EVIDENCE-BASED REVIEW OF SEEDING IN POST-FIRE REHABILITATION AND NATIVE PLANT MARKET FEASIBILITY

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ABSTRACT

EVIDENCE-BASED REVIEW OF SEEDING IN POST-FIRE REHABILITATION AND NATIVE PLANT MARKET FEASIBILITY

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A changing climate and fire regime shifts in the western United States have led to an increase in revegetation activities, in particular post-wildfire rehabilitation and the need for locally-adapted plant materials. Broadcast seeding is one of the most widely used post-wildfire emergency response treatments to minimize soil erosion, promote plant community recovery, and reduce non-native species invasions. However, these treatments can have negative ecological effects, due in part to the continued use of non-native species, although the use of native species has increased.

We undertook an evidence-based systematic review to examine post-fire seeding treatments´ effectiveness and effects on soils and plant communities in forests of the western U.S. Out of the 27 studies providing evidence regarding post-fire seeding effects on soil erosion, 33% of the studies showed seeding to be effective, an equal percentage of studies (26% each) showed minimal effectiveness or ineffectiveness, and 15% showed no difference in effectiveness of seeding in minimizing soil erosion. However, based on quality of evidence criteria, only one of 12 studies reported in the two highest quality categories qualified seeding effectiveness for soil erosion. Seventy-eight percent of study sites in publications evaluating soil erosion showed that seeding provides no additional benefit in reducing erosion relative to unseeded controls. Studies consistently showed that seeding reduced native species cover (62%) and/or suppressed recovery of native plants (60%), although long-term data on these effects are limited. Seeding was effective

in reducing non-native species invasions 54% of the time; however, of those treatments, 83% introduced additional negative impacts on native communities by seeding with non-native species. Post-fire seeding is costly and the scientific literature and management documentation show that it does little to protect soil and promote plant recovery in the short-term and may introduce potentially negative effects with long-term ecological consequences.

Through a literature search, interviews and site visits, we identified existing native plant markets to use as models to assess the feasibility of a native plant market in the southern Colorado Plateau. We used web-based surveys to identify critical native plant material needs and concerns. Survey results indicate that management policy strongly drives decisions regarding the use and purchase of native plant materials. From a demand perspective, lack of availability and high cost of native plant materials has kept purchasing minimal, despite policy changes favoring the use of natives. For suppliers, further development of native plant materials is limited by inconsistent and unreliable demand and lack of production knowledge. The knowledge and tools necessary to initiate a native plant materials market are available. However, communication among producers, land managers, buyers, and researchers, as well as partnerships with local growers, appear to be vital to initiating a functional market.

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PREFACE

This thesis contains two chapters intended for publication and is written in manuscript format. The manuscripts are Chapter 2: “Does seeding after severe forest fires in the western USA mitigate negative impacts on soils and plant communities?” and Chapter 3 “Market perceptions and opportunities for native plant production on the southern Colorado Plateau.” Tables, figures, and a list of literature cited appear at the end of each chapter. Chapter 2 and 3 use “we” instead of “I” because these papers have co-authors. The text has been edited to avoid redundancy wherever possible.

CHAPTER ONE

Introduction

Over the past century, land use and management practices in conjunction with changing climate conditions have led to alteration of native ecosystems and fire regime shifts in the western United States (Covington and Moore 1994; Belsky and Blumenthal 2002; Westerling et al. 2006). In recent decades, areas of high-severity forest fires have increased by as much as an order of magnitude in the western United States (Westerling et al. 2006). Climate projections consistently indicate that trends of altered precipitation patterns and increasing size and severity of wildfires will continue (McKenzie et al. 2004; Westerling et al. 2006; Seager et al. 2007). A changing climate and fire regime shifts may have direct effects on local plant community composition and structure (Hanson and Weltzin 2000; Wang and Kemball 2005; Hunter and Omi 2006) and fire relations within communities (Ryan 1991; Bachelet et al. 2001). In light of these concerns, interest in restoring these disturbed lands has become more widespread (Allen et al. 2002; McKay et al. 2005).

Post-fire emergency rehabilitation efforts have increased in the western United States in response to the growth in severe wildfires (Robichaud et al. 2000). According to recent reviews (Robichaud et al. 2000; Beyers 2004), broadcast seeding is one of the most widely use and cost-effective post-fire emergency response treatments to minimize soil erosion, promote plant community recovery, and reduce non-native species invasions in forested ecosystems throughout the West (Richards et al. 1998; Robichaud et al. 2000; Beyers 2004). Previous post-fire seeding research has indicated that seeding treatments often do not result in high vegetative cover and can negatively impact native plant communities (Robichaud et al. 2000; Beyers 2004) by competing with recovering native species (Schoennagel and Waller 1999; Barclay 2004; Keeley 2004; Kruse et al. 2004), persistence of seeded non-native species (Sexton 1998; Barclay et al. 2004; Hunter et al. 2006), introducing non-natives (Sexton 1998; Hunter et al. 2006) and changing fine fuels which may further alter fire regimes (Schoennagel and Waller 1999; Keeley 2004). Thus, seeding may impose long-term ecological changes to ecosystem composition and structure (Beschta et al. 2004).

Since the reviews by Robichaud et al. (2000) and Beyers (2004), several important developments have altered the context of post-fire seeding: 1) increasing size and severity of wildfires across the West (McKenzie et al. 2004; Westerling et al. 2006); 2) increased use and allocation of funds for native seed mixes (Wolfson and Sieg, in press); 3) increased research on post-fire seeding and plant community interactions; and 4) stronger policy direction for the use of genetically appropriate seed sources (seed sources adapted to local site conditions and genetically compatible with existing plant populations) and quantitative monitoring (GAO 2003; USDA 2006). In Chapter 2, I present a systematic evidence-based review of the scientific literature, theses, and burned area rehabilitation monitoring reports to provide an up-to-date synthesis of knowledge about post-fire seeding in forested ecosystems across the western U.S. and its effects and effectiveness on soils and native plant communities.

In recent years, major wildfires such as the 2000 Cerro Grande and the 2002 Rodeo-Chediski have become primary drivers of revegetation activities, and more specifically, post-fire seeding efforts in the Southwest (Friederici 2003). Revegetation policies have recently begun to recognize the importance of using genetically-appropriate materials during restoration and rehabilitation activities (Richards et al. 1998, Erickson 2008). However, although national policies for federal land management agencies direct the use of locally-adapted plant species as a first choice in revegetation activities, the use of non-native species in revegetation projects throughout the region continues. Justifications for non-native plant use include the increasing need for post-fire emergency rehabilitation as well as the limited availability and high cost of locally-adapted plant materials.

New revegetation policies and funding sources have emerged as a result of increased recognition from Congress of the need for an abundant supply of native plant materials and the establishment of the Federal Interagency Native Plant Materials Development Committee in 2000 (USDA and USDI 2002). Since 2000, interagency projects have been developed to meet the need for increased native plant material availability and production information (Pellant et al. 2004; Shaw et al. 2005). Unfortunately, only minimal native plant production efforts currently exist in the Southwest and, due to scarcity locally-adapted plant materials, regional projects frequently incorporate genetic materials from distant sources which may have negative effects on native plant communities (Lynch 1991; Hufford and Mazer 2003). In response to the need for native plant materials in the Southwest, in Chapter 3 I assess the prospects for a native plant market on the southern Colorado Plateau.

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CHAPTER TWO

Does seeding after severe forest fires in the western USA reduce negative impacts on soils and plant communities?

Abstract

Broadcast seeding is one of the most widely used post-wildfire emergency response treatments intended to minimize soil erosion, promote plant community recovery, and minimize establishment and spread of non-native plant species. However, these treatments can also have negative effects, including facilitation of weed invasions and competition with recovering native plant communities. We conducted an evidence-based review to examine the effectiveness and effects of post-fire seeding treatments on soil stabilization and plant community attributes in western U.S. forests. We reviewed 94 scientific papers, theses, and agency monitoring reports selected using a systematic search protocol. The majority of studies (78%) evaluating soil erosion in seeded versus unseeded controls showed that seeding did not reduce erosion relative to unseeded controls. Even when seeding significantly increased vegetative cover, seeded sites rarely supported sufficient plant cover to stabilize soils within the first and second year post-fire. A majority of studies reported that seeding reduced native species cover (62%) and/or suppressed (60%) recovery of native plants, although long-term data on these effects are limited. According to papers evaluating seeding effectiveness for curtailing invasions of non-native plant species, an almost equal percentage found seeding treatments to be an effective (54%) or ineffective (45%) measure to reduce non-natives. However, 83% of treatments regarded as effective caused additional negative impacts on native communities by seeding with non-native species. The use of native species has increased in recent years; yet use of non-native annuals continues. Some native species

used may not be locally-adapted and genetically-appropriate (seed sources adapted to local site conditions and genetically compatible with existing plant populations) for areas seeded. The scientific literature and management documentation suggest that costly post-fire seeding does little to protect soil and promote plant recovery in the short-term and has potentially negative effects with long-term ecological consequences.

Introduction

Land management agencies in the U.S. such as the Forest Service, National Park Service, Bureau of Land Management are required by federal burned area emergency rehabilitation policy (USDI and USDA 2006) to prescribe emergency watershed-rehabilitation measures when and where deemed necessary to: 1) stabilize soil; 2) control water, sediment, and debris movement; 3) prevent ecosystem degradation; and 4) minimize threats to human life or property. Historically, aerial broadcast seeding of grasses, typically non-native annuals or short-lived perennials, has been the most commonly used post-fire rehabilitation treatment (Robichaud et al. 2000; Beyers 2004). As an emergency treatment, rapid vegetation establishment has been regarded as the most cost-effective method to mitigate the risks of increased runoff and soil erosion, and establishment of non-native species (Richards et al. 1998; Robichaud et al. 2000; Beyers 2004; Wolfson and Sieg, in press). Federal policy in the U.S. currently mandates use of seed from native species for post-fire rehabilitation when available and economically feasible (Richards et al. 1998). Although the use of native species has increased (Beyers 2004; Wolfson and Sieg, in press), high costs and limited availability often limits inclusion of native plants in post-fire seedings. Furthermore, a vague definition of the term “native” has led to broad and inconsistent interpretations regarding the types and origins of native species used (Richards et al.1998) and concerns over their use. Despite ongoing debates over the efficacy of post-fire seeding and potential negative impacts on natural plant community recovery, seeding remains a widely used rehabilitation treatment in forested ecosystems throughout the West (Robichaud et al. 2000, Beyer 2004).

Robichaud et al. (2000) published an extensive review summarizing the effectiveness of post-fire rehabilitation treatments used by the U.S. Forest Service. Among other topics, the review addressed post-fire seeding, a practice Robichaud et al. (2000) described as the most widely used post-fire rehabilitation treatment. Studies occurring in chaparral and conifer forests suggested that seeding did not consistently assure high plant cover during the critical first year after burning. In nine seeding studies in conifer forests providing quantitative ground cover data from seeded and unseeded treatments, about a third of seeding treatments reported less than 30% ground cover and less than a fourth of these treatments provided at least 60% ground cover, the percentage of ground needed to adequately reduce soil erosion in the first year post-fire (Noble 1965; Orr 1970). A recent review of post-fire seeding effectiveness (Beyers 2004) reported that seeding seldom produces effective cover to mitigate erosion; however, in cases where post-fire growth of seeded species provides adequate cover to substantially reduce erosion (> 60%), seeding can suppress native plant community recovery including shrub and tree seedlings. Both reviews recognized the importance of quantified monitoring to properly evaluate the effectiveness and impacts of post-fire seeding.

Since publication of Robichaud et al. (2000) and Beyers (2004), several developments have altered the context of post-fire seeding, including increasing size and severity of wildfires across the West (McKenzie et al. 2004; Westerling et al. 2006), increased use and allocation of funds for native seed mixes (Wolfson and Sieg, in press), increased research and quantitative monitoring on post-fire seeding and plant community interactions, and stronger policy direction for the use of locally-adapted and genetically appropriate seed sources (seed sources adapted to local site conditions and genetically compatible with existing plant populations) (GAO 2003; Rogers and Montalvo 2004; USDA 2006).

We conducted an evidence-based systematic review of the scientific literature, theses, and burned area rehabilitation monitoring reports to provide an up-to-date synthesis of knowledge about post-fire seeding in forested ecosystems across the western U.S. We addressed three questions pertaining to post-fire seeding relative to overall treatment effectiveness and effects on soils and plant communities: 1) Does seeding after severe forest fires reduce soil erosion? 2) Does seeding after severe forest fires reduce negative impacts on plant communities? and 3) Does seeding curtail and/or introduce non-native species?

Methods

The systematic review methodology is relatively new in natural resource disciplines but has been widely used in medical sciences (Fazey et al. 2005, Pullin and Stewart 2006). This methodology follows a rigorous, predetermined protocol to ensure that the synthesis of available literature is thorough, unbiased, and evidence-based. We conducted a formal systematic review using guidelines established by Pullin and Stewart (2006). The guideline stages were: 1) question formulation; 2) protocol formation and search strategy; 3) data extraction; and 4) analysis. A team of five members planned and conducted the review.

For this review, we defined forested ecosystems as those dominated by tall-stature coniferous and/or deciduous trees occurring at elevations above grasslands, pinyon-juniper woodlands, or chaparral vegetation in the western U.S. The review team developed primary and secondary study questions, which were further refined by managers, scientists, and outside experts.

We developed a review protocol which guided decisions regarding sources of information included in the synthesis. Key decisions included: 1) search, inclusion, and rejection criteria; 2) extracting evidence; and 3) comparing evidence. Managers and scientists in the field reviewed the protocol. Additionally, we submitted our review to The Centre for Evidence-Based Conservation (http:\\www. cebc.banor.ac.us/index.htm), an international organization that hosts systematic review protocols online and facilitates review by a worldwide audience.

We searched online databases (JSTOR, Google Scholar, Forest Science Database, Ingenta, Web of Science, AGRICOLA), online government collections, and electronic university libraries using combinations of key search terms: seeding AND fire, seeding AND burn, seeding AND wildfire, seeding AND erosion, and seeding AND native species. Referred journal articles, peer-reviewed reports (such as government documents and conference proceedings), theses, and unpublished literature were considered during our search. Potential studies were then evaluated for inclusion using specific criteria based on the subject, treatment, and outcome of the study.

- *Subject(s) studied* – Seeding studies conducted in forests burnt by wildfire in the U.S., predominately coniferous forests of the West since 1970. Experimental seeding studies in controlled burns, such as prescribed fires, were also included if the information was deemed relevant to post-fire seeding. Non-wildfire seeding data were summarized separately from wildfire data.
- *Treatment(s)* – Seeding herbaceous plant or shrub seed alone or in combination with other post-fire rehabilitation activities such as mulching, fertilizing, water-bars, and log erosion barriers.
- *Outcome(s)* – Change in plant community attributes such as cover, richness diversity, biomass, and composition of native and non-native herbaceous plants and shrubs, and soil stabilization attributes (runoff, surface erosion, sediment yield).

All potentially relevant publications were imported into a database. Those publications listed as "possibly relevant" were examined by the review coordinator for final inclusion decisions. Duplicate references were discarded from the database. The total number of articles found in the search, those rejected under the inclusion criteria, and those ultimately used in the review are shown in Table 1.

Qualitative data extracted from the reviewed papers included study design, land and fire attributes, types of treatments, study results, and conclusions. We characterized the types of plant species seeded as non-native or native, in most cases following the author's classifications from the paper. When available, information about the origin of seed sources used is presented. However, lack of a widely accepted definition of "native"

(Jones 2003) may cause definitions to differ between papers. Quantitative data included all relevant variables related to soil and/or plant community attributes. In some instances, authors reported results from the same fire in different papers. In these cases, data from each paper were extracted independently but the overlap in studies was noted.

For consistency, each paper was reviewed by two members of the review panel. Reviewers did not evaluate papers they authored. After all publications were reviewed twice we formed a master list of all publications and reviews; this list was then reviewed by the review coordinator to locate any inconsistencies in recorded data which were discussed with panel members and resolved through consultation with the review coordinator.

We developed criteria to evaluate the the strength of evidence in each study based on design and statistical robustness (Table 2). We judged post-fire seeding effectiveness based on the treatment's ability to mitigate negative impacts in three categories: 1) erosion control; 2) plant communities; and 3) non-native species (Table 3); then we evaluated post-fire seeding treatment effectiveness in relation to these impact categories (Table 4). When available, quantitative data from seeded and unseeded treatments were compared. Some studies had multiple sites; we made comparisons based on the number of sites instead of the total number of publications. We used descriptive statistics and correlation/regression to explore relationships between post-fire seeding treatments and associated variables as well as the influence of time since fire. Regression analysis was completed using an alpha level of .05.

Erosion control is strongly related to the amount of cover (Robichaud et al. 2006; Rough 2007), so we used increased plant cover (hereafter "success") as an indicator of potential erosion control effectiveness (Dadkhah and Gifford 1980; Bruggink 2007). We assessed seeding "success" in the first and second year after fire from studies comparing seeded treatments to unseeded plots. Following the example of Robichaud et al. (2000), we used two levels of cover in assessing seeding effectiveness in reducing erosion potential: > 30% and > 60%. We divided relevant papers into ecoregions (Bailey 1983) for further analysis of climatic influences.

For each review question, we drew conclusions (when possible) based on data from 1970 to 1999 (papers previously reviewed by Robichaud et al. 2000), and since 2000. The latter date was chosen to follow the most comprehensive previous review of post-fire seeding (Robichaud et al. 2000).

Results and Discussion

Considering the entire dataset (*n* = 94, Appendix I), the largest category of papers reviewed was replicated and randomized experiments (19%, Fig. 1). In the most recent period, 2000-2009 (*n* = 57), there was an increase in replicated randomized experiments (46%), review papers (29%), and expert opinions (27%). Using quality of evidence criteria, during the time period between 1970 and 1999 (*n* = 37), 6 papers (16%) were of highest quality, 5 papers (14%) were of high quality, 4 papers (11%) were of medium quality, and the majority (22 papers, 60%) were in the low and lowest quality category (Fig. 2). From 2000 to 2009 the number of papers in these categories changed slightly with the greatest increase in the high quality of evidence category (16 papers, 28%); 11 papers (19%) were of highest quality, 6 papers (11%) were of medium quality; 5 papers

(9%) were of low quality, and one-third fell into the lowest quality category (19 papers, 33%).

