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Aspen Ecology and Harvesting Responses Panel II.

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Panel II.

Aspen Ecology And Harvesting Responses

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Type Variability And Succession In Rocky Mountain Aspen[1]

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Abstract.--Most of the 6 million acres of aspen lands in the West occur in the Central Rocky Mountains. The ability of western aspen to occupy a wide variety of sites, the great genetic diversity among clones, and the role of aspen as both a dominant successional and stable species severely complicate management. Such ecological and genetic diversity results in considerable variability in both resource production and potential response to management. Progress in classifying the ecological variability of aspen lands is slow; useful partitioning of genetic diversity is nil.

INTRODUCTION

Quaking aspen (*Populus tremuloides* Michx.) occupies a unique position as a dominant forest tree. It is the most widely distributed tree in North America; the aspen type is recognized for its multiple values of wood, livestock forage, wildlife habitat, and esthetics; yet in the West it has received very little management or research attention. Lack of interest in the past probably stems from the weak demand for aspen wood products, which is certain to change with time. Demands for all of the multiple products obtainable from our aspen lands will undoubtedly increase. Already our resource managers are facing the problems created by the broad range of environmental conditions where the type occurs and by the genetic diversity of aspen itself, both of which severely complicate development of reliable management practices.

DISTRIBUTION

Aspen extends across the North American continent from Labrador to Alaska, and as far south as Mexico (Little 1971). It occupies approximately 6 million acres (2.5 million ha) of the western United States. The most extensive stands in the West are found in the Central Rocky Mountains. Colorado and Utah alone contain over 4 million acres (Jones and Markstrom 1973). Although widely distributed elsewhere in the West, in these areas aspen is usually confined to small, isolated stands or rather narrow, transitional zones between conifer forests and grasslands.

Aspen grows under a wide variety of environmental conditions. However, its range in the Rocky Mountains appears to be related to cool, relatively dry summers and winters with abundant snow. Summer temperatures above 90° F (32° C) are rare, while winter temperatures below 0° F (-18° C) are common. Annual precipitation ranges from about 16 inches (40 cm) to over 40 inches (100 cm), mostly in the form of a deep winter snowpack which, upon melting, recharges the soil with moisture sufficient to meet most of the water requirements of aspen during its period of active growth.

Aspen grows at elevations ranging from less than 3,000 feet (923 m) in northerly latitudes to over 10,000 feet (3,077 m) in the more southerly latitudes. In Colorado and Utah, aspen commonly occurs in an elevational belt between about 6,500 feet (2,000 m) and 10,500 feet (3,230 m). Aspen is found on a wide variety of soils ranging from rocky talus slopes to deep, heavy clays. The better stands, however, are usually found on deep, loamy soils.

GENETIC VARIABILITY

Aspen in the Central Rocky Mountains is recognized as a probable climatic race distinct

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from that extending across Canada and into the Lake States. The Rocky Mountain aspen is designated by the varietal name *Populus tremuloides* var. *aurea*. Great and unclassified variability exists within variety *aurea*, which confuses attempts to develop precise management guides.

Anyone familiar with aspen soon becomes aware of the striking variability in growth form and in coloration of different clones. The almost exclusive vegetative mode of reproduction gives rise to genetically idential trees within a clone (Barnes 1966), which emphasizes the visual impact of phenotypic differences between clones.

Clones of eastern aspen vary markedly in stem form, branching habit, height and diameter growth, leaf morphology, leaf flushing, fall colors, leaf drop, and susceptibility to disease (Barnes 1969; Wall 1971). Similar phenotypic variability apparently exists in western aspen. Barnes (1975) sampled over 1,200 clones from Colorado to British Columbia, and by multivariate analysis of only leaf, bud, and twig characteristics demonstrated variation among 24 basic populations. He found a gradient in leaf characteristics from southern Utah to northern Idaho and Montana. Tew (1970) observed that the nutrient content of aspen foliage differed appreciably among clones of western aspen. For example, clonal differences in protein content ranged from 11.8 to 16.2 percent, suggesting considerable clonal variability in the value of aspen suckers for wildlife browse. It is very likely that growth rates, longevity, and other important but obscure physiological processes also differ markedly among clones. Such clonal variability might well affect the potential of different clones for producing wood products as well as the clone's response to harvesting and other management practices.

Unfortunately, progress in partitioning genetically similar strains within the Rocky Mountain variety of quaking aspen has been minimal.

SERAL VS. STABLE ASPEN

Aspen has generally been regarded as a fire-induced successional species able to dominate a site until replaced by less fire-enduring but more shade-tolerant and environmentally adapted conifers. The extensive stands of aspen throughout the Rocky Mountains are usually attributed to repeated wildfires. This is no doubt true for many of our aspen lands, as evidenced by aspen's relatively rapid replacement (within a single aspen generation) by conifers upon curtailment of fire. In areas of optimum aspen development in western Colorado and central Utah, however, conifer invasion can be so slow that well over 1,000 years of fire-free conditions may be required for aspen stands to progress to a conifer climax.

The uneven-age distribution of aspen trees in some stands suggests that under certain conditions aspen can be self-perpetuating without requiring a major rejuvenating disturbance such as fire or cutting. From a management standpoint, these relatively stable stands of aspen can be considered *de facto* climax. We expect them to remain dominated by aspen in the foreseeable future.

The successional status of aspen on a given area and the ability to recognize seral versus stable stands have considerable management significance. Obviously, we should be wary of planting conifers on stable aspen sites. Also, we must be alert to the need for removing conifers from seral aspen sites if we wish to maintain aspen dominance.

Even though we are reasonably certain that both stable and seral site conditions exist, progress in developing criteria that define environmental conditions indicative of seral and stable aspen communities has been minimal. Harper (personal communication) suggests that the rate of conifer succession might be predicted from knowledge of understory species. For example, on the Wasatch Plateau in Utah, Oregon grape and myrtle pachistima are indicative of areas subject to rapid invasion by conifers, but mountain snowberry and red elderberry indicate a relatively stable aspen community. Harper found that although seral aspen stands appear to be associated with sandstone soils on the Wasatch Plateau, they are associated with basaltic soils on the Aquarius Plateau and with granitic soils in the LaSal Mountains.

As yet, the most valid general indicator of a seral aspen situation appears to be the presence of conifers, which suggests active replacement of the aspen overstory by a more shade-tolerant tree. Mere presence of conifers, however, is not the infallible indicator of a seral condition that one might suppose. Occasional conifers can be found in a basically stable aspen community because of a highly unusual and temporary combination of circumstances favoring conifer establishment. In such cases, a stable aspen community might contain a few scattered, uneven-aged conifers but lack subsequent conifer reproduction. Presence of a multiaged conifer understory is generally reliable evidence of a seral aspen site.

In addition to replacement by conifers, aspen can also be replaced by shrublands or grasslands. Such replacement usually occurs on sites not suited for the establishment and growth of conifers and where aspen fails to regenerate. Regeneration can fail when apical dominance prevents suckering during gradual deterioration of the clones (Schier 1975). Where suckering does occur in a decadent clone, continued heavy browsing of sprouts by deer, elk, or livestock can prevent successful regeneration and cause conversion to shrublands or grasslands.

TYPE VARIABILITY

The ability of aspen to thrive under a wide range of environmental conditions contributes not only to the confusion in identifying stable and successional stands, but also is reflected in substantial variability in the ability of aspen-dominated sites to produce wildlife habitat, livestock forage, wood, and other needed resources. For example, aspen with a predominant understory of grasses is markedly different wildlife habitat than aspen with an understory dominated by shrubs. Livestock forage production in one range condition class in aspen can vary from 600 to 2,000 pounds of air-dry herbage per acre (672 to 2,242 kilo/ha) because of differences in site potential (Houston 1954). Wood production, measured as annual bole increment, can range from 42 to 194 cubic feet per acre (2.9 to 13.6 m^3/ha) because of site and genetic variability (Jones and Trujillo 1975). Theoretically, we should be able to identify meaningful environmental differences among sites and relate these to quantity and quality of resource production.

Attempts to classify aspen sites, as with most other forest and range types, have relied heavily upon using the vegetation as an integrator of the many factors constituting "environment." Such approaches categorize on the basis of species composition in stable, relatively undisturbed plant communities. Such classification efforts for aspen sites have been few and geographically narrow. The difficulty in developing a site potential classification for aspen is compounded by aspen's questionable status as a stable or seral tree on a given site.

