Artificial Regeneration of Five-Needle Pines of Western North America: A Survey of Current Practices and Future Needs

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Abstract

After the introduction of the pathogen causing white pine blister rust, the perpetuation of five-needle white pines (5NP) in western North America is partially dependent on successful deployment of genetically resistant seed and seedlings. We surveyed managers, researchers, horticulturists, growers, and academics throughout western North America to (1) review why managers plant 5NP; (2) describe and attempt to quantify efforts to grow and plant 5NP in the West, focusing on actual deployment of seed and seedlings; (3) describe perspectives on artificial regeneration research needs; and (4) outline how managers can continue in their critical roles. We found a dedicated array of people invested in successful seed collection, disease resistance screening and deployment, orchard development, and outplanting survival.

Introduction

White pine blister rust (WPBR), caused by the fungal pathogen *Cronartium ribicola* (J.C. Fisch. ex. Rabenh), has caused widespread damage to North American five-needle white pines (5NP) since the early 1900s (Shaw and Geils 2010). In the West, WPBR spread through the range of western white pine (WWP) (*Pinus monticola* Douglas ex. D. Don) and subsequently into the range of other susceptible pine species: sugar (SP) (*P. lambertiana* Douglas), whitebark (WBP) (*P. albicaulis* Engelm), limber (LP) (*P. flexilis* E. James), southwestern white (SWWP) (*P. strobiformis* Engelm), and Rocky Mountain bristlecone (RMBP) (*P. aristata* Engelm). Foxtail pine (FP) (*P. balfouriana* Balf.) in northern California were also recently reported as infected (Kliejunas and Dunlap 2007, Maloney 2011). Great Basin bristlecone pine (GBBP) (*P. longaeva* D.K. Bailey) are susceptible but have not been discovered as field-infected to date (Sniezko and others 2011b). The decline of WWP and SP led to the establishment of tree improvement programs in the 1950s that are still active today, although WPBR intensity and mortality varies widely in both species (Bingham 1983, McDonald and others 2004, Schwandt and others 2010).

The initial WWP program began in Idaho and Montana with 400 plus tree selections (field trees exhibiting no to very few WPBR signs or symptoms) (Bingham 1983), with work in Oregon and Washington starting soon afterwards. Disease screening trials assess multiple resistance mechanisms, generally separated into partial resistance ("slow-rusting," thought to be controlled by several to many genes) and complete resistance ("immunity," controlled by a single gene) (Hoff and others 1980, Hoff 1986, Sniezko and others 2008, Sniezko and others 2011b). The gene-for-gene interaction in the 5NP/WPBR pathosystem, in which a single gene confers heritable resistance (major gene resistance [MGR]) against the pathogen has been found in SP, WWP, SWWP, and LP (Kinloch and Littlefield 1977, Kinloch and others 1999, Kinloch and Dupper 2002, Schoettle and others 2011). WWP breeding in the Inland Empire (eastern Washington, northern Idaho, and western Montana) has been characterized by three phases: Phase I (initial 400 plus tree selections), Phase II (selection of resistant progeny from 3,100 candidate WWP) (McDonald and others 2004), and Phase III (selection for resistance and gene conservation across the WWP geographic range). Phase III is just beginning, with initial screenings of phenotypic selections scheduled for 2015 (M. Rust, pers. comm. 2012). Other breeding programs have similar strategies for selection of resistance where partial resistance is more common than MGR (McDonald and others 2004). The resistance screening and breeding programs have a long, rich publication history (see Bingham 1983, Fins and others 2002, McDonald and others 2004, Sniezko and others 2008, King and others 2010, Sniezko and others 2011b for comprehensive reviews). The ecological roles, silvics, and future outlooks of many 5NP species have also been thoroughly reviewed (Arno and Hoff 1989, Kinloch and others 1996, Fins and others 2002, Schoettle 2004, Tomback and Achuff 2010, Schwandt and others 2010, Tomback and others 2011).

A synthesis of western 5NP artificial regeneration projects from operational and research standpoints has not been compiled to our knowledge, although some species have been synthesized separately. For example, Izlar (2007) developed a database of Intermountain West WBP planting projects from

1989 to 2005 and reported 120 WBP planting sites across several States, with very little interagency coordination of restoration efforts at the time. Compiled information of 5NP projects across the West are valuable to managers, who are relied on to incorporate research related to these species operationally. Managers benefit from knowing the details of how and where other managers are planting, what leads to success or failure, and that the efforts made across the landscape are cumulative and contributing towards widespread restoration. Since many of these projects have not been published, we conducted informal surveys of managers, researchers, seed and seedling growers/horticulturists during spring 2012 regarding planting, research, nursery and seed orchard production, and personal opinions regarding future needs and manager roles. Our specific objectives were to (1) review why managers plant 5NP, (2) describe and attempt to quantify efforts to grow and plant 5NP, (3) describe perspectives on regeneration research needs, and (4) outline the ongoing roles of managers. The full set of questions is available upon request. Survey respondents work for a wide variety of agencies (U.S. Department of Agriculture [USDA]), Forest Service; U.S. Department of the Interior, Bureau of Land Management (BLM) and National Park Service (NPS); U.S. Department of Defense; state and tribal governments; and Canadian provincial governments), universities, private companies, and nonprofit organizations. Our survey findings should be viewed as a subsample of 5NP management and research in the West because we were not able to survey every group involved in 5NP artificial regeneration efforts, nor do we include all relevant literature. Our intentions were to focus primarily on responses of those surveyed and supplement literature where appropriate.

Seed Collection, Resistance Screening, and Seed Orchards

Across the spectrum of managers surveyed, all have invested to some degree in cone (seed) collections, screening families (seedlings from the same parent tree) for resistance, and planting seedlings primarily from those resistant families; this practice was particularly prevalent for SP and WWP. Three major blister rust disease screening facilities are in the West—all are administered by the USDA Forest Service: Dorena Genetic Resource Center, OR (DGRC), Placerville Nursery, CA, with additional research screening conducted at the nearby Institute for Forest Genetics (IFG), and Coeur d'Alene Nursery, ID (CDA) (Sniezko and others 2011b). Screening is conducted for both partial resistance and MGR (figure 1). Some managers use only seed from their land base while others also use seed collected from other areas within the same seed zone; enhancing genetic diversity was cited as the primary reason for using seed from other source areas. Although seed collections are preferably from trees with known resistance (MGR and/or partial resistance), collections from plus trees in areas with high levels of WPBR infection are used where resistance screening is not yet complete.

Figure 1. Resistance-screening trial for whitebark pine at Dorena Genetic Resource Center (DGRC) in Oregon. Each row represents one family. (Photo by Richard Sniezko, DGRC 2006).