In the overall set of papers, a majority of information on seeding comes from well designed experimential studies. However, in recent years since the publication of reviews by Robichaud et al. (2000) and Beyers (2004), there has been greater emphasis on study designs of quantitative experimental nature (Fig. 3).

Does seeding after severe forest fires in western USA reduce soil erosion?

Of the entire data set, 27 studies provided evidence regarding post-fire seeding effects on soil erosion. Authors defined erosion control in terms of decreased sediment yield, runoff, or surface erosion. Using effectiveness ratings described in Table 4, 33% of studies showed seeding, with non-native and/or native species, to be effective, an equal percentage (26%) showed minimal effectiveness or complete ineffectiveness (26%), and 15% showed no difference in effectiveness of seeding in reducing erosion. However, the evidence for seeding effectiveness dropped substantially when the quality of evidence criteria was considered: two of the four studies with highest quality evidence found seeding to be ineffective in reducing soil erosion while the other two found no difference in effectiveness when compared to unseeded control plots. For example, Robichaud et al. (2006), in a study conducted in north-central Washington, used a randomized block design of four plots (each plot with a different experimental treatment) with control treatments, replicated eight times to compare the effects of seeding with winter wheat (*Triticum aestivum*) and fertilizing on post-fire erosion rates. They found no reduction in erosion rates for seeding or fertilization treatments, alone, or in combination at any time during the four-year study. Five of the eight studies with high quality evidence found seeding to be ineffective while two of the other three studies reported minimal effectiveness. The remaining study in the high quality evidence category reported that seeding (seeded species unknown) was effective for erosion only in combination with mulching and log erosion barriers on a fire in southwestern Colorado (DeWolfe et al. 2008). Using the two highest quality categories, only one of 12 studies reported qualified seeding effectiveness for soil erosion. Support for seeding effectiveness was apparent only in studies with lower quality evidence. Only one of the three studies having medium quality, three of the four studies having low quality evidence, and all of the eight studies with lowest quality evidence found seeding to be effective or minimally effective in reducing erosion. In one publication having lowest quality evidence, two study areas (non-random, unreplicated, and uncontrolled) were set up within a single burned area in the Black Hills, South Dakota, each with eight plots to assess sedimentation and runoff. This study revealed that a mixture of seeded non-native and legume species dominated the cover at both sites throughout the study and further postulated that neither site would have reached a 60% ground-cover requirement for minimum soil stability within four years without seeding (Orr 1970).

As sampling designs have become more rigorous in recent years, evidence that seeding is ineffective in reducing erosion has strengthened. Papers published since 2000 (16 total) conclude that seeding is ineffective or has no difference in effectiveness compared to control treatments in reducing soil erosion (50% each), whereas 27% of papers published before 2000 (11 total) suggest seeding as ineffective and 9% having no difference in effectiveness compared to controls. Only 9% of earlier papers met the criterion of highest or high quality, whereas 71% of papers since 2000 met this criterion.

Post-fire sediment yields in forested ecosystems in the West are most closely associated with the amount of surface erosion and rainfall erosivity (MacDonald and Larsen, in press), so studies providing erosion data (n = 9) used direct measures of sediment yield in seeded versus unseeded sites to assess post-fire seeding effectiveness. Seeded sites produced less sediment more often than did unseeded sites (Fig. 4). However, 78% found no statistically significant decrease in erosion relative to unseeded sites. The nonsignificant trend toward sediment yield reduction in the first year decreased in measurements in the second year and even more so into the third, fourth, and fifth year post-fire. This indicates that seeding had no additional benefit in reducing erosion relative to unseeded sites within any study period.

Comparing cover measurements between seeded and unseeded plots across 20 studies containing a total of 29 study sites, forty-one percent (12 sites) of study sites found that seeding significantly increased total plant cover by the end of the first year after fire (Table 5). Fifty-five percent (16 sites) of the seeded sites had greater than 30% total plant cover in the first year after fire, compared to only 31% (9 sites) of the unseeded sites. Fourteen percent (4 sites) of seeded sites had more than 60% total plant cover after the first year post-fire, compared to none of the unseeded sites. As 60% total plant cover is typically regarded as the threshold to reduce soil erosion following fire events (Noble 1965; Orr 1970), we infer that about one-seventh of the seeded sites supported sufficient cover to effectively prevent soil erosion in the first year after fire. None of the unseeded sites met the 60% plant cover target. Of the 12 sites were erosion was measured, none showed that seeding significantly reduced erosion in the first year after fire.

In the second year after fire, seeded sites were nearly four times more likely to stabilize hillslopes than untreated sites based on cover percentage. Second-year seeded sites had greater total cover than did unseeded sites 39 percent of the time. Eighty-three percent (15 sites) of the seeded sites had greater than 30% cover, compared to 50% (9 sites) of unseeded sites. Twenty-eight percent (5 sites) of seeded sites had adequate cover to reduce soil erosion to negligible amounts, compared to only 6% (1 site) of unseeded sites. Yet, only one of the studies measuring erosion in the second year showed that seeding significantly reduced erosion. A main focus of post-wildfire rehabilitation treatments is on reducing soil erosion in the year immediately following a fire (Kruse et al. 2004). However, seeding appears to have a low probability of effectively reducing erosion within the first year and even into the second year. Furthermore, it appears that greater cover does not always produce less erosion (Robichaud et al. 2000).

Authors of all review papers agreed that the studies reviewed lacked any notable relationship between establishment of vegetative cover and reduction of erosion within the first year after fire (Beschta et al. 2004; Beyers 2004; Wolfson and Sieg, in press). This is not surprising as the majority of sediment movement often occurs before plant cover is established (Robichaud et al. 2000). However, our review suggests that seeding was more likely to increase plant cover and therefore potentially reduce soil erosion Marine and Mediterranean Regime Mountain ecoregions than in Temperate Steppe Regime Mountains (Table 5, Fig. 5).

In the Intermountain West high intensity short duration rainfall events often occur shortly after severe wildfires (Robichaud et al. 2000). Watersheds within this region are therefore prone to high erosivity due to these storm events (Wagenbrenner et al. 2006; Kunze et al. 2006; Rough 2007). Within forests of the Marine and Mediterranean Regimes, most annual precipitation occurs during the winter months as snow subsequent to mid-late summer wildfires, allowing seeded species to germinate under more ideal conditions (Roby 1989; Amaranthus et al. 1993; Robichaud et al. 2006).

Multiple studies provide evidence that seeding for erosion control may be more effective when done in concert other treatments (Maloney and Thornton 1995; Meyer et al. 2001; Earles et al. 2005; DeWolfe et al. 2008). Other studies provide evidence showing no reduction in erosion rates for either seeding alone or in conjunction with these treatments. Robichaud et al. (2006) studied the effect of seeding with winter wheat and fertilizing, alone and in combination, on post-fire erosion rates in north-central Washington. Their results revealed that neither seeding and/or fertilizer treatments significantly increased ground cover compared to untreated areas; nor did these treatments reduce post-fire erosion rates at any time during the four-year study. More recent studies suggest that mulch treatments alone are more effective than seeding in reducing erosion. For example, in a study conducted in northwestern Montana, Groen and Woods (2008) found straw mulch application at a rate of 2.24 Mg/ha resulted in 100% ground cover and reduced rainsplash erosion by 87% whereas aerial seeding with a mixture of native grasses failed to provide enough ground cover to reduce the erosion rate relative to untreated areas. In studies conducted in Colorado’s Front Range, MacDonald and Larson (in press) and Wagenbrenner et al. (2006) also found dry mulch to be more effective than other applied treatments (seeding alone, seeding and mulching, contour-felled logs, hydromulch, and polyacrylamide) for reducing soil erosion following wildfires. Seeded species in MacDonald and Larson (in press) included native cultivars and sterile cereal grains, whereas Wagenbrenner et al. (2006) used a mixture of non-natives, sterile and non-sterile cereal grains. This evidence suggests that seeding may be more effective when used with other erosion control measures, but mulching alone can provide as much or more cover then all other treatment combined.

Does seeding after severe forest fires in the western USA reduce negative impacts on plant communities?

Post-fire seeding treatments are often intended to promote recovery of plant communities by allowing re-establishment of native plant species over time (USDI and USDA 2006). However, across forested ecosystems, there is evidence that seeded species suppress recovery of native graminoids, forbs, and shrub and tree seedlings. Effects of seeding on native plant recovery are strongly influenced by what species are seeded, post-fire precipitation, and time since fire (Schoennagel and Waller 1999; Barclay et al. 2004; Robichaud and Elliot 2006; Wagenbrenner et al. 2006; Peterson et al. 2007; Rough 2007).

Twenty-six papers specifically addressed post-fire seeding effects on native plant cover. Grouped by effectiveness ratings (Tables 3 and 4), a majority (62%, 16 papers) showed seeding, regardless of seeded species type, as ineffective, 19% (5 papers) showed seeding to be effective, 8% (2 papers) showed minimal effectiveness, and 12% (3 papers) showed no difference in effectiveness in increasing native plant cover compared to unseeded controls. When considering quality of evidence criteria, three of the six papers (50%) of highest quality evidence showed seeding to be ineffective and one each of the remaining papers showed seeding as having no difference in effectiveness, minimal effectiveness, or effective in increasing native cover. Two out of five papers (40%) providing high quality evidence showed seeding to be ineffective, while two stated seeding as effective, and the remaining study showed minimal effectiveness in increasing cover. Of all studies in the highest and high quality of evidence categories (11 papers), almost half (45%, 5 papers) found seeding to be ineffective in increasing native plant cover. Six of the seven papers (86%) providing medium quality evidence agreed that seeding was ineffective in increasing native cover, and of the low and lowest quality of evidence categories combined, 63% determined seeding to be ineffective.

Of those studies in the highest and high evidence categories finding a reduction of native plant cover (5 papers), three indicated that seeding treatments leading to the suppression of native plants in the first year could have persistent effects on post-fire vegetation recovery. For example, Stella (2009) found that annual and biennial native forbs were significantly reduced as compared to forbs in control treatments as a result of seeded annual species on fires in the Southwest and that this reduction persisted into the second year even though the cover of seeded species was reduced. Another southwestern U.S. study found a similar effect of seeding annual ryegrass (*Lolium perenne ssp. multiflorum*) on native forbs (Barclay et al. 2004): cover of native forbs in non-seeded areas increased from year one to year two, but native forb cover in seeded areas remained constant while ryegrass cover declined. The remaining study, conducted in the eastern Cascades, showed a reduction of native early-successional species and fire-dependent colonizers as a result of high frequency and cover of seeded non-natives. The researchers suggested further that seeding effects could therefore alter native plant communities well beyond the life of seeded species (Schoennagel and Waller 1999).

In three out of the four (75%) highest or high quality of evidence studies showing no difference or minimal effectiveness in increasing native cover relative to unseeded sites, variable precipitation was a major determining factor in the success in seeding various mixtures of non-natives, natives, and sterile cereal grains and subsequent impact on recovery of native vegetation (Robichaud et al. 2006; Wagenbrenner et al. 2006; Peterson et al. 2007). Only two studies within the highest and high quality of evidence categories (Springer et al. 2001; Hunter and Omi 2006) showed that seeding enhanced native plant cover. Hunter and Omi (2006) examined how seeded species (a mixture of native cultivars and non-native annual grasses) and native grasses responded to increased availability of soil nitrogen and light after the Cerro Grande burn in New Mexico. They found that cover of native species (those not seeded during post-fire rehabilitation efforts) increased over a four-year period in seeded areas of low fire severity and did not differ between seeded and unseeded areas of high fire severity although seeded grass cover remained high. However, seeding treatments did reduce native species richness, at least at small scales (Hunter and Omi 2006). Springer et al. (2001) seeded with native species considered to be "weed free" in areas subjected to a prescribed burn in northwestern Arizona; seeded native species therefore may have contributed to an increase in perennial native species cover three years after burning.

These results suggest, in part, that both seeded species and native plant cover are highly influenced by post-fire precipitation. When unfavorable conditions (e.g. low precipitation) occur, seeding often has no effect on native species cover and/or recovery. In contrast, under favorable conditions seeded species rapidly dominate the post-fire environment, which in turn may lead to low first-year native plant recruitment and subsequent reductions in these species over time. However, a rare long-term studied revealed that thirty-one years after a fire in north-central Washington, non-native cultivars which dominated seeded sites initially were completely replaced on seeded sites by a diverse mixture of native graminoids, forbs, shrubs and trees (Roche et al. 2008). This study suggests that non-native grasses seeded after wildfires do not always have persistent effects on native plant communities, but long-term datasets like this one are rare so we cannot determine if these findings hold true across studies.

Some studies suggest that seeding treatment performance and effects are related to length of time since fire (Robichaud and Elliot 2006; Rough 2007). Cover data from 15 studies containing 57 different study sites showed a significant relationship between the ratio of seeded cover to control cover versus time since fire (p-value = 0.0447, Fig. 6). Although significant, other climatic factors such as precipitation are also important controls of cover. Total cover on seeded plots was more variable but only slightly more abundant on average than total cover on control sites for two years post-fire; after two years, control cover consistently became more abundant than seeded cover. However, of 13 study sites showing greater cover on seeded sites than unseeded controls in the first and/or second year post-fire, the majority of the sites (77%, 10 sites) occurred in ecoregions characterized by favorable rainfall intensity, amounts, and timing. In addition, in all of these study sites, annual cereal grains or non-native perennial species were either seeded alone (62%, 8 sites) or as a predominant proportion of a mix with natives cultivars and legumes (46%, 6 sites) (Anderson and Brooks 1975; Griffin 1982; Amaranthus 1989; Amaranthus et al. 1993; Holzworth 2003; Keeley 2004; Logar 2006; Roche et al. 2008). These results suggest that time since fire plays a major role in natural recovery and is an important factor to consider when assessing seeding affects on native plant communities. We can further speculate that seeded species, in particular annual cereal grains, may exit the system quickly (after two years) or be outcompeted by native or naturalized species after this amount of time. However, long-term assessment (beyond two years) of seeded annual cereal grains is rarely completed, so studies quantifying their ability for rapid die-off are limited.

Based on data from above referenced 57 sites, four years after fire, both seeded and control sites supported approximately 45% total plant cover, and five years after fire both supported 40-41% total plant cover (Fig. 7). These data suggest that seeding has limited effect on overall cover during the first five years after fire events. Seeded cover remained relatively high for the first three years after fire (in fact almost exactly the same as control cover during the first two years), but dropped off substantially to 13% and 14% in years four and five, respectively. The higher initial seeded cover suggests that one of the major goals of post-fire rehabilitation was being effectively met through seeding: seeded species established themselves quickly and lasted for a few years, but then decreased relative to other species. However, total cover in seeded sites and controls were nearly identical by years four and five suggesting that the remaining seeded species may be offsetting local plant species which would otherwise occupy the site. Regardless of species seeded, total cover values converged at four to five years post-fire. This suggests that ecosystems may only support a threshold level of plant cover (Connell and

Slatyer 1977; Noble and Slatyer 1977), and post-fire seeding actually suppresses the establishment of local species after fires (Keeley et al. 1981; Taskey et al. 1989). Data from this review cannot assess the differences in vegetation composition between seeded and non-seeded sites. Longer-term monitoring results (e.g., > 5 years) are needed to assess lasting impacts of seeded species. Assessment of soil seedbanks is also needed to determine whether seed of non-persistent species can remain viable within the seed bank (Griffin 1982).

Seven of nine papers (78%) reviewed assessing the effect of seeding on native species richness reported adverse effects, while the remaining two showed no difference in native species richness on seeded versus unseeded controls. Eighty-six percent of the papers providing highest and high quality evidence reported that seeding decreased on native species richness. Two-thirds of these papers have been published since 2000. Reduced native species richness is often a function of high dominance by seeded species (Conard et al. 1991; Amaranthus et al. 1993; Sexton 1998; Schoennagel and Waller 1999; Keeley 2004). Authors defined seeded species dominance in terms of high cover, biomass, density, and/or frequency. In five cases, studies reported high seeded species dominance coincident with reduced native species richness. Conversely, Kruse et al. (2004) reported cereal barley (*Hordeum vulgare)* cover to have no effect on native richness on a fire in northern California. Instead, this study linked reduced native species richness with cover of straw mulch, showing that direct competition for water or nutrients with actively growing seeded species was not the only way for a suppressive effect to occur (Kruse et al. 2004). Barclay et al. (2004) only noted a reduction in native forb richness in the second year following fire in north-central New Mexico. However, this reduction coincided with low seeded annual ryegrass cover. The authors suggested that dominant ryegrass cover may have led to the suppression of native species in the first year, causing subsequent lack of reproduction of native forbs in the second year after ryegrass left the system. However, total cover was also reported to be low; thus, the overall abundance of seeded species in comparison to all species may have remained relatively high. In the two studies noting no difference in native species richness between seeded and unseeded plots, one showed inadequate cover of seeded annual species in both the first and second year post-fire in the Southwest (Stella 2009). The other demonstrated that although seeded non-native annual and perennial grass and legume species had high dominance (cover and frequency) in seeded plots in the eastern Cascades, a native pinegrass (*Calamagrostis rubescens*) also dominated the site which may have counteracted any effects of seeded species dominance (Schoennagel 1997).

Overall, the reviewed literature suggests that seeded species dominance plays a critical role in determing species richness in the first and/or second year after fire. In cases where seeding is successful, reduced native species richness is a likely result. Mulching may also provide as much as an inhibitory effect on native species as seeded species (Schuman et al. 1991; Bakker et al. 2003; Kruse et al. 2004) as well as having the ability to introduce non-species if the mulch used for rehabilitation is not free of weeds (Kruse et al. 2004).

A number of studies examined competitive effects of seeded grasses on woody plant establishment. The ability of seeded grasses to compete with woody plant species can be viewed as positive or negative depending on the ecosystem or site being rehabilitated, although we assessed the latter. Of those papers investigating post-fire seeding (non-native and/or native species) effects on tree seedling growth and shrub cover (14 papers), the majority (79%, 11 papers) found seeding to have adverse impacts on these variables. All studies used for this comparison seeded only graminoids in treated plots. Half of the papers providing highest to high quality evidence (2 out of 4 papers) showed seeding negatively affected tree seedling and/or shrub growth and survival. One paper reported seeding had no effect on the growth and survival of tree and shrub species, while the other showed seeding improved establishment. Of five studies quantifying shrub cover in sites seeded with non-native species versus unseeded controls (16 sites), shrub cover in unseeded plots was almost always higher than in seeded plots (Fig. 8).

