United States Department of Agriculture

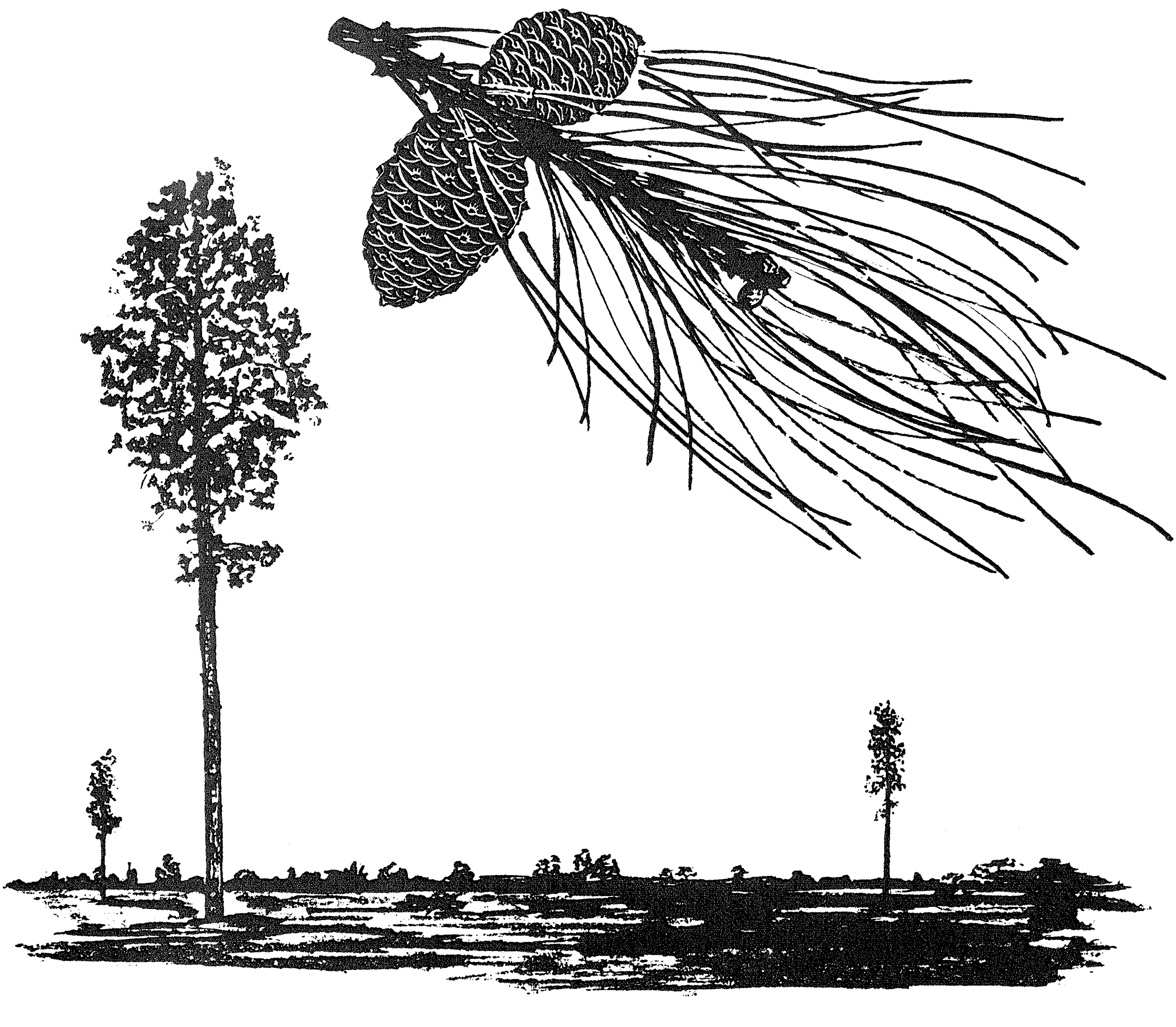
Forest Service

North Central Forest Experiment Station

General Technical Report **NC-129**

Fire Effects in Northeastern Forests: Red Pine

Cary Rouse



Preface

This is the fourth in a series of papers dealing with fire effects in northeastern forests. The 21-State region incorporates many diverse ecosystems--the northern hardwoods of New England, the boreal forests of Minnesota, the oak-hickory forests of Missouri, and fine hardwoods in the Central States. Although all forests have some aspects in common, each ecosystem responds somewhat differently to fire. Although we in the Northeast know less about our fire ecology than people in other regions know about theirs, a small body of information is scattered throughout the literature. The purpose of this series is to gather this information in one place and make it readily available to managers. Each paper in the series summarizes the literature, and readers can obtain detailed information on specific topics from the accompanying references. Other papers available in the series include: aspen, oak, and jack pine.

