An Overview of Key Silvicultural Information for Ponderosa Pine[1]

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Abstract

This paper provides a selected list of classical references for the important silvicultural findings for ponderosa pine, and categorizes some of the key current literature, as well as some of the older, lesser known but important literature. The paper also provides some history of scientific developments, and sources of further information.

Introduction

In this paper we review what we consider to be the key silvicultural information for ponderosa pine (*Pinus ponderosa* P. & C. Lawson*)*. Our experience with ponderosa pine and consequently much of our information comes from Oregon and California. We did not attempt to examine the entire literature on this species, which is enormous! Rather, we focused on what we think is the most important information in fifteen categories. We included older information that is often overlooked, probably because it is not in bibliographic electronic databases. Also, proceedings of at least two symposia that are devoted primarily to ponderosa pine (Baumgartner and Lotan 1988 and Robson and Standiford 1983) and summaries of ponderosa pine silvics (Barrett 1979 and Oliver and Ryker 1990) and silvicultural systems (Schubert 1974, Oliver and others 1983, Ryker and Losensky 1983, and Boldt and others 1983), Ronco and Ready (1983) include very helpful information. Syntheses of regeneration practices are also very important (Schubert and Adams 1971, Cleary and others 1978, Hobbs and others 1992)

Our review is divided into categories under the twin headings Reforestation and Timber Stand Improvement and Stand Growth, and we provide an abstract summarizing the main points in these parts of the literature. The categories overlap. For example, information on bark beetles occurs under stand growth and density as well as under insects, pathogens, animal, and snow damage.

Undoubtedly we omitted important information that ought to be included. Perhaps this review can be considered a work in progress.

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Regeneration and Timber Stand Improvement

Fully recognizing that regeneration and timber stand improvement (TSI) are best thought of as a complete system, and that failure occurs if any single component fails, for the purposes of this presentation, we divided "regeneration" and "TSI" into five categories: natural regeneration, seed collection and handling, nursery practices, site preparation and release, and precommercial thinning.

Natural Regeneration.

Natural regeneration, with seed-tree or shelterwood systems, has been used effectively in many parts of ponderosa pine's natural range (for example, Heidmann 1988, McDonald 1976a, 1976b, 1976c, McDonald and Abbot 1994, Muelder and others 1963, Roy 1983, Shearer and Schmidt 1970, 1971), especially if sites are well-prepared, include rodent control, and coincide with good seed crops. Pearson (1923) was the earliest example of the rich scientific literature we found. Advanced regeneration can also be considered as natural regeneration.

Seed Collection and Handling

In contrast to the other major western conifer species, proper collection and seed handling methods for artificial regeneration of ponderosa pine were comparatively easy to determine and are well established (Fowells and Schubert 1956). Early work (in the 1940's and 1950's) focused on germination and cold storage. The most significant single development was the establishment of seed zones, elevational bands, and seed transfer guidelines, beginning in the 1940's in California (Fowells 1946, Buck and others 1970), later elsewhere (for example, starting in the 1950's in Oregon, Roy 1955).

Nursery Practices

Volumes have been written over the last 5 decades about culturing ponderosa pine seedlings, a subject that now is very well understood and practiced. We focus on just three key developments. The first was the development of fumigation (initially primarily methyl bromide) to control root diseases in bare-root seedlings (Bega and Smith 1960, Smith and Bega, 1966). Although ponderosa pine is somewhat resistant to seedling root diseases compared to most other commercial western conifers, fumigation use significantly improved production efficiencies for ponderosa pine. The second key development was the concept of how nursery practices and seed source (genetics) affect the potential for growing new roots upon out-planting (root growth capacity or root regeneration potential) and lifting windows (Jenkinson 1980, Stone 1955, Stone and Benseler 1962, Stone and Schubert 1959a 1959b, and Stone and others 1963). The third key set of developments was the enormously successful technology of container nurseries, starting in the 1960's (Tinus and McDonald 1979, Tinus and others 1974). This technology is best summarized in The Container Tree Nursery Manual (Landis and others 1989, 1990a, 1990b, 1992, 1995). Container nursery technology continues to improve in the western United States and Canada, primarily by private nurseries, often in cooperatives.

Site Preparation and Release.

There is considerable literature on the theory and practice of controlling unwanted vegetation (for example the Proceedings of the Annual Forest Vegetation Management Conference, starting in 1981, and Walstad and Kuch 1987). The scientific basis for predicting ponderosa pine responses to effective control of competing vegetation is well established. Practices have undergone continual development, in part to reduce unit costs, and to reduce controversies over herbicide use. Just about every conceivable alternative to herbicide use has been tried somewhere during the last three decades (including dynamite for site preparation!).