Soil moisture likely influences establishment and survival of trees and shrubs; soil moisture can be depleted more rapidly on seeded sites yielding high plant production, thus limiting water availability to woody plant species (Elliott and White 1987). For example, Amaranthus et al. (1993) demonstrated that seeded annual ryegrass suppressed first-year pine seedling growth in southwestern Oregon by lowering soil moisture availability and reducing root-tip and mycorrhiza formation, necessary components for conifer seedlings' establishment. In contrast, Sexton (1998) noted no difference in tree and shrub seedlings' establishment on seeded annual ryegrass plots versus controls in south-central Oregon and he also noted that soil moisture was similar on seeded and control plots. A prescribed burn study in northwestern Arizona showed increased shrub cover on seeded plots, but shrubs were included in the seeding treatment (Springer et al. 2001). Eight out of nine (89%) studies in the lower quality of evidence categories consistently showed reduced conifer seedlings and/or shrub growth and survival on sites dominated by seeded annual non-native species (Griffin 1982; Conard et al. 1991; Schoennagel and Waller 1999; Barclay et al. 2004; Keeley 2004; Kruse 2004). These results suggest that seeding non-native annual species may negatively affect woody plant species through competition for available resources (specifically soil moisture), space, and light during the first two years after fire (Beyers 2004).

Does seeding reduce non-native species invasions?

In eleven of the twelve papers with direct evidence regarding the role of seeding in reducing non-native species abundance, more than half (56%, 6 papers) showed seeding (non-natives and/or native species) to be effective, whereas 45% (5 papers) showed seeding did not reduce non-native species' abundance. When considering quality of evidence criteria, three out of five papers (60%) of highest quality showed seeding to be effective, compared to two out of five (40%) finding seeding to be ineffective for reducing non-natives. However, two of the three highest quality studies showing seeding to be effective were conducted in prescribed burn or slash pile burned areas. Two of the three papers of high quality showed seeding to be ineffective for reducing non-natives species. When we include studies of both highest and high quality evidence for evaluation, an equal amount of papers (50% each) found seeding to be either effective or ineffective. The remaining three lower quality-of-evidence categories gave mixed results.

From these results, determining whether seeding is effective in reducing non-natives is difficult. However, of the papers showing seeding to be effective, 83% incorporated non-native or exotic annual species into seeding treatments. Successful exclusion of non-natives is generally reported when seeded species have high dominance (Barclay et al. 2004; Keeley 2004). Thus, the high percentage of studies reviewed showing successful suppression of undesirable species or noxious weeds appears to result from the competitive advantage of non-native annual or perennial seeded species in increasing dominance (Schoennagel and Waller 1999; Barclay et al. 2004; Keeley 2004). However, it is well-documented that these seeded species also may competitively displace native species (Sexton 1998; Schoennagel and Waller 1999; Barclay et al. 2004; Keeley 2004; Logar 2006). Although annual or non-persistent species are often selected because they are believed to disappear in one year, studies have shown they can persist beyond the first and second year post-fire (Sexton 1998; Barclay et al. 2004). Thus, the problems of using non-native annual or non-persistent species is two-fold: 1) rapid die-off of annual or non-persistent species after the first year post-fire may re-create conditions suitable for exotic invasions; and 2) continued persistence of these species could introduce new non-natives genotypes to native plant communities.

Sixty percent of the papers reporting seeding treatments to be ineffective in reducing non-natives reported no significant difference in cover between seeded and unseeded sites (Sexton 1998; Hunter and Omi 2006; Stella 2009). Hunter et al. (2006) showed that undesirable species cover was positively associated with seeded species cover. Unsuccessful attempts in reducng non-natives may be therefore attributed in part to the production of inadequate cover to exclude non-natives. Four of the five studies (80%) reporting seeding as ineffective used non-native species solely or in mixes with natives. In three cases, seeded non-persistent species persisted beyond the first year post-fire (VanZuuk 1997, Sexton 1998, Hunter et al. 2006). Thus, these treatments also intentionally introduced non-natives which may have negative consequences on native plant communities. Moreover, in two out of three ineffective treatments using mixes comprised of native and non-native species, seed mixes were contaminated with exotics (Sexton 1998; Hunter et al. 2006). This adds to evidence suggesting that broad application of seed mixes following fire may promote establishment of non-native species due to contamination of these mixes.

The use of native species may be preferable to seeding non-natives, but few studies have investigated the use of native species for reducing non-native invasions. Of the papers reviewed regarding this issue, only three investigated the use of native seed mixes for seeding burned areas. However, of these, only one was conducted after a wildfire (Stella 2009). In the remaining two papers, one was conducted following a prescribed burn in northwestern Arizona (Springer et al. 2001), the other examined seeding following slash pile burning in northern Arizona (Korb et al. 2004). Stella (2009) found that non-native species richness and abundance did not differ among seeding treatments incorporating non-native and native species' mixes on three high-severity wildfires in Arizona. Springer et al. (2001) found that seeding certified "weed-free" native seeds were ineffective in reducing non-natives, whereas Korb et al. (2004) noted seeding of native species was effective although only with the addition of soil amendments. Based upon the limited number of studies available, it is hard to determine if the use of native species for seeding can help to prevent non-native invasions although two of three papers suggest seeding with native species is ineffective. However, some native grasses have been shown to suppress growth of conifer seedlings (Larson & Schubert 1969; Pearson 1972), and using non-local native seed sources may contaminate local gene pools (Huenneke 1991; Schmid 1994; Linhart 1995; Hufford and Mazer 2003; Rogers and Montalvo 2004). Conserving local genotypes of plant populations is a vital mechanism by which plant communities can adapt and evolve to survive in a changing climate (Huenneke 1991, Rogers and Montalvo 2004). Thus, incorporating locally-adapted and genetically appropriate seed sources in post-fire seeding treatments should be of importance.

Information on the effectiveness of seeding in curtailing non-native species is based on a limited number of papers, 12, all of which were published since 1998. This perhaps is due to the recent emphasis on seeding to displace or prevent non-native species. Longer-term quantitative monitoring is needed to assess the overall effectiveness of seeding to prevent non-native species invasions.

Conclusions

Severe wildfires have profound effects on soils and plant communities. Over the last decade areas of high-severity forest fires have increased by as much as an order of magnitude in the western United States (Westerling et al. 2006). Climate projections consistently indicate that trends in increasing size and severity of wildfires will continue (McKenzie et al. 2004). If correct, the need to rehabilitate burned areas will undoubtedly escalate. Across agencies, post-fire seeding treatments continue to be used as a first choice rehabilitation measure, although use of these treatments in achieving specified rehabilitation objectives remains highly debated.

Across 94 reviewed papers, seeding has both positive and negative effects on post-fire ecosystems. Seeding was shown to be effective in increasing plant cover to reduce soil erosion; but few studies showed that the reductions in eroded sediment on seeded sites were significantly lower relative to controls. In fact, untreated controls appeared to recover as effectively from the effects of erosion compared to sites seeded. These results suggest that seeding has minimal potential to reduce erosion, especially not in the first critical erosion years after fire (Kruse et al. 2004). Mulching appears to have greater impact in reducing soil erosion than seeding; however, mulching may also negatively affect ecosystems by suppressing plant community recovery and introducing non-native species. Increased research investigating the effects and effectiveness of mulching are needed to clarify the impacts of this practice within post-fire ecosystems.

Seeding effects on plant community recovery are similar to those on soil erosion; seeding increases plant cover in the first several years after fire, but cover of seeded sites appears to stabilize at the same rate as unseeded sites by the fourth and fifth year post-fire. Seeded species tend to decline rapidly after the first two years after seeding; however individuals do persist for several years after seeding, especially when perennial species are used. This is concerning in that use of annual cereal grains and sterile hybrid grains has increased under the premise that these species disappear quickly; yet some studies showed their ability to persist. Furthermore, rapid establishment of seeded non-natives often leads to suppression of native species and ineffective recovery after seeded non-natives disappear. Although seeding with native species has increased, natives are typically used in mixes with non-native species, and are rarely used by themselves. As a result studies examining the effects of seeding with purely native species are extremely limited. Furthermore, seeding with "native" species from distant sources may also have detrimental effects on local plant gene pools (Huenneke 1991; Linhart 1995; Hufford and Mazer 2003; Rogers and Montalvo 2004). Therefore, locally-adapted and genetically-appropriate seed sources should be used when seeding treatments incorporate native species. Until supplies of these species increase, alternative rehabilitation methods (e.g. mulching, log-erosion barriers) should be considered.

In recent years, the use of post-fire seeding to reduce non-native species invasion has increased, but studies quantifying the effectiveness of seeding treatments to reduce these invasions are limited. Regardless, seeding was only effective in curtailing non-native species invasions about 50% of the time; of those treatments the majority introduced additional negative impacts on native communities by seeding with non-native species. We were unable to determine whether seeding with natives would be more effective; more work is needed to determine their effectiveness to reduce non-native plant invasions.

The scientific rigor of studies has increased since recent reviews on post-fire seeding (Robichaud et al. 2000; Beyers 2004) declared a need for better designed studies to evaluate the effectiveness of seeding. Evidence that seeding may be ineffective in meeting post-fire management objectives has strengthened as improved sampling designs have rendered more statistically robust data. The scientific literature and monitoring data show that costly post-fire seeding does little to protect soil and promote plant recovery in the short-term but has the ability to introduce potentially negative effects with long-term ecological consequences. Erosion may be better controlled by mulching, but care must be taken to ensure that mulch is free of non-native seed. Plant community recovery may be improved with the use of locally-adapted, genetically appropriate plant materials, although more research regarding the effects and effectiveness of these species is critical. If the only choice is to use mulch potentially contaminated with non-native seed or seed from species of unknown collection and genetic origin, taking no action may be the best alternative. Lastly, early detection of new undesirable species invasions through monitoring of post-fire environments in combination with rapid response methods to quickly contain, deny reproduction, and eliminate these invasions (Westbrooks 2004), may allow better control of non-native species invasions.

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Table 1. Number of papers included at each of the systematic review stages

Systematic review stage	No. of Articles
Studies captured using search terms in electronic databases (excluding duplicates) and gray literature searches	*19,455
References remaining from electronic database and unpublished search after inclusion criteria assessment	143
Relevant studies remaining following further examination by the review coordinator	120
Relevant studies remaining subsequent to the first full review meeting search term and/or relevancy requirements	94

* Approximate figure only

Table 2. Criteria for rating the quality of evidence presented in the papers reviewed and their respective categories

Study design and statistical robustness	Quality of Evidence
Statistically robust evidence obtained from replicated randomized and controlled experiments with sampling occurring after seeding treatments in areas burned by wildfire, prescribed burn, of slash pile burning	Highest
Unreplicated, controlled, observational or monitoring report (multiple locations); Before and After Control Impact study (BACI) with reliable quantitative data from sampling occurring after seeding treatments in areas burned by wildfire, prescribed burn, or slash pile burning; peer-reviewed reviews on post-fire seeding	High
Unreplicated, controlled, observational or monitoring report (single location) with reliable quantitative data	Medium
Unreplicated, uncontrolled, observational or monitoring report; quantitative data	Low
Unreplicated, uncontrolled, qualitative data; anecdotal observation; expert opinion; or review of post-fire seeding (not peer-reviewed with qualitative data)	Lowest

Major study design categories included: replicated randomized experiment, observational (multiple location case study), observational (single location case study), monitoring report with quantitative data, monitoring report with qualitative data, BACI, review paper, and expert opinion.

Table 3. Negative impact categories used to judge overall seeding treatment effectiveness

Category	**Negative Impacts Addressed**
Erosion Control	Increased runoff, surface erosion, or sediment yield
Plant Communities	Negative changes to plant community attributes such as cover, biomass, composition, frequency, richness, and density
Non-Native Species	Increased cover, frequency, density, richness, and reburn potential

Table 4. Criteria for rating seeding treatment effectiveness and their respective categories

Criteria for rating seeding treatment effectiveness	**Effectiveness Rating**
Sufficient evidence exists to conclude that seeding was statistically or perceivably effective in decreasing erosion, increasing cover, or reducing non-native species invasions without negative effects	Effective
Sufficient evidence exists to conclude that seeding was effective under some but not all circumstances or seeding was effective, but with potentially negative effects	Minimal effectiveness
Sufficient information exists to conclude that seeding treatments in treated and untreated controls were not statistically or perceivably different in their effectiveness for increasing cover, reducing erosion, and/or reducing non-native species invasions	No difference in effectiveness
Sufficient evidence exists to conclude that seeding was completely ineffective in reducing erosion, increasing cover, and/or reducing non-native species invasions; potentially negative effects exist	Ineffective

Table 5 – Number of sites in published studies reporting measures of seeding "success" by ecoregion (Bailey 1983) during the first 2 years following fire

Sites Showing Cover Measure-ments	Those Showing Seeding Significantly Increased Cover	% of Sites Showing > 30% Cover (No. of Sites)		% of Sites Showing >60% Cover (No. of Sites)		Sites Showing Erosion Measure-ments	Those Showing Seeding Significantly Reduced Erosion
		Seeded	Unseeded	Seeded	Unseeded		
———————— *No.* ————————		————————*Percent*————————				———————— *No.* ————————	
		Post-fire Year One					
Marine Regime Mountains							
6	3	33 (2)	17 (1)	0	0	5	0
Temperate Steppe Regime Mountains							
8	0	50 (4)	50 (4)	0	0	4	0
Tropical/Subtropical Regime Mountains							
3	0	100 (3)	100 (3)	0	0	0	—
Mediterranean Regime Mountains							
12	9	58 (7)	8 (1)	33 (4)	0	3	0
Combined							
29	**12**	**55**	**31**	**14**	**0**	**12**	**0**
		Post-fire Year Two					
Marine Regime Mountains							
4	1	100 (4)	75 (3)	0	0	5	0
Temperate Steppe Regime Mountains							
7	0	71 (5)	71 (5)	0	14 (1)	5	1
Mediterranean Regime Mountains							
7	6	86 (6)	14 (1)	71 (5)	0	0	0
Combined							
18	**7**	**83**	**50**	**28**	**6**	**10**	**1**

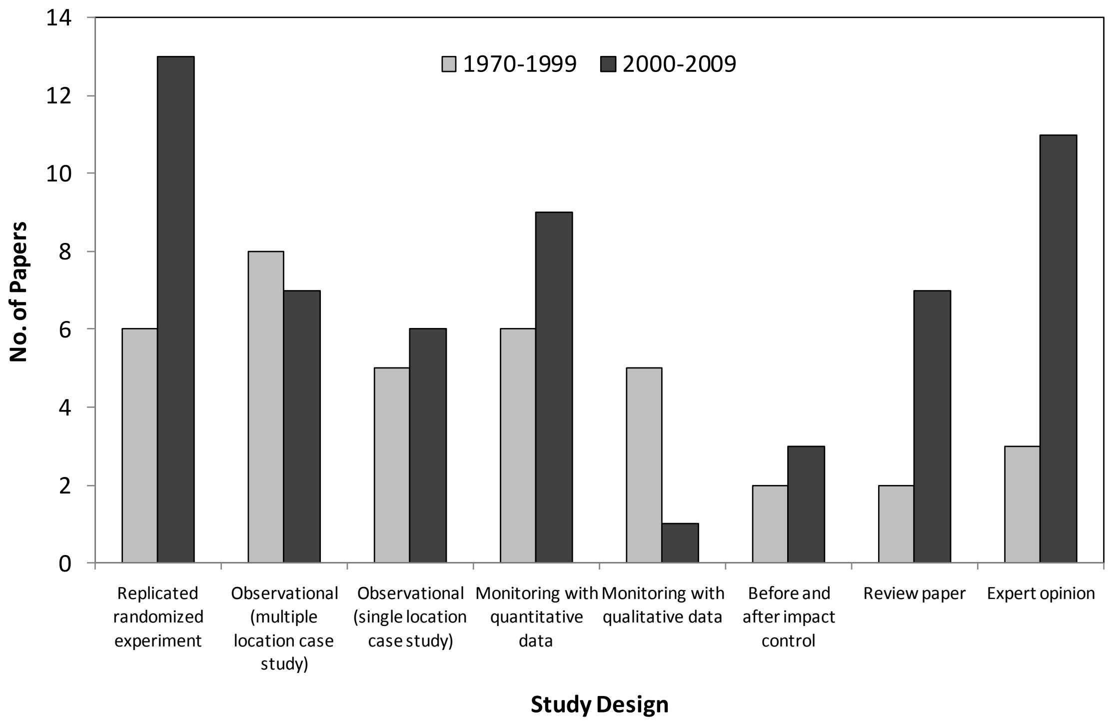

Figure 1. The number of papers by study design category for studies reviewed from 1970 to 1999 (37 papers) and those since 2000 (57 papers)

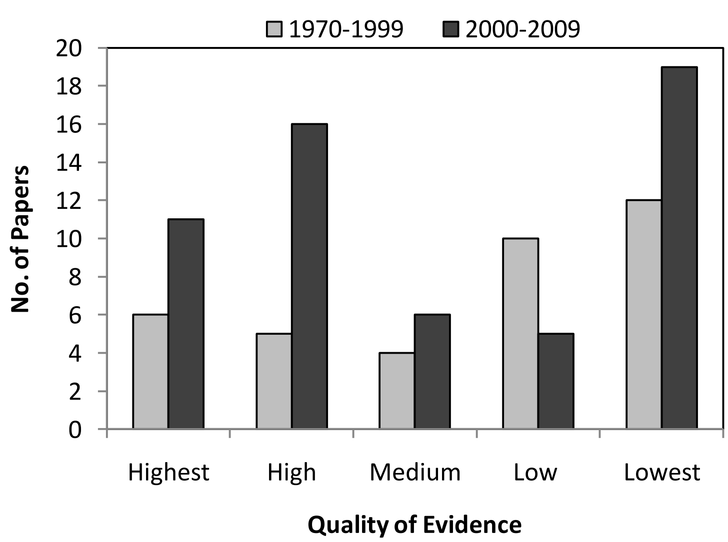

Figure 2. The number of papers by quality of evidence for studies reviewed from 1970 to 1999 (37 papers) and since 2000 (57 papers)

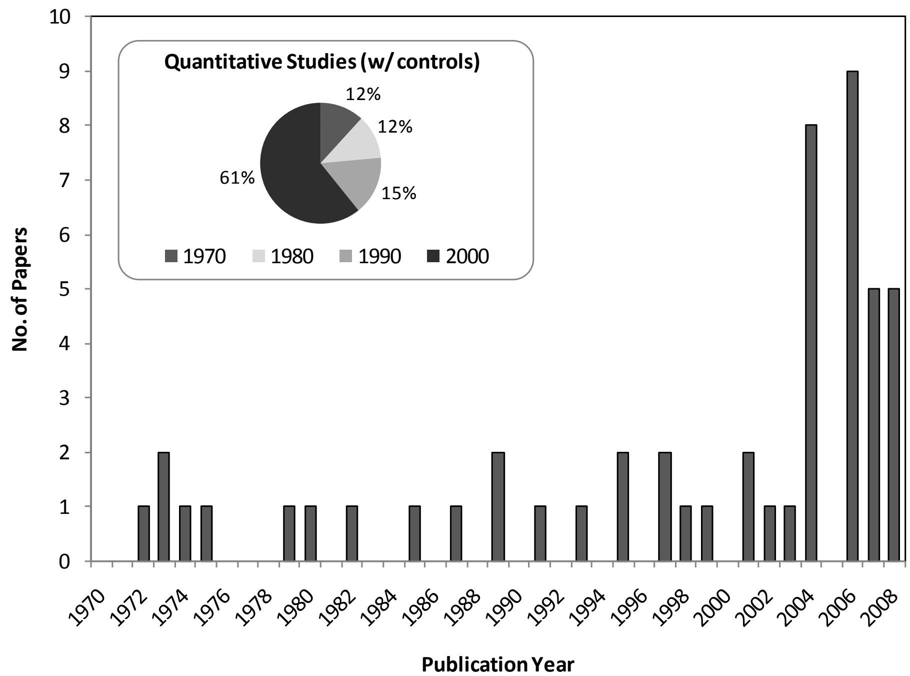

Figure 3. Number of studies reviewed with quantitative data (w/ controls) by publication year. The insert shows the number of quantitative studies by decade as a percent of the total.