Acknowledgment

I would like to thank Fred McCauley for his excellent cover design.

North Central Forest Experiment Station
U.S. Department of Agriculture--Forest Service
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication December 15, 1988
1988

Fire Effects in Northeastern Forests: Red Pine

Cary Rouse

". . . almost every forest climax of North America displays a fire subclimax . . ." (19).

Fire is Important

Fire has played a major role in the forest ecosystems of North America. The place of fire in red pine (*Pinus resinosa*) regeneration has long been a subject for speculation and experimentation. Although researchers have recognized fire as important (39), much of the literature lacks the prefire vegetation, weather, and fire behavior documentation necessary to predict fire effects. Without such information, comparisons among and predictions of effects from fires become questionable at best. This report summarizes existing information about the effects of fire on the red pine forest type in eastern North America and suggests silvicultural uses of prescribed fire in red pine.

HISTORY

Fire Cycles and Strategies

In several studies in the North Central States and adjacent Canadian Provinces (14, 21, 34), researchers used historical records and/or dendrochronological data to determine fire frequency. They found that before European settlement, fires occurred at intervals ranging from 14 years (14) to 50 years (41). Heinselman (21) reported that frequent severe fires usually discourage red pine establishment and encourage jack pine. Because open-grown red pine does not normally bear cones until it is about 20 to 25 years old (17), at least one fire-free period of that duration is necessary to produce seeds for regeneration. On the other hand, jack pine can bear cones when 3 to 5 years old (13); although more typically jack pine produces them between 10 and 15 years of age. When heat opens these serotinous cones, seeds can be regularly distributed by frequent forest fires.

Mutch (29) hypothesized that plant communities in repeatedly burned areas evolve to become more flammable to maintain themselves. Fire-adapted plants have evolved three main responses to fire:

1. Mature stands die after fire. These species often produce dense, even-aged stands that promote severe fires. When a fire occurs, it may regenerate the stand. Jack pine is an example of such a species (32).
2. Stands resprout after fire. The ability of the plant to sprout after fire is a primary characteristic of these species. They can be perpetuated after a fire of almost any severity. Aspen is an example of a species with this response to fire.

CARY ROUSE, Research Forester, North Central Forest Experiment Station, East Lansing, MI.

3. Mature stands generally live after fire. These species have characteristics (e.g., insulating bark) that help them survive a fire. Red pine is an example.

Red Pine Response

Generally, red pine has developed thicker bark and grows taller than its associates such as white pine and spruce (17, 20). In addition, red pine seeds germinate best in close, if not direct, contact with mineral soil (2). Given such characteristics, it is likely that fire enhances the natural regeneration of red pine.

Before the Europeans arrived, fires probably burned until they met an obstacle (such as a river, lake, or change in cover type) or until weather conditions changed and made fuels less flammable. After settlement and logging, much more intense fires burned through logging slash, destroying the humus layer and leaving only mineral soil (5). Some fires were so destructive that sites originally occupied by red pine reverted to jack pine (16). Similarly, some sites previously occupied by white pine sometimes reverted to red pine (20).

FIRE EFFECTS

Factors

Several factors determine if fire injures or kills a tree. In red pine they include lethal temperature, season, bark characteristics, size and vigor of tree, and specific fire characteristics.

Lethal Temperature

Fire can injure or kill any living tissue, including the cambium and needles of a red pine tree. Researchers have shown that when living tissue reaches 147°F (64°C), it dies almost instantaneously (6). Although this temperature is a good general figure, the death of plant tissue is a function of both temperature **and** time.

Season

During the winter, most trees are generally less susceptible to injury because they are dormant (18). Dormant buds—the next year's growth—are well protected (42). In addition, because ambient air temperature is lower in the winter than at other times of the year, a more intense fire is necessary to raise a tree's internal temperature to the lethal point (6). In the natural range of red pine, snow usually negates the possibility of fires in the winter.

In spring, the litter layer is winter cured and dry; the duff fermentation and humus layers are moist. Wildfires spread quickly in red pine stands, yet they burn shallowly, causing little damage to the soil or roots. Vigorous re-sprouting normally follows these spring fires.