Sugar Pine

In California, many land managers work in close collaboration with the USDA Forest Service Regional Genetic Resources Program to collect seed, screen families, and share the resulting seed from identified resistant trees; most of these efforts have focused on SP (table 1). California landowners also share the resistant genetic material for orchard establishment; this cooperative effort creates a buffer against loss of any single orchard (McDonald and others 2004). For example, the USDA Forest Service has established three clonal SP seed orchards that include both MGR and partial resistance and represent three breeding zones targeted to supply seed to the western Sierra Nevada range (table 1) (USDA 2012; B. Boom, J. Dunlap, pers. comm. 2012); 500 resistant clones are duplicated in the Sierra Pacific Industries orchards (table 2, G. Lunak, pers. comm. 2012). The BLM has a long history with SP seed orchard development in western Oregon, with first-generation resistant orchards developed in the 1970s and 1980s. They have recently installed a 1.5-generation orchard with space to include second-generation material in the near future. The BLM works cooperatively with USDA Forest Service (including resistance screening at DGRC) and private industry to disseminate seed from their orchards. Internal BLM demand for seed in southwestern Oregon is 121 lb (55 kg) annually, with industry demands of an additional 24 lb (11 kg) (M. Henneman, pers. comm. 2012).

Western White Pine

Only portions of the WWP range (Oregon and Washington) contain MGR, and then only in low levels (Kinloch and others 1999, McDonald and others 2004), thus the selection and breeding programs for WWP often focus on partial resistance (King and Hunt 2004, King and others 2010, Mahalovich 2010). In the Inland Empire, the Phase I early selection and seed collections included 400 trees, while Phase II screening trials included many more (table 1) (Bingham 1983, Mahalovich 2010). Seed orchard establishment is more advanced for WWP than SP (table 2). In the Inland Empire, the USDA Forest Service established eight orchards and one 19-acre

Table 1. Survey responses related to seed collection efforts for sugar pine (SP), western white pine (WWP), and whitebark pine (WBP) for different resistance types (single gene [MGR] or partial) across land ownerships and locations.

5NP species	Number of families MGR	Number of families MGR and/or partial resistance (screened or in screening)	Estimate of annual seed production or total inventory	Location/land ownership	Personal communication/ literature source
SP	1,807	909	2,007 lb (910 kg)	California—all ownerships	USDA 2012, J. Dunlap, B. Boom
	300			Sierra Pacific Industries, CA (1.7 mil acres/688,000 hectares)	G. Lunak
	41			Soper-Wheeler Co., LLC, CA (60,000 acres/24,000 hectares)	P. Violett
	64			Lake Tahoe Basin, CA and NV	M. Mircheva
	6			Blodgett Forest, University of California (4,000 acres/1,620 hectares)	K. Somers
WWP		400 (Phase I)	2,500 lb (inv)* (1,134 kg)	Inland Empire, non-Federal	M. Rust
		3,438 (Phase II)	1,372 lb (inv)** (622 kg)	Inland Empire, Federal	M. Mahalovich
WBP		823		Northern Rockies, Federal	M. Mahalovich
		380		Oregon, Washington, and British Columbia, Canada	Sniezko and others 2011
		359	275,000 seeds (inv)	Oregon and Washington	Aubry and others 2008

*17-yr supply, Phase I; **8.5-yr supply, Phase II

Table 2. Seed orchard status and production for sugar pine (SP), western white pine (WWP), and whitebark pine (WBP).

5NP species	Total size (ac/ha)	Number of orchards	Production	Number of breeding zones	Number of seed zones	Number of parents represented	Location/land ownership	Personal communication/ literature source
SP	60/24	Multiple*	NA**	NA	NA	NA	Oregon and Washington, Federal	Lipow and others 2002, A. Bower
	70/28	3	~960 cones (2009, 1 orchard)	3	10	>700	California, Federal	USDA 2012, J. Dunlap, B. Boom
	15/6	NA	In development	5	22	NA		J. Dunlap
	NA	2	In development	2	NA	500	Sierra Pacific Industries, CA	G. Lunak
WWP	90/36	Multiple	NA	NA	NA	NA	Oregon and Washington, Federal	Lipow and others 2002, A. Bower
WWP	NA	1	Expected in 3–5 yrs	NA	NA	46	Quinault Indian Reservation, WA	J. Plampin
WWP (Phase I)	42/17	4	12,360 lb (5,606 kg) (1970–2010)	NA	NA	NA	Inland Empire, Federal	Mahalovich 2010, M. Rust
WWP (Phase II)	30/12	4	NA	NA	NA	NA	Inland Empire, Federal	Mahalovich 2010
WWP	NA	2	Advanced generation orchards in development	NA	2	NA	British Columbia, Canada	N. Ukrainetz
WBP	12/5	4	In development	4	NA	NA	Northern Rockies, Federal	M.F. Mahalovich

*Exact data not provided. **NA = data were not provided by survey respondents. Only the Inland Empire WWP program includes specific phases.

(7.7-hectare) clone bank that are producing seed (table 2) (Mahalovich 2010). The R.T. Bingham Seed Orchard, part of the Phase I breeding program, began producing seed in 1970 and is now the primary seed source in the Inland Empire for non-Federal entities (table 1). The Quinault Indian Reservation (QIR), WA has also established an orchard (J. Plampin, pers. comm. 2012) which is expected to produce seed in the near future (table 2); past and current QIR plantings are from resistant seed collected from the USDA Forest Service Denny Ahl Seed Orchard in cooperation with the USDA Forest Service (J. Plampin and A. Bower, pers. comm. 2012). In British Columbia, Canada, WWP seed orchards are producing seed from screened parents and progeny; continued breeding is underway with enhanced genetic material expected from the coastal program (pollinated using MGR trees to build more durable resistance) in 2 to 5 years and from the interior program (one-half of these orchards are composed of Idaho breeding program material) in 10 to 15 years (table 2) (N. Ukrainetz, pers. comm. 2012, King and Hunt 2004, King and others 2010).

Whitebark Pine

Many regions are actively collecting WBP seed for restoration programs, WPBR screening trials, and gene conservation (Mahalovich and Dickerson 2004; Mahalovich and others 2006; Aubry and others 2008; Mahalovich 2011; Sniezko and others 2011a, 2011b; M.F. Mahalovich, pers. comm. 2012). A comprehensive restoration plan has been designed for WBP in the Pacific Northwest (table 1) (Aubry and others 2008) and more recently for the entire WBP range (Keane and others 2012). Of the six high-elevation 5NP species, WBP has the most parent trees in rust-resistance screening trials, including families from California, Oregon, Washington, the Northern Rockies (Idaho, western Montana, and Wyoming), and Canada (Sniezko and others 2011b) (table 1).

Seed orchards are now being established for WBP, with the first scion planted in 2009 on the Lolo National Forest, MT (table 2). A breeding orchard is in development, with pollen collection beginning in 2011 (M.F. Mahalovich, pers. comm. 2012). Recent research suggests that five seed zones fully capture the genetic variation throughout the Northern Rockies (Mahalovich in press). Eight long-term performance tests are planned, with the first two installations expected in 2014 (Mahalovich 2011). It is not known yet if seed orchards are a viable option for WBP in Oregon and Washington, although pilot grafting and scion projects are underway and 15 to 30 resistant families will be planted in WBP habitat for future seed production (Aubry and others 2008).