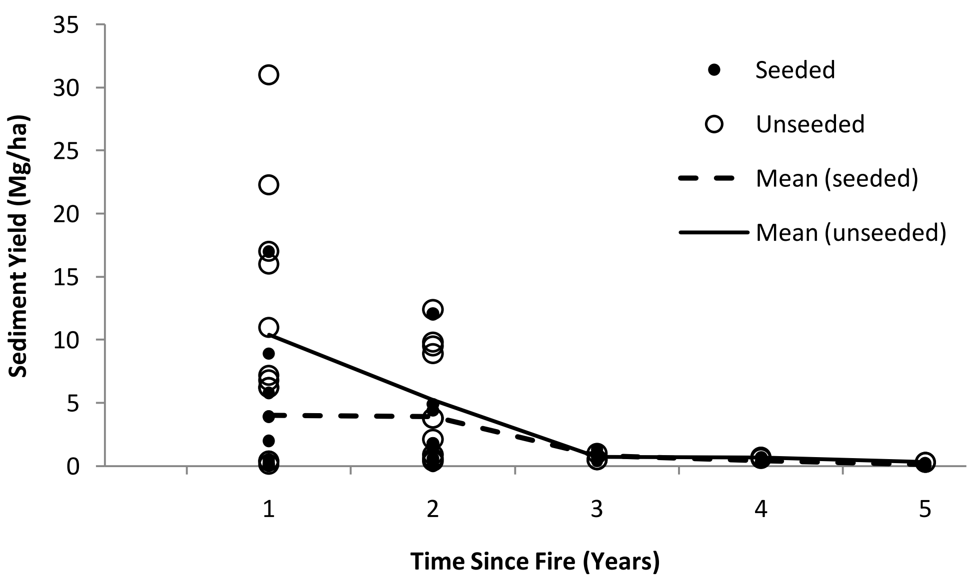

Figure 4. Amount of sediment yield versus time since fire in seeded plots and unseeded plots (data from 30 sites)

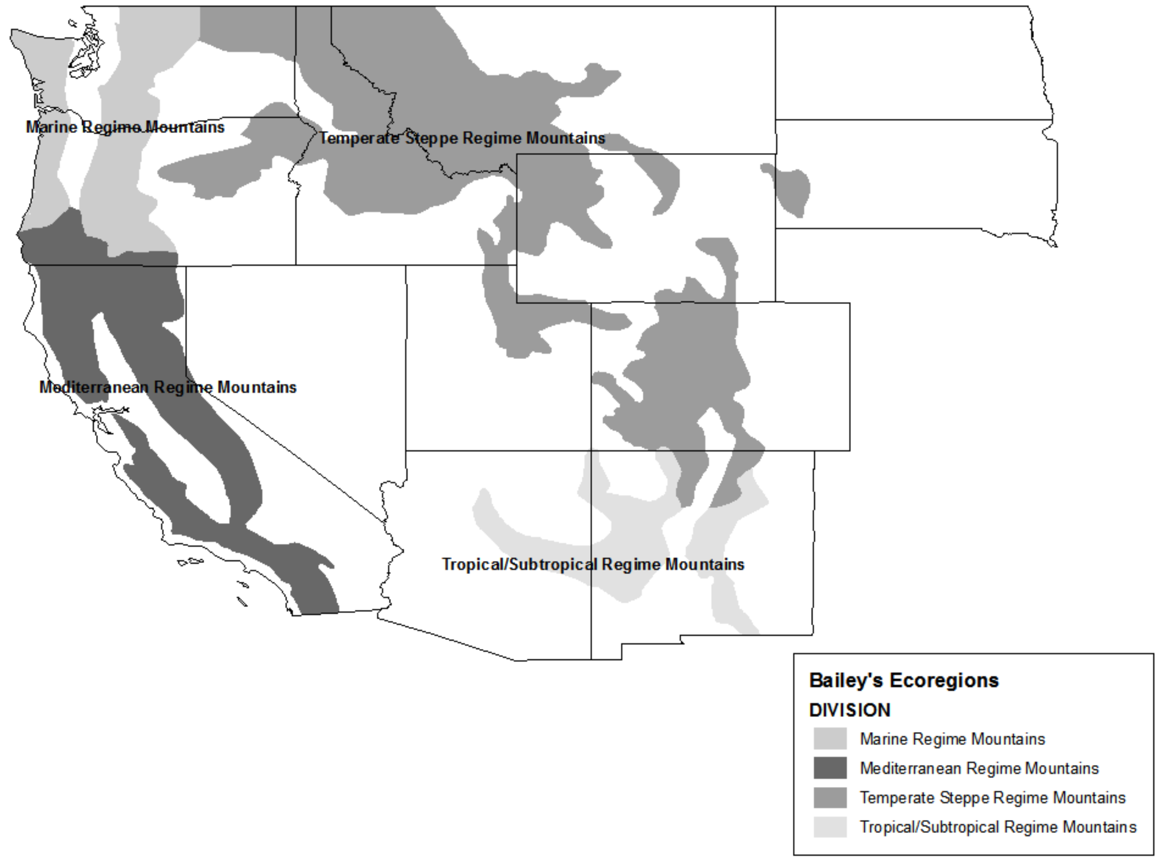

Figure 5. Map of ecoregions (Bailey 1983) containing published studies reporting measures of seeding "success" during the first 2 years following fire (Table 5).

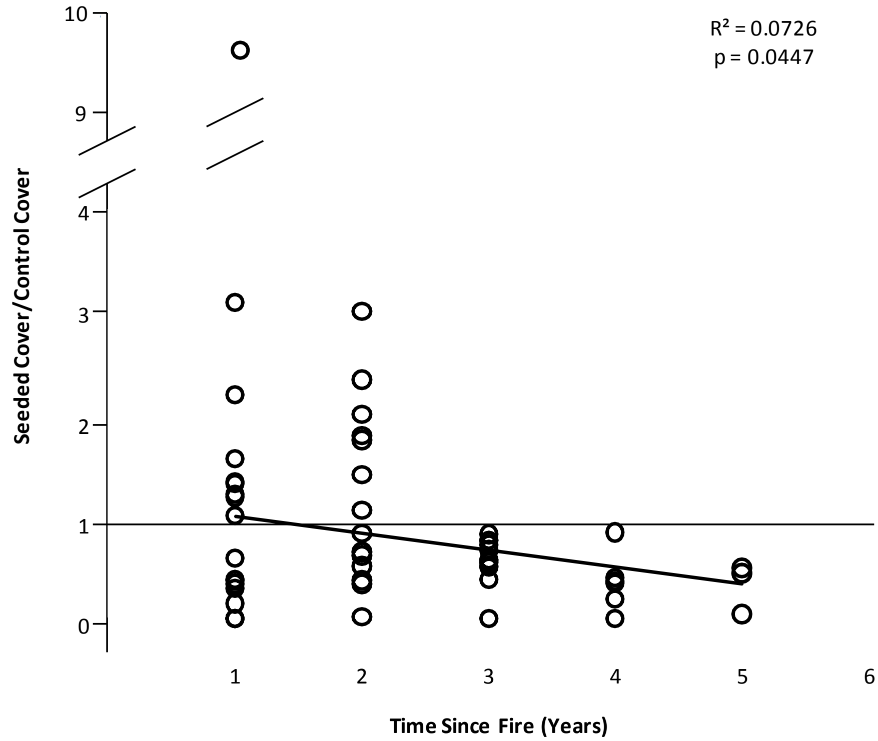

Figure 6. Ratio between seeded and control cover estimates versus time since fire in years (data from 57 sites). Ratios greater than one have greater seeded cover than control cover.

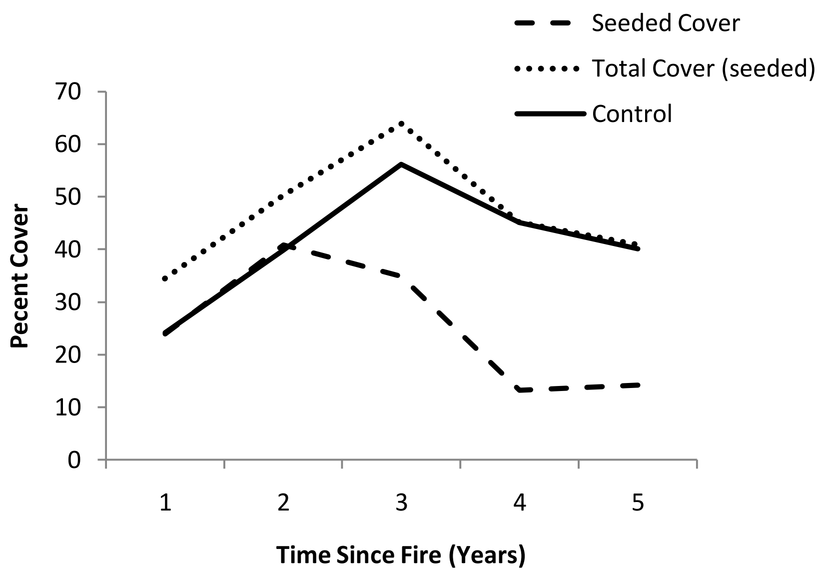

Figure 7. Average seeded cover and total cover across seeded sites and total cover in control sites versus time since fire (data from 57 sites)

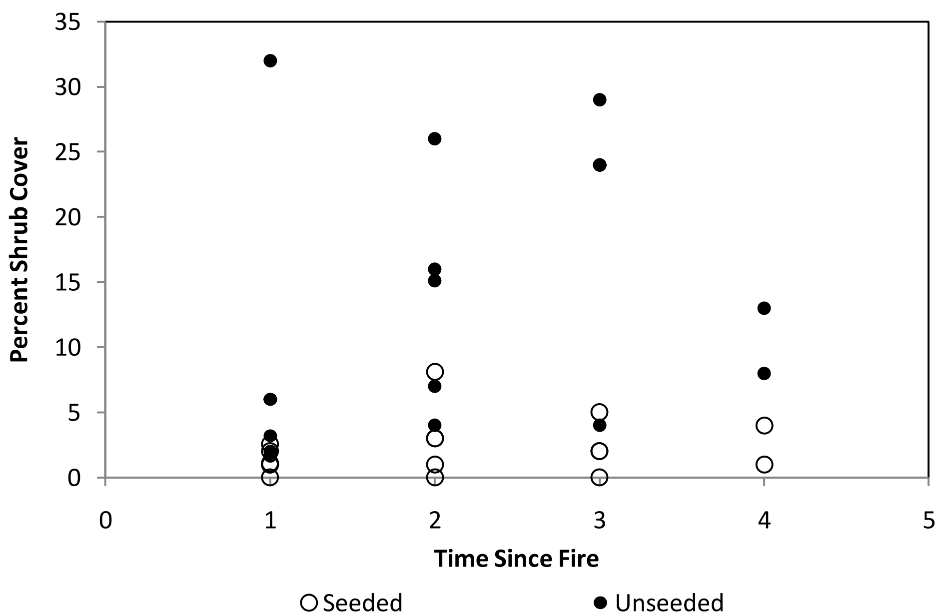

Figure 8. Percent shrub cover in seeded and unseeded sites versus time since fire in years (data from 16 sites)

CHAPTER THREE

Market perceptions and opportunities for native plant production on the southern Colorado Plateau

Abstract

Increases in revegetation activities have created a large demand for locally-adapted native plant materials in the southwestern United States. Currently there is a minimal supply of local genotypes to meet this demand. We investigated the potential for the initiation of a native plant market in the southern Colorado Plateau. Through a literature search, interviews, and site visits, we identified existing native plant markets outside of the region as useful models to help initiate a regional market. We used web-based surveys to identify and analyze current and future native plant material needs and concerns. Survey results indicate that management policy strongly drives decisions regarding the use and purchase of native plant materials. From a demand perspective, lack of availability and cost of native plant materials has kept purchasing minimal, despite policy changes favoring the use of natives. For suppliers, further development of native plant materials is limited by inconsistent and unreliable demand and lack of production knowledge. The knowledge and tools necessary to initiate a native plant materials market are available, but inadequate funding sources and insufficient information sharing hinder its development. Communication among producers, land managers, buyers, and researchers, as well as partnerships with local growers, appear to be vital to initiating a functional market.

Introduction

Over the past century, in the Southwest, land use and management practices in conjunction with changing climate conditions have led to alteration of native ecosystems and a fire regime shift from frequent, low-intensity surface fires to large high-intensity crown fires (Covington & Moore 1994; Westerling et al. 2006). Many native species in southwestern *Pinus ponderosa* Dougl. ex Laws. (ponderosa pine) forests are well adapted to periodic drought and fires of low intensity (Hunter & Omi 2006). However, drought conditions and wildfires are projected to increase in the region (McKenzie et al. 2004; Westerling et al. 2006; Seager et al. 2007). As a result, prolonged drought stress and a changing fire regime may have direct effects on local plant community composition and structure (Hanson & Weltzin 2000; Wang & Kemball 2005; Hunter & Omi 2006). In light of these concerns, interest in restoring these disturbed lands has become more widespread (Allen et al. 2002; McKay et al. 2005).

In recent years with major fires such as the 2000 Cerro Grande and the 2002 Rodeo-Chediski, wildfires have arguably become the primary driver of restoration and rehabilitation efforts in the Southwest (Friederici 2003). Land management agencies such as the U.S. Forest Service (USFS) and U.S. Bureau of Land Management (BLM) are required to prescribe emergency watershed-rehabilitation measures when and where deemed necessary to (1) stabilize soil; (2) control water, sediment, and debris movement; (3) prevent ecosystem degradation; and (4) to minimize threats to human life or property. Among post-fire rehabilitation treatments, grass seeding is the most commonly used and cost effective method to stabilize soils and establish ground cover for erosion control

(Richards et al. 1998; Robichaud et al. 2000; Beyers 2004; Wolfson & Sieg, In press) on firelines and hillslope areas determined to require protection.

In Arizona and New Mexico, both the area burned by wildfire and the funding allocated for post-fire seeding have increased dramatically in the last 30 years (Wolfson & Sieg, In press, Fig. 1). Regionally, seed used for post-fire seeding has shifted from mixes dominated by perennial non-native species to mixes incorporating more native species (Wolfson & Sieg, in press), although non-natives are still used. Beyond post-wildfire rehabilitation, revegetation is an integral component of other land management practices in the region including invasive species management, livestock grazing, wildlife habitat management, roadside rehabilitation, mine reclamation, and recreational use.

Within the last 30 years, revegetation policies have increasingly stressed using native plant materials (NPM), and more recently, recognized the importance of using locally-adapted NPM during restoration and rehabilitation activities (Richards et al. 1998, Erickson 2008). However, although national policies for federal land management agencies like the USFS and BLM direct the use of native plant species as a first choice in revegetation activities, non-native species may be used when using native species is deemed impractical (Richards et al. 1998; Soller 2003; Beyers 2004); for example, in emergency conditions to protect resource values or when native plant materials are not available or economically feasible (Erickson 2008). Consequently, non-native species continue to be used in revegetation projects throughout the region often due to the increasing need for post-fire emergency rehabilitation in conjunction with the lack of availability and high cost of NPM (Wolfson & Sieg In press) which are locally-adapted and genetically compatible with existing plant populations (Rogers & Montalvo 2004) (hereafter “local genotypes”).

New revegetation policies and funding sources have emerged as a result of increased recognition from Congress of the need for an abundant supply of NPM and the establishment of the Federal Interagency Native Plant Materials Development Committee in 2000 (USDA & USDI 2002). Since 2000 interagency projects have been developed to meet the need for increased NPM availability and production information (Pellant et al. 2004; Shaw et al. 2005). Unfortunately, only minimal efforts currently exist in the Southwest and, due to the lack of local genotypes available, federal, state, tribal, nonprofit, and private entities presently purchase restoration materials from distant sources. Thus, regional projects continually incorporate non-local genetic materials which may be more susceptible to the negative effects of changing environments (Huenneke 1991; Schmid 1994; Rogers & Montalvo 2004) and threaten the long-term sustainability of restored sites (Lynch 1991; Hufford & Mazer 2003), as well as other local populations (Linhart 1995; Montalvo & Ellstrand 2001) with which they may interbreed.