Reed (1971) concluded that a single, stable aspen/snowberry type exists in the Wind River Mountains of Wyoming along with seral aspen communities that are succeeded by Douglas-fir, lodgepole pine, and limber pine at the higher elevations. Severson and Thilenius (1976) found both relatively stable and obviously seral aspen stands in the Black Hills and Bear Lodge Mountains of South Dakota and Wyoming which they classified into nine "aspen groups" according to similarity of vegetation and site. Judging from understory composition, Bunin (1975) determined that four stable aspen associations occupy the west slope of the Park Range in Colorado (1) aspen/Gambel oak - serviceberry - me rue, (2) aspen/sticky laurel, (3) aspen/ rue - aster, and (4) aspen/bracken fern parsnip. She also recognized a seral ty is rapidly succeeded by subalpine fir. Pfister (1972), while developing a subal forest classification for Utah, found ap stable aspen communities at lower elevat but concluded that aspen on upper elevat sites is usually a dominant seral specie will eventually progress to spruce-fir cl

Such studies as these have helped us understand the ecological variability of communities throughout the Rocky Mountain But this understanding is far from comple We have hardly begun to provide land mana with the guidelines necessary to reliably relate aspen site variability to the pote of these sites to produce important resou and to determine how these various sites respond to management. Development of su guidelines must be in two steps. First, must develop a realistic classification wh partitions the spectrum of variability in capabilities; then we must quantitatively late resource production and management to these classification units. Once these st are taken we will be able to offer precise management prescriptions for specific aspe sites.

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Physiological And Environmental Factors Controlling Vegetative Regeneration Of Aspen[1]

George A. Schier[2]

Abstract.--Formation of suckers on aspen roots is suppressed by auxin transported from the stem. Cutting or injuring the stem decreases the auxin-growth promoter ratio in roots enabling suckering to occur. Carbohydrate reserves supply the energy necessary for bud initiation and shoot outgrowth. Soil temperature is the most important environmental factor controlling suckering.

INTRODUCTION

Aspen (*Populus tremuloides* Michx.) occurs in clones of genetically identical individuals throughout its range (Barnes 1966). The clonal growth habit has resulted because aspen has the ability to regenerate vegetatively by adventitious shoots (suckers, or root sprouts) that originate irregularly on its roots. Under existing climatic conditions in the Rocky Mountains, aspen rarely reproduces from seed (Moss 1938). It has been able to remain a widespread and abundant species only because of its root suckering ability. Fire has played an important role in aspen ecology (Loope and Gruell 1973). Repeated occurrence of fire has enabled clones to increase in size because it resulted in the successive generation of shoots on a continually expanding root system.

Regeneration of aspen will be crucial in any program to manage the species. Because successful regeneration depends on our ability to stimulate sucker production, we should have some knowledge of the physiological and environmental factors controlling sucker formation.

ORIGIN OF SUCKERS

Suckers arise from the numerous ropelike lateral roots of aspen that occur near the soil surface. They do not originate from preexisting suppressed buds that arise during normal development of primary tissue in the roots as they do in the balsam and black poplars (Schier and Campbell 1976). Instead, they develop from meristems that appear to arise any time during root growth after the formation of the cork cambium. Meristem development probably occurs in response to a stimulus resulting from disturbances in the clone (Schier 1973b). These meristems may develop into buds and then elongate into shoots, but frequently they do not develop beyond the primordial stage. Later, in response to another stimulus, they may develop further. By peeling off the cork, one can usually see very small mounds, preexisting primordia, protruding from the cork cambium.

APICAL DOMINANCE

There is substantial evidence that the development of suckers on aspen roots is suppressed by auxin transported from growing shoot parts, a phenomenon known as apical dominance (Farmer 1962; Eliasson 1971b, 1971c; Schier 1973d, 1975; Steneker 1974). The transport of auxin to roots must be continuous if inhibiting levels of auxin are to be maintained because auxin is rapidly inactivated (Eliasson 1971c, 1972). Interference with the auxin supply by cutting, burning, girdling, or defoliation decreases auxin concentrations in roots. This enables suckers to be initiated or, if their

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growth was suppressed by auxin, to continue to grow.

After logging, the number of suckers on aspen roots is proportional to the number of stems removed; the greatest number of suckers arise after a complete clearcut. Not only does removal of all stems reduce apical control to a minimum, but it also enables this shade-intolerant species to grow in full sunlight where it makes its maximum growth.

Sucker formation does not require anything as drastic as logging or fire. This is evident from the occurrence of thousands of shoot primordia and numerous suckers in various stages of development on the roots of relatively undisturbed aspen clones (Schier 1973b). Subtle environmental changes may weaken apical dominance and trigger sucker formation. During normal seasonal tree growth, there may be periods when auxins are at low levels in roots. This is the case in early spring prior to bud burst when temperatures are high enough for the initiation of suckers. This is generally the only time when potted aspen will produce suckers. However, sucker initiation and growth of established suckers is inhibited after buds have flushed out and apical control has reasserted itself.

Apical dominance also plays an important role in limiting regeneration after an aspen clone is cut. Elongating suckers produce auxins (Eliasson 1971a) and translocation of these into the roots may subsequently increase auxin concentrations to levels that inhibit the initiation and development of additional suckers (Schier 1972).

GROWTH PROMOTERS

Adventitious shoot development in aspen roots is probably initiated by cytokinins, hormones that are synthesized in root tips (Peterson 1975; Skene 1975; Williams 1972). High cytokinin-auxin ratios favor shoot initiation while low ratios inhibit it (Winton 1968; Wolter 1968). Obviously then sucker production can be promoted by decreasing the concentrations of auxin or increasing the concentration of cytokinins. Both of these changes do in fact occur in the roots when a stem is cut because auxins can no longer move into them and cytokinins accumulate where they are synthesized. Less success is probably achieved in stimulating sucker production by girdling a stem than by cutting it because, although downward movement of auxin in the phloem is stopped, translocation of cytokinins into the stem via the xylem is not impeded. Consequently, cytokinins do not accumulate in the roots (Farmer 1962; Skene 1975).

Another growth regulator that appears to promote sucker production is a gibberellic acidlike compound (Schier 1973a; Schier and others 1974). It appears to stimulate shoot elongation after suckers have been initiated. Therefore, any interference with its biosynthesis could affect sucker production even if cytokinin concentrations are high.

CARBOHYDRATE RESERVES

After shoot initiation in aspen is triggered by a change in hormone balances, carbohydrate reserves supply the energy necessary for bud initiation and shoot outgrowth. The regions of the root that give rise to shoot primordia actually may be stimulated by heavy accumulations of starch (Thorpe and Murashige 1970). An elongating sucker remains dependent upon root reserves until it emerges at the soil surface and can carry on photosynthesis (Schier and Zasada 1973). The number of suckers arising on aspen roots generally is not limited by the concentration of stored carbohydrates. However, because sucker growth through the soil is sensitive to slight changes in carbohydrate concentration, the density of regeneration is related to the levels of reserves. Low supplies of carbohydrates might be expected to have a greater impact on deep-rooted clones than on shallow-rooted clones because the former would be required to expend a greater amount of energy to put a sucker at the soil surface.

Although aspen has a high capacity to regenerate itself vegetatively, there are limits to how much abuse it can take. Repeated destruction of new suckers by burning, cutting, herbicide spraying, or heavy grazing can exhaust carbohydrate reserves and cause a drastic reduction in sucker production (Baker 1918; Sampson 1919). Defoliation by insects can also cause root reserves to be depleted and to reduce the amount of aspen regeneration produced when a clone is cut.

ENVIRONMENTAL FACTORS

Soil temperature is one of the most important environmental factors affecting suckering by aspen (Maini and Horton 1966; Williams 1972; Zasada and Schier 1973). High soil temperature in exposed grasslands adjacent to aspen clones is thought to be the primary reason for aspen being able to invade these areas (Barley and Wroe 1974; Maini 1960; Williams 1972). The absence of aspen on cooler sites in interior Alaska is probably due to the inhibiting effect of low soil temperature on sucker regeneration (Zasada and Schier 1973).

A great deal has been made of evidence that increased soil temperatures resulting from insolation can cause suckers to arise from roots of uninjured aspen (Maini and Horton 1966). However, it has also been shown that an increase in soil temperature may not always be sufficient to override the effects of apical dominance, although the temperature increase will promote sucker growth after apical dominance is broken (Steneker 1974).

When suckers arise from roots of undisturbed clones as a result of high soil temperature, as in aspen invasion of grassland, temperature probably has modified the effects of apical dominance by its effect on cytokinin-auxin balances (Williams 1972). High temperature may lower the effective amount of auxin in the roots by causing its degradation. In contrast, cytokinin production by root meristems is increased (Williams 1972). The resulting high cytokinin-auxin ratio stimulates sucker production.