Other 5NP Species

Seed collection and storage efforts are ongoing for LP, GBBP, RMBP, and FP for the national Genetic Conservation Program through USDA Forest Service, Forest Health Protection (Dunlap 2011; Mangold 2011; A. Schoettle, M. Mircheva, pers. comm. 2012; Schoettle and others 2011; Sniezko and others 2011b). Extensive research and, to a lesser extent, operational collections have been made across USDA Forest Service and BLM land ownership in the Inland Empire, central and southern Rocky Mountains, and some populations in the Southwest for LP, RMBP, and GBBP (A. Schoettle, pers. comm.). Pollen has also been collected from resistant LP trees in the southern Rocky Mountains (A. Schoettle, pers. comm.). Operational collections of SWWP were completed periodically since the 1980s; collections will commence for the Genetic Conservation Program in 2012 (by authors). Resistance screening (both short- and long-duration tests for an array of resistance mechanisms) for LP (Schoettle and others 2011), RMBP (Vogler and others 2006, Schoettle and others 2011), GBBP, and FP are underway at DGRC and IFG (Sniezko and others 2011b). Screening for a diverse array of resistance mechanisms in SWWP is also underway at DGRC, IFG, and CDA (Sniezko and others 2008, 2011a).

Seedling Production

From a production standpoint, most growers producing 5NP found them to be harder to propagate than other western conifers. WBP was often cited as the most difficult species to grow. Successful seed treatment and storage protocols to maximize seedling production methods for both WWP and WBP have been developed (Burr and others 2001; Bredeen and others 2007; Riley and Coumas 2007; K. Eggleston, pers. comm. 2012). A common problem with both SP and WWP seeds is *Fusarium* spp. (T. Jopson, pers. comm. 2012; James 1985; Jenkinson and McCain 1993) and is mitigated through proper nursery management and growing conditions (T. Jopson, pers. comm. 2012). Root aphids can also be a problem in WWP during the summer growing season (D. Livingston, pers. comm. 2012). Both WWP and SP are notorious for their lack of fine root development, although techniques such as q-plugs, transplanting, and improved container stock production methods have alleviated this issue somewhat (K. Wearstler, pers. comm. 2012).

Despite these challenges, many nurseries successfully propagate and produce 5NP seedlings annually (figure 2, table 3); although 5NP are often only a small percentage of overall production (T. Jopson, D. Livingston, K. Wearstler, pers.

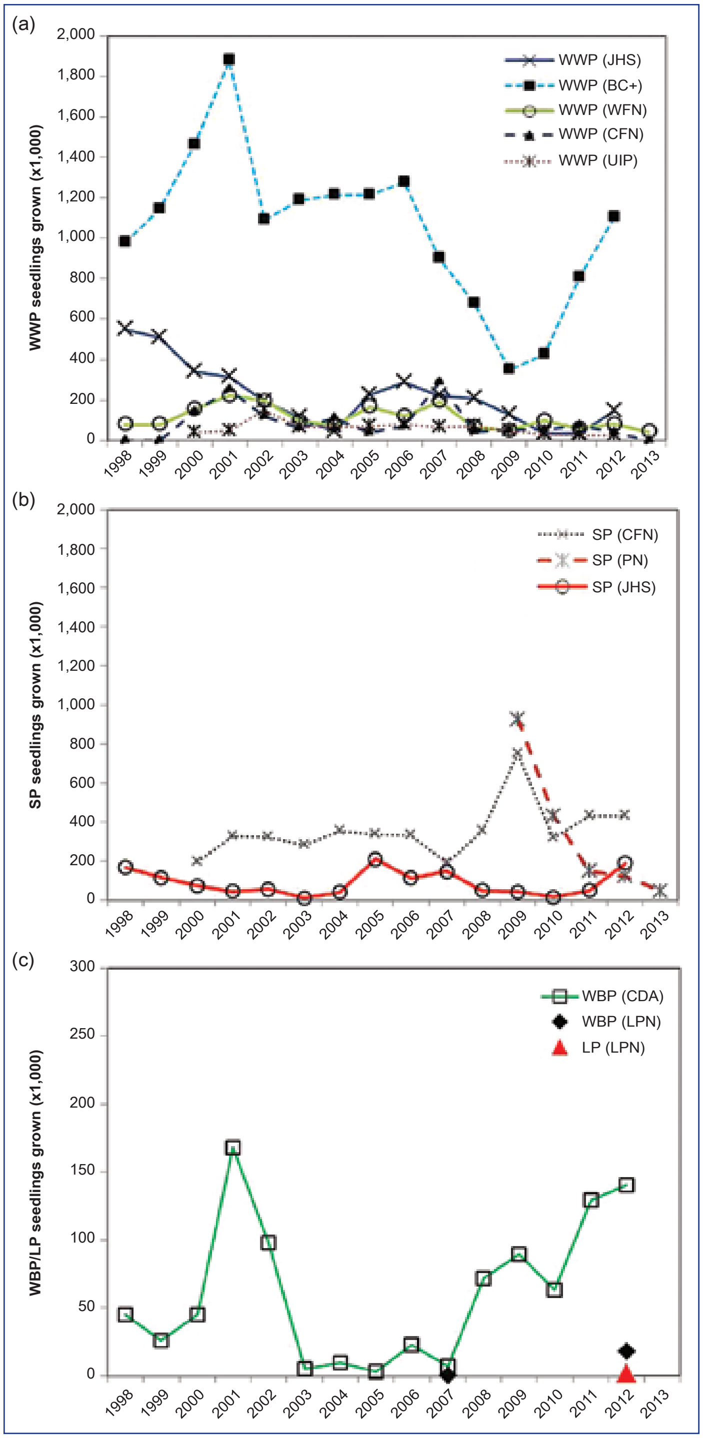

Figure 2. Annual number of (a) western white pine (WWP), (b) sugar pine (SP), (c) whitebark pine (WBP), and limber pine (LP) seedlings grown at nurseries throughout western North America.

BC+ = British Columbia, Canada nurseries, including 8 Pacific Regeneration Technologies, Inc., nurseries and 13 additional BC nurseries; CDA = Coeur d'Alene Nursery, ID. CFN = Cal-Forest Nurseries, CA. JHS = J. Herbert Stone Nursery, OR. LPN = Lucky Peak Nursery, ID. PN = Placerville Nursery, CA. UIP = University of Idaho Pitkin Nursery, ID. WFN = Webster Forest Nursery, WA. No marker indicates zero seedlings that year. Note the difference in seedling production scale of WBP (c) relative to SP (a) and WWP (b). All seedlings are container grown with the exception of bareroot seedlings produced at JHS. (Data sources: B. Boom [PN], A. Brusven [UIP], J. Dunlap [PN], K. Eggleston [CDA], T. Jopson [CFN], D. Livingston [BC+], R. Mallory [JHS], J. Sloan [LPN], and J. Trobaugh [WFN]).

comm. 2012). In addition to larger scale annual production of SP, WWP, and WBP by several nurseries (figure 2), Lucky Peak Nursery (LPN) in Idaho has historically grown WBP and LP less frequently in smaller amounts, but expects the demand to grow and has started programs to produce 2,000 LP and 18,000 WBP annually (J. Sloan, pers. comm. 2012) (figure 2). In addition, growers at Charles E. Bessey Nursery (NE) recently produced 1,000 2-0 LP seedlings for outplanting in Colorado and also sell 6,000 to 12,000 SWWP annually for windbreaks across eastern and central Nebraska (R. Gilbert, pers. comm. 2012).