With NPM production efforts currently established in surrounding regions, increased policy recognizing the value of using NPM, and needs for locally-adapted plant supplies, market opportunities exist that may directly benefit the southern Colorado Plateau’s diverse ecosystems. This study addresses the following four questions: 1) Could native plant markets outside of the region serve as models to guide the development of a NPM market in the region? 2) What role does current policy play on the use and demand for NPM? 3) What are the needs and concerns of both supply and demand stakeholders involved with NPM? 4) What factors limit the initiation of a NPM market in the southern Colorado Plateau?

Methods

This study assesses the opportunity to initiate a native plant and seed industry in the southern Colorado Plateau (Fig. 2). To explore market development methodologies and perceptions, we investigated existing native plant markets and administered web-based surveys to natural resource professionals and selected seed companies in the southern Colorado Plateau and in nearby regions.

To identify potential models which could be used to help guide the development of a regionally based NPM market, we reviewed current literature including scientific journals, unpublished theses and reports, and government documents. We then interviewed natural resource professionals within the region to gain further insight on markets previously identified. The most relevant markets were selected based on their similarity to the southern Colorado Plateau's size and market demands.

We developed two distinct web-based surveys to assess current native plant market perceptions. A demand survey was administered to a target group of individuals from federal, state, private, and nonprofit entities who were actively involved in restoration in the region (Table 1a, Appendix II). A supply survey was administered to a targeted group of individuals from both large and small-scale seed production companies in Arizona, New Mexico, nearby western and Great Plains states, and other successful seed production companies (Table 1b, Appendix II). Complete details on the survey methodology are available from the authors (Appendix III).

We developed 42 questions for the demand survey and 37 questions for the supply survey based on preliminary information from interviews and current literature (Richards et al. 1998; Soller 2003; Hooper 2003). Each survey question was arranged into a series of related survey questions and placed within five thematic areas pertaining to NPM: 1) policy and regulation; 2) issues and concerns; 3) purchasing and expenditures; 4) future use and needs; and 5) collaboration and funding. We created and administered finalized surveys (42 demand and 39 supply) online (Andrews et al. 2003; Kaplowitz et al. 2004; Ryu et al. 2005) using the web tool SurveyMonkey (www.surveymonkey.com).

Analysis of final survey response datasets was completed using Statistical Package for the Social Sciences (SPSS) software (SPSS 2007). We calculated survey answer frequencies (n) and valid percents of respondent participation for each question. Survey responses "Don't know" and "Decline to answer" are not included in the valid percent calculations. For questions that offered multiple responses, total percentages may exceed 100. Percents are rounded which may cause totals to be slightly greater or less than 100%.

Results

Model Markets

We identified the BLM Great Basin Restoration Initiative's (GBRI) Great Basin Native Plant Selection and Increase Project (GB Project) and the Uncompahgre Plateau Project's Native Plant Program (UP Project) as useful models for guiding the development of a native plant market in the southern Colorado Plateau. Within their respective regions, these Projects have helped to increase the supply of NPM for restoration practices through multi-organizational collaborations and partnerships with private growers (Pellant et al. 2004; US GAO 2008a). Funding provided to the Projects is used, in part, to conduct research on key native plant species to develop critical production methodologies and seed sources. Research results and information are then transferred to growers and land managers. In addition, growers are given an opportunity to participate in buy-back programs, which aim to encourage suppliers to grow native species not yet marketed (Shaw et al. 2005; UP Project 2007). Under the buy-back program, minimal amounts of stock seed, along with associated production information is provided to growers under an agreement that the Projects will buy-back a small portion of the seed produced for distribution to additional growers or in some cases to provide NPM for research needs. Meanwhile, growers are given a chance to sell the additional seed produced on the open market.

Within the Great Basin, market demands are primarily driven by needs of government agencies for post-fire rehabilitation and restoration (GBRI 2001). Funded entirely through the BLM GBRI, total five-year funding for the GB Project was approximately $4.5 to $6 million between 2001 and 2006 (GBRI 2001, Pellant 2006). On the Uncompahgre Plateau, although market demands are driven by private and public land needs for habitat improvement, NPM production focuses on providing local-source seed for government agency use. The UP Project, which was modeled after the GB Project, has a separate nonprofit management group as well as a formalized Memorandum of Understanding (MOU) with the BLM, USFS, and the Colorado Division of Wildlife which allows the group to receive both direct and in-kind funding from federal, state, private, and nonprofit entities (US GAO 2008a). Additional funding provides financial support to local growers for producing NPM. Between 2002 and 2007, the program received approximately $2.4 million in funding, with the majority coming from the BLM (50%) and the USDA Forest Service (USFS) (35%) (UP Project 2007). Based on annual operating costs for both the GB and UP Projects, the estimated cost for collection, research, increase, and release is approximately $15,000-25,000 per species annually and requires approximately four to 12 years to develop a species (CPNPI 2007).

Survey

We received 37 completed demand (88% response rate) and 33 completed supply (85% response rate) surveys from the targeted sample group (Appendix IV). Due to non-random sample selection and a small sample size (demand survey n = 42, supply survey n = 39), extrapolation of results and conclusions to a larger population should be considered cautiously (Babbie 2004); however, an effort was made to include all involved stakeholders.

The majority of demand survey respondents were employed by “federal” or “state” agencies (47% and 27% respectively), and currently implemented seeding as a management practice (83%). Of supply survey respondents, 94% were currently involved in selling NPM of which the majority (97%) sold either “native seed” solely (32%) or NPM and non-native seed (65%).

Native plant policy and regulation

Demand respondents indicated that "organization policy" (25%) followed by "availability of native seed" (21%) were the most important factors influencing the purchase of native seed. The majority (80%) of respondents' organizations or agencies currently required the use of certified native seed; seed meeting certification procedures which provide verification of source, genetic identity, and genetic purity of wildland collected or field grown plant germplasm materials (AOSCA 2003). For those organizations or agencies that did not currently require the use of certified native seed, 67% of the respondents anticipated requirements to do so within the next five years.

Native plant material concerns

The majority of all respondents (65%) found defining the term "local genotype" difficult and suggested the definition is species specific and highly dependent upon topography, elevation, and climatic conditions within a region. In follow-up questions, an overwhelming majority of buyers (93%) indicated that their organization was concerned about the genetic source of native seed; yet 41% of respondents used non-native seeds in restoration efforts. Half of demand respondents agreed "lack of availability" was the primary limiting factor preventing their organization from buying local seeds and "availability" (27%) along with the "cost" (22%) of seed were the greatest obstacles to overcome in order to initiate a successful NPM market in the southern Colorado Plateau (Fig. 3a). The majority of buyers (87%) foresaw a need for local genotypes for seeding practices within the next five years.

Producing local genotypes was “somewhat” (47%) or “very important” (33%) to suppliers and the majority (70%) agreed that there is a current market for local genotypes used in large-scale restoration projects. However, suppliers commented that supplying local genotypes is difficult due to the costs and limited resources available during the wildland seed harvesting and agricultural seed production process. In addition, growers were more interested in supplying seed that is currently in large demand. Furthermore, from the supply perspective, the “lack of consistent and reliable demand” (38%), and “knowledge of native plant production” (21%) were the most significant limitations to supplying NPM (Fig. 3b).

Native plant material use and needs

Of demand respondents who currently seed, just over one-quarter (26%) primarily apply seed for “ecological restoration;” while “wildlife habitat improvement” and “burned area rehabilitation” were close seconds (22% each, Fig. 3c). When demand respondents were asked about the five most desirable species to be brought into commercial production (n=149), respondents selected in order of highest demand (23% of the total responses): *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths (blue grama), *Festuca arizonica* Vasey (Arizona fescue), *Elymus elymoides* (Raf.) Swezey (squirreltail), *Atriplex canescens* (Pursh) Nutt. (fourwing saltbush), and *Poa fendleriana* (Steud.) Vasey (muttongrass). In contrast, among all responses from suppliers (n=53), the five species for seeds in highest demand (19% of the total responses), in order of frequency were: *Pseudoroegneria spicata* (Pursh) A. Löve (bluebunch wheatgrass), *Achnatherum hymenoides* (Roem. & Schult.) Barkworth (Indian ricegrass), *Pascopyrum* *smithii* (Rydb.) A. Löve (western wheatgrass), *Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould (thickspike wheatgrass), and *Elymus elymoides*. Overall, seed of grass species was in highest demand by both demand and supply respondents, but only *Elymus elymoides* was listed among the top five by both groups; this difference in plant lists was a direct result of buyers and suppliers being surveyed in different geographic areas. Appendix V provides a complete species list (scientific names and authorities) of native and non-native species used throughout the surveys.

Native plant material purchasing and expenditures

The BLM spent the most on NPM in 2006, followed by the USFS (Fig. 3d). In 2006, the top two management activities for which native seed was purchased included “burned area rehabilitation” and “ecological restoration.” However, 61% of all the native seed purchased was for burned area rehabilitation activities (10,843 kilograms), amounting to 42% of the overall expenditures on native seed in 2006 ($344,000, Fig. 4). According to the demand survey, almost half (44%) of respondents’ native seed supply came from out-of-state sources within the same ecological region in which the rehabilitation or restoration was conducted (e.g. Great Basin, Colorado Plateau, etc.).

Collaboration and funding

Among buyers, collaboration occurred most often between “federal” (22%) and “state” agencies (20%). Over one-half (57%) of buyers currently received “federal” or “state” monies or incentives to assist with seeding practices. Most suppliers’ (62%) current native plant operations are supported internally, while one-third (33%) are supported by both internal and external funding.

Discussion

Market models and survey results revealed that many factors limit the NPM market in the southern Colorado Plateau, including the need for: 1) stronger collaboration among federal, state, private, and nonprofit entities; 2) increased communication among seed producers, land managers, buyers, and researchers; 3) funding mechanisms for development of local genotype plant materials; 4) an agreement regarding the scale of "local-genotypes" 5) increased availability and reduced costs of local genotypes; and 6) native plant market stability.

The GB and UP Projects were useful models in guiding development of a NPM market in the southern Colorado Plateau. These projects provide a framework of how factors related to limited collaboration, insufficient funding, and lack of communication can be overcome. It appears that multi-agency collaboration can be used to acquire long-term funding sources needed to increase NPM development. These models suggest that between $2.4 and $6 million over a five-year period is needed to initiate a similar project in the southern Colorado Plateau (GBRI 2001; Pellant 2006; UP Project 2007).

Partnerships between government agencies and private growers appear to be essential as improved information sharing and buy-back options give growers tools and incentives needed to enhance development of NPM. Beyond buy-back options, stewardship contracting, available through the BLM and USFS, authorize these agencies to enter into long-term agreements (up to 10 years) with communities, private sectors, and others to meet land management objectives associated with improving forest and rangeland health while benefiting communities (US GAO 2008b). Indefinite-delivery/ indefinite-quantity contracts (which agree to award payment upon completion of specified tasks in a fixed period of time) have also been used by the BLM and USFS in several western states to produce required quantities of seed from specific areas for planned projects (Erickson 2008; Nancy Shaw, USDA Forest Service, personal communication). Utilizing contracting options provided through the USFS and BLM would further encourage market development.

Our survey indicates that policy strongly influences agency decisions regarding NPM use. Due in part to difficulties interpreting current native plant policy and economic constraints, federal policy on use of NPM has been implemented erratically (Richards et al. 1998) and on the southern Colorado Plateau, lack of availability and high costs of local genotypes has made existing native plant policies moot, thereby allowing the continued use of non-native species (Wolfson & Sieg, in press). Stronger and more consistent policies for their use (Richards et al. 1998) could enhance the regions' NPM market potential by helping to increase their demand. For example, implementation of stronger native plant policies has stimulated the development of new certified seed categories that accommodate the use of native plant germplasm (Jones & Young 2005). According to current literature (Jones & Young 2005; Loftin 2004), many states have adopted seed certification policies specifically accommodating NPM and, because of this, suppliers now offer certified native seed as the demand for it has increased.

According to the survey, the genetic source of seed appears to be a concern for land managers and seed companies, yet an inconsistent demand and lack of reliable production knowledge make suppliers hesitant in furthering the development of local genotype plant materials. These issues are further complicated by difficulties in determining what constitutes a "local genotype" (Mortlock 1999; Burton & Burton 2002;

Williams & Price 2002) as well as by varying requests for species, types of genetic materials, and amounts needed. Confusion over these issues creates dilemmas for suppliers when faced with deciding on what types and how much material to produce and market (Hooper 2003). Determining target species, finding common ground on the genetic classification of local plant materials, and consolidating NPM requests are critical first steps to effectively building a regional NPM market and developing local genotype plant materials.

One approach to the "local genotype" scale issue is to delineate seed transfer zones based upon geographic and elevational boundaries in which plant materials can be transferred with little risk of being poorly adapted (Mahalovich & McArthur 2004, Aubry et al. 2005). Forested areas of Arizona and New Mexico are already divided into 10 physiographic-climatic tree seed zones (Schubert & Pitcher 1973), which could be used as surrogates for grass seed transfer zones (Soller 2003). Consistent funding for research and development will be needed to enable completion of research projects exploring the basic genetic information for determining appropriate seed collection zones.

According to the survey, suppliers appear to lack the knowledge necessary to successfully produce NPM. Over the years a wealth of information has been accumulated regarding NPM production. Within the region, increased information transfer regarding available production guidelines (Potts et al. 2002) would further encourage potential suppliers to grow needed NPM. Greater information sharing may also help to lower NPM costs by providing suppliers with cost-effective production techniques. Minimal research may be needed to develop production guidelines for regionally-specific species for which information is not available.

According to our survey results, focusing on grass seed production will be important during the market initiation phase. Demand for grass species is promising as the majority of research on NPM production has focused on development of grass species (Robichaud et al. 2000). Many of the desirable grass species identified are readily available through commercial seed producers outside the region. Therefore, focusing on producing and marketing locally collected and grown grass species (e.g. specialty market) could alleviate competition pressure from non-regional suppliers.

Specialty NPM markets have been assessed in Nevada and created in Utah. In 2005, the Nevada Wildland Seed Producers Association requested a feasibility study to evaluate the potential for a native plant and seed market, as well as interests in forming a cooperative among Nevada NPM producers (Curtis et al. 2005). Within this cooperative, 30 producers each invest approximately $5,000 and obtain additional funding through credit or loan options to finance the cooperative start-up cost. Profits are made by marketing locally developed, certified, and labeled "Nevada Grown" materials. This study estimated total operational expenses at approximately $6 million annually. Utah Intermountain Native Plant Growers Association produced a similar market for "Utah Choice" NPM (Meyer 2005). The Nevada and Utah NPM markets appear to be primarily supported by demand for NPM for fire prevention and rehabilitation efforts (Curtis et al. 2005, Meyer 2005).

Burned area rehabilitation plays a large role in the demand for and purchase of NPM in the southern Colorado Plateau, specifically grasses used for post-fire seeding (Beyers 2004, Wolfson & Sieg in press). Our survey indicates that the BLM followed by the USFS purchase the majority of the seed in the region and according to agency policy the use of native species is preferred (USDA & USDI 2002). The total burned area that has been seeded within USFS Region 3 has increased annually since 1990 (Table 2). Assuming that policies continue to favor seeding following disturbance, a future native plant market may continue to be driven by federal government demand for post-fire seeding materials, and more specifically those which are native.

The variable demand for NPM results from unpredictable fire frequency and size (Richards et al. 1998; USDA & USDI 2002; Jones and Young 2005). The unpredictability of fires from year to year can cause high demands for large quantities of native grass seed at short notice, and often at a time when NPM supplies are low (Dunne & Dunne 2003). In turn this forces buyers to purchase materials from outside the region (Curtis et al. 2005) at high costs (Dunne & Dunne 2003). Increasing the region's storage capacity (USDA & USDI 2002; Soller 2003) may be one way to address issues of on-demand availability and alleviate high market prices often associated with native seed in short supply (Jones & Young 2005). Adequate long-term seed storage facilities would allow for seed to be purchased and stored in favorable seed production years (Williams & Price 2002; USDA & USDI 2002, Soller 2003). This would stabilize availability during unfavorable seasons (Mortlock 1998) or in heavy fire years. However, suppliers answering the survey stressed that providing NPM for an unreliable market is often infeasible and that it is more profitable to produce and sell NPM which have the highest consistent demand. Moreover, suppliers surveyed expressed that lack of funding is a major obstacle in providing native seed, which is often limited due to the greater costs associated with collecting and producing it (Mortlock 1998; Burton & Burton 2002). Forms of contracting may be necessary to insure growers that the seed they produce will be purchased and, in some instances, provide them with seed stock accompanied by associated production information. A synergistic approach of increasing storage capacity while offering suppliers market incentives may provide an effective mechanism to increase the supply of needed NPM within the region.

What is needed for market initiation?

A diverse approach is needed to overcome the many challenges of initiating a NPM market in the southern Colorado Plateau. Based on the GB Project and the UP Project, greater collaboration, funding opportunities, and communication are essential to increasing NPM. Because of the large role that policy plays in agencies' decisions regarding when and where to use and purchase NPM, stronger policies and support from federal and state governments (Mortlock 1998) will be needed to help increase supplies and lower cost of local genotype plant materials.

There is an apparent disconnect between market perceptions among buyers and producers. It is clear that for a market to be developed, an integrated collaborative strategy is needed among producers, land managers, government agencies, organizations, and researchers at both local and regional scales. Collaborative efforts should focus on developing a guiding framework to address these primary issues (Williams & Price 2002): 1) increasing communication among stakeholders; 2) increasing genetic research for the development of appropriate seed zones; 3) increasing information transfer regarding reliable methods for producing NPM; 4) finding the most effective methods to improve market stability; and 5) securing a stable funding mechanism for market initiation and continued research and development. Obtaining appropriate long-term funding may be the most critical factor to overcome to initiate a regional market.

Two main investment structures could be used for market initiation within the region, a purely government funded approach, or a collaborative effort between government agencies and private entities. The GB Project is strictly government funded and demand is primarily driven by multiple government agency needs. The Project uses its funding to conduct extensive research on key native plant species. The production information obtained together with a small quantity of seed stock is then provided to growers along with a buy-back option as a market incentive. Only a minimal amount of seed is bought-back leaving the rest of the supply become available for sale on the open market. The cost estimate needed to initiate a market under this scenario is between $4.6 and $6 million over a five-year period (GBRI 2001; Pellant 2006). The UP Project exemplifies government and private funding. Demand is driven by both private and public land NPM needs, with a focus on providing a local-source of seed for agency use. Major funding is secured through government agencies, and additional outside funding is obtained to provide financial support and buy-back options to local growers. An estimated $2.4 million of government funding over a five-year period would be needed under this scenario (UP Project 2007).