Light and soil moisture may also play an important role in aspen regeneration. Light is not essential for sucker initiation, but it is necessary for good sucker growth (Farmer 1963). Soil moisture may be critical when there is either too much or too little of it (Maini and Horton 1964). Aspen growing under conditions of severe drought or in soil saturated with moisture produces few suckers.

CLONAL VARIATION

Large clonal differences in the relative capacity of clones to produce suckers have been found when suckers are propagated from root cuttings under controlled environmental conditions (Farmer 1962; Maini 1967; Schier 1973d, 1974; Schier and Zasada 1973; Tew 1970; Zufa 1971). The magnitude of the differences among clones varies with the date of collection (Schier 1973d). The number of suckers produced by a clone is determined by the physiological and anatomical characteristics of the roots at the time of collection. Genotype probably has a large influence on these characteristics, but nongenetic factors such as clone history, stem age, clone age from seed, and site could also be major contributors. Sucker production from roots of different clones often responds differently to chemical treatments (Schier 1973a, 1973c) and to temperature treatments (Maini 1967; Zasada and Schier 1973). There is evidence that the natural variation in sucker initiation, development, and response to treatment may be due to clonal differences in concentration of endogenous growth regulators (Barry 1972; Schier 1973d), carbohydrate reserves (Schier and Johnston 1971; Tew 1970), and to differences in the developmental stages of the shoot primordia (Schier 1973a, 1973c).

The occurrence of clones with an uneven-aged stem structure indicates there are clones in which mortality is quickly replaced by new suckers (Alder 1970). There may be clones in which apical control is so weak or the concentration of growth-promoting factors so high that they sucker vigorously at the least disturbance.

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Diseases Of Western Aspen[1]

Thomas E. Hinds[2]

Abstract.--Decay fungi cause the greatest impact of all diseases affecting aspen's potential for utilization. Trunk cankers kill trees and cause unknown volume losses. Other diseases presently appear to play only a minor role.

Hardwoods, mainly aspen (Populus tremuloides Michx.) currently play a minor role in the timber resources of the Rocky Mountains. By the year 2,000, however, the Forest Service projects that hardwood sawtimber removals could be increased from the 1970 level of 13 million board feet to 232 million board feet providing substantial changes occur in hardwood values, plant capacity, and markets (U.S. Forest Service 1973). If these greatly increased volumes of aspen are to be available and utilized in the future, we will need considerably more information on the impact of diseases on aspen management.

Although many diseases attack aspen, relatively few cause loss in living trees. Of these, decay fungi cause the greatest loss in merchantable volume and are responsible for shortening the rotation age. Cankers not only kill the bark and distort the merchantable portions of the trunk, but also cause extensive mortality. The root pathogens not only cause extensive butt rot, but more importantly, predispose trees to windthrow. While leaf diseases may cause some growth loss, they seldom kill trees, and are not usually considered important.

The relative importance of the diseases of aspen found in the West differ from those found in the eastern United States and Canada. This discussion summarizes our present knowledge on some of the important disease problems concerned with management and utilization of aspen in the southern Rocky Mountains.

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DECAY

Losses Due to Decay

Baker (1925) was the first to stress the role of decays in aspen management in the West. He presented criterion for site quality, and gave gross cull estimates based on his studies in central Utah. Baker recommended a pathological rotation age of about 110 years on what he had defined as sites 1 and 2, the better aspen sites, to minimize decay losses.

The only quantitative study of aspen decay in the West was by Davidson et al. (1959) in Colorado. In the Colorado study, 53 percent of 976 trees sampled contained decay, which averaged 8.4 percent of the total cubic foot volume. Although there was little relationship between decay and site class for younger stands, the differences were marked in older stands. In 100-year-old stands, cubic foot decay averaged 4 percent on site 1, 8 percent on site 2, and 13 percent on site 3. The incidence of decay was considerably lower than that reported by Meinecke (1929) for aspen in one locality in northern Utah.

The merchantability of aspen on a board-foot basis was recently analyzed[3] by grouping the Colorado data (Davidson et al. 1959) for individual trees (minimum tree d.b.h. 8.0 inches) by 10-year age classes. Cull due to decay plotted as a function of these age classes for Baker's sites 1 and 2 (Baker 1925) showed an essentially linear relationship for the range of the data--40 to 170 years:

3/ Hinds, T. E., and E. M. Wengert. Growth and decay losses in Colorado aspen. Manuscript in preparation, Rocky Mountain Forest and Range Experiment Station.

Tree Age (years)	Percent board foot cull due to decay	
	Site 1 [4/]	Site 2 [5/]
60	6	7
80	13	16
100	21	25
120	28	34
140	36	44
160	44	53

[4/] Site 1 percent cull = -17 +.38 tree age, r = .93

[5/] Site 2 percent cull = -21 + .46 tree age, r = .96

The amount of cull for trees on site 3 averaged 65 percent between 70 and 150 years, but the variation was too large to obtain meaningful relationships.

It appears that sawtimber harvest of aspen on sites 1 and 2 should be optimum when stands are between 90 and 120 years of age. Defect should range between 17 and 34 percent. On poorer sites only marginal utilization of the stands can be expected. In essence, the Colorado and Utah studies dispel the idea that western aspen should be managed on a short rotation period (from about 30 years on poor sites to 50 or 60 years on good sites) similar to the Lake States aspen (Brinkman and Roe 1975).

Types of Decay

Trunk rot was responsible for two thirds of the aspen board foot cull in Colorado[3/]. Decay by Phellinus tremulae (=Fomes igniarius), commonly recognized as the principal cause of trunk rot cull in aspen, was found in 15 percent of the trees and was responsible for a third of the total cull. Many trees with extensive trunk rot have conspicuous conks (fruiting bodies) on the trunk. The estimated board foot cull for an individual tree with 1 to 3 conks at any height, or any number of conks 0 to 16 feet on the bole, is 59 + 3 percent. A tree with conks not in these two classes should be considered a total cull (Hinds 1963).

The second most important trunk rot fungus is Peniophora polygonia. Although its incidence of infection is greater than P. tremulae, it causes much less loss. The fungus does not fruit readily on infected trees, consequently there are no external indications that decay is present. Actual cull attributed to this rot is probably less than that scaled because the incipient stage does not fall out when sawn lengthwise, and is usually considered stained wood.

The remaining trunk rot fungi, with the exception of Libertella sp., cause only minor amounts of decay.

More species of fungi are associated with butt rots than trunk rots. Although butt rots were responsible for only a third of the decay volume in Colorado (Davidson et al. 1959), their true importance is unknown. If the volume losses attributable to windthrow due to root diseases were included (Ross 1976a), their impact would be much greater.

Collybia velutipes causes the greatest amount of butt cull (Davidson et al. 1959). The brown mottle rot often extends above 16 feet in older trees. Ganoderma applanatum (=Fomes applanatus) may be as important as C. velutipes because it not only causes a brown mottle butt rot, but also decays the large roots (Ross 1976b) and is a major cause of windthrow (Landis and Evans 1974). Fruiting bodies of the fungus found at the base of a tree indicate butt cull. They are found in almost all aspen stands. With the exception of Pholiota squarrosa, the other butt rot fungi apparently cause only minor amounts of decay (Ross 1976b).

CANKERS

Trunk cankers are the most obvious disease problem on aspen (Hinds and Krebill 1975). Many fungi infect trunk wounds and kill the living bark tissue, causing annual and perennial cankers. The perennial cankers are the most important for they gradually enlarge until they girdle and kill the tree. Although the slow-growing persistent infections may never girdle, the infected trunk becomes so deformed that it is useless for commercial purposes.

The only study to determine the distribution and abundance of the different aspen cankers in the Rocky Mountains was made in Colorado in 1960. Based on 31 plots (129 sub-plots) in 5 National Forests, canker incidence on live trees was: Cytospora, 4.3 percent; Cenangium, 2.4 percent;

Ceratocystis 4.1 percent; and Hypoxylon, 0.2 percent (Hinds 1964). Nine percent of the trees were dead but still standing. The proportion of the dead trees with cankers was: Cytospora, 54 percent; Cenangium, 51 percent; Ceratocystis, 9 percent; and Hypoxylon, 2 percent. The cankers, with the exception of Hypoxylon, were fairly well distributed throughout the Forests. Several types of trunk wounds were also noted.

Trunk wounds are the infection site for most aspen canker diseases. The relationship of trunk wounds to canker-caused mortality was brought out by Krebill (1972) in his study of aspen mortality on the Gros Ventre elk winter range. Aspen mortality in campgrounds is likewise related to camper-caused trunk wounds. Over 50 percent of the trunk wounds in an extensive campground study were infected, and 98 percent of the tree mortality was attributed to the various canker organisms (Hinds 1976).

The important canker diseases are discussed below.