Individual seedling costs varied widely, with resistant WWP and SP seedlings selling for as little as \$0.18 to \$0.28 per seedling, depending on stock type and container size (table 3). Managers working on small restoration projects reported higher costs of \$1 to \$2 per seedling. By species, screened WBP generally costs more (a result of the need for seed scarification and hand-sowing); however, the WBP seedling cost has dropped from more than \$4.00 per seedling in 1999 (K. Eggleston, pers. comm. 2012; Mahalovich 2011, table 3). WWP and SP are consistently grown and outplanted using 5, 6, 8, or 10 in^3 (82, 98, 131, or 164 cm^3), 1-year-old container stock. Most CDA Nursery customers purchase container 98 super cell, 10 in^3 (164 cm^3), 1- or 2-year-old WBP container stock (K. Eggleston, pers. comm. 2012). The Placerville Nursery reported 95 percent of its SP are sold as 1-year-old 10 in^3 container (B. Boom, pers. comm. 2012), while the University of Idaho Pitkin Nursery reported that WWP survival is greater using 2-year-old, 20 in^3 (328 cm^3) container stock, although 5.5 in^3 (90 cm^3), 1-year-old container stock is preferred for large operational plantings due to lower costs (A. Brusven, pers. comm. 2012). Several managers also reported using seedlings leftover from screening trials at DGRC at minimal costs. Several nurseries reported a decline in demand for WWP in recent years (figure 2), citing drought and a perception of low survival rates as potential causes. Demand for SP appears stable while WBP demand has been increasing (figures 2 and 3).

Operational and Research Outplanting

Outplanting Project Sizes

We found managers actively outplanting SP, WWP, and WBP (figures 3 and 4, table 4). Acreage planted operationally with 5NP is dominated by these three species and is echoed in the trend for nursery production (figure 2), but other 5NP are also used for trial and research outplanting. Outplanted WWP since 1973 and WBP since 1988 on Intermountain West

Table 3. Seedling prices reported for 5NP species by five nurseries in western North America.

Species	Nursery	Stock type	Price reported	Personal communication/ literature source
SP	USDA Forest Service, J. Herbert Stone Nursery, Central Point, OR	1-0 bareroot	$256/M*	K. Wearstler
		1-0 bareroot	$256/M	R. Mallory
		1-1 bareroot	$410/M	
		1P-1 bareroot	$163/M	
		1P-2 bareroot	$326/M	
		2-0 bareroot	$338/M	
		2-1 bareroot	$484/M	
		3-0 bareroot	$405/M	
		Q-plug-1	$312/M	
		Q-plug-1.5	$339/M	
		Q-plug-2	$383/M	
WWP	Pacific Regeneration Technologies, Inc., British Columbia, Canada	1-0 Plug Styroblock™ (4.9 in^3; 80 cm^3)	$0.25/sdlg	D. Livingston
		1-0 Plug Styroblock™ (5.8 in^3; 95 cm^3)	$0.25/sdlg	
		1-0 Plug Styroblock™ (7.6 in^3; 126 cm^3)	$0.30/sdlg	
	USDA Forest Service, Coeur d'Alene Nursery, Coeur d'Alene, ID	2-0 container	$0.34/sdlg	K. Eggleston, M.F. Mahalovich, 2011
WBP	USDA Forest Service, Coeur d'Alene Nursery, Coeur d'Alene, ID	2-0, 98 supercell container (10 in^3; 164 cm^3)	$1.70-2.06/sdlg	
WBP and LP	USDA Forest Service, Lucky Peak Nursery, Boise, ID	1-0 bareroot	$420/M	J. Sloan
		2-0 bareroot	$448/M	
		Styroblock™ 112/105 (6.5 in^3; 107 cm^3)	$575/M	
		Styroblock™ 160/90 (5.5 in^3; 90 cm^3)	$490/M	
		Styroblock™ 45/340 (20 in^3; 328 cm^3)	$817/M	
		Styroblock™ 91/130 (8.0 in^3; 131 cm^3)	$707/M	
		Styroblock™ 77/172 (10 in^3; 164 cm^3)	$653/M	
		1 gal pot	$7/sdlg	
LP	USDA Forest Service, Charles E. Bessey Nursery, Halsey, NE	1-0 container (6.5 in^3; 107 cm^3)	$0.62/sdlg	R. Gilbert
		2-0 container (40 in^3; 656 cm^3)	$5.00/sdlg	
SWWP	USDA Forest Service, Charles E. Bessey Nursery, Halsey, NE	2-0 bareroot stock	$0.59/sdlg	

*M = 1,000 seedlings.

Federal land were reported as totaling 175,818 and 3,004 acres (71,181 and 1,216 hectares), respectively (figure 4); 16,617 acres (6,728 hectares) of SP have also been planted since 1997, excluding California (M.F. Mahalovich, pers. comm. 2012, data not shown). In this survey, outplanting project sizes varied by species and project and not all plantings were summarized spatially (table 4). Approximately 2 million WWP seedlings are planted annually on Federal lands in Oregon, Washington, Idaho, and Montana (M.F. Mahalovich, pers. comm. 2012) and an additional 1 million WWP are planted annually on non-Federal lands across the Inland Empire (M. Rust, pers. comm. 2012) (table 4). Izlar (2007) reported more than 210,000 WBP seedlings were planted at 120 sites (30 to approximately 10,000 seedlings per site) from 1989 to 2005 (acreage likely included in acres reported by M.F. Maholovich, pers. comm. 2012). Sierra Pacific Industries plants 360,000 resistant SP annually in California, amounting to approximately 4,000 acres (1,619 hectares) at 15 to 25 percent of the total species composition (table 4). Several national parks including Glacier, Waterton Lakes, and Crater Lake, have planted WBP and/or LP as research or operational plantings (J. Asebrook, J. Beck, and C. Smith, pers. comm. 2012) (table 4). Six trial sites across southern Wyoming and the Colorado Front Range were planted with 2,160 LP seedlings to help develop forest-scale planting methods (Casper and others 2011) (table 4). In 2011, 1,000 WBP seedlings were outplanted on five Deschutes

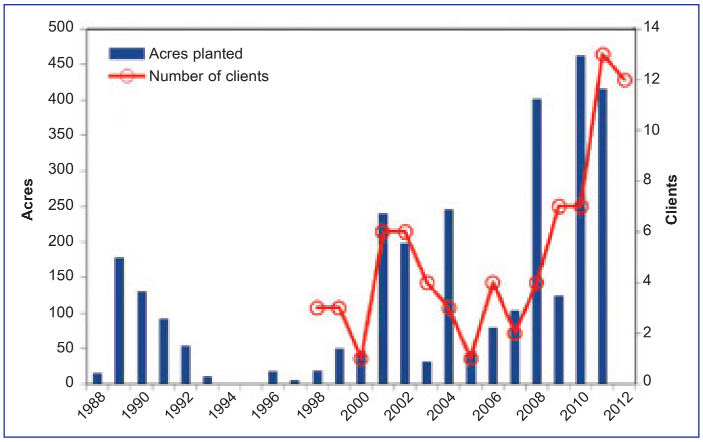

Figure 3. Annual number of Federal acres planted with whitebark pine (WBP) from 1988 to 2012 in the Northern (Region 1), Rocky Mountain (Region 2), and Intermountain (Region 4) Regions and number of clients (national forests, national parks, Bureau of Indian Affairs reservations) requesting WBP seedlings annually from Coeur d'Alene nursery, 1998 to 2012. (Data sources: M.F. Maholovich, pers. comm., 2012 and K. Eggleston, pers. comm., 2012, respectively).