An entirely privately funded market initiation approach is most likely infeasible due to the substantial initial investment needed. Based on survey results, the southern Colorado Plateau market is primarily driven by government needs. This suggests that all, or at least half, of the funding should come from government agencies and primarily those responsible for burned area rehabilitation seeding activities.

Burned rehabilitation plays a central role in the demand for NPM in the southern Colorado Plateau. A determination of how much seed is needed to meet post-fire seeding demands will be important to accurately assess the feasibility of market initiation. We produced a theoretical example to determine an estimated annual budget for post-burn seeding efforts in the region. Between 1990 and 2005 the USFS typically seeded ca. 5,700 hectares per year (Wolfson & Sieg, in press). Based upon our survey results of area seeded, we assume that the BLM seeds about the same area as the USFS, and that all other agencies combined seed about half this area. Cumulatively we estimate that approximately 14,250 hectares are seeded annually in Arizona and New Mexico as part of burned rehabilitation efforts. This would require an annual investment of $373,000 from government agencies, and roughly 183 hectares of production area from seed companies (Table 3). Assuming a 20% fluctuation between mild and severe fire seasons, between 11,400 and 17,000 hectares could require seeding in Arizona and New Mexico annually. This would require between $297,000 and $444,000 annually from government agencies, and between 146 and 218 production hectares from seed companies.

We based estimates on the average yield and maturity of production fields for the top eight grass species in demand (from survey results) in weighted-ranked order (varying weight given to species based on ranking order) and the burned hectares seeded per year (Wolfson & Sieg, in press) while assuming the average percent seed viability/species (85%-97%, Damon Winter, Granite Seed, personal communication), roughly a 50% discount to federal agencies that purchase native seed in bulk or through a competitive bidding process (Curtis et al. 2005), and an average wildfire seeding rate of 600 pure live seeds per square meter (PLS/m^2, Hunter et al. 2006). The species used in this scenario are not a recommended list of species but act as a single example for determining the financial investment needed based on a NPM market driven by fire rehabilitation efforts. For rehabilitation efforts to be successful, using materials that are genetically diverse should be a priority. Furthermore, this hypothetical example varies substantially from figures estimated from the GB and UP Project. Because of this, a thorough economic analysis will be needed to determine actual market expenditures.

Concerns over the effects increased disturbance will have on native plant communities (Huenneke 1991) underscores the importance of using both locally-adapted and genetically diverse plant materials to maintain the genetic integrity of ecosystems. Therefore, the development of any NPM market should not be viewed as a financial burden, but rather an ecological investment necessary for the future stability and adaptability of ecosystems' native plant communities. Although this paper is regionally focused, it builds on information gained from similar studies worldwide (Mortlock 1999; Burton & Burton 2002; Williams & Price 2002), and provides additional insight into issues and attitudes of those involved in a NPM industry. There is reason to believe those involved in restoration as well as land managers will utilize our study to expand upon the findings we have presented here, in order to overcome challenges that may directly affect the development and continuation of the NPM industry worldwide.

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Table 1. Total number of survey participants by market type: a) Total number of potential demand respondents in all of Arizona and New Mexico by agency type, b) Total number and location of potential commercial seed company respondents.

a)

Agency Type	Number of Demand Participants
Federal	21
State	8
Nonprofit	7
Private	3
Tribal	3
Total	**42**

b)

State	Number of Supply Participants
Arizona	4
California	4
Colorado	7
New Mexico	4
Utah	5
Other	15
Total	**39**

Table 2. Total number of acres seeded by year in USFS BAER Region 3 (Arizona and New Mexico) from 1990-2005 and 2000-2005 (adapted from data Wolfson and Sieg, in press)

Year	Total hectares seeded
1990	7,733
1991	192
1992	0
1993	648
1994	1,945
1995	769
1996	7,993
1997	0
1998	607
1999	0
2000	16,020
2001	1,039
2002	29,634
2003	9,293
2004	16,199
2005	4
Avg 1990-2005	**5,755**
Avg 2000-2005	**12,031**

Table 3. Estimated total production hectares and government investment needed to supply the southern Colorado Plateau with enough seed to meet post-fire seeding demands (hectares) during an average fire year. Estimates and assumptions for this table are referenced in the Discussion.

Top 8 species in highest demand (next 5 years)	Avg. Yield kg ha^{-1} (1)	Seeds/kg (2)	Production hectares	Viability (3)	Commercial price/kg (4)	Discount	Total Investment	Avg. wildfire seeding rate PLS/m^2	Hectares Seeded
Bouteloua gracilis (Blue grama)	157	1,818,823	47	0.87	$26.46	50%	$84,119	600	4,761
Festuca arizonica (Arizona fescue)	224	1,212,549	30	0.97	$26.46	50%	$86,131	600	3,250
Bouteloua curtipendula (Side-oats grama)	157	421,085	24	0.90	$30.86	50%	$53,178	600	597
Achnatherum hymenoides (Indian ricegrass)	392	310,853	24	0.93	$44.09	50%	$196,254	600	1,139
Poa fendleriana (Muttongrass)	39	1,962,124	21	0.85	$198.42	50%	$69,710	600	568
Elymus elymoides (Squirreltail)	224	423,290	14	0.90	$88.19	50%	$128,260	600	507
Distichlis spicata (Inland saltgrass)	168	1,146,410	11	0.92	$110.23	50%	$94,550	600	810
Sporobolus airoides (Alkali sacaton)	168	3,858,110	11	0.90	$39.68	50%	$33,298	600	2,665
Interested Membership							50.00%		
Total			**183**				**372,751**		**14,298**

(1) USDA Forest Service Fire Effects Information System (USFS 2008) and NRCS Plant Guides (NRCS 2008)
(2) Granite Seed website (www.graniteseed.com)
(3) Damon Winter, Granite Seed, personal communication
(4) Western Native Seed (www.westernnativeseed.com)

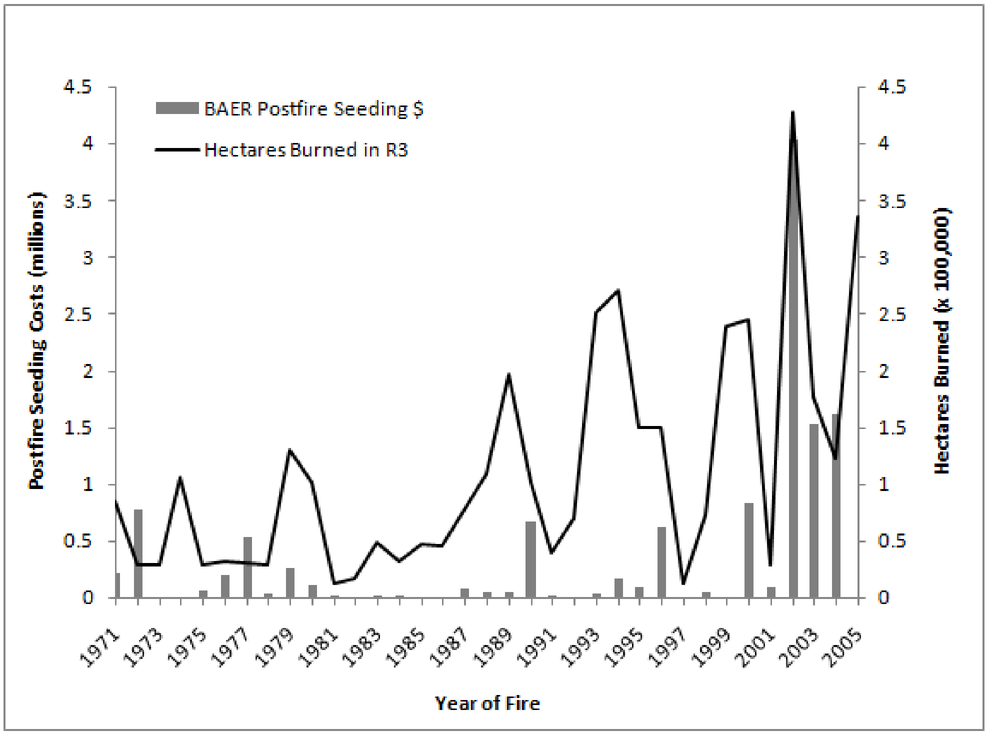

Figure 1. Spending on seeds purchased for post-fire rehabilitation (bars) in USDA FS Region 3 (Arizona and New Mexico) BAER projects between 1971-2005 (Wolfson and Sieg, in press) compared with the total hectares burned (line) on all federally-administered lands in AZ and NM from 1971-2005(Sackett et al. 1994; Swetnam and Betancourt 1998; Snider et al. 2003; SWCC).

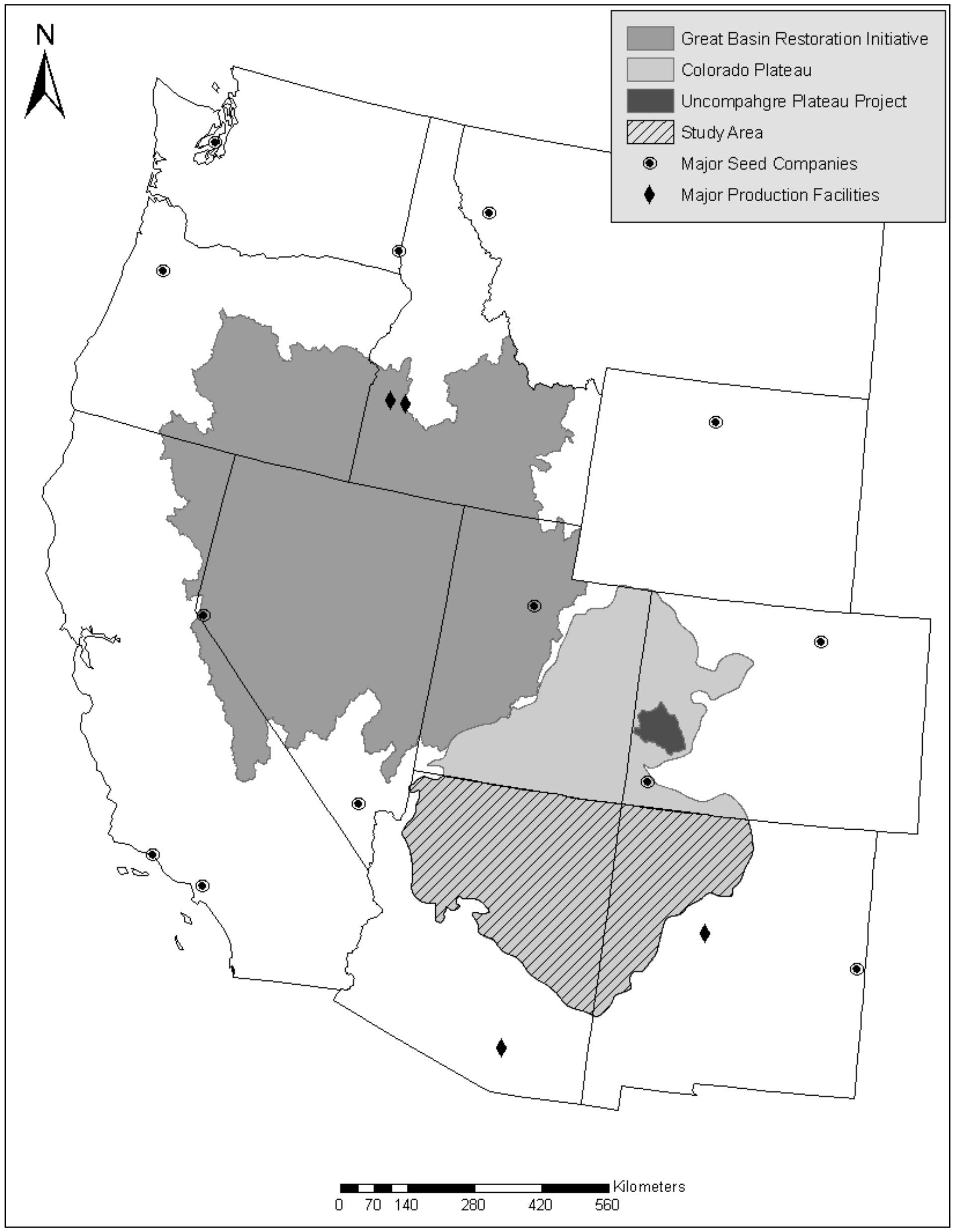

Figure 2. Current cooperatives, seed suppliers, and facilities within the Colorado Plateau and other nearby regions

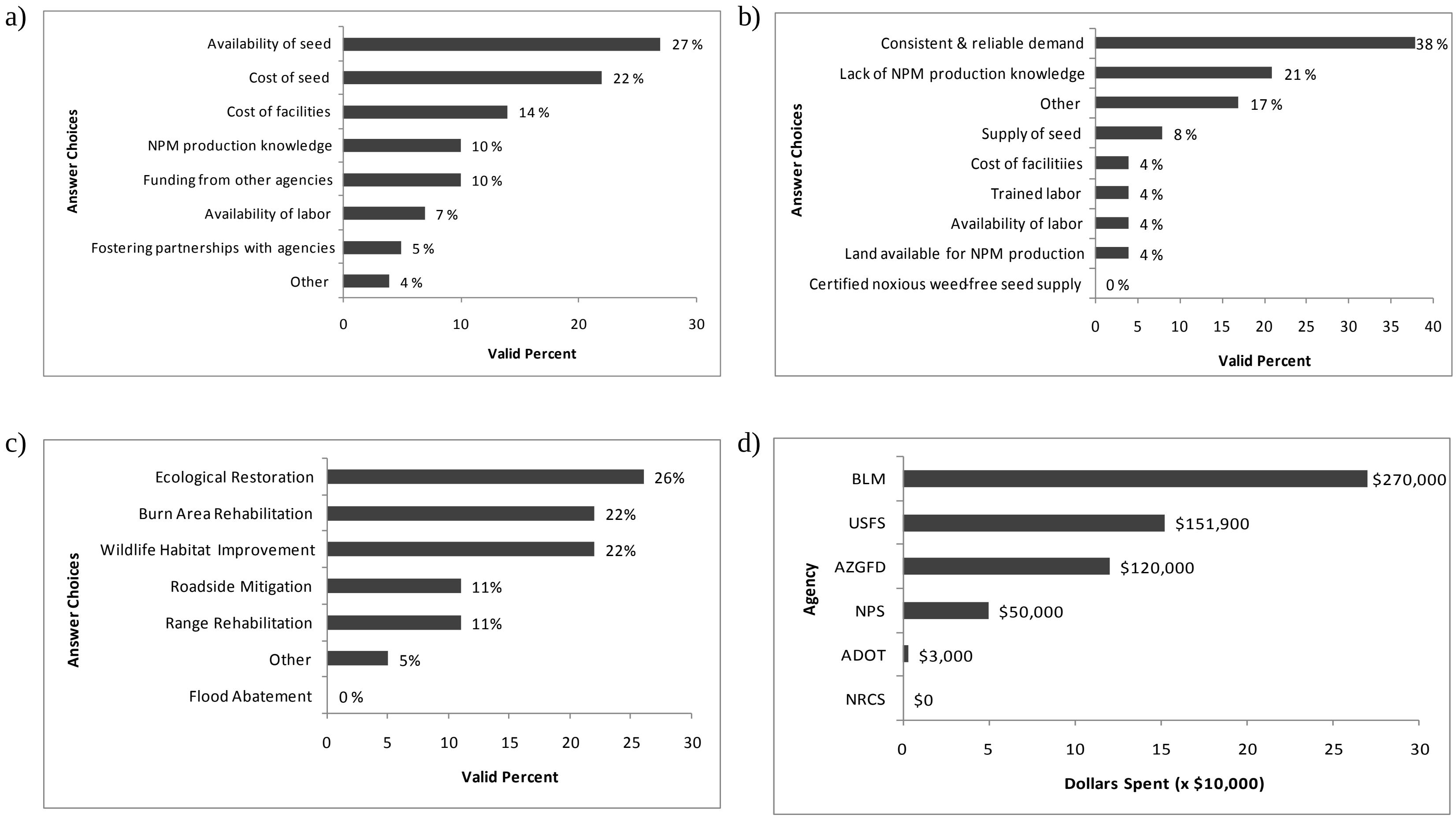

Figure 3. Results of web-based surveys by survey question: a) greatest obstacles to overcome in order to initiate a successful NPM market in the southern Colorado Plateau according to those in demand of NPM, b) most significant limitations to a business involved in the production of NPM, c) primary land management practices those in demand of native seed implement seeding for, and d) dollars spent in 2006 on native plant materials by agency type.

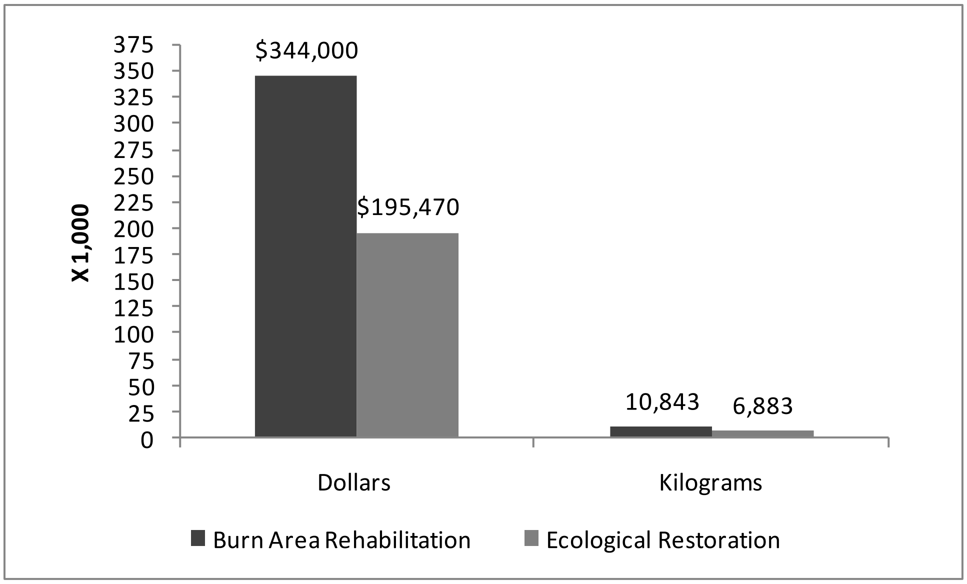

Figure 4. Quantity (kilograms) of native seed purchased versus dollars (US) spent on native seed in 2006 for ecological restoration and burned area rehabilitation

CHAPTER FOUR

Conclusions

If the projections of increased fire activity in the western U.S. are correct, the need to revegetate disturbed lands, and more specifically those areas burned in high-severity wildfires, will undoubtedly escalate. Across agencies, post-fire seeding treatments continue to be used as a first choice rehabilitation measure, although use of these treatments in achieving specified rehabilitation objectives remains debatable. Apart from the use of seeding in post-wildfire rehabilitation, however, revegetation is an integral component of other land management practices such as invasive species management, livestock grazing, wildlife habitat management, roadside rehabilitation, mine reclamation, and recreational use. The use of genetically-appropriate plant materials will be important as maintenance of genetic diversity is a vital mechanism by which plant communities can adapt and evolve to survive in a changing climate (Huenneke, 1991).