Cenangium Canker

Sooty-bark canker, caused by Cenangium singulare, is one of the major causes of aspen mortality in the West. The fungus was associated with the canker in 1956 (Davidson and Cash 1956), and has since been found from British Columbia southward through the Rocky Mountains into New Mexico and Arizona (Andrews and Eslyn 1960). The fungus infects trunk wounds, penetrates the inner bark and cambium, and spreads rapidly. Cankers can extend to 40 inches in length in 1 year, and reach 12 feet long by 29 inches in width in 4 years (Hinds 1962). Trees of all sizes are killed, usually within 3-10 years. Sapwood stain is common behind the canker, but decay does not usually develop because the dead bark dries out fairly rapidly. A cankered live tree should not be considered a cull, even though the canker is extensive.

Ceratocystis Canker

Black canker is the common name given to this canker (Boyce 1948) described over half a century ago (Long 1918). The canker is characterized as "target-shaped" when young, but is ragged in appearance due to massive callus folds and flaring dead bark which is black when the infection is many years old. While it is probably the most common canker found in western aspen stands, tree mortality is not great (Hinds 1964). Ceratocystis fimbriata can attack through the epidermis of leaf blades, petioles, and young stems (Zalasky 1965) but trunk wounds are considered to be the primary courts of infection (Hinds 1972a) and insects the primary vectors (Hinds 1972b). The major impact of Ceratocystis canker is trunk deformity; it is not usually associated with decay.

Hypoxylon Canker

Hypoxylon canker of aspen, caused by Hypoxylon mammatum, causes serious mortality only in localized areas in the southern Rockies (Hinds 1964, Hinds and Jones 1965). It was first observed in the western United States in 1955 (Davidson and Hinds 1956) and has since been observed more frequently on individual trees in the more open aspen stands. While it is estimated that Hypoxylon canker kills 1-2 percent of the aspen volume annually in the Lake States region (Anderson 1964), its overall importance in western commercial stands is unknown.

It does not normally cause trunk rot or tree breakage in the West, where cankers may be 20+ years old before they girdle large aspens. Because the dead cankered tissue and underlying sapwood dry out fairly rapidly, a cankered tree should not be considered a cull.

Cytospora Canker

Cytospora chrysosperma causes bark necrosis, lesions, and cankers on trunks, large limbs, small branches, and twigs. The fungus is a normal inhabitant of the aspen bark microflora, and readily enters and parasitizes bark that has been injured or weakened (Christensen 1940). The disease is most serious on young suppressed trees, and trees that have been stressed by environmental or biological agents (Long 1918). Although Cytospora is often found associated with other cankers, it is not considered a primary parasite on healthy trees.

Cryptosphaeria Canker

Cryptosphaeria canker is a relative newcomer to the list of aspen cankers. Although the fungus Cryptosphaeria populina was collected on aspen in Colorado in 1897 by E. Bethel, it has only recently been associated with cankers. The elongated trunk cankers, common in many western aspen stands (Hinds 1976, Krebill 1972) are 3-20+ feet long but only 2-6 inches wide. They may spiral around the tree like a snake. Extensive trunk rot is associated with the canker, and trees with large cankers are frequently broken off by the wind. Based on canker symptoms alone, this canker probably has been misidentified as Cytospora canker in the past. The importance of this canker in causing tree mortality and its associated decay remains to be determined.

STAIN AND WETWOOD

Stain (discoloration) is very common in aspen. The discolorations include hues of black, brown, red, yellow, and green. Although decay and canker fungi are frequently associated with various stains, many other microorganisms are involved, some in a successional manner leading to decay (Shigo 1967). Stain normally affects lumber quality rather than quantity; cull deduction is not usually made when the stain is firm and light in color. (U.S. Forest Service 1964).

The amount of stain in western aspen is unknown, but it may be extensive in trees of saw log size. In an Ontario aspen decay study, the proportion of two types of stain increased from about 13 percent of the merchantable volume in stands 41 to 60 Years old to over 24 percent in stands over 120 years old (Basham 1958). The effect of stain on lumber degrade loss needs study.

"Wetwood," a water-soaked condition of wood in living trees, is likewise common in both sapwood and heartwood of aspen (Knutson 1973). Wetwood areas are usually slightly discolored on a cross section of the bole. While wetwood has been associated with wood borers, wounds, and frost cracks in western aspen (Davidson et al. 1959), it also occurs without obvious associations. High populations of bacteria and yeast are found in wetwood, but their role in wetwood formation is uncertain (Knutson 1973).

Lumber drying is perhaps the biggest problem associated with wetwood. The discoloration largely disappears upon drying, but the wood may collapse at the zone between heartwood and sapwood, split and crack, and not meet thickness requirements. Air-seasoning boards containing wetwood prior to kiln-drying reduces collapse losses at mills (Clausen et al. 1949). There are no data on losses attributed to wetwood during the milling process.

MISCELLANEOUS DISEASES

Leaf diseases may have local significance, but their damage is usually confined to reduced growth of severly affected trees. Small trees suffer the most damage, and are sometimes killed by repeated infections. Clonal susceptibility to individual foliage diseases is common, but under optimum conditions whole stands become infected.

The black leaf spot caused by Marssonia populi is probably the most common leaf disease on western aspen. Damage is sometimes widespread covering several hundreds of acres. It has been reported to cause twig and branch mortality, and dieback in the Intermountain Region (Mielke 1957). Annual infection usually repeats only in the lower crown, and the dieback report has not been substantiated.

Ink spot, caused by Ciborinia whetzelii (Baranyay and Hiratsuka 1967) periodically causes considerable early defoliation, particularly on small trees and the lower portion of larger trees.

The "shepherd's crook" disease, manifested by a blackened reflexed shoot with dead leaves, is caused by Venturia tremula (Dance 1959). While larger trees may be relatively unaffected, the current growth of suckers may be severely attacked, resulting in deformed stems. The disease can be severe on regeneration in clear cut areas. Leaf rusts occur sporadically throughout the region, with Melampsora medusa being the most common (Ziller 1965). The alternate hosts needed for the rust's life cycle include several conifers commonly associated with aspen. The primary effect of Melampsora, like Marssonia, is premature leaf drop in the fall. Damage in aspen stands is not considered serious.

Fungi are associated with two types of rough-bark common on the otherwise smooth aspen bark. The fungus Diplodia (Macrophoma) tumefaciens causes woody galls on branches and twigs and gray to black rough bark outgrowths which tend to encircle the bole (Zalasky 1964). Bark infected by Rhytidiella baranyayi tends to be more corky and lighter in appearance, with smaller affected areas frequently angular shaped on larger trees (Funk and Zalasky 1975). Both fungi may persist in the bark many years, but apparently do little harm to the tree.

FUTURE OUTLOOK

Because most aspen stands in the southern Rockies originated following fires within the last 150 years, we cannot expect to see much further expansion of the type. Today it is not unusual to find two age-class stands. Three-age and uneven-aged stands are also to be found. The differences between age classes must be recognized in assessing merchantability of aspen stands.

It is estimated that 29 percent of the commercial aspen forests in the National Forests of the southern Rockies contain sawtimber: trees over 11.0 inches d.b.h. (Green and Setzer 1974). In many of these older stands, decay cull can be expected to run over 20 percent.

Many of these stands are deteriorating and the sites are reverting to conifers. Unless the rate of harvest increases in these older stands, there is the danger of losing untold acres of the aspen type. These older stands on the better sites should be harvested soon so that the site can be retained by aspen and once again made productive.

Half of the commercial areas contain poletimber stands: trees 5.0-10.9 inches d.b.h (Green and Setzer 1974). It is this important size class which should be harvested in the next 2 or 3 decades while the net growth increment is still high. Tree age presently ranges up to 80 years on the better sites.

Although decay will continue to have a long-term impact on the harvest of aspen, the role of canker mortality should not be overlooked. Future studies may show that losses to leaf and root diseases are important under more intensive management.

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Aspen Harvesting And Reproduction[1]

John R. Jones[2]/

Abstract.--When aspen stands are clearcut, regeneration by root suckers is usually prompt and abundant and grows rapidly. Partial cutting results in an inferior replacement stand. Dense young stands thin themselves. Artificial thinning is not advised. Many old stands are too decayed to harvest, and constitute a major management problem. Additional overmature stands, uncut, continually move into the cull category.

INTRODUCTION

A major purpose in harvesting aspen is to perpetuate aspen forest for all of its resource values--esthetics, wildlife habitat, and watershed cover as well as for lumber and fiber. Timely and proper harvest is especially important with aspen because aspen does not store well on the stump. Old aspen trees usually become rotten, and old stands may be succeeded by conifers or possibly by sagebrush and bunchgrass (DeByle 1975). Besides harvesting, the other major means of rejuvenating aspen stands, a severe fire, is hard to get when you want it (Fechner and Barrows 1976). And severe fire may be undesirable in many cases, or even unacceptable, for assorted reasons.