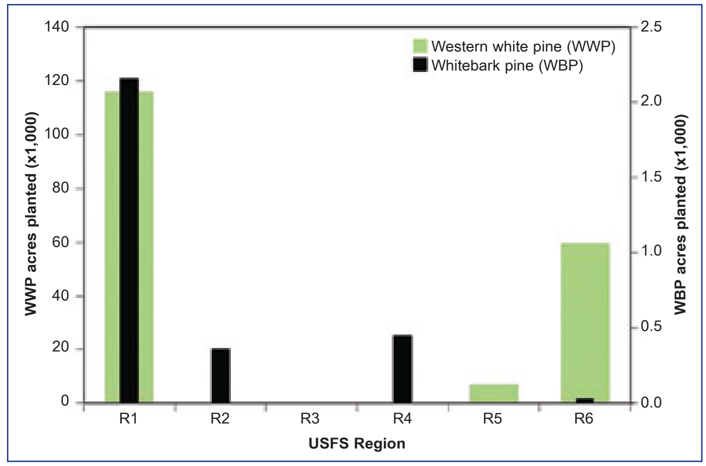

Figure 4. Federal acres planted with western white pine (WWP) and whitebark pine (WBP) by USDA Forest Service region from 1973 to 2012 (WWP) and 1988 to 2012 (WBP). R1 = Northern Region, R2 = Rocky Mountain Region, R4 = Intermountain Region, R5 = Pacific Southwest Region, R6 = Pacific Northwest Region. Note the scale difference in acres planted between WWP and WBP. (Data source: M.F. Mahalovich, pers. comm., 2012).

Table 4. Outplanting project sizes (acres or number of seedlings), operational planting densities (trees per acre), and survival rates (percent survival) reported by survey respondents.

Species	n*	Project size				Personal communication/literature source
SP+	3	1,000–360,000 sdlgs				D. Stubbs, G. Lunak, K. Somers
WWP+	8	7–1,200 ac (2.83 – 486 ha), 500–2 million sdlgs				A. Brusven, M.F. Mahalovich, M. Rust, N. Waldren, D. Omdal, M. Jenkins, N. Ukrainetz, C. Dowling
WBP	15	1–63 ac (0.4–26 ha), 96–5,160 sdlgs				D. Stubbs, J. Nakae, C. Smith, K. Buermeyer, R. Niman, J. Asebrook, J. Beck, V. Walker, M. Jenkins
LP	3	1–2 ac (0.4–0.8 ha), 26–1,312 sdlgs				C. Smith, W. Jacobi, J. Asebrook
Species	**n***	**Density mean TPA (TPH)****	**Density range TPA (TPH)**			**Personal communication/literature source**
SP	8	265 (678)	110–600 (282–1,536)			G. Lunak, D. Henneman, M. Crawford, M. Mircheva, K. Somers
WWP	7	362 (927)	110–600 (282–1,536)			D. Henneman, M. Crawford, C. Dowling, M. Jenkins
WBP	10	195 (500)	50–300 (128–768)			E. Jungck, D. Stubbs, J. Daily, J. Nakae, V. Walker, S. Dittman, M. Klinke, K. Buermeyer, M. Jenkins
Species	**n***	**Survival (low mean %)**	**Survival (high mean %)**	**Survival (range, %)**	**Years reported**	**Personal communication/literature source**
SP	5	72	75	10–95	1–10	G. Lunak, M. Mircheva, K. Somers, M. Crawford, D. Henneman
WWP	8	66	83	20–100	1–10	D. Stubbs, A. Brusven, B. Larkin, N. Ukrainetz, N. Waldren, V. Walker, D. Omdal
WBP	7	86	91	74–100	1–3	D. Stubbs, J. Nakae, J. Daily, R. Niman, S. Haeussler, S. Dittman, J. Beck, C. Smith, J. Asebrook
LP	4	28	57	0.5–96	1–5	W. Jacobi, C. Smith, J. Asebrook

sdlgs = seedlings. SP = sugar pine. WBP = whitebark pine. WWP = western white pine. LP = limber pine.

Notes: All species planted are included in the total; only whitebark pine is routinely planted in monoculture. Research projects often involved much higher densities and are not included here. Where a range of densities or survivals was provided, the n and mean include the high and low number from the range.

* Number of projects with specific size, densities, or survival numbers reported by survey respondents.

**TPA (TPH) = trees per acre (trees per hectare).

+ Generally not planted as monoculture so seedling numbers also provided.

National Forest (OR) sites to evaluate long-term WPBR microsite associations (C. Jensen, A. Schoettle, pers. comm. 2012). A small LP outplanting has also been planted on the Deschutes National Forest (C. Jensen, A. Schoettle, pers. comm. 2012). In Oregon and Washington, WBP plantings across nearly all conservation areas are planned as part of the Restoration Strategy (Aubry and others 2008).

Sugar and Western White Pine

The most common reasons for planting SP and WWP included maintenance of species diversity and restoring historic species mixtures on the landscape. Many managers reforest sites post-fire, with higher demand in some areas for seedlings after years with larger burned acreage (figure 2). Managers also cited maintenance of healthy populations of these species, deployment of resistant genes, and commercial value as reasons for planting these two 5NP species. In the Northwest and Inland Empire, WWP is planted on sites where root diseases (frequetly caused by *Armillaria*, *Phellinus,* and *Leptographium* species) are prevalent because WWP is less susceptible to these pathogens. We did not speak with any managers operationally planting WWP in California, because of its presence only in higher elevation forests.

Managers primarily use only resistant SP and WWP stock. Nonresistant stock (not yet screened), ideally from plus trees, is used only if screened parent trees are unavailable from a specific seed zone. In general, such trees have poor long-term survival relative to resistant stock (Bingham 1983, Kearns and others 2012). Managers relying on phenotypic resistance, however, plant these trees in areas where little-to-no WPBR mortality has occurred.