We focus on three key aspects: the development and application of herbicides, the USDA Forest Service National Administrative Study, and the scientific understanding of the interaction between site quality and tradeoffs between release vs. precommercial thinning.

Herbicide use started in the 1950's with adaptation of agricultural aerial application techniques of the phenoxy herbicides. Later, appropriate use of a much broader range of herbicides was established on a scientific basis, including human health and ecological risk considerations. Additions to the scientific literature continue, and (in part because of legal challenges) comprehensive risk assessments are scheduled for almost continuous updating. The current risk assessments for hexazinone, sulfometuron methyl (OUST), imazapyr (Arsenal®, Chopper®, and Stalker®[4] formulations), glyphosate, and triclopyr are available online (SERA 1997, 1998a, 1998b, 2003a, 2003b).

The National Administrative Study focused on release in northern California (a 20-year-plus study), and continues to establish much of the long-term scientific basis for herbicide and non-herbicide treatments (Fiddler and McDonald 1984). Comparable long-term study results for site preparation and release are becoming available elsewhere in California and in Oregon.

Our third focus is on the relationship between determining needs for release vs. precommercial thinning, as influenced by site quality. Numerous studies have quantified effects of shrub competition and release treatment on conifer growth (Baron 1962, Crouch 1971, 1979, Doescher and others 1989, Fiddler and McDonald 1984, Lanini and Radosevich 1986, Tappeiner and Radosevich 1982, White and Newton 1989). When investment funds are limited, and only one kind of treatment can be done, which treatment should receive priority, and how does site quality affect the decision? Bill Oliver compared results of both kinds of treatments on a high-quality and a low-quality site in northern California (McDonald and Oliver 1984), and established the important principle that on low-quality sites, inter-tree competition in ponderosa pine plantations is insignificant, compared to competition between the trees and shrubs. That is, precommercial thinning is a wasted investment unless the thinning follows, or is done concurrently with, effective release treatments to control shrubs. On such sites, lack of effective release treatments can result in unacceptably high tree mortality rates. In contrast, on high-quality sites, inter-tree competition can be greater than tree-shrub competition, so a single precommercial thinning treatment can yield a better investment return compared to a single release treatment.

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[4] The use of trade or firm names in this publication is for the reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Precommercial Thinning

Practical experience with early ponderosa pine plantations (early part of the 20th century) and widely-distributed spacing studies led to commonly-used residual stocking levels of approximately 100 to 250 trees per acre, depending on site quality, management objectives (including wood quality), and other factors. Two significant quantitative models for predicting growth of pre-commercial-sized ponderosa pine in plantations have been developed. Oliver and Powers (1978) developed the first quantitative model for spacings of 6, 8, 10, and 12 feet, respectively, for a range of site qualities in northern California. Powers and others (1989) and Ritchie and Powers (1993) described the first quantitative model (SYSTUM-1) to include the effects of shrub competition (also at different tree spacings), based largely on ponderosa pine and Douglas-fir plantation data from southwestern Oregon and northern California.

Stand Growth

Genetics, Autecology.

Conkle (1973) reported on the ponderosa pine elevational study from the Sierra Nevada. In this study, trees from low-, mid and high-elevation seed sources were reciprocally planted at these elevations. Ponderosa pine height growth varied by elevation. Trees from high elevation seed sources grew slower than those from other elevations, and had lower height-to-diameter ratios. Trees from mid-elevation sources appeared to be most productive and can be moved more readily than those from low and high elevations, but they were susceptible to snow damage when planted at high elevations.

Ponderosa pine has the ability to grow roots into rock fissures in the unweathered soil horizons and extract water stored there. Shrubs that grow on the same sites have the same ability; however, Douglas-fir is much less able to use water stored in rock fissures (Zwieniecki and Newton 1994, 1995, 1996).

Growth and Yield

Much early research on this species was focused on growth and yield, and was presented in tabular form. Examples of published yield tables include: Dunning and Reineke (1933), Meyer (1934, 1938), Oliver and Powers (1978). More recently, growth and yield information usually takes the form of computer simulators (e.g. DeMars and Barrett 1987, Hann 1981, Hann 2003, Ritchie and Powers 1993, Wensel and Koehler 1986).

Site productivity, traditionally reflected in site index curves have been developed for many regions within the range of ponderosa pine (Barrett 1978, Biging 1985, Dunning 1942, Lynch 1958, Oliver 1972, Powers and Oliver 1978, Hann and Scrivani 1987, Verdyla and Fischer 1989).

Tree Growth and Stand Density (tree and shrub)—Thinning

Several studies on thinning response and the growth of ponderosa pine at a range of stand densities have been reported in the last several decades. These studies indicate that young, even-age ponderosa pine stands respond to thinning like most other conifer species. Thinning increases diameter growth, and maintains crown lengths (Barrett 1982, Cochran and Barrett 1993, Fiddler and others 1989, McDonald and others 1992, Oliver 1984, 1997). Heavy thinning tended to decrease volume yield per unit area, but at high densities or with light thinning net volume yield was low because of mortality from bark beetles. Mechanical treatments may impact soil characteristics and site productivity (Busse and others 1996, Helms and Hipkin 1986, Helms and others 1986).