To get healthy fully stocked aspen replacement stands that are esthetically pleasing and will produce good crops of timber requires more than just harvesting however. It requires correct harvesting.

Kim Harper and I are writing a book on the ecology and management of western aspen, with help from Norb DeByle and Gene Wengert. It is a detailed reference work. Here I will simply hit some key features of harvesting and reproduction.

SITES

Many aspen stands grow on sites that don't have the potential to produce economic crops of lumber or fiber. They may however produce usable crops of browse, autumn color, or fuelwood. The culture of aspen may be desirable on such sites, and the most economical means may be deficit sales for fuelwood or chips.

But in this talk I will consider only sites that can produce sawtimber at reasonable rotation ages. Decay makes long rotations highly questionable on most sites. A site that takes, say, 130 years to produce codominant trees 10 to 12 inches in diameter is seldom a commercial site for aspen because of decay. It may be someday, but not today or tomorrow.

Aspen stands on some sites may be heavily invaded by Engelmann spruce, subalpine fir, white fir or Douglas-fir in various combinations, or occasionally by other conifers. Where such a site produces good crops of aspen it may still be preferable to favor the coniferous understory in management and grow a coniferous forest on the site. But even very careful harvesting of the aspen will cause some gaps in the coniferous understory, and aspen root suckers will then result in at least a light mixture of aspen, occupying gaps. That is desirable. Should wildfire, wind, or beetles ravage the conifers later, the scattered aspen would reforest the site promptly with root suckers, once again to provide a favorable microsite for reestablishment of the conifers.

From here on I will talk about the harvesting of productive sites where aspen is to be retained as the cover type.

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HOW HEAVILY TO CUT

In general, researchers and experienced aspen managers in the Lake States, Canada, and the West favor or even insist on clearcutting aspen, to get regeneration stands with a minimum of gaps and the best possible growth (Weigle and Frothingham 1911; Sampson 1919; Baker 1925; Zehngraff 1947, 1949; Curtis 1948; Sandberg 1951; Perala 1972; Brinkman and Roe 1975).

On the other hand, Steneker (1972) stated that in central Canada, leaving culls was not detrimental to suckering if the culls "do not form a closed canopy." Larson (1959) reported that cutting only 45 percent of an Arizona stand provided full restocking, with sucker height at age 7 not much less than on an adjacent clearcut. That paper may have influenced thinking on how heavily aspen must be cut to get a good replacement stand in the West. However, the much more complete data in the office report do not agree with the publication. On the study block, in contrast to the operation as a whole, partial cutting had reduced stocking much more than 45 percent--actually to less than 15 ft^2 of basal area per acre. That approaches a clearcutting.

A nearby 50-year-old stand had been highgraded, leaving a basal area of 69 ft^2 per acre. Fifteen years later, whatever suckers may have resulted had disappeared (Martin 1965).

Aspen harvests on the San Juan National Forest have been partial cuts, often heavy. Culls and trees too small for the market were left. They were more or less numerous. Suckering often was heavy, but somewhat irregular. Sucker growth was even more irregular. Growth has been good in the open, for these are good sites. Where residual canopy trees were more numerous, the suckers did not grow well. The result is a stand of irregular structure and growth, distinctly inferior to the parent stands.

These young stands would be better, in many cases much better, if the unmerchantable older trees had been felled at the time of logging or right afterward. The felling of unmerchantable trees on new aspen cutovers has been a standard practice on National Forests in the Lake States for many years (Brinkman and Roe 1975).

As a rule of thumb, I suggest that if the residual unmerchantable stand will be as much as 10 ft^2 of basal area per acre, unmerchantable trees should be felled. That is a judgement figure.

Aspen advance regeneration is likely to be of inferior quality. If there are patches of it in the stand, they usually should be destroyed. They are good places to fell tops or rout skidders through.

Curtis (1948) cited a suggestion from Utah that about 60 percent of the stand volume be taken in a first cut, accelerating growth in the smaller canopy trees, which would be cut about 10 years later when they had grown larger. Something much like that was done in a Minnesota experiment. Variable suckering resulted from the partial cuttings. Sucker growth was inferior to that on an adjacent clearcut. The residual stands were completely removed 6 years later. The suckers resulting from the final cut were suppressed by the poor suckers from the first cut. The replacement stands were the inferior result of the first cut--poor stands on good sites.

A poor stand on a good site is not what we want. We have too many of those already.

SKIDDING

Heavy equipment running all over the place can be bad news. This is particularly obvious on sites where a stand of mixed conifers has been heavily cut and the slash bulldozed. On such areas, even where aspens were numerous in the overstory, suckering is often very patchy--largely absent where traffic was heaviest. There may be very few or no suckers on and around the sites of slash piles or log landings.

Almost all aspen suckers arise from roots within a few inches of the surface (Sandberg 1951). Jammer skidding and heavy tractor traffic tear up a lot of these shallow roots, and poor restocking can result. Skidders can move around freely to hook up with no harm. But once they have their load they should use established trails repeatedly instead of bee-lining for the landing.

This may sound peculiar to some of you who are aware that disking was at one time recommended in the Lake States to stimulate suckering (Zehngraff 1946, 1949; Zillgitt 1951). Stimulation of suckering probably resulted from destruction of competing hazel and mountain maple brush to a large extent. Disking also disrupted the apical dominance of remaining unmerchantable trees.

This too should have helped suckering (Zehngraff 1949). Development of the regeneration stands after disking was not good however, and disking is no longer recommended (Perala 1972, Brinkman and Roe 1975).

THE SUCKER STAND

Aspen sucker stands on a clearcut or burn can look terribly overstocked. Actually, 20 or 30 thousand suckers per acre does not seem excessive at all, and there is no evidence that even 100,000 are too many to start with. Studies in Utah and Arizona (Sampson 1919, Baker 1925, Smith et al. 1972, Jones 1975, Jones and Trujillo 1975) as well as in Michigan (Graham et al. 1963) and Canada (Pollard 1971) indicate that early natural thinning is heavy and effective. The least vigorous suckers die during the first year or two. This first thinning reduces sucker clumps to one or two dominant sprouts. Many other suckers are overtopped soon afterward and die within a few years. Four years after clearcutting on some Arizona plots, about 40 percent of the recognizable suckers had died, leaving about 15,700 survivors per acre. About 40 percent of the survivors were overtopped. As stands continue to develop there is a constant dropping out of canopy trees into the overtopped class, and periodic die-offs of overtopped trees.

Dominants in the sucker stand commonly measure 5-10 feet tall 4 years after clearcutting in the West (Smith et al. 1972; Jones 1967a, 1975; Jones and Trujillo 1975).

During the first few years there are continuous losses of suckers to browsing by deer and elk. In heavily stocked sucker stands these losses are of little consequence, even if they number a few thousand per acre (Smith et al. 1972, Jones 1975). Heavy stands provide an adequate buffer unless sheep use the area the first 3 or 4 years or unless the concentrations of elk or deer are exceptionally high (Sampson 1919, Westell 1956, Packard 1942, Larson 1959, Jones 1967b, Smith et al. 1972). Poorly stocked stands are much more susceptible to being browsed out.

Everything considered, the dense regeneration which normally follows the clearcutting of aspen stands is a plus in providing abundant high-quality forage for big game while providing enough survivors for well-stocked sapling stands. And self thinning avoids stagnation.

None the less, the high density of many aspen regeneration stands has repeatedly spurred interest in thinning. A considerable literature has grown up on precommercial thinning of young aspen (Baker 1925; Zehngraff 1947, 1949; Zasada 1952; Strothmann and Heinselman 1957; Steneker and Jarvis 1966; Sorensen 1968; Schlaegel 1972; Bella 1975). Precommercial thinning has only a minor effect on the diameter growth of dominants, although the growth improvement in codominants is more substantial. Thinning reduces stand volume growth.

Thinned plots in young aspen appear to be growing much better than adjacent unthinned plots, but the appearance is deceiving. The many scrawny overtopped trees on the unthinned plots have a strong visual impact. On the thinned plots one sees only dominants and strong codominants.

Meanwhile thinning increases susceptibility to the poplar borer (Ewan 1960). Sunscald has not been reported from thinned sapling stands. But hypoxylon canker, and in the West other cankers, increase after thinning, because of bark wounding and perhaps in part to increased insect activities (Gruenhagen 1945, Graham and Harrison 1954, Anderson and Anderson 1968, Bagga and Smalley 1969, Hinds 1976).

