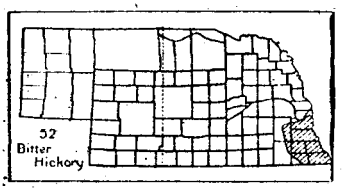
Walnut

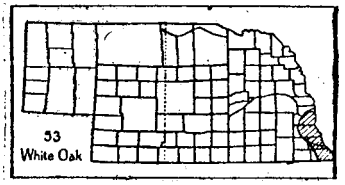

48
Shellbark
Hickory

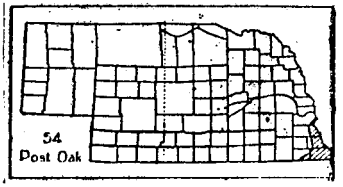

49
Big
Hickory Nut

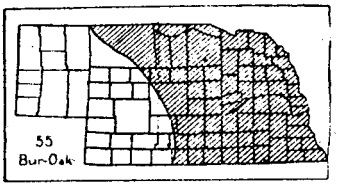

50
Mocker Nut

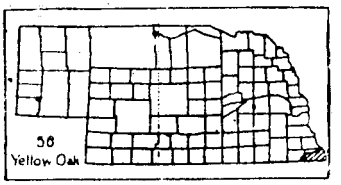

51
Pig Nut

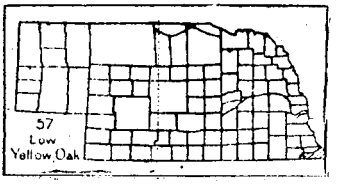

52
Bitter
Hickory

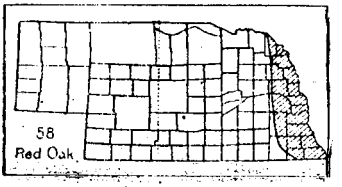

53
White Oak

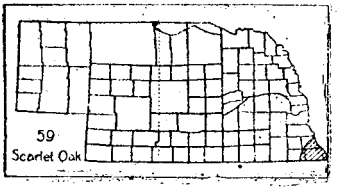

54
Post Oak

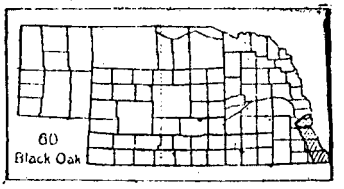

55
Bur-Oak

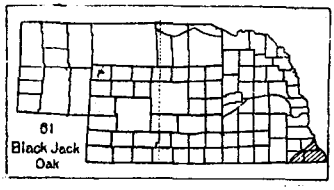

56
Yellow Oak

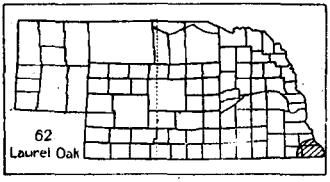

57
Low
Yellow Oak

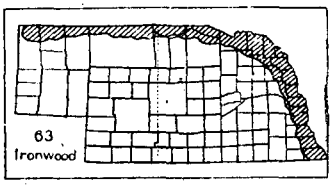

58
Red Oak

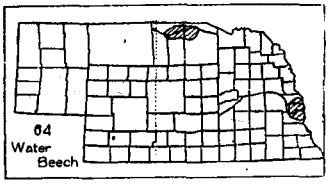

59
Scarlet Oak

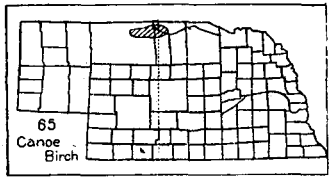

60
Black Oak

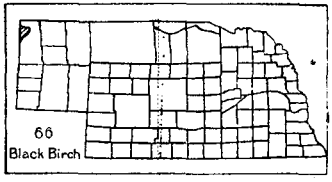

61
Black Jack
Oak

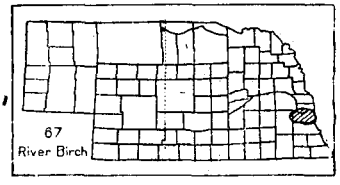

62
Laurel Oak


63
Ironwood


64
Water
Beech


65
Canoe
Birch


66
Black Birch


67
River Birch