During the summer, the moisture content of herbaceous fuels is high, making wildfire occurrence unlikely. Soil moisture is normally high then as well. However, during periods of extended drying, the moisture content of the duff and humus layers decreases, and herbaceous fuels that are normally green become cured. Fires occurring during these periods burn deeply, cause severe root damage, and greatly reduce sprouting of shrubs and hardwoods.[1] Because brush is the worst enemy of red pine reproduction, fires that reduce understory "... can be of benefit to red pine" (16).

---

[1] *Personal communication from John W. Benzie, Project Leader, Forestry Sciences Laboratory, Grand Rapids, MN; June 10, 1987.*

Fall burns can be similar to both spring and summer burns. If there is adequate soil moisture, only surface fuels (newly fallen leaves and cured herbaceous material) are consumed. Root damage can be even less severe than during spring burns because the litter layer has often not been completely cured. If fall burns occur in conjunction with periods of extended drying, however, they can cause severe root damage.

Bark

Bark insulates and protects the tree's cambium. Although thermal conductivity of bark is an important factor in a tree's susceptibility to fire, bark thickness is equally important (and much easier to measure). Bark thickness in most species is related to age "... the older the tree, the thicker the bark, and consequently the more resistant the tree to fire" (6). Red pine is well known for its ability to produce thick bark and in old age is particularly resistant to fire (39).

Size and Vigor Play a Related Role

Until a red pine tree is 60 feet tall (roughly 50 years old), either the basal cambium or the crown can be killed. Once the tree reaches this height, however, the bark is thick enough to protect the cambium from all but the most extreme fires (39). Although tall trees are still susceptible to crown damage, they may survive even though 85 percent of their original crown was scorched (26, 40).

Large trees are able to survive intense fires more often than small trees (23, 37) because large trees have a larger area of cambium that can continue to function if a portion is killed. The potential longevity (100+ years) of red pine allows for the development of trees 2 or more feet in diameter (20).

Fire Characteristics

Fire characteristics differ among fires and even within a fire. Fire behavior depends upon several factors—most importantly, fuel characteristics and weather (13). Red pine stands contain flammable fuels in the form of deep, loose needle litter (39). The amount of litter produced is based on the site index and stand density. Red pine stands on better sites (S.I. 60+) produce more fine fuels than those on poorer sites, but production drops off and reaches an equilibrium soon after crown closure. Although litter is produced faster on better sites than on poorer ones, crown closure also occurs sooner on better sites, thus shortening the period when wildfires are likely to crown (7, 22). (Once the crowns close, lower branches die and a widening gap develops between the ground and the lower crown.)

Byram's (11) fire intensity model measures fire behavior in terms of heat released per unit time per unit length of fire line. Greater fire intensity means that more energy is directed at the tree, and the probability of injury increases. Fireline intensity is the product of energy contained in the fuel, fuel consumption, and rate of spread. The intensity of a flaming front can also be estimated from flame length. Methods (with or without instruments) to estimate both rate of spread and flame length in the field have been devised (4, 31, 35).

REPRODUCTION AND STAND ESTABLISHMENT

Red pine has far more exact requirements for establishment than jack pine. For example, red pine seed production is erratic; "bumper cone crops are produced only once every 10 or 12 years" (17). In addition, red pine cones are easily destroyed by crown fires, while jack pine's serotinous cones open and disperse seed after fire (1).

Requirements

Regeneration of red pine requires a combination of "... good seed production, seedbed preparation, and favorable precipitation during germination and seedling establishment" (3). Seed production, which is best in 50- to 150-year-old trees with good seed crops every 3 to 7 years (17), is mainly outside our control. We certainly have no influence over future precipitation to make it favorable for germination and establishment. Therefore, the only control we have is over seedbed preparation.

Seedbed Preparation

Red pine seeds require close contact with mineral soil to germinate. After establishment, red pine does not grow rapidly at first. It is relatively intolerant and will not survive in a pre-existing stand (30). Ahlgren (1) found that red pine needs about 3 postfire years of freedom from competing vegetation to dominate a site.

Fire can create relatively bare ground and eliminate competition. For example, in Ontario, areas that had undergone prescribed burns produced many more red pine seedlings than did unburned areas (38). In addition,

- sufficient duff was removed when its moisture content was about 60 percent or less (meaning burning must be done in summer);
- undesirable hardwoods were controlled by two consecutive annual fires;
- good 10-year-growth of red pine seedlings occurred only without an overstory (seeds must come from adjacent stands, shelterwood, and/or artificial seeding);
- the higher the fire intensity, the better the site preparation and hence the pine regeneration (39).

