Fire and Red Pine

C. E. VAN WAGNER

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IN 1935, D. K. Maissurow published an article in the Journal of Forestry entitled "Fire as a necessary factor in the perpetuation of white pine." After an examination of both virgin and cutover pine stands, he concluded that white pine did not usually succeed itself as a fully stocked forest except with the help of fire, either in the natural forest or after logging. It is safe to say that red pine, even more than white pine, depends on fire for its existence in any quantity in the natural forest. Such a general statement, however, immediately prompts many questions about the precise nature of the reaction between red pine and fire, such as:

1) What specific properties of red pine make fire necessary for regeneration?
2) How liable are red pine stands to fire?
3) How are red pine trees affected by fire?
4) Exactly what kind of fire is best for perpetuating red pine in the natural forest?
5) And finally, what kind of prescribed fire would be most useful in managing red pine?

To begin, a few introductory remarks about the species. Red pine (*Pinus resinosa* Ait.) is a noble tree, second only to white pine in size among the common members of the northeastern North American forest. Its range is rather limited, lying only between 51 and 43 degrees of latitude in a 500-mile band that extends from Minnesota and Manitoba to the Atlantic coast. This area just about matches the overlap between jack pine (which extends farther north) and white pine (which extends farther south), so that the three species are to some extent in competition. They may all be found sometimes in the same stand, but normally jack pine keeps to itself while red and white pine often grow together. All variations of this mixture from pure white pine to pure red pine occur, but pure white pine is more common than pure red pine. The red pine timber resource in Canada is, in fact, only one-quarter that of white pine (Horton and Bedell, 1960). Red pine may grow 150 ft tall and 5 ft in diameter, but more common limits are 110 ft and 3 ft.

The literature contains few specific references to red pine and fire. These are used where possible, but the paper is based mainly on the accepted silvical knowledge about red pine (Horton and Bedell, 1960), and on the results of forest fire research at the Petawawa Forest Experiment Station. The value of a quantitative measure of forest fire was obvious early in this work, not only for correlation with various fire effects, but also to match weather conditions with the behaviour of the fire. (The same probably applies to most investigations of the ecology and use of fire.) The measure adopted was the energy output rate per unit length of fire front in Btu/sec-ft, first described by Byram (1959), and also discussed by Van Wagner (1965).

First, consider the properties of red pine that render it dependent on fire. These have almost solely to do with establishment and early growth. Red pine needs either a mineral seedbed or one lightly covered with duff, as well as fair freedom from brushy competition in the first few years. It is also rather intolerant of shade and does poorly under a full canopy. Fire is the only natural agent capable of providing all the required conditions. Generally speaking, the more intense the fire, the better the job of ground preparation.

It further appears that red pine differs from pines of the southeastern U. S. where frequent periodic fire is required to prevent excessive fuel accumulation and catastrophic fires. In red and white pine stands the available litter fuel stabilizes after several years and does not drape the brush. The understory usually decreases fire hazard rather than contributes to it. Furthermore, fires of more than moderate intensity during the first 50 years would likely destroy the whole stand. Only during the last few years before the regenerating fire would one or two light fires be of value in controlling brush, but this kind of timing is hardly to be counted on. It is probable that red pine's dependency on fire is usually satisfied by just one fire of the right sort per rotation.

Second, consider the proneness of red pine to fire. There is little doubt that red pine produces the most flammable pure stand of any northeastern tree species when growing at high density with a clean floor. The reasons are a well-aerated needle litter that resists compaction for the entire snow-free period, and a crown structure ideally suited to the propagation of crown fire. In Canada, however, most red pine occurs in combination with white pine or the intolerant hardwoods, and flammability is somewhat reduced. Also, on the moister sites a considerable brush or fir understory is usually present. Pure jack pine stands, therefore, are usually more flammable than mixed red and white pine stands.

Our experience with experimental fires in mature red and white pine stands (Van Wagner 1965), and young red pine plantations (Van Wagner 1968) suggests that pine stands maintain maximum flammability up to heights of about 60 feet, and thereafter the possibility of crown fire is lessened by the increasing height of the open trunk space. Crown fire in mature red and white pine stands is thus a rare occurrence. In 50-foot-high red pine plantations, however, we have observed small crown fires with energy outputs up to 6500 Btu/sec-ft, a level of intensity that is seldom exceeded in the natural northeastern forest. Such fires, in fact, must be rare in red pine country, since the species cannot survive them at any age. It follows further that red pine is seldom found as a dense, young, plantation-like stand; in this condition it is too flammable to guarantee the long-term survival of the species.