Neither SP nor WWP grows naturally in pure stands, although WWP was historically a dominant component in some areas (Fins and others 2002, Harvey and others 2008). Managers primarily plant SP in mixtures as 20 to 25 percent of the species composition and WWP in mixtures from 20 to 100 percent of the species composition. SP was most commonly planted with a mixture of ponderosa pine (*Pinus ponderosa* Lawson and C. Lawson), white fir (*Abies concolor* [Gord. and Glend.] Lindl. ex Hildebr.), incense-cedar (*Calocedrus decurrens* (Torr.) Florin), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), and Jeffrey pine (*Pinus jeffreyi* Balf.). In California, one manager frequently includes giant sequoia (*Sequoiadendron giganteum* (Lindl.) J. Buchholz) in the species mixture (K. Somers, pers. comm. 2012). No managers reported planting SP monocultures even at small scales; some cite the more virulent strain of the *C. ribicola* pathogen (vcr1) as the reason. WWP is occasionally planted as a monoculture, but more frequently in a mixture with ponderosa pine, lodgepole pine (*Pinus contorta* Douglas ex Loudon), grand fir (*Abies grandis* [Douglas ex D. Don] Lindl.), noble fir (*Abies procera* Rehder), Pacific silver fir (*Abies amabilis* [Douglas ex Loudon] Douglas ex Forbes), western larch (*Larix occidentalis* Nutt.), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), western redcedar, (*Thuja plicata* Donn ex D. Don), and Douglas-fir. Planting densities ranged widely (table 4), with most plantings done at regular spacing with allowance for deviations related to microsite variation.

Whitebark Pine

Planting of WBP has increased in recent years, partially because of publicity of the species becoming a candidate for listing under the Endangered Species Act in 2011 and the Whitebark Pine Restoration Program initiated by USDA Forest Service, Forest Health Protection (figure 5) (Schwandt and others 2010, Schwandt 2011, Tomback and others 2011, USFWS 2011). Restoration guidelines for WBP that include steps from seed collection to outplanting and monitoring seedlings have been developed (Aubrey and others 2008, McCaughey and

Figure 5. Planted pair of whitebark pine seedlings, Shoshone National Forest. (Photo source: Betsy Goodrich, Northern Arizona University, 2008).

others 2009, Keane and others 2012). According to survey respondents, the dominant reasons for planting WBP include postfire regeneration, overstory mortality related to WPBR and bark beetles, and the need to ensure future cone crops. Additional reasons included postdisturbance plantings, species maintenance and diversity, wildlife habitat improvement, and future plans to increase national park visitor awareness of the species (J. Beck, pers. comm. 2012, Hudson and Thomas 2010). Stock that has not been screened for resistance to WPBR may be planted on sites with immediate regeneration needs (for example, postfire needs) because screening is a multiyear process. In parts of the United States and Canada, where screening programs are less developed, seedlings are planted using plus tree seed collections.

Whitebark pine is generally planted as a single species but other species may be retained or seed naturally onto the site including lodgepole pine, subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.), and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.). Competing vegetation is often removed after planting to give WBP a competitive advantage. Planting densities of WBP ranged by project (table 4) with spacing of operational plantings ranging from 6 to 15 ft (1.8 to 4.6 m), with deviation of 3 to 20 ft (0.9 to 6.1 m) allowed for microsite selection. Planting WBP costs approximately $95 to $150 per acre ($38 to $61 per hectare) using contractors in the more rugged and high elevation terrain where WBP is often found (V. Walker, M. Jenkins, pers. comm. 2012).

5NP Seedling Survival

Survival of outplanted 5NP seedlings varies but, in general, has increased in the past few decades with increasing experience in both nursery production and planting (table 4). All researchers and managers emphasized the importance of careful selection of overall site and microsite planting conditions for success, a point that is also documented in the literature (Izlar 2007, McCaughey and others 2009). Survival rates range from 90 percent or more in the first year after planting to around 70 percent in the third year (table 4). Early, high mortality rates in SP and WWP were reported occasionally, with mortality related to non-WPBR agents. For example, in western Montana, heavy browse damage reduces survival. Browse preference is for resistant, planted seedlings with higher nitrogen content than wild seedlings; the higher nitrogen is likely a result of nursery practices or site-specific management (B. Larkin, pers. comm. 2012; Larkin and others 2012). Use of volunteers and choice of sites appeared to affect early survival rates of SP in the Lake Tahoe Basin (M. Mircheva, pers. comm. 2012). Long-term survival rates of WWP tend to follow expectations that resistant stock will perform better than unimproved stock, but rates of infection and mortality may still be high (Fins and others 2002, Bishaw and others 2003, Kearns and others 2012). Ultimately, field infection and survival show strong correlations with abiotic site factors (such as temperature, humidity, and presence and density of the alternate host, *Ribes* spp.), with trees growing on more susceptible sites exhibiting higher levels of infection and mortality (Bishaw and others 2003, Kearns and others 2012).

A synthesis of WBP seedling survival 3 to 15 years postplanting on 36 sites averaged 38 percent (range 19 to 78 percent), while first year survival at more recently planted sites was much higher at 74 percent (range 56 to 95 percent) (Izlar 2007). In WBP seedlings planted in four different physiographic conditions on the Gallatin National Forest (MT), 10-year survival rates ranged from 2 to 47 percent when 2-year survival was originally 58 to 100 percent (McCaughey and others 2009). This was echoed in our survey respondents where early WBP survival rates, in general, were high (table 4). Herbivory by pocket gophers was consistently noted as a cause of mortality, as was competition with other tree species and vegetation, including beargrass (*Xerophyllum tenax* [Pursh] Nutt.). These observations are also recorded in published literature (Izlar 2007, McCaughey and others 2009). Research indicates that ectomycorrhizal fungi may also influence seedling survival (Mohatt and others 2008, Cripps and Grimme 2011). Limber pine seedling survival was reported as low in some areas where postplanting summers were hot and dry; however, survival seems to be improving with increasing planting experience (Asebrook and others 2011, Smith and others 2011, Casper and others 2011) (table 4). Plastic netting was used to protect outplanted seedlings in Waterton National Park; those with netting were taller than those not protected, but the netting did not increase survival (Smith and others 2011). Survival was highest in areas planted with LP under denser overstory canopy cover; microsite planting appeared to improve health and survival where implemented (Casper and others 2011). An experimental planting of GBBP in California demonstrated the important effects of microsite on survival with 3-percent survival in open conditions, 10-percent survival under sagebrush cover, and 28-percent survival under wood pieces (C. Maher, pers. comm. 2012). Herbivory from small mammals was a major cause of mortality in forested areas but not outside the forest (C. Maher, pers. comm. 2012). Southwestern white pine seedlings will be operationally planted as a minor component (10 percent) in burned areas of northern Arizona in 2012 and 2013 with ponderosa pine, Douglas-fir, and white fir (A. Stevenson, pers. comm. 2012).

Direct Seeding Trials

Managers and researchers have limited success when direct seeding WBP and LP by caching clusters of seeds underground (Tomback and others 2005, Smith and others 2011, Schwandt and others 2011, McLane and Aitken 2012). Steel wire mesh “hardware cloth” can be used for seed protection, although predation may still occur (Tomback and others 2005, Schwandt and others 2011, Smith and others 2011). Where seeds are buried (plant litter versus soil) also affects germination (Tomback and others 2005). Whitebark pine direct seeding efforts in Glacier National Park had only 3 of 723 seeds germinate (Asebrook and others 2011). In Waterton Lakes National Park, 144 out of 338 cached LP seeds germinated by year 2, but 72 percent of the 133 monitored seedlings died by year 2 (Smith and others 2011). Schwandt and others (2011) conducted direct seeding trials of WBP in Oregon, Montana, and the Idaho/Montana border and found that survival was greatest in caged seeds. These and other WBP seed trials are continuing and being monitored for survival (C. Jensen, pers. comm. 2012). Assisted migration trials of WBP using direct seeding practices (two-seed caches) have found that seeds germinated across all planting areas, even outside the current WBP distribution (McLane and Aitken 2012). Seed sorting (by x-ray) and treatments (stratification and nicking seed coats) affected germination, while seed mass, temperature, and snowpack variables influenced survival and growth (McLane and Aitken 2012).