ESTABLISHED STANDS

Young Stands Vulnerable

Fire can devastate young red pine stands. Young, densely planted stands have been called the "... most flammable pure stand(s) of any northeastern tree species ..." (39). This is due to the well-aerated litter layer under a young pine stand and the continuous crown structure, which is well suited to crown fire. Flaky bark also helps a fire jump into the crown.

Increase Growth

In some instances, prescribed burning may increase the growth of established red pine stands. In Connecticut, red pine on sandy soil grew in height and volume, although not in diameter, throughout 20 years of annual burning, but unburned stands did not. The increases were thought to be due to increased pH as well as available phosphorus and exchangeable calcium (25).

Control Pests

Where natural seeding is important in the Lake States, the red pine cone beetle can be reduced with low intensity fires carried out between October 22 and May 10 (28). Judicious use of fire might also limit other pests. For instance, hare and mice could be deterred by eliminating understory cover. Burning might also curtail sweetfern on sites where this alternate host for the spittlebug is present. Although duff could be reduced to lessen the impact of the pine root collar weevil, this might require fire behavior destructive to red pine.

Control Vegetation

Fire can control undesirable understory species such as balsam fir. In Ontario, Methven and Murray (27) used fires of low intensity to kill balsam fir saplings, which were easily girdled by "gentle" surface fires. However, more than one such burn may be required to kill balsam fir understory.[1]

SUMMARY AND MANAGEMENT IMPLICATIONS

Fire in the Past

Red pine, because of its good growth characteristics, high productivity (24), and versatile wood (33), has been a favored species in the Lake States since the last century when Europeans found more than 7-million acres of these trees (33). The desire to regenerate today's red pine stands has stimulated an interest in how natural stands developed. Fire has been identified as a part of past natural red pine systems. Table 1 summarizes some findings about the use of fire in red pine stands.

Table 1.—Summary of fire use in red pine

Objectives	Location	Conditions	Fire behavior	Reference
Natural regeneration (duff removal)	Ontario	Moisture content of litter—60%	High intensity	(38)
Seedbed preparation (competition removal)	North Central States	Summer fires in slash soon after harvest (one or more fires)	Hot	(2)
Hardwood control	Ontario	Two consecutive summer burns	Gentle	(38)
Hardwood control (hazel)	Minnesota	Moisture content of humus—37-40%, summer fires	--	(8 and 9)
Balsam fir control	Ontario	Fire Weather Index 14-19[1]	Gentle	(27)
Understory fuel reduction (wild-life food increase)	North Central States	Periodic underburning	--	(2)
Red pine cone beetle reduction litter layer consumed or scorched no patch of ground to be unburned burning done while beetles on floor	Lake States	Burning Index[2] 11-41, Spread Index--8-31	Low intensities —back fire or strip head fire	(28)

[1] Fire Weather Index—a Canadian numerical rating of potential fire intensity (12). It is based on the effects of rainfall, relative humidity, windspeed, and temperature on fine fuels and duff.

[2] Burning Index and Spread Index are from the National Fire-Danger Rating System (15). The Burning Index is related to the amount of effort needed to contain a fire. The Spread Index is related to the forward rate of spread of a fire.

Regeneration

Van Wagner (39) suggests that fire should be reintroduced into natural red pine stands only in areas that will allow a maximum range of fire intensities. This would enable the fire(s) to remove duff, control hardwood brush, and remove overhead canopy in patches. These small areas would be prepared for regeneration, and in the interspersed patches, large red pine would have to remain as seed sources. On the other hand, Ahlgren (1) concludes that because human-induced change has taken place in most natural red pine stands, fire (prescribed or "natural") may be one of several alternatives for regenerating red pine.

Use of Fire

In summary, fire can have a place in red pine management. In addition to its previously described silvicultural role, fire can help maintain "parklike" stands (2). In areas valued for recreation, fire can make a stand more accessible as well as more visually pleasing. Also, frequent (5- to 10-year intervals), low intensity fires may kill aerial portions of any hardwood vegetation and thus promote low coppice growth, which would provide wildlife browse.

Obstacles

Although fire in red pine has many uses, it is not currently applied with any regularity. The limited number of days when fire weather is conducive to burning is a major physical obstacle to rapid expansion of prescribed burning in red pine (10). For example, during the spring in lower Michigan, fire weather appropriate for prescribed burning rarely lasts more than 1 day (36).