Based on our results in Chapter 2, seeding can have both positive and negative effects on post-fire ecosystems. In several studies seeding was shown to be effective in increasing plant cover to reduce soil erosion (Orr 1970; Anderson and Brooks 1975; Maloney and Thornton 1995); however, based on the quality of evidence criteria, only one of 12 studies reported in the two highest quality categories qualified seeding effectiveness for soil erosion. In addition, 78% of study sites evaluating soil erosion showed that seeding provides no additional benefit in reducing erosion relative to unseeded controls. Furthermore, using total vegetation cover thresholds for soil erosion as a matrix for seeding treatment success, only one-seventh of the seeded sites supported sufficient cover to effectively prevent soil erosion. These results corroborate previous reviews suggesting that seeding often fails to reduce erosion (Beschta et al. 2004; Beyers

2004; Wolfson and Sieg, in press), especially not in the first critical years after fire (Kruse et al. 2004). Mulching may be more effective in reducing soil erosion than seeding, but may inadvertently introducing non-native species (Keeley 2004). Increased research investigating the effects and effectiveness of mulching will be important.

Post-fire seeding treatments are often implemented to promote recovery of native plant communities over time. However, across forested ecosystems, reviewed papers showed seeding to reduce (62%) and/or suppress (60%) recovery of native graminoids, forbs, and shrub and tree seedlings (Amaranthus et al. 1993; Schoennagel and Waller 1999; Barclay et al. 2004). Furthermore, seeded species had persistent effects on native vegetation beyond the first year or two after fire (Schoennagel and Waller 1999; Barclay et al. 2004; Stella 2009). This is a concern in that use of annual cereal grains and sterile hybrid grains has increased under the premise that these species disappear quickly. Although seeding with native species has increased, they are typically used in mixes with non-native species, and are rarely used by themselves. Thus, studies examining the effects of seeding with 100% native species are extremely limited. Increased research will be needed to determine the overall effectiveness and effects of seeding with native species.

In recent years, the use of post-fire seeding to reduce non-native species invasion has increased, but studies quantifying the effectiveness of seeding treatments to curtail these invasions are limited. The existing data show that seeding was only effective in reducing non-native species abundance about 50% of the time; of those treatments, the majority introduced additional negative impacts on native communities by seeding with non-native species. Insufficient literature exists to determine whether seeding with natives would be more effective. More work is needed to determine the effectiveness of seeding with native species to reduce non-native invasions.

The scientific literature and management documentation show that costly post-fire seeding does little to protect soil and promote plant recovery in the short-term but may introduce potentially negative effects with long-term ecological consequences. Alternative actions for erosion control should be considered. If seeding continues to be widely used, the use of locally-adapted, genetically-diverse plant materials will be important, although more research regarding the effects and effectiveness of these species is critical. Lastly, rapid detection methods may allow better control for non-native species invasions.

What does this mean for a native plant market based driven by post-fire seeding? If post-fire seeding treatments remain widely used, the demand for locally-adapted plant materials based on post-fire seeding needs may create the ideal opportunity for a market initiation. Although a diverse approach will be needed to overcome the many challenges of initiating a native plant market in the southern Colorado Plateau, market models and funding options exist for development of plant materials based on these demands.

If post-fire seeding treatments decline as a major post-fire rehabilitation practice, demand for locally-adapted plant materials will remain as revegetation is an integral component of other land management practices in the region including invasive species management, livestock grazing, wildlife habitat management, roadside rehabilitation, mine reclamation, and recreational use. Based on our survey results, ecological restoration was the second largest driver of demands for locally-adapted plant materials. However, policy will ultimately drive overall agency decisions regarding the use and purchase of native plant materials. Model markets could still be used as a template of how to overcome challenges of market initiation.

Regardless of what is driving the demand for native plant materials, a market opportunity exists on the southern Colorado Plateau. It is clear that for a market to be developed, an integrated collaborative strategy is needed among producers, land managers, government agencies, organizations, and researchers at both local and regional scales. Collaborative efforts should focus on developing a guiding framework to address primary issues (Williams and Price 2002) regarding: 1) increasing communication among stakeholders; 2) increasing genetic research for the development of appropriate seed zones; 3) increasing information transfer regarding reliable methods for producing locally-adapted plant materials; 4) finding the most effective methods to improve market stability; and 5) securing a stable funding mechanism for market initiation and continued research and development.

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APPENDICES

Appendix I: Evidence-Based Review References (w/ quality of evidence ratings)

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Quality of Evidence Rating: *Highest*

Amaranthus, M. P., J. M. Trappe, D. A. Perry. 1993. Soil Moisture, native revegetation, and *Pinus lambertiana* seedling survival, growth, and mycorrhiza formation following wildfire and grass seeding. Restoration Ecology 1: 188-95.
Quality of Evidence Rating: *Highest*

Anderson, W.E., and L.E. Brooks. 1975. Reducing erosion hazard on a burned forest in Oregon by seeding. Journal of Range Management. 28:394-398.
Quality of Evidence Rating: *Medium*

Barclay, A.D., J.L. Betancourt, C.D. Allen. 2004. Effects of seeding ryegrass (*Lolium multiflorum*) on vegetation recovery following fire in a ponderosa pine (*Pinus ponderosa*) forest. International Journal of Wildland Fire 13:183-194.
Quality of Evidence Rating: *Highest*

Becker, R. 2001. Effective aerial reseeding methods: Market search report. USDA Forest Service 5100 - Fire Management, 0151 1204 - San Dimas Technology & Development Center, San Dimas, CA.
Quality of Evidence Rating: *Lowest*

Beschta, R.L., J.J. Rhodes, J.B. Kauffman, R.E. Gresswell, G.W. Minshall, J.R. Karr, D.A. Perry, F.R. Hauer, C.A. Frissell. 2003. Postfire management of forested public lands of the western United States. Conservation Biology 18:957-967.
Quality of Evidence Rating: *High*

Beyers, J.L. 2004. Post-fire seeding for erosion control: effectiveness and impacts on native plant communities. Conservation Biology 18:947-956.
Quality of Evidence Rating: *High*

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Quality of Evidence Rating: *Highest*

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Quality of Evidence Rating: *Low*

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Quality of Evidence Rating: ***Lowest***

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Quality of Evidence Rating: ***Highest***

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Quality of Evidence Rating: ***Low***

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Quality of Evidence Rating: ***Lowest***

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Quality of Evidence Rating: ***Highest***

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Quality of Evidence Rating: ***Lowest***

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Quality of Evidence Rating: *Lowest*

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Quality of Evidence Rating: *High*

Hunter, M.E. 2004. Post-fire grass seeding for rehabilitation and erosion control: Implications for native plant recovery and exotic species establishment. Ph.D. Dissertation Colorado State University
Quality of Evidence Rating: *Highest*

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Quality of Evidence Rating: ***Lowest***

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Quality of Evidence Rating: ***High***

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Quality of Evidence Rating: ***Highest***

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Quality of Evidence Rating: ***Medium***

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Quality of Evidence Rating: *Lowest*

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Quality of Evidence Rating: *Highest*

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Quality of Evidence Rating: *Lowest*

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Quality of Evidence Rating: *Lowest*

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Quality of Evidence Rating: *Lowest*

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Quality of Evidence Rating: *Lowest*

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Quality of Evidence Rating: *High*

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Quality of Evidence Rating: *Highest*

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Quality of Evidence Rating: *Medium*

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Quality of Evidence Rating: *Medium*

Rough, D. 2007. Effectiveness of rehabilitation treatments in reducing post-fire erosion after the Hayman and Schoonover fires, Colorado Front Range. M.S. Thesis Colorado State University.
Quality of Evidence Rating: *Highest*

Ruby, E.C. 1989. Rationale for seeding grass on the Stanislaus Complex burnt. In: Berg, Neil H., tech. coords. Proceedings of the symposium on fire and watershed management, October 26-28,1988, Sacramento, California. Gen. Tech. Rep. PSW-109. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 125-130.
Quality of Evidence Rating: *Lowest*

Schoennagel, T. 1997. Native plant response to high intensity fire and seeding of non-native grasses in an *Abies grandis* forest on the Leavenworth district of the Wenatchee National Forest. M.S. Thesis Univeristy of Wisconsin-Madison.
Quality of Evidence Rating: *High*

Schoennagel, T.L., and D.M. Waller. 1999. Understory responses to fire and artificial seeding in an eastern Cascades *Abies grandis* forest, U.S.A. Canadian Journal of Forest Research 29:1390-1401.
Quality of Evidence Rating: *High*

Sexton, T.O. 1998. Ecological effect of post-wildfire management activities (salvage-logging and grass-seeding) on vegetation composition, diversity, biomass, and growth and survival of *Pinus ponderosa* and *Purshia tridentata*. M.S. Thesis Oregon State University.
Quality of Evidence Rating: *Highest*

Sirucek, D. 1987. The north hills fire-erosion event. Proceedings of XVIII International Erosion Control Conference, February 26-27, 1987, Reno, NV. 199-202.
Quality of Evidence Rating: *Lowest*

Springer, J.D. 2007. Understory seeding in southwestern forests following wildfire and ecological restoration treatments. , Northern Arizona University: Working Paper 19, 8p.
Quality of Evidence Rating: *Lowest*

Springer, J. D., A.E.M. Waltz, P.Z. Fulè, M.M. Moore, W.W. Covington. 2001. Seeding versus natural regeneration: A comparison of vegetation change following thinning and burning in ponderosa pine. USDA Forest Service, Rocky Mountain Research Station Proceedings RMRS-P-22.
Quality of Evidence Rating: *High*

Stella, K.A. 2009. Effects and effectiveness of seeding following high-severity wildfires in northern Arizona ponderosa pine forests. M.S. Thesis. Northern Arizona University.
Quality of Evidence Rating: *Highest*

Stewart, W.L. 1973. Emergency rehabilitation of watersheds denuded by wildfire in the ponderosa pine and douglas-fir zones of north-central Washington. M.S. Thesis Washington State University.
Quality of Evidence Rating: *Medium*

Story, M.T., and R. Kracht. 1989. Memo: Emergency watershed stabilization, BMP implementation review storm creek fire. Unpublished Report on File at: U.S. Department of Agriculture, Forest Service, Gallatin National Forest, MT.
Quality of Evidence Rating: *Lowest*

Sullivan, J., P.N. Omi, A.A. Dyer, A. Gonzales-Caben. 1987. Evaluating the economics efficiency of wildfire rehabilitation treatments. Western Journal of Applied Forestry 2:58-61.
Quality of Evidence Rating: *Low*

Tiedmann, A.R., and G.O. Klock. 1973. First-year vegetation after fire, reseeding, and fertilization on the Entiat Experimental Forest. Research Note PNW-195, 23 p.
Quality of Evidence Rating: *High*

U.S. Department of the Interior and U.S. Department of Agriculture. 2006. Interagency Burn Area Emergency Response Guidebook. Interpretation of Department of the Interior 620 DM 3 and USDA Forest Service Manual 2523. Version 4.0. February 2006. Washington, D.C.
Quality of Evidence Rating: *Lowest*

VanZuuk, K. 1997. Memo, Crystal Burn monitoring. Unpublished Report on File at: U.S. Department of Agriculture, Forest Service, Tahoe National Forest, CA.
Quality of Evidence Rating: *Lowest*

Wagenbrenner, J.W., L.H. MacDonald, D. Rough, D. 2006. Effectiveness of three post-fire rehabilitation treatments in the Colorado Front Range. Hydrological Processes 20:2989-3006.
Quality of Evidence Rating: *High*

Weigel, T.J. 2007. Assessing post-fire reseeding potential using Bureau of Land Management criteria in northeastern Nevada: A spatial modelling appoarch. M.S. Thesis University of Nevada, Reno.
Quality of Evidence Rating: *Low*

Wolfson, B.A.S., and C.H. Sieg. 40-year post fire seeding trends in Arizona and New Mexico. Rocky Mountain Research Station General Technical Report. (In press).
Quality of Evidence Rating: *High*

Woodsmith, R.D., K.B. Vache, J.J. McDonnell, J.D. Helvey. 2004. Entiat experimental forest: Catchment-scale runoff data before and after a 1970 wildfire. Water Resources Research, 40:W1170, 5p.
Quality of Evidence Rating: *High*

Appendix II: Demand Survey Contact List

Last Name	First Name	Organization	Street	City	State	Zip Code
Aumack	Ethan	Grand Canyon Trust - Restoration Programs Director	2601 N. Fort Valley Rd	Flagstaff	AZ	86001
Austin	Bill	US Fish and Wildlife Service - Flagstaff	1585 S. Plaza Way, Suite 160	Flagstaff	AZ	86001
Blake	Brad	NAU Greenhouse Complex	Pine Knoll	Flagstaff	AZ	86001
Boyd	Carol	USFS Coconino NF - Stewardship Staff	1824 S. Thompson St.	Flagstaff	AZ	86001
Brady	LeRoy	Arizona Department of Transportation	24251 N. 7th Avenue	Phoenix	AZ	85027
Bumpus	Deb	Apache Sitgreaves NF - BAER	PO Box 640	Springerville	AZ	85938
Busco	Janice	NPS - Grand Canyon NP/ Horticulturist	PO Box 129	Grand Canyon	AZ	86023
Cassady	Steve	Natural Resource Conservation Service - Range	230 N. First Avenue, Suite 509	Phoenix	AZ	85003
Chapman	Neil	Nature Conservancy - Hart Prairie Preserve	114 N. San Francisco St #205	Flagstaff	AZ	86001
Cordasco	Billy	Babbitt Ranches, Inc. - President	PO Box 520	Flagstaff	AZ	86002
Crisp	Debbie	US Forest Service - Botanist	1824 S. Thompson St	Flagstaff	AZ	86001
Eckler	Tom	ADOT - Natural Resource Flagstaff Manager	1801 S. Milton	Flagstaff	AZ	86001
Ellis	Bruce	Bureau of Reclamation Phoenix Area Office	6150 N. Thunderbird Rd	Glendale	AZ	85306
Farrell	Grey	Navajo Nation - Big Boquillas Ranch	PO Box 767	Tuba City	AZ	86045
Greco	Bruce	USDA Coconino NF - Fire	1824 S. Thompson St.	Flagstaff	AZ	86001
Hannemann	Mike	USFS Kaibab National Forest - Stewardship Staff	800 South Sixth Street	Williams	AZ	86046
Harcksen	Kathleen	BLM - Arizona Strip Field Office and GCPNM	345 E. Riverside	St. George	UT	84790
Harper-Lore	Bonnie	Federal Highway Administration	1200 New Jersey Ave.	Washington	DC	20590
Haskins	Kristin	Flagstaff Arboretum	4001 S. Woody Mtn Dr.	Flagstaff	AZ	86001
Hughes	Lee	BLM Arizona Strip Field Office - Botanist	345 E. Riverside	St. George	UT	84790

Last Name	First Name	Organization	Street	City	State	Zip Code
Huling	Karlynn	Kaibab NF – Range Natural Resource Specialist	800 South Sixth Street	Flagstaff	AZ	86001
Kloeppel	Heidi	Landscape Architect and Yuma Wetlands	9730 N. Rosewood Dr.	Flagstaff	AZ	86001
Lerich	Scott	National Wild Turkey Federation	P. O. Box 2180	La Luz	NM	88337
Macauley	Mike	AZ Assoc. of Conservation Districts/Perrin Ranch	PO BOX 365	Williams	AZ	86046
McDonald	Charlie	USFS - Region 3 Botanist and NNIS	333 Broadway SE	Albuquerque	NM	87102
Miller	Rick	Arizona Game and Fish Department	3500 S. Mary Lake Rd	Flagstaff	AZ	86001
Moore	Amy	El Paso Natural Gas Company - Western Pipeline	PO Box 1087	Colorado Springs	CO	80944
Murphy	Terry	Bureau of Reclamation Lower Colorado Region	PO Box 61470	Boulder City	NV	89006
Nelson	Harlan	Arizona State Lands Department - Prison	3650 Lake Mary Rd	Flagstaff	AZ	86001
Pajkos	Keith	Arizona State Lands Department - Forestry	3650 Lake Mary Rd	Flagstaff	AZ	86001
Phillips	Barb	Coconino National Forest - Zone Botanist	1824 S. Thompson St	Flagstaff	AZ	86001
Prosser	Bob & Judy	Diablo Trust - Potential Grower and Bar T Ranch	PO Box 190	Winslow	AZ	86047
Rogers	Andi	Arizona Game and Fish	3500 S. Mary Lake Rd	Flagstaff	AZ	86001
Roth	Daniela	Navajo Natural Heritage Program Botanist	PO Box 1480	Window Rock, Navajo Nation	AZ	86515
Sandberg	Bob	BLM Arizona Strip Field Office - Range	345 E. Riverside	St. George	UT	84790
Sieg	Ron	Arizona Game and Fish Department	3500 S. Mary Lake Rd	Flagstaff	AZ	86001
Spence	John	Glen Canyon National Recreation Area - Botanist	PO Box 1507	Page	AZ	86040
Stiverson	Keri	Museum of Northern Arizona	3101 N. Fort Valley Rd	Flagstaff	AZ	86001
Stuever	Mary	White Mountain Apache Tribe- Tribal Forestry	PO Box 700	Whiteriver	AZ	85941
Widmark	Derrick	Diablo Trust Program Coordinator	PO Box 3058	Flagstaff	AZ	86003
Wilson	Barbara	Glen Canyon National Recreation Area	PO Box 1507	Page	AZ	86040
Yanske	Kari	Grand Canyon-Parashant NM - Botanist	345 E. Riverside	St. George	UT	84790