Regeneration Research Needs, Current Projects, and Management Perspectives

Some survey respondents felt that artificial regeneration of 5NPs, particularly SP and WWP, was fairly well understood, with few research needs. Other managers had specific species questions that could be answered by those with more experience or by existing research (table 5). We strongly recommend managers and researchers communicate frequently to share information and answer questions posed by those with less experience. Themes across species included a strong need for continuation of the resistance and breeding work, including seed collections, screening, and resistance durability (table 5).

A number of ongoing research projects were consistently highlighted as important by survey respondents, including ongoing disease screening trials and research to test the resistance durability under virulent strains of WPBR (A. Schoettle, pers. comm. 2012, Sniezko and others 2011b). In addition, field trials are underway in Oregon and Washington to validate resistance results from artificial inoculation trials and to follow resistance durability of WWP, SP, and WBP (R. Sniezko, pers. comm. 2012). Development of effective WPBR site hazard rating systems was noted as extremely important in durability testing and choosing where to plant. Ongoing research related to seedling physiology and seed germination may facilitate applications to long-term survival as well (C. Harrington, pers. comm. 2012). In western Montana, field trials comparing cold hardiness and success of stock produced from seed orchard seed with natural reproduction are planned on the eastern edge of the WWP range (B. Larkin, pers. comm. 2012), and other studies on adaptive traits are ongoing for several 5NP species (table 5). Current research in WBP and WWP incorporating ectomycorrhizal associations with seedling survival and the role of endophytes in resistance and survival were listed as promising and necessary (Cripps and Grimme 2011, Larkin and others 2012). Direct seeding, including the development of seed protection and treatment protocols, was stressed as a knowledge gap for WBP and LP and could lead to larger operational plantings. Managers appear confident in the WBP restoration programs across the regions (Mahalovich and Dickerson 2004, Aubry and others 2008, Mahalovich 2011) but listed needs to improve seedling quality and reduce costs. There appears to be a need in the northern range of WBP to determine whether methods developed elsewhere are sufficient farther north. For RMBP, GBBP, SWWP, and FP, very little regeneration and outplanting information exists, which increases the need to quantify and define nearly everything associated with successful restoration of these species (figure 6, table 5).

The virulent strains of the WPBR pathogen affecting WWP and SP have left some managers feeling vulnerable to high loss and advocating for research into clonal propagation of seedlings with durable resistance (table 5). In addition, we found regional differences in attitudes about 5NP, in particular for WWP. We routinely heard that managers are not achieving the success rates they expected from resistant stock, which can lead to reluctance in investing limited resources into a species with high mortality rates. Collaborations in place may need to emphasize realistic expectations of gain and mortality, in addition to the general importance of these species in the landscape. The current 60- to 70-percent survival rate of WWP on low to moderate hazard sites is encouraging from a genetics perspective but is often considered too low and too costly by managers.

Table 5. Research and monitoring needs identified by survey respondents for seven five-needle pine species: SP = sugar pine, WWP = western white pine, WBP = whitebark pine, LP = limber pine, RMBC = Rocky Mountain bristlecone pine, GBBC = Great Basin bristlecone pine, and SWWP = southwestern white pine.

Research and monitoring needs listed by survey respondents	Species						
	SP	WWP	WBP	LP	RMBC	GBBC	SWWP
Continuation of the breeding program to maintain durable resistance	X	X	X				
Continued screening for resistance	X	X	X	X	X	X	X
Histology of white pine blister rust (WPBR): mechanisms of infection, resistance and tolerance, and interactions between the host and pathogen		X	X	X	X		X
Continued research on inheritance of WPBR resistance mechanisms	X	X	X	X	X		X
Species genomics to speed the screening process using genetic markers	X	X	X	X	X		X
Continued work on operational (pathological) pruning	X	X		X	X		
Development of effective site hazard rating systems	X	X	X	X	X	X	X
Species adjacency and growth response	X	X					
Long-term plantation and operational planting success (>20 yrs old), including resistant vs. nonresistant survival rates	X	X					
Other pathogen ecology and damage	X			X	X	X	X
Why regeneration is less after clearcut harvesting	X						
Where should planting occur to maximize genetic mixing (near healthy/declining populations? In areas where species used to exist?)	X			X			
Rangewide understanding of population structure (including hybrid zone) and gene flow			X	X			X
Management options for introducing resistant trees in late successional reserves under the new Northwest Forest Plan		X					
Can seedling production be altered to lower susceptibility to ungulate browse?		X					
Ribes ecology and distribution maps		X					
Continued work on mycorrhizal relationships/seedling survival			X	X			
Climate change effects on species and ecosystem interactions, assisted migration, seed transfer guideline adjustments			X	X	X	X	X
Adaptive traits and resistance relationships			X	X	X	X	X
What is the best site prep to support high survival of planted seedlings? In areas where you cannot Rx burn?			X	X			X
When is the optimal time in the invasion process to plant resistant stock or stimulate natural regeneration in populations with resistance? Under what conditions?				X	X	X	X
Outplanting survival (< 20 yrs) (seasonality, microsites, locations)			X	X	X	X	X
What is the potential for understory release for different species?			X	X			
Seed storage, germination knowledge, effective planting strategies					X	X	X
Determine best season to plant				X	X	X	X
Reduce seedling costs			X				
Operational direct seeding			X	X			

Roles of Managers in 5NP Management

Survey responses regarding what the role of managers should be in 5NP research and management fell into three major categories: collaboration, management strategies, and policy/funding. Continued collaboration across regions and institutions was deemed important for all 5NP species. Working collaborations already exist for WWP and SP in Oregon and Washington, SP in California, WWP in the Inland Northwest, WBP in Oregon, Washington and the Interior West, and LP in the southern Rocky Mountains. Every 5NP species needs (and seems to have) a group of committed managers, researchers, and academics for species persistence in our current and future landscapes.

Managers are critical to the continued maintenance and restoration of these species; as such, they need to be informed of the most up-to-date strategies and tools available for successful management. Specific tools include hazard rating and site selection, resistant stock availability, silvicultural tools, and regeneration/species ecology. Managers can then use these best management practices for each species, evaluate and support continued research, and aggressively deploy hearty,

Figure 6. Newly emerged southwestern white pine seedling being grown for research. (Photo source: Betsy Goodrich, Northern Arizona University, 2012).

resistant stock. Managers must also embrace some level of flexibility in meeting stand management goals, and implement adaptive management and continuous monitoring of plantings and natural regeneration.