In addition to this physical limitation, there are also attitudinal obstacles, e.g., memories of recent and historical destructive fires such as the Mack Lake Fire in Michigan (36); organizational biases, e.g., managers trained to control fire rather than use it; and the widespread acceptance of other methods, e.g., chemical, mechanical, and silvicultural techniques (10). The large acreage of red pine plantations is a monument to these methods.

Prediction is Difficult

Research about fire's place and use in red pine has provided much information but no universal answers. Results of burning on one area are often not repeatable on another. As more site-specific information is collected, managers can gain confidence in prescribed burns, and burning will be viewed as an accepted management practice, especially for site preparation.

LITERATURE CITED

(1) Ahlgren, Clifford E. 1976. **Regeneration of red pine and white pine following wildfire and logging in northeastern Minnesota**. Journal of Forestry. 74(3): 135-140.

(2) Benzie, John W. 1977. **Manager's handbook for red pine in the North Central States**. Gen. Tech. Rep. NC-33. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 22 p.

(3) Benzie, John W.; McCumber, James E. 1983. **Red pine**. In: Burns, Russell M., comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture, Forest Service: 89-91.

(4) Blank, Richard W.; Simard, Albert J. 1983. **An electronic timer for measuring spread rates of wildland fires**. Res. Note NC-304. St. Paul, MN:

U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 4 p.

(5) Braun, E. Lucy. 1964. **Deciduous forests of eastern North America**. New York, NY: Hafner Publishing. 596 p.

(6) Brown, Arthur A.; Davis, Kenneth P. 1973. **Forest fire: control and use**. 2d ed. New York, NY: McGraw-Hill. 686 p.

(7) Brown, James K. 1963. **Crown weights in red pine plantations**. Res. Note LS-19. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 4 p.

(8) Buckman, R.E. 1962. **Two prescribed summer fires reduce abundance and vigor of hazel brush regrowth**. Tech. Note 620. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 2 p.

(9) Buckman, Robert E. 1964. **Effects of prescribed burning on hazel in Minnesota**. Ecology. 45(3): 626-629.

(10) Buckman, Robert E. 1965. **Silvicultural use of prescribed burning in the Lake States**. In: Proceedings, 1964 Society of American Foresters convention; 1964 October 24-28; Detroit, MI. Washington, DC: Society of American Foresters: 38-40.

(11) Byram, George M. 1959. **Combustion of forest fuels**. In: Davis, Kenneth P., ed. Forest fire: control and use. New York, NY: McGraw-Hill: 61-89.

(12) Canadian Forestry Service. 1984. **Tables for the Canadian Forest Fire Weather Index System**. For. Tech. Rep. 25. 4th ed. Ottawa, ON: Environment Canada, Canadian Forestry Service. 48 p.

(13) Cayford, J.H.; McRae, D.J. 1983. **The ecological role of fire in jack pine forests**. In: Wein, Ross W.; MacLean, David A., eds. The role of fire in northern circumpolar ecosystems. Scope 18. New York, NY: John Wiley and Sons: 183-199.

(14) Cwynar, Les C. 1977. **The recent fire history of Barron Township, Algonquin Park**. Canadian Journal of Botany. 55(11): 1524-1538.

(15) Deeming, John E.; Lancaster, James W.; Fosberg, Michael A.; Furman, R. William; Schroeder, Mark J. 1972. **The National Fire-Danger Rating System**. Res. Pap. RM-84. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 165 p.

(16) Eyre, Francis H.; Zehngraff, Paul J. 1948. **Red pine management in Minnesota**. Circ. 778. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 70 p.

(17) Fowells, H. A., comp. 1965. **Silvics of forest trees of the United States**. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture, Forest Service. 762 p.

(18) Greulach, Victor A. 1973. **Plant function and structure**. New York, NY: MacMillan Press. 575 p.

(19) Haig, Irvin T. 1938. **Fire in modern forest management**. Journal of Forestry. 36(10): 1045-1049.

(20) Harlow, William M.; Harrar, Ellwood S. 1969. **Textbook of dendrology**. New York, NY: McGraw-Hill. 512 p.

(21) Heinselman, Miron L. 1973. **Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota**. Journal of Quaternary Research. 3(3): 329-382.

(22) LaMois, Lloyd. 1958. **Fire fuels in red pine plantations**. Sta. Pap. 68. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 19 p.