These studies indicate that western pine beetles may determine the upper levels of stand density (Oliver 1995). Also snow breakage is another important cause of mortality at high densities. On dry sites shrubs (Ceanothus and Manzanita sp.), may reduce ponderosa pine growth during stand establishment and reduce or delay it even after the ponderosa pine has overtopped the shrubs (Gordon 1962, McDonald and Oliver 1984, Oliver 1984, 1990, Powers and others 2005, Shainsky and Radosevich 1986). It appears that eventually the pines may shade out the shrubs and increase their growth rates.

Fertilization, Stand Growth Effects of Shrubs

Ponderosa pine responds to fertilizers but only after shrub control. Where shrub density is high, control of shrubs appears necessary to provide the water needed for fertilizers to be effective. Under combined shrub control-fertilization, most growth response resulted from removal of shrubs; the direct effect of fertilizers is secondary (Powers and Jackson 1978, Powers and Ferrell 1996, Powers and others 1988, Walker 1999a, 2002, White and Newton 1989).

Measures of Stand Density

Measures of density for stands in the pine region have been developed around stand density index (Reineke 1933). Stockability, (the potential stand density for a site) can be adjusted for specific sites (Dunning and Reineke 1933, Cochran 1992, Cochran and others 1994; Hall 1983, Peterson and Hibbs 1989).

Uneven Age Management

Techniques for developing stocking guidelines for uneven aged stands are based on distributing the desired residual SDI (possibly half of maximum) throughout several diameter classes, resulting in a large variety of possible stand structures. The resulting distribution can be evaluated by calculating the numbers of trees and basal area by diameter class. Shifting different amounts of SDI into various diameter classes can modify the distribution. Thus the method is quite flexible and a large number of structures are possible (Cochran 1992, McDonald and Abbott 1994, Lillieholm and others 1990, O'Hara 1996, O'Hara and Gersonde 2004, Olson and Helms 1996).

Insects, Pathogens, Animal, and Snow Damage

Drought, diseases, bark beetles, and high stand densities, all influence ponderosa pine mortality (Barrett and Roth 1985). Root diseases (*Heterobasidium*) and mistletoes, and high density weaken trees and make them susceptible to bark beetles

(*Dendroctonus*) especially during periods of drought and also to damage by heavy, wet snow (Hawksworth and Wiens 1996, Filip 1986, Filip and others 1989, 1999, Megahan and Steele 1987, Miller and Keen 1960, Scharpf and Bega 1981, Schmid and others 1994, Smith 1982). Bark beetle attacks may indicate trees under stress (Storm and Halvorson 1967, Stoszek 1973).

Old Stand and Tree Management

Early work has provided tree classification systems for determining the vigor of ponderosa pine and its susceptibility to insects (Dunning 1928 and Keen 1936, 1943). Recent work has shown that older ponderosa pine stands and trees can respond to thinning. For example a sustained 1.5 to 2.0 percent increase in tree basal area growth was common for trees (+200yr) in stands previously thinned 15 to 30 years earlier (Dolph and others 1995). Removal of understory trees established after fire cessation in the early to mid 1900s may improve the vigor of old ponderosa pine as well as protect them from fire (Latham and Tappeiner 2002, McDowell and others 2003, Biondi 1996).

Understory Vegetation and Stand Density

Recent studies have documented the interactions between overstory density and understory development (Riegel and others 1992, 1995). At higher levels of overstory density, understory is "shaded out" and its density is reduced in response to scarce water and light. Understory vegetation, however can increase organic matter and nutrients in the forest floor (Busse and others 1996, Harris and Covington 1982).

Fire History and Use of Prescribed Fire/Thinning

The history of fire in ponderosa pine has been studied extensively, and prescribed fire and thinning are being increasingly used to reduce the risk and intensity of fire in ponderosa pine stands (Covington and Sacket 1984, 1986; Covington and Moore 1994; Harris and Covington 1982, Hall 1976, 1983; McNeil and Zobel 1980, Bork 1985). Some important emerging issues include the effect of fire on mortality of large trees, minimization of slash/dead trees after initial prescribed fire, and the effects of fire in stimulating germination of buried seed and vegetative buds (Mutch and Parsons 1998; Parsons and DeBenedetti 1979, Weaver 1959, 1961, White and others 1973). More research and practical experience is needed on the use of fire, and mechanical methods in commercial and precommercial thinning and combinations of treatments to achieve fuel reduction.

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