Third, consider the direct effect of fire on red pine trees. There are three organs of interest: bark, crown, and seed. The bark of pines as a class is certainly more impervious to fire than that of other species at equal age, such as spruce, fir, aspen, maple, and birch. Also red pine is judged by some authorities to have a more resistant bark than white pine. This advantage, however, is mainly confined to old age since young red pine bark is still too thin to stand more than gentle surface fires, and its tendency to flake promotes flaming far up the stem. Large tree boles can withstand fairly intense surface fires, but are often found scarred on the downwind side where flames are concentrated.

The usual limitation to the survival of red pine in a surface fire is probably its susceptibility to crown scorch by hot gas rising above the flames. Red pine needles may be harder to kill than those of other pines or spruce because of their larger diameter, but the difference is marginal. Although air temperature and wind have some effect, the height to which foliage is scorched is primarily a function of fire intensity. Thus, gentle surface fires of less than 200 Btu/sec-ft will leave mature red pine crowns untouched. However, a surface fire of, say, 1000 Btu/sec-ft will kill any red pine stand just as surely as a crown fire ten times as intense. An intensity of 500 Btu/sec-ft is probably on the edge of the dangerous range for the largest red pines. Excessive crown scorch kills quickly; cambial damage, on the other hand, is much slower in taking effect. A girdled pine may live for 3 or 4 years, and fire scars may not be fully open and obvious until more than 10 years later. Observations on fire-damaged red and white pine at Petawawa suggest that if more than 75 percent of its crown foliage is killed, a tree will die. However, no large pines have been seen to die of cambial damage alone. This suggests that a surface fire will scorch the crown of a large red pine before it will girdle the cambium, and that crown scorch is the limiting factor in survival.

The seed in red pine cones matures in the autumn and most is shed soon afterward. Although seed inside a cone may survive a surface fire while foliage is killed, it is most unlikely that any seed would complete its development in a crown killed by fire during spring and summer. A fire that killed the crown foliage just as the seed matured would be a rare occurrence indeed, and not to be counted on for the survival of the species. To be sure of seeding after fire, then, a red pine tree must remain alive.

What, then, are the ideal circumstances for the establishment of a red pine stand by fire? The required effects are easily stated, at least qualitatively:

1) removal of duff to provide a seedbed,
2) control of brush to reduce low-level competition, and

3) killing of overstory to provide light.

A paradox is at once apparent, since the fire intense enough to do all these things well is also likely to kill the red pine seed trees. The ideal situation probably comprises the following conditions:

1) a sparse but adequate stocking of mature red pines,
2) other stand components more easily killed by fire than red pine,
3) a good red pine seed year,
4) a considerable period of dry weather,
5) a summer surface fire of intensity 200 to 500 Btu/sec-ft,
6) satisfactory post-fire weather for germination and early growth, and
7) freedom from further fire for several decades.

This constitutes a fairly demanding order, and a good many variations on it are possible. For example, small burned areas might be regenerated from an outside seed source. Note also that in order to burn a large area a fire must be fairly intense and fast-spreading. The most desirable large fire is, therefore, one in which the fire behaviour varies considerably on a small scale. In this way some red pines can be left alive near areas suitably opened and prepared by higher intensity fire. Thus, as Spurr (1954) observes, one can often find some of the old parent trees still standing in or near a stand of younger red pine. These constitute insurance against loss of the new stand before it is capable of withstanding fire and producing seed. It is, in fact, by overlapping its generations that red pine preserves its hold on an area; the greater the overlap, the more secure the hold. For example, Spurr shows a cross-section of one 220-year-old red pine that was scarred six times during its life. It is worth noting that the first time was not until about age 50, and that even then none of the fires could have been more than several hundred Btu/sec-ft in intensity near the tree; otherwise the tree would not have been spared.

All these considerations lead to the further conclusion that, in the long run, red pine is most likely to do well in rough topography or lake country that favours small-scale variation in fire intensity and consequent overlapping of generations. In flat featureless country, red pine is safest in open stands without sufficient fuel for fires of lethal intensity.

Logging has certainly had a pronounced effect on the fate of red pine. The Ottawa Valley was logged 70 to 100 years ago, and large mixed stands of red and white pine of that age now exist. The old loggers, it is fairly well known, did not remove all trees, but left many that did not meet their high standards or were hard to get at. The fires that inevitably followed early logging were of just the right intensity to prepare the ground, and good stocking of second growth pine was the result. It is even probable that red pine stocking is higher in this new forest than in the original one. A substantial portion of this second growth pine forest was destroyed by fire during the early decades of the twentieth century. Being too young to survive fire or bear seed, and having by then lost the original parent trees, it was followed by stands of intolerant hardwoods and brush.

Modern logging is somewhat different. Log standards are lower, and no seed trees are likely to escape unless deliberately spared. Then, whether fire follows or not, little or no natural red pine reproduction can be expected.