Having said all this, I will mention a stand in which thinning at age 5 ot 6 is said to have improved volume growth markedly. No particular disease problem resulted. This stand is on the Mancos District of the San Juan National Forest. I hope to measure some plots there shortly.

Compared to precommercial thinning, commercial thinning has the added attraction of partly or entirely paying for itself, and a number of studies have been reported (Bickerstaff 1946, Pike 1953, Heinselman 1954, Martin 1965, Steneker and Jarvis 1966, Schlaegel and Ringold 1971, Hubbard 1972). There have been modest growth increases on the remaining trees. In some cases subsequent veneer production was increased. Trees which would otherwise have been lost were salvaged. Overexposed trunks are subject to sunscald however, and canker infections may increase substantially.

I do not recommend commercial or precommercial thinning. There may be situations where thinning is desirable--where it improves stand values and is safe. If so, we need to define situations and methods before we launch any thinning programs

DECADENT STANDS

Many good aspen sites bear stands that are growing poorly and have litte commercial volume. This is because of old age, fire scars, irregular stand structures or other reasons. These stands may be almost completely cull, and in some locales they are the rule.

Yet the sites they occupy have the potential to grow 100-200 cubic feet of usable bole wood per acre per year (Green and Setzer 1974, Jones and Trujillo 1975). Occupied by cull stands they produce no usable wood at all.

These are the real problem stands.

Fortunately, if stocking is not extremely poor, old cull stands have the potential to produce heavy stands of healthy suckers if clearcut or burned (Weigle and Frothingham 1911, Baker 1925, Maini 1968, and personal observation). Uncut, they get worse year by year, and additional stands join their ranks. At the present rate of cutting, cull stands will be a much greater problem in the year 2010 than they are now.

Replacing existing cull stands with young vigorous stands is not a matter of marketing and utilization. It is a matter of purpose, will, and financing. However, harvesting other mature and overmature stands on good sites--stands still merchantable--can reduce recruitment to the cull class. And that is a matter of marketing and utilization.

CONCLUSION

Aspen on good sites is a highly productive forest type, and silviculturally our simplest. It is currently suffering from neglect or poor handling because markets do not support satisfactory silviculture. We have the know-how right now, however, to manage aspen well on good sites when markets allow.

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The Aspen Forest After Harvest[1]

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Abstract.--Aspen is a unique forest tree with respect to regeneration. It produces abundant root suckers, up to 40,000 per acre are common, after clearcutting or fire removes the parent stand. The rapidly growing sucker stand competes well with other vegetation, but is susceptible to destruction by excessive ungulate browsing. Clearcut areas produce more streamflow and more growth on shrubs and herbaceous vegetation than does the uncut forest. The patchwork of age classes that results from even-age management optimizes wildlife habitat requirements for several desired species.

INTRODUCTION

Quaking aspen (Populus tremuloides Michx.) occupies perhaps the greatest geographic range of any North American forest tree species. Its ability to regenerate prolifically with root suckers that grow rapidly and successfully compete with other vegetation may have played a major role in establishing this large range. Aspen is a pioneer seral species that colonizes denuded areas. In the northern parts of its range, where growing seasons are relatively short, cool, and moist, regeneration will be by seed and by root suckering. Here, in the southern part, regeneration is almost exclusively by root suckering.

Some speculate that the ortets (seedling parents) of Rocky Mountain aspen clones may have germinated 10,000 or more years ago, when the climate here was more conducive to aspen seedling survival. With periodic wildfire to return the sites to an early seral stage, these aspen were favored and the clones expanded through many generations of root suckering into the aspen forests we find today in the West, particularly in the central Rocky Mountains.

In relatively recent years man has had considerable impact on the western aspen habitat: (1) His livestock have overgrazed many ranges, which decimated young suckers, especially if they occurred sporadically as advance regeneration in the understory. (2) He has managed big game (deer, moose, and elk) populations to maintain relatively stable numbers near the carrying capacity of the ranges; again, aspen suckers were browsed back repeatedly on many areas. And, most important, (3) he has prevented wildfire from periodically killing the forest, and thus, favoring extensive aspen sprouting.

As a result of these impacts, aspen on millions of acres will be replaced by conifers or by brush and grass within a century. Through proper management this trend can be halted. Harvesting the aspen, and tending the vigorous sucker stands that develop, has been proven through many years of study and experience in the Lake States and adjacent Canada to be an effective way to perpetuate this seral forest type.

HARVESTING AND POSTHARVEST TREATMENTS

Clearcutting is the only harvesting method that will allow a satisfactory stand of suckers to develop (Baker 1925; Graham and others 1963). Partial cuts result in fewer and less vigorous

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suckers and encourage invasion by more tolerant species. The size of clearcut units will be dictated by economics, environmental constraints, and expected browsing pressure by wild ungulates on the developing stand. Silvicultural constraints are minimal; except for a trivial strip along shaded boundaries, sucker regeneration should be uniformly dense across the entire clearcut area (Jones 1975). If a reasonably well-stocked aspen stand is harvested, in most instances the recommended minimum (Graham and others 1963) of 6,000 suckers per acre should be produced. Clearcutting in Arizona resulted in approximately 14,000 sprouts per acre (Jones 1975). Smith and others (1972) found 30,000 to 50,000 sprouts per acre after clearcutting in Utah.

The manner in which felled trees are limbed, bucked, and transported, and their degree of utilization, will affect associated forest resources and the amount and success of aspen suckering. In a Minnesota study (Zasada 1972), the common practice of limbing and bucking at the stump followed by skidding or carrying the logs to haul roads resulted in the least disturbance to the residual stand, understory, and soil when compared to tree-length or full-tree harvesting systems. Limbing at the stump and skidding tree-length logs was intermediate. Most destruction of the residual stand and understory came from a mechanized full-tree system. Mechanically harvesting full trees leaves virtually no residue in the forest. Zasada reported that destruction of the residual stand and understory brush was necessary for successful growth and survival of suckers under Lake States conditions. This can be accomplished at the time of clearcutting, or by subsequent treatment.

A requirement to cut all stems over 2 inches d.b.h. on the clearcut also goes a long way toward assuring an adequate postharvest sucker stand.

Western conditions are different enough that full-tree mechanized systems and maximum site disturbance may not be most desirable. Slopes are steeper and longer and species composition in the aspen understory is entirely different. Erosion potential from these mountainous lands must be more seriously considered than in Minnesota.

Postlogging treatment may be necessary to assure a fully stocked stand of vigorous aspen suckers. Broadcast burning within a year of harvesting will aid in killing understory brush and residual trees (Graham and others 1963; Horton and Hopkins 1966). However, western aspen sites are difficult to satisfactorily burn--burning conditions may not be acceptable during the first or even second postharvest years. And, if burning is delayed any further the residual parent aspen roots may not re-sucker sufficiently to fully stock the area after the fire (Perala 1974). Fire can be a very useful tool in aspen management, but one that cannot be relied upon.

An alternative to fire is the use of herbicides. Individual unwanted trees may be killed by using a tree injector, or the entire clearcut may be aerially sprayed in late summer (Perala 1971) to kill the residual overstory and brush. Again, spraying must be done within a year or two of harvesting to avoid damage to the suckering capacity of the aspen roots.

ALTERNATIVES TO HARVESTING

It is not necessary to employ the axe, chain saw, or mechanical tree harvester to manage aspen. If the aspen type has sufficient values in the form of wildlife habitat, forage, watershed protection, natural firebreaks, and esthetic qualities to warrant the investment, or if these values plus anticipated future worth in wood products are sufficient, then prescribed fire or herbicides can be used to kill the overstory, retard the brushy understory, and regenerate decadent stands.

A single aerial spraying of 3 pounds per acre of 2,4-D or 2,4-D/2,4,5-T mixture in late summer will accomplish that objective (Perala 1971). The resulting release of a dense brushy understory may require a later re-spraying.

Prescribed burning will effectively kill both the aspen stand and the understory. Excellent regeneration will follow. I recommend it wherever and whenever it can be used. Unfortunately, proper burning conditions are too infrequent in standing western aspen to make this a very reliable technique. The juxtaposition of aspen with much more flammable vegetation types precludes the use of fire as a controllable tool in aspen stands in many mountainous western areas.

TENDING THE GROWING FOREST

Little care is needed once a fully stocked, rapidly growing, even-aged aspen stand has been established. If too dense, the stand will thin itself with little loss in growth due to competition (Perala 1972).

Thinning has been shown to increase production somewhat on saw-log and veneer quality trees (Hubbard 1972; Graham and others 1963), but under western conditions, with questionable economic return.

From the practical standpoint, one can do virtually nothing to prevent or minimize disease and insect damage to the developing forest. Cultural practices, such as thinning, may increase such damage (Perala 1972).