Finally, managers have a role in the funding and policy aspects of 5NP management. This may include everything from securing funding for seed collections and outplanting pilot programs, securing sites for field resistance trials, continuing and/or finding more commercial applications for the nontimber species, and writing restoration plans. To be successful, managers need to be aggressive in communicating to upper level management that these species should remain present on the landscape and in facilitating grassroots organizations and volunteer opportunities to keep species visible to nonscientific communities. Managers needing to meet economic objectives may have difficulty explaining high losses from planted trees and be encouraged to plant other species instead; in such instances, having strong backing from researchers and specialists may enable continued planting even with economic loss. Some survey respondents said that industry, employers, and stakeholder groups needed to be convinced that conservation and restoration are necessary. In speaking with managers, we found this principle already deeply embedded in the management of both WWP and SP, suggesting that communication needs to occur in both directions. Perhaps the most important role is finding creative means and partnerships for securing the funding required to conserve and restore 5NP species.

Conclusions

Across the West, a dedicated and diverse array of people continues long-standing efforts to perpetuate, conserve, and restore 5NP in the landscape. Experience from SP and WWP has carried over to more recent work in WBP and other high-elevation 5NP species; continued research and management successes across all species should be shared to ensure a greater proportion of success. Regeneration of 5NP increases the diversity of western forests, and deployment of resistant genes into the landscape paves the path for future self-sustaining and genetically diverse 5NP populations. We appreciate the dedication of those involved in artificial regeneration efforts in 5NP, the enthusiasm of most people for our project, and their willingness to spend valuable time providing the information presented here (appendix A). We welcome additions to our data and would be glad to help connect managers, researchers, horticulturists, academics, volunteers, and any others interested in perpetuating 5NP in the West.

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Acknowledgments

The authors thank the many people listed in appendix A for the advice, information, and reviews they provided. In particular, Richard Sniezko and Mary Frances Mahalovich were instrumental in helping us complete this project.

Appendix A. Names and titles of survey respondents. Contact information provided with permission of respondents.

Contact		Title	Company/agency/university	E-mail
Asebrook	Jennifer	Biological Science Technician	Glacier National Park, Montana	
Beck	Jen	Botanist	Crater Lake National Park, Oregon	jen_beck@nps.gov
Boom	Bruce	Placerville Nursery Manager	Pacific Southwest Region Genetics—Sugar Pine Rust Resistance Program, Placerville Nursery—Eldorado National Forest, California	
Bower	Andy	Area Geneticist and Pacific Northwest Region Whitebark Pine Restoration Program Lead	Olympic National Forest, Washington	abower@fs.fed.us
Brusven	Annette	Nursery Sales and Extension Associate	University of Idaho Pitkin Forest Nursery, Idaho	
Buermeyer	Karl	North Zone Vegetation Manager	Blackrock Ranger Station, Bridger-Teton National Forest, Wyoming	
Clason	Alana	PhD Student	Bulkley Valley Research Centre, University of Northern British Columbia, Canada	
Crawford	Mike	Seed Orchard Program Manager, Tyrell Seed Orchard	Bureau of Land Management, Oregon	
Daily	John	District Silviculturist	Okanogan-Wenatchee National Forest, Washington	
Dittman	Sidnee	Forestry Technician/Culturist	Idaho Panhandle and St. Joe National Forests, Idaho	
Dowling	Chris	Supervisory Forester/Timber and Vegetation Program Manager/Forest Silviculturist	Olympic National Forest, Washington	cdowling@fs.fed.us
Dunlap	Joan	Forester/Geneticist	Pacific Southwest Region Genetics—Sugar Pine Rust Resistance Program Placerville Nursery—Eldorado National Forest, California	
Eggleston	Ken	Horticulturist/Forester	Coeur d' Alene Nursery, Idaho	
Gilbert	Richard	Nursery Manager	Charles E. Bessey Nursery, Nebraska	regilbert@fs.fed.us
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Harrington	Connie	Research Scientist	USDA Forest Service, Pacific Northwest Research Station, Washington	charrington@fs.fed.us
Henneman	Dave	Natural Resource Specialist	Bureau of Land Management, Oregon	
Jacobi	William	Professor, Plant Pathology	Colorado State University, Colorado	
Jebb	Tamara	Horticulturist	Bureau of Land Management, Oregon	
Jenkins	Melissa	Forest Silviculturist	Flathead National Forest, Montana	mmjenkins@fs.fed.us
Jensen	Chris	Genetics and Reforestation Forester	Bend Ft. Rock Ranger District, Deschutes National Forest, Oregon	
Jopson	Tom	Owner	Cal-Forest Nursery, California	
Jungck	Ellen	Zone TMA/Silviculturist	Shoshone National Forest, Wyoming	
Keane	Robert	Research Ecologist	Rocky Mountain Research Station Missoula Fire Sciences Laboratory, Montana	rkeane@fs.fed.us
Kearns	Holly	Plant Pathologist	USDA Forest Service, Forest Health Protection, Oregon	
Klinke	Mark	Forest Culturist	Clearwater National Forest, Idaho	
Larkin	Beau	Research Scientist and Property Manager	MPG Operations, Montana	beaularkin@mpgranch.com
Livingston	Dan		Pacific Regeneration Technologies, Inc., Canada	
Lunak	Glenn	Tree Improvement Manager	Sierra Pacific Ind., California	
Maher	Colin	PhD Student	University of Montana, Montana	

Appendix A. Names and titles of survey respondents. Contact information provided with permission of respondents. (continued)

Contact		Title	Company/agency/university	E-mail
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Nakae	Jon	South Zone Silviculturist	Gifford Pinchot National Forest, Washington	jnakae@fs.fed.us
Niman	Randy	Vegetation Manager	Chelan District, Okanogan-Wenatchee National Forest, Washington	
Omdal	Daniel	Forest Pathologist	Department of Natural Resources, Washington	DANIEL.OMDAL@dnr.wa.gov
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Sanchez-Meador	Andy	Forest Restoration Program Manager	Lincoln National Forest, New Mexico	
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Smith	Cyndi	Conservation Biologist	Waterton Lakes National Park, Canada	Cyndi.Smith@pc.gc.ca
Sniezko	Richard	Center Geneticist	Dorena Genetic Resource Center, Oregon	
Somers	Ken	Professional Forester	Blodgett Forest, University of California—Berkley, Center for Forestry, California	
Stevenson	Andy	Silviculturist	Coconino National Forest, Arizona	
Stubbs	Donna	Assistant Forest Silviculturist (Genetics-FACTS-Silviculture)	Fremont-Winema National Forests, Oregon	
Tomback	Diana	Professor	Department of Integrative Biology, University of Colorado, Denver, Colorado	
Trobaugh	John	Program Manager	Webster Forest Nursery, Washington	
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Violett	Paul	Chief Forester	Soper-Wheeler Company, LLC, Calfornia	
Vogler	Detlev	Research Geneticist/Plant Pathologist	USDA Forest Service, Pacific Southwest Research Station, Institute of Forest Genetics, California	
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Wilcox	Craig	Forest Silviculturist	Coronado National Forest, Arizona	
Wunz	Eric	District Silviculturist	Blue Mountain Ranger District, Malheur National Forest, Oregon	

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