The picture of red pine that emerges from the foregoing considerations is of a species that depends heavily on fire because of its silvics but has evolved very little in any way that takes positive advantage of fire. The physical features that distinguish red pine from most other tree species with respect to fire are the flammability of its stands, and its relatively resistant bark. And yet the very flammability that invites the necessary fire also works against red pine, since it is very liable to total destruction before the age (about 50) at which it produces appreciable seed and has a fairly protective bark.

A point that deserves special mention is red pine's weak seeding habit. Good seed crops occur only about every 5 years, with bumper crops only about every 10. This means that most fires suitable for red pine establishment occur during years of light seedfall and, since fire-prepared seedbeds deteriorate quickly from year to year, are likely to result in low red pine stocking. In contrast, most other tree species in direct competition with red pine have more successful means of reproduction. Jack pine matures much earlier and has developed a remarkable feature, cone serotiny, which enables it to store several years of protected seed available at any time should a fire occur. Although fire normally destroys a jack pine stand completely, viable seed is shed in abundance. White pine, like red pine, is also dependent on fire to maintain extensive stands, especially on the better sites, and has no special positive adaptation to help it. However, white pine is a more frequent seed-producer and is much more capable than red pine of establishing and maintaining an advance growth in the undisturbed stand. (Logan's (1966) comparison of the light requirements of the three northeastern pines shows clearly why white pine can flourish under a canopy but red pine cannot.) These same properties allow white pine to seed in successfully after a somewhat gentler fire than is necessary for red pine.

Among other tree species, the principal competitors for control of a burned area are the intolerant hardwoods, aspen and white birch. Both are prolific annual seeders with a much longer range than the pines; in the main, however, they depend on very successful means of vegetative reproduction. Since they are fast-growing but short-lived, it is only by outlasting them that red pine (with or without white pine) can take over a site on which they are well established. A high fire intensity is required to control aspen and birch well enough to give red pine seedlings a fair start.

Such dependence on fire in the natural state suggests at once some use of fire in the management of red pine. The three basic requirements are:

1) to remove a good proportion of the duff layer,
2) to control hardwood brush, and
3) to remove a good proportion of the overhead canopy.

The first two can be accomplished by fire, the third by cutting. To be useful, of course, the effects of fire must be predictable to within a reasonable degree. Field experiments to measure the effects of fire in 90-year-old red pine stands were started 10 years ago in two places, near Grand Rapids, Minnesota, and at Petawawa, Ontario. Published results of the Minnesota study, begun by R. E. Buckman in 1960, have described the effects of repeated fire on duff removal, hazel sprouting and aspen suckering (Buckman 1962 and 1964, Buckman and Blankenship 1965). Up to 1964, no natural regeneration was possible owing to failure of seed crops; whether this step has been accomplished since then I have not heard.

At Petawawa, there have been several related series of prescribed burns in red and white pine stands, about 20 fires in all. Only the first series has been reported (Van Wagner 1965). The principal findings have been, in brief:

1) Sufficient duff was removed only when the moisture content of the duff layer was about 60% or less.
2) Good control of hardwood brush was achieved by two consecutive annual fires, but one fire at very low duff moisture did a passable job. Balsam fir understory, also a common undesirable competitor, is readily killed by one gentle fire.
3) Good 10-year survival and growth of red pine seedlings occurred in the open but not under a canopy.
4) Pines with more than 75 percent of crown killed by heat died within 1 year, but no large pines have apparently been killed by basal cambial damage alone.
5) The higher the fire intensity, the better the ground preparation and subsequent pine regeneration.
6) An intensity of about 200 Btu/sec-ft is the approximate upper limit if crown scorch is to be avoided in 70 to 80 foot pines.

These results are by no means definitive, and the research is being continued. Also, there are several practical considerations not yet settled. For example, when should partial cutting take place, before or after fire? If two fires are planned, how should they be fitted into the schedule? Is it reasonable to depend on the natural seed source, or would artificial seeding or planting be safer and cheaper in the long run? It is also necessary to consider whether a mixed stand of red and white pine should be deliberately managed for red pine at all, since white pine has a more dependable seeding habit, and can survive and grow in less light. In other words, the choice of year and weather conditions for prescribed fire are less critical for white pine than for red.

In view of its rather difficult requirements for regeneration, it may well be that natural red pine is, in the evolutionary sense, slowly on the way out. Fowler and Lester (1970) quote several authors of the opinion that red pine is a declining species that is slowly failing as the climate within its range becomes cooler with less frequent fires.

Perhaps, in future, the main source of red pine will be the plantations, whose area is increasing rapidly. In these the natural flammability of red pine is at its absolute peak, and the possibility of total destruction is always present. Even in a negative sense, then, the connection between red pine and fire remains very close indeed.

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