A dense stand of aspen regeneration (40,000 or 50,000 suckers per acre, for example) can withstand considerable browsing. But, this impact must be controlled during the first 10 to 15 years after stand establishment. Aspen suckers are preferred browse by wild ungulates. They can virtually prevent aspen regeneration on winter ranges, and can cause impact on summer ranges, too. Domestic sheep and, to a lesser extent, cattle should be kept out of aspen clearcuts for the first couple years after harvest. Later use should be carefully managed until regeneration is well out of their reach, about 15 feet tall and 2 inches d.b.h.

IMPACTS ON OTHER FOREST RESOURCES

No one value dominates in the aspen type--it truly has multiple values and thus is a multiple use type. A sample of Rocky Mountain forest managers recently placed wildlife habitat as the top value, followed by esthetics and recreation, water, livestock, forage, and wood products in descending order. They felt wood products would become more valuable in the future, but not to the point of dominating management policy. Therefore, the effects of aspen harvesting and management on associated resources must seriously be considered. Only recently have these resources been given their due attention in research on aspen management in the West. Thus, there are limited data upon which conclusions can be based.

Water Quantity and Quality

Water yields will increase about 4 to 6 area-inches from aspen clearcuts (Johnston and others 1969; Johnston 1970; Verry 1972). This increased streamflow will diminish as the new stand occupies the site and probably will disappear within 10 to 15 years from sites satisfactorily regenerated with aspen. The increment to streamflow will occur as base flow and interflow. It comes from more water being retained in the soil mantle at the end of each growing season during the years following cutting, before the upper 6 to 12 feet of soil again become occupied by aspen roots.

There is very little overland flow in an undisturbed aspen forest. Properly done, clearcutting should not increase overland flow appreciably. On sloping lands, at least 65 percent cover of some kind needs to be maintained (Marston 1952). Serious soil erosion will occur from overland flow if cover is depleted below this level. Some overland flow can be expected from roads and, to a lesser extent, from skid trails. These flows usually can be infiltrated into the forest floor before they reach the stream if the road and skid trail network is correctly designed, located, and properly treated.

Water quality may be slightly altered. Increased flow and the possibility of overland flow from the disturbed area have the potential for increasing stream sediment load. However, if properly conducted, clearcutting should produce very little sediment, and that for only a year or two before the site becomes fully revegetated.

Nutrient cycling is temporarily halted by clearcutting--which may produce an increase in dissolved ions in streamflow. Typically, this will occur as a surge during the first 2 years after harvesting. Prescribed fire is likely to increase the magnitude of this nutrient flush (DeByle, in press). These predicted water quality changes in part are extrapolated from other forest types. Aspen clearcutting, in at least one instance, resulted in no detectable changes in stream-water quality (Verry 1972).

Soil

Except for possible depletion of some plant nutrients with short rotations or with whole-tree utilization over many cutting cycles (Stone 1973; Boyle and others 1973) the soil should not be significantly affected in the long term from careful aspen harvesting. Temporary changes to be expected are decreased amounts of organic matter and total nitrogen and altered contents of available nutrients. These changes are due to increased radiation reaching the forest floor, an altered soil microclimate, less organic debris added annually, and an interrupted nutrient cycle (DeByle 1976). Rapid regeneration of aspen will quickly dampen these effects on good sites (Boyle and others 1973).

If carefully done, aspen clearcutting should not disturb the mineral soil sufficiently to cause significant erosion. Generally, aspen sites revegetate readily; any bared soil again should be protected within a year or two. However, pocket gophers can consume some of the protective mantle of herbaceous vegetation and expose soil to erosion on Rocky Mountain aspen sites (Ellison 1946; Marston and Julander 1961).

Wildlife

Wildlife populations will be affected by aspen harvesting. From man's point of view, most of the effects are favorable. Providing even-aged patches of aspen representing all age classes will benefit deer, moose, elk, and grouse. Browse for ungulates is present in abundance during the early years (Graham and others 1963; Byelich and others 1972) and grouse habitat is best if all aspen age classes are present in close proximity (Gullion and Svoboda 1972). Aspen browse and leaves are often the most abundant components of deer diets (McCaffery and others 1974; Julander 1952). Clearcut harvesting of eastern hardwoods and the resulting even-aged regeneration provide nesting habitat for a greater diversity of bird species than no cutting (Conner and Adkisson 1975). Beaver almost exclusively use aspen and other closely related species for food and dam building (Bailey 1922). In short, merely keeping a diversity of habitats and maximum of edge through maintaining and managing the aspen type will benefit many wildlife species.

Forage and Understory Production

The production of forage as well as the composition and production of all understory plants will be influenced by aspen harvest. There is a paucity of data from the West in this regard. Ellison and Houston (1958) found increased production of selected species in openings and on trenched plots under aspen as compared to plots under undisturbed aspen forest. More recently, research being conducted by the Intermountain Forest and Range Experiment Station indicates what will happen to production during the first year after clearcutting or after burning.

A year after aspen clearcutting in northern Utah approximately 1,850 pounds per acre was produced as current year's growth on shrubs, forbs, grasses, and annuals on cut plots as compared to roughly 1,600 pounds per acre under the undisturbed aspen canopy. A year of precut sampling showed about 100 pounds per acre less production on the plots to be clearcut than on the controls. Thus, there is indication of an increase of 300 to 400 pounds per acre following cutting.

Because of damge to the understory, burning an aspen stand in northwest Wyoming in 1974 produced the opposite results. Production of grasses, forbs, and especially shrubs was markedly decreased. Prior to burning in 1974 there was 1,550 pounds per acre production on the control plots as compared to 1,265 pounds on the plots to be burned, a difference of 18 percent. In 1975 there was 2,012 pounds per acre production on the controls and only 925 pounds on the burned area, a difference of 54 percent.

In both instances, these are only first-year results. The temporary setback in understory production after burning could be negated by high production in succeeding years. The understory reduction from fire favors aspen sucker production during the first few postburn years.

Esthetics

Esthetics will be improved in the long run, but perhaps adversely affected in the short run, by managing and harvesting aspen. Harvesting requires roads for access. To minimize several adverse impacts (erosion, stream sedimentation, visual impact, and unwanted and uncontrolled public access), these roads should be minimal in number and closed and "put to bed" when not needed.

Clearcutting causes adverse visual impact in any forest type. Fortunately in aspen, because of the lush, rapid-growing understory, this impact is minimal and short-lived. Keeping the clearcut patches small and irregular in shape will reduce the visual esthetic impact.

Harvesting, and thus maintaining aspen as a forest type in juxtaposition with conifer forests, brushlands, and grasslands will maintain and improve the amenity of the western mountain landscape. The alternative is to erase much of the aspen from these landscapes within a century through succession to conifers or brushlands.

SUMMARY

On most sites aspen is a seral species, dominating the community for a span of 50 to 200 years or more. Harvesting the aspen forest by clearcutting on approximately 80- or 90-year cycles will set back the successional process and maintain the aspen type on sites where it is desired. The alternatives to clearcut harvesting (fire or herbicides) will accomplish the same objective, but do not utilize the wood. For economic reasons, it is doubtful that much aspen acreage will be managed without wood utilization.

The ideal aspen clearcut several years after harvesting will have about 12,000 vigorously growing sprouts per acre. For the following decade or more it will provide an abundance of browse for big game, will yield a third of a foot more water than the mature aspen stand, and will be visually acceptable or even pleasing as part of the landscape. During the first year or two after harvest the quality of streamflow may be slightly lowered with dissolved nutrients and sediment. The soil and site are disturbed by the harvesting process, but they rapidly return to preharvest conditions as the aspen suckers again develop a closed forest canopy.

Within 2 decades after harvesting a good site will have essentially returned to the conditions found in a mature aspen stand. Breeding grouse habitat is ideal in these pole-sized stands, increment of wood is now at its peak, and the forest appears most vigorous.

From about 30 years to the end of the cutting cycle at 80 or 90 years, the aspen forest continues to grow and to naturally thin itself to some 300 to 600 stems per acre. Shade-tolerant tree species, such as spruce and fir, begin to invade the stand. It is essentially a mature aspen forest with respect to all resources except wood production. When it matures for production of wood, the stand is clearcut and the cycle begins anew.

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Response Of Aspen To Various Harvest Techniques[1]

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Abstract.--Aspen is an important component of both the Engelmann spruce/subalpine-fir and the Douglas-fir/white fir types. On all recent San Juan National Forest sales, aspen has been part of the included timber. Harvesting responses differ for three situations - aspen is a mature part of a coniferous overstory; aspen is an overstory with a fully stocked coniferous understory; aspen is a pure stand with no coniferous mixture. Effects of grazing, residue volume, and cutting intensity are considered.