(23) Little, S. 1946. **The effects of forest fires on the stand history of New Jersey's pine region**. For. Manage. Pap. 2. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 43 p.

(24) Lothner, David C.; Bradley, Dennis P. 1984. **A new look at red pine financial returns in the Lake States**. Res. Pap. NC-246. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 4 p.

(25) Lunt, Herbert A. 1951. **Liming and twenty years of litter raking and burning under red (and white) pine**. In: Proceedings, Soil Science Society of America conference, 1950; [dates and location unknown]. Madison, WI: Soil Science Society of America: 381-390.

(26) Methven, Ian R. 1971. **Prescribed fire, crown scorch and mortality: field and laboratory studies on red and white pine**. Inf. Rep. PS-X-31. Chalk River, ON: Canadian Forestry Service, Petawawa Forest Experiment Station. 10 p.

(27) Methven, Ian R.; Murray, W.G. 1974. **Using fire to eliminate understory balsam fir in pine management**. Forestry Chronicle. 50: 77-79.

(28) Miller, William E. 1978. **Use of prescribed burning in seed production areas to control red pine cone beetle**. Environmental Entomology. 7(5): 698-702.

(29) Mutch, Robert W. 1970. **Wildland fires and ecosystems—a hypothesis**. Ecology. 51(6): 1046-1051.

(30) Roberts, M.R.; Hruska, A.J. 1986. **Predicting diameter distributions: a test of the stationary Markov model**. Canadian Journal of Forest Research. 16: 130-135.

(31) Rothermel, Richard C.; Deeming, John. 1980. **Measuring and interpreting fire behavior for correlation with fire effects**. Gen. Tech. Rep. INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.

(32) Rundel, P.W. 1981. **Fire as an ecological factor**. In: Lange, O.L., *et al.*, eds. Physiological plant ecology. Vol. 12A. Responses to the physical environment. Berlin: Springer-Verlag: 501-538.

(33) Schone, J.R.; Bassett, J.R.; Montgomery, B.A.; Witter, J.A. 1984. **Red pine plantation management in the Lake States: a handbook**. Publ. 4. Ann Arbor, MI: The University of Michigan, School of Natural Resources, Michigan Intensive Forestry Systems Project. 43 p.

(34) Simard, Albert J.; Blank, Richard W. 1982. **Fire history of a Michigan jack pine forest**. Michigan Academician. 15(1): 59-71.

(35) Simard, Albert J.; Eenigenburg, James E.; Adams, Kenneth B.; Nilssen, Roger L., Jr.; Deacon, Arthur G. 1984. **A general procedure for sampling and analyzing wildland fire spread**. Forest Science. 30(1): 51-64.

(36) Simard, Albert J.; Haines, Donald A.; Blank, Richard W.; Frost, John S. 1983. **The Mack Lake Fire**. Gen. Tech. Rep. NC-83. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 36 p.

(37) Somes, H.A.; Moorhead, G.R. 1950. **Prescribed burning does not reduce yield from oak-pine stands of southern New Jersey**. Sta. Pap. 36. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 19 p.

(38) Van Wagner, C.E. 1963. **Prescribed burning experiments: red and white pine**. Publ. 1020. Ottawa, ON: Canadian Department of Forestry, Forestry Research Branch. 27 p.

(39) Van Wagner, C.E. 1970. **Fire and red pine**. In: Proceedings, 10th annual Tall Timbers fire ecology conference; 1970 August 20-21; Fredericton, New Brunswick. Tallahassee, FL: Tall Timbers Research Station: 211-219.

(40) Van Wagner, C.E. 1973. **Height of crown scorch in forest fires**. Canadian Journal of Forest Research. 3: 373-378.

(41) Van Wagner, C.E. 1978. **Age-class distribution and the forest fire cycle**. Canadian Journal of Forest Research. 8: 220-227.

(42) Wright, Henry A.; Bailey, Arthur W. 1982. **Fire ecology, United States and southern Canada**. New York, NY: John Wiley and Sons. 390 p.

Rouse, Cary.
1988. **Fire effects in northeastern forests: red pine**. Gen. Tech. Rep. NC-129. St.Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 9 p.

Fire and red pine are closely associated. Fires can provide red pine with the mineral soil and freedom from competition it needs to become well established. Fire can also be used to control pests, increase tree growth, enhance aesthetics, and improve wildlife habitat.

KEY WORDS: *Pinus resinosa*, ecology, fire management, silviculture.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1989—655-884/80123