Commercial aspen type occurs on 269,000 acres or 21% of the commercial forest land on the San Juan National Forest. Within the aspen type, approximately 20% of the cubic foot volume of the stands is associated softwoods. Of the 269M acres of aspen type, 66.5M acres are classed as sawtimber, 119M acres are classed as poletimber and 85.5M acres are seedling-sapling or non-stocked.

Analysis of the stand age data indicates that many of the stands reach rotation age without growing to sawtimber size. Hinds has recommended a rotation of 80 to 100 years in the Rocky Mountains. There are 89.5M acres over 100 years old. For this to happen, at least 23M acres of pole timber must be over rotation age.

Aspen also occurs as a component in the conifer types. Within the spruce-fir sawtimber type, aspen represents 5% of the cubic foot volume, or 3% of the board foot volume of the stands. In the Douglas-fir--white fir sawtimber stands, aspen represents 11% of the cubic foot volume or 7% of the board foot volumes of the stands. Aspen is almost totally absent from the ponderosa pine type, representing less than 1% of the cubic foot volume of these stands.

During the previous 10 years, the San Juan has harvested an average of 4.1 MBF per year of aspen sawtimber. There are only minor markets for products other than sawlogs. The cut of aspen sawlogs has not been a major part of the Forest harvest, representing only 5½% of the total sawlog harvest. While aspen is not a major part of our harvest, we have not entirely ignored the silvicultural management of the type.

On all of the recent timber sales on the San Juan, aspen has been a part of the included timber. Falling and removing of designated aspen is required on these sales. The more recent timber sales in the spruce-fir type, and the Douglas-fir--White-fir type, have generally received an intermediate cut or a first-stage shelterwood cut. These sales have been individual tree marked. No attempt has been made to eliminate aspen as a component of these stands. When mature aspen trees are encountered, they are marked for removal. Because of differences in rotation age between aspen and conifers, and because the aspen is often residual trees on sites that have converted to conifers, the harvest of aspen from these stands is frequently greater than the part of the stand in aspen. Conifer sales containing 10-15% aspen volume are not uncommon.

Aspen has responded well to this treatment. There are sufficient overstory conifers to maintain the conifer type. Small openings have regenerated to aspen. Thus aspen will continue to be an important component of these stands.

Aspen occurs as an almost pure overstory in stands with full stocking of conifer understory. We have made overwood removal cuts in these stands, removing all aspen over 8" DBH

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(fig.1). The response has been favorable. The conifers have increased both in diameter and height growth. Due to irregularities in stocking or to logging damage, the conifer reproduction seldom fully occupies the site. Where openings occur, aspen reproduction has been quite abundant (6,000-10,000 trees per acre). Aspen will continue to be a strong component of these stands but the future stand will probably be typed as a conifer stand.

Figure 1.--Aspen overwood removal two years after harvest.

Aspen also occurs in essentially pure aspen type. There have been a variety of harvest techniques in these stands. In the mid 1960's, a sale was let where only the merchantable trees were felled and removed. Later sales in the late 1960's required all trees over a given diameter (either 8" or 10") to be felled and removed. The response to this type of harvest is directly related to the amount of residual stand left after harvest. The most recent sales in this type have required that all aspen trees over 2" DBH be felled. Falling unmerchantable trees can either be the purchaser's responsibility, under the terms of the timber sale contract, or can be done by the Forest Service with deposited KV funds.

A series of aspen cuts made in 1965 and 1966 is worthy of mention. These stands were decadent at the time of harvest. Only merchantable trees were felled. This resulted in a residual stand of decadent trees and very light slash on the ground. The area has had unrestricted cattle use since harvest. Today, these areas have essentially converted to grass. Because of the partial cut, aspen reproduction was weak. Data are not available, but reproduction was probably about 1,000 trees per acre. The overstory undoubtedly suppressed the height growth of these trees. Cattle browsing and trampling damaged what reproduction did occur. Today there are no reproduction trees which can be considered as potential crop trees. This system of management is not recommended if the intent is to produce crops of aspen. However, it appears to have merit if the intention is to reduce the area of aspen and increase the area of rangeland.

Other areas cut to a minimum diameter limit, usually 10" DBH, have responded well and are now overstocked with potential crop trees. These stands were not decadent at the time of harvest. Generally, there were sufficient trees of merchantable size that a relatively light residual stand was left. Regeneration occurred and height growth has not been retarded. Residual basal area appears to have been in the range of 30 to 60 square feet per acre. Some of these stands have now been recut to remove the residual trees from the original harvest. This recut is only one or two years old but it appears that the damage to the 10-15 years old reproduction is within acceptable limits. New sprouting is occurring in openings in these stands.

Some, but not all, of the areas cut in the 1960's have received moderately heavy grazing use. The trees in these areas appear sound and well formed. Browsing was not heavy enough in these stands to restrict height growth. The trees are now 10 feet or taller and above any browsing damage. However, many of these trees show signs of basal scars, probably caused by trampling. Most of these basal scarred trees have a discoloration of the heartwood. The pathology lab has identified this as an unknown stain causing fungus. Whether or not this fungus will prevent the trees from producing usable sawlogs remains to be determined.

The most recent sales in pure aspen type have been true clearcuts. All aspen trees 2" DBH and larger have been felled. The response to this treatment has been impressive. Sprouting has occurred at the rate of 6,000 - 10,000 stems per acre. In the second growing season, dominant trees are 6 feet tall (fig.2). There is only minor sign of wildlife browsing and no cattle damage. None of the trees yet show any sign of the unidentified stain-causing fungus. Because all of the trees were felled, the areas are more pleasing visually (fig. 3); the ragged appearance following commercial clearcutting is absent. The unmerchantable debris on the ground has created a barrier which discourages cattle use (fig. 4). Although this debris is now serving a useful purpose of discouraging animals use, it remains to be seen if this debris will also discourage future silvicultural activities in the stand.

Figure 2.--Aspen clearcut second growing season after harvest.

Figure 3.--Aspen clearcut second growing season after harvest.

Figure 4.--Aspen clearcut two weeks after harvest.

Harvesting and obtaining regeneration is not an end in itself. Once regeneration is established, the new stand must be properly tended. Various research studies, along with local observations, show that unrestricted browsing and trampling can destroy a new sprout stand. Therefore, some measure must be taken to restrict this usage. In most cases, complete protection is not practical and probably is not necessary. The key seems to be restricted use, either by range management practices or by leaving sufficient debris so as to discourage animals from using the area.

There is a wide spectrum of opinion regarding the desirability of precommercial thinning in aspen stands. Research papers can be found which support both sides of the question. I consider that pre-commercial thinning is desirable on the San Juan. Our management is based on sawtimber production. Many wild stands have reached rotation age while still in the poletimber size class.

The foregoing is based on several years' observation of aspen response on the San Juan. Unfortunately, exact numerical data are not available.

Table 1.--Area of commercial forest land on the San Juan National Forest

Type	Acres
Spruce-fir	421,021
Ponderosa pine	342,548
Douglas-fir-white fir	231,529
Aspen	268,864

Table 2.--Area of aspen by stand size class

SSC	Acres
Sawtimber	66,505
Pole timber	118,703
Seedling-Sapling	23,634
Non-stocked	60,022

Table 3.--Area of aspen by age class

Age Class	Acres
0-20	60,022
21-40	14,209
41-60	67,844
61-80	33,624
81-100	3,623
101-120	25,498
121+	64,044

Table 4.--Cubic-foot volume of aspen in sawtimber stands, by timber type

Type	MCF
Spruce-fir	64,470
Ponderosa pine	1,888
Douglas-fir--white fir	43,933
Aspen	108,301
	218,592

Table 5.--Board foot (Scribner) volume of aspen in sawtimber stands, by timber type

Type	MBF
Spruce-fir	226,514
Ponderosa	-0-
Douglas-fir--white fir	111,479
Aspen	337,600
	675,593

Table 6.--Board foot (Scribner) volume per acre of aspen in sawtimber stands, by timber type

Type	BF/A.
Spruce-fir	590
Ponderosa pine	-0-
Douglas-fir--white fir	570
Aspen	5076

Table 7.--Board foot (Scribner) volume of aspen and percent of total cut in the past decade

CY. Year	MBF Cut	% of Forest Harvest
1966	6,692	7.5
1967	3,440	3.7
1968	2,489	2.4
1969	4,219	5.5
1970	3,913	5.5
1971	3,452	4.8
1972	3,874	5.5
1973	5,371	7.8
1974	4,591	8.2
1975	3,372	8.1

Ten Year Average: 4,141