Appendix II: Supply Survey Contact List

Last Name	First Name	Business	Street	City	State	Zip Code
Ames	Paul	Utah Native Seed	PO Box 355	Eureka	UT	84628
Barajas	Gilbert	S & S Seed	5690 Casitas Pass Rd	Carpintena	CA	93014
Barraclough	Ed	Rocky Mountain Seed Company	PO Box 5204	Denver	CO	80217
Bartel	Bill	Westland Seed Inc.	1308 Round Butte Rd	Ronan	MT	59864
Becker	Chad	Treasure State Seed Inc.	PO Box 698	Fairfield	MT	59436
Behrent	JoAnn	Geertson Seed Farms	1665 Burroughs Rd	Adrian	OR	97901
Benson	Jerry	BFI Native Seeds	1145 S. Jefferson	Moses Lake	WA	98837
Berni	Gary	Wildlands Restoration	2944 N. Carstro Ave	Tucson	AZ	85705
Boyce	Orson	Wheatland West Seed LLC	PO Box 513 1780 No. Hwy 38	Brigham City	UT	84302
Carter	Bill	Prairie Moon Nursery	Route 3 Box 1633	Winona	MN	55987
Chapman	John	Chapman Farms	17648 Northside Blvd	Nampa	ID	83687
Cook	Robin	Sunmark Seeds International	906 NW Corporate Drive	Troutdale	OR	97060
Dean	Alan	Alplains Seeds	PO Box 489	Klowa	CO	80117
Deguilio	Alan	Idaho Grimm Growers	PO Box 276	Blackfoot	ID	83221
Dressen	David	Los Lunas Plant Materials Center	1036 Miller Street SW	Los Lunas	NM	87031
Edminster	Craig	Pacific Northwest Natives	1525 Laurel Hts. Dr.	Albany	OR	97321
Fleege	Clark	Lucky Peaks Nursery - USFS Nursery Manager	15169 E. Highway 21	Boise	ID	93716
Garner	Ramona	Tucson Plant Materials Center	3241 North Romero Rd	Tucson	AZ	85705
Giplin	David	Pacific Coast Seed	6144A Industrial Way	Livermore	CA	94550
Hanes	Robbie	Southwest Seed - owner	13260 CR 290	Dolores	CO	81323
Herrman	Paul	L & H Seeds, Inc.	4756 W. Sr 260	Connell	WA	99326
Hijar	Don	Pawnee Buttes Seed Co. *Attn Don*	PO Box 100	Greeley	CO	80632
Holzhauser	Russ	Wind River Seed	3075 Lane 51 1/2	Manderson	WY	82432
Hyatt	Jen	Arkansas Valley Seed, Inc.	4625 Colorado Blvd.	Denver	CO	80216

Last Name	First Name	Business	Street	City	State	Zip Code
Kennard	Celeste	Utah Native Plant Society	PO Box 520041	Salt Lake City	UT	84152
Knutson	Stephen	Stover Seed Company	PO Box 21488	Los Angeles	CA	90021
Loe	Kevin	Oregon Wholesale Seed	PO Box 885	Silverton	OR	97381
McDonnell	Stephen	Circle S Seeds of Mt., Inc.	PO Box 130	Three Forks	MT	59752
Mckenzie	Nancy	Lawyer Nursery *Attn Nancy*	950 Hwy 200 W	Plains	MT	59859
Miller	Kevin	Grassland West Company	908 Port Drive	Clarkston	WA	99403
Musto	Mark	Landmark Native Seed Co. *Attn Pam*	N. 120 Wall St, Suite 400	Spokane	WA	99201
Parenteau	Kathy	T. Payne Fdn. For Wildflowers and Native Plants	10459 Tuxford St	Sun Valley	CA	91352
Powell	Cindy	Environmental Seed Producers *Attn Cindy Powell*	PO Box 2709	Lompac	CA	93438
Ralston	Troy	Bailey Seed Company, Inc.	PO Box 12788	Salem	OR	97309
Richards	Glenn	Johnston Seed Company	319 West Chestnut	Enid	OK	73701
Schafer	Keith	Seed-Rite, Inc.	PO Box 496	Odessa	WA	99159
Schutt	Brad	Todd Valley Farms	East Highway 92	Mead	NE	68041
Shillinglaw	Kirk	Prairie Nursery, Inc. V.P. Sales and Marketing	PO Box 306	Westfield	WI	53964
Sparks	Nigel	Flagstaff Native Plant and Seed	400 E. Butler Ave	Flagstaff	AZ	86001
St John	Loren	Aberdeen Plant Materials Center	PO Box 296	Aberdeen	ID	83210
Stevens	Jason	Great Basin Seed Company	PO Box 335070 N.	Las Vegas	NV	89033
Stevenson	Ron	Stevenson Intermountain Seed	PO Box 2	Ephraim	UT	84627
Swift	Dean	Dean Swift Seed Company	PO Box 908	Alamosa	CO	81101
Tonnesen	Alex	Western Native Seed	25 Pine Edge Drive	Coalside	CO	81222
Walla	Chuck	Desert Seed Source	PO Box 25555	Tempe	AZ	85285
Westbrook	Susan	Plants of the Southwest *Attn Susan*	3095 Aqua Fria	Santa Fe	NM	87507
Winterfield	Delbert	Cedera Seed, Inc.	PO Box 97	Swan Valley	ID	83449
Wood	Harold	Rainer Seeds, Inc	PO Box 1549	Port Orchard	WA	98366
	Damon	Granite Seed	1697 W. 2100 North	Lehi	UT	84043

Last Name	First Name	Business	Street	City	State	Zip Code
	Chad	Curtis and Curtis *Attn Chad*	Star Route Box 8A	Clovis	NM	88101
	Ed	Comstock Seed	917 Hwy 89	Gardnerville	NV	89410
		Mesa Garden Plant and Seed List	PO Box 72	Belen	NM	87002

Appendix III: Complete Survey Methodology

Model Markets

Through an investigation of current literature, interviews, and site visits we aimed to identify NPM markets in nearby regions which could be used as models to help guide the development of a regionally-based NPM market in the southern Colorado Plateau. We searched scientific journals, unpublished theses and reports, and government documents to identify preliminary model markets. We interviewed natural resource professionals within the region to gain further insight on the markets previously identified. Final model markets were selected based on their similarity to the southern Colorado Plateau's size and market demands.

Survey

We developed two distinct web-based surveys to assess current native plant market perceptions and the opportunity to initiate a native plant and seed industry in the southern Colorado Plateau. Through an extensive interview and searching process, participants were identified. Preliminary information gained from interviews helped guide survey question development. Pre-testing allowed for assessment of survey question comprehension, efficiency, relevancy and format organization. From pre-testing feedback the final surveys were created and administered by a web-based approach. The techniques used to develop and administer the survey proved to be effective and yielded high response rates. The information gained highlights key elements that may be needed to stimulate a native plant market.

Sample of Demand and Supply Survey Respondents

A demand survey was administered to a target group of individuals from federal, state, private, and nonprofit entities who were potentially or actively involved in restoration in the southern Colorado Plateau. We administered a supply survey to a targeted group of individuals from both large and small-scale seed production companies from Arizona, New Mexico, nearby western and Great Plains states, as well as to other successful seed production companies. In addition, individuals, identified through preliminary background interviews, who showed potential interest in initiating a native plant materials production company in the region, were added to the supply group sample.

Question Development and Survey Construction

To understand the context and design of a useful survey, a preliminary background investigation was conducted to determine current issues and trends pertaining to the use of native plant materials. Interviews were conducted with natural resource managers from regional government agencies, private entities, and non-profit organizations, and private native plant landscaping and nursery owners in the southern Colorado Plateau. The preliminary information was used to help guide in the development of relevant survey questions. After the content of the surveys was determined, preliminary supply and demand surveys were created.

The research operations manager of Northern Arizona University's Social Research Laboratory (SRL) was consulted for the survey's design and content. This guided the use of proper survey language and clear, unambiguous and concise wording to help eliminate question bias and survey fluency. Survey questions were grouped into appropriate context categories. In order to conduct the study, an Initial Application for Research along with the survey instrument was submitted to the Institutional Review Board at Northern Arizona University. The application was approved in October 2007.

Once question order, content, and format were finalized, a web-based survey was programmed for both the supply and demand markets using SurveyMonkey (www.surveymonkey.com). SurveyMonkey is an online survey tool which was selected for its ease of use and capability to create professional surveys.

A web-based survey methodology was selected over traditional mail survey methods due to its capability for automatic verification and storage of survey responses using database technology as well as its ability to eliminate transcription errors (Andrews, Nonnecke, and Preece, 2003). Data, exported into an Excel spreadsheet, can then be checked to eliminate programming errors. This method eliminates unanswered questions by use of special features and reduces administration time and cost. Use of question "skip logic" enabled the respondent to be redirected to a relevant question within the survey based on the previous response. To alleviate questions from being skipped entirely, all questions were programmed so the respondent could not continue without answering a question.

Survey Content

We developed 42 questions for the demand survey and 37 questions for the supply survey based on preliminary information from interviews and current literature (Richards et al. 1998; Soller 2003; Hooper 2003). The average length of time to complete the survey was approximately 15-20 minutes. Each survey began with an introduction page. The purpose of an introduction page is to help establish a trusting relationship with the prospective respondent and encourage the respondent to complete the survey (Andrews, Nonnecke, and Preece, 2003). The introduction of each survey included: (1) identification of the researcher, (2) explained the survey's purpose, (3) explained how the results would be used, (4) guaranteed respondent confidentiality and anonymity and, and (5) explained the sampling methodology.

We asked a series of survey questions within six thematic areas pertaining to NPM: 1) policy and regulation; 2) issues and concerns; 3) purchasing and expenditures; 4) future use and needs; 5) equipment and operations; and 6) collaboration and funding. We created and administered finalized surveys online (Andrews et al. 2003; Kaplowitz et al. 2004; Ryu et al. 2005).

Each survey consisted of a variety of formats including close-ended, "select all that apply," and open-ended questions. Close-ended questions, where respondents selected an answer from a given list also included an "Other" category and, at times, a comment section. The “Other” category allowed the respondent to select an answer that was not on the predetermined list. “Select all that apply” questions allowed for the survey participant to select multiple answer choices. Open-ended questions were included to encourage the survey participant to expand on issues not fully addressed in a closed-ended question format and enabled the responses to be assessed in a qualitative format.

Participant memory recall is often limited when information being requested is too far in the past. For this reason, questions where designed for the survey participant to recall information one year prior to the current year (2006). For each question, a “Don’t Know” and “Decline to Answer” answer category was available to allow the respondent the choice not to answer a question. Before exiting the survey, a short paragraph thanked survey respondents and explained how the survey results would be used and incentives award for their participation.

A large body of literature exists about the role of incentives play and its effect on survey response rates. There is overwhelming agreement among social scientists that incentives increase overall response rates (Ryu et al., 2005). For this reason, a copy of the final feasibility study report and a chance to win a Starbucks Coffee Company donation was offered as an incentive to each survey participant. Starbucks Coffee Company generously donated $100 worth of Starbucks coffee and merchandise to be used as an incentive to complete the survey. Each survey participant was entered into a drawing for a chance to win the prize.

Survey Pre-testing

A total of two pre-tests, one paper version and one web-based version were completed prior to the administration of the finalized web-based surveys. Prior to the development of web-based survey questions, draft paper-based survey questions were administered to the Northern Arizona Native Seed Alliance (NANSA) for feedback on survey content. Revisions were made according to NANSA feedback and a web-based survey was created. Fifteen professionals were asked to complete the web-based supply and demand surveys as a pre-test. This allowed for testing survey question comprehension, efficiency, relevancy and format organization. Seven natural resource managers from the northern Arizona region and three NAU researchers familiar with native plant material practices were selected to pre-test the demand survey. Three government agency personnel directly involved in purchasing or housing seed for restoration practices and two representatives from native plant material production companies located in Arizona were selected to pre-test the supply survey. Of the 15 survey pre-test participants, three individuals were included in the final sample database as they were major entities in the demand for native plant materials.

Prior to administering the web-based pre-test surveys, each potential survey pre-test recipient was contacted by telephone to explain the purpose of the survey and to gain consent to complete the survey. It has been demonstrated that pre-notification contact has the strongest response rate impact (Kaplowitz et al., 2004). Upon gaining approval to take the survey, the pre-test group was sent a personalized email with instructions on how to complete the survey as well as the survey link. A unique identifying number was assigned to each survey pre-test respondent. This created a coded survey link which allowed survey responses to be associated with the respondents' contact information.

All survey pre-test respondents were given approximately two weeks to complete to the survey. A follow-up email was sent one week into the survey response period to those respondents who had not yet submitted their survey. Studies have shown that a follow-up email often has a positive effect on response rates (Andrews, Nonnecke, and Preece, 2003). At the end of the two week survey response period, eight out of ten demand surveys were completed (80% response rate) and three out of five supply surveys were returned (60% response rate). All responses and feedback from the pre-test group were evaluated and surveys were amended to reflect relevant recommendations from this group.

Survey Distribution

The survey sample database files were finalized with a total of 42 demand and 39 supply contacts (Appendix II). An attempt was made to contact each potential survey participant directly by telephone prior to sending the final survey link. Pre-notification explained the purpose of the survey, how the results would be used, and to gain approval to participate. Of the 42 demand participants, 31 could be reached on the telephone and agreed to take the survey. Of the 39 supply contacts, 27 could be reached directly on the telephone and agreed to participate in the study. For the remaining 11demand participants and the 12 supply participants who could not be reached, messages were left on answering machines or with other associates. All potential survey participants, including those not reached directly on the telephone, were sent their relevant surveys to allow for participation and increase response rates. Survey links were embedded into personalized emails as well as instructions on how to successfully complete the survey, a deadline date, and an explanation of the Starbucks prize which was used as an incentive to complete the survey. All survey participants were given approximately two weeks to respond to the survey. A unique identifying number was assigned to each survey participant. This identifying number allowed survey responses to be associated with the respondents' contact information. Additionally, the identifying number allowed for follow-up of ambiguous answers. Consequently, survey responses remained confidential and anonymous and were reported as an aggregate.

A reminder email with each coded survey link and a deadline date reminder was sent one week into the survey response period to those respondents who had not yet completed the survey. At the end of the first survey response period, 29 returned a complete demand survey (69% response rate) and 25 completed the supply survey (64% response rate). Participants who had not yet responded to the surveys after the two week response period were contacted again. A total of 13 demand and 14 supply contacts were called directly by telephone. The survey administration method previously used was followed again. At the end of the second week response period the demand survey gained eight additional completed surveys and increased the response rate to 88% (37 responses total). The supply survey gained four respondents, increasing the response rate to 85% (33 responses total). Contact by telephone prior to sending the surveys, personalized emails, follow-up contact, and an incentive led to a high response rate. Applying these tactics increase response rates, augments the validity and reliability of the survey data, and the resulting research conclusions.

Analysis of Survey Results

We used Statistical Package for the Social Sciences (SPSS) software (SPSS 2007) to analyze final survey response datasets. Survey questions were analyzed by calculating answer frequencies (n) and valid percents of respondent participation for each question. For respondents answering “Don’t Know” and “Decline to Answer,” those responses were counted as missing and were not included in the valid percent calculations. For multiple choice questions stating “Select all that apply,” total percent may exceed 100, as respondents could answer multiple times. Valid percents, in these cases, were calculated by dividing the total response for each category by the total number of responses for that question. Percents were rounded which may cause total percents to be slightly greater or less than 100.

Answers within a “comment” or “other” response were tabulated and analyzed. Responses fitting into the original question categories were recoded accordingly and included in final valid percent and frequency results. For ease of the analysis, open-ended and other responses were summarized. For question where open and other responses that were repetitive are listed below the corresponding question and delineated with the number of duplicate responses in parenthesis. Questions and corresponding results are discussed in the survey results section and summarized in an Annotated Questionnaire format (Appendix IV).

Appendix IV: Annotated Questionnaire - Demand

A total of 42 questions were administered to 37 consumers of native seed in the Northern Arizona Native Plant Materials Market Feasibility Survey. Answer frequencies (*n*) and valid percents of survey results for each question are summarized in an Annotated Questionnaire below.

In cases where respondents answered "Don't Know" and "Decline to Answer," these responses were counted as "missing" and were omitted in calculating valid percent. In addition, valid percents were rounded which may cause total percents to equal slightly more or less than 100. For the multiple response questions, where respondents were able to select more than one answer, the total n may be higher than the number of respondents. In these cases, valid percents were calculated by the number (*n*) in each response category divided by the total number of responses for the question. Where respondent answers were identical in the open response questions/sections, the total (*n*) duplicated responses are represented in parenthesis after the stated response. See Appendix V for a full list of scientific names and authorities used in this questionnaire.

Q1. Does your organization or agency unit you represent currently implement seeding practices?

	Valid Percent	Frequency (*n*)
Yes	82 %	27
No	18 %	6
Total	100 %	33

Q2. For which of the following does your organization or agency unit you represent currently implement seeding practices for? Select all that apply. (multiple response question)

	Valid Percent	Frequency (n)
Ecological restoration	26 %	23
Burn area rehabilitation	22 %	19
Roadside mitigation	11 %	10
Flood abatement	3 %	3
Wildlife habitat improvement	22 %	19
Range rehabilitation	11 %	10
Other	5 %	4
Total	100 %	88

Other responses Q2:
1. Restoration upon completion of construction activities
2. Seeding for cattle forage under irrigation.
3. Mitigation for disturbance from timber operations
4. Road closures, timber sales (after completion of treatment on areas such as slash piles)

Q3. In 2006, how much native seed did your organization or agency unit you represent purchase for seeding practices. Please specify amount in POUNDS?

	Valid Percent	**Frequency (*n*)**
0-100 lbs	26 %	6
101-500 lbs	26 %	6
501-1000 lbs	9 %	2
1001-5000 lbs	13 %	3
5001-10000 lbs	0 %	0
More than 10,000 lbs	9 %	2
Other	.04%	1
Total	101 %	23

Other responses Q3:
1. It was not native seed

Q4. In 2006, how much money did your organization or agency unit you represent spend on native seed? Please specify amount in DOLLARS?

	Valid Percent	**Frequency (*n*)**
$0-$1,000	16 %	3
$1001-$5000	26 %	5
$5001-$10,000	5 %	1
$10001-$50,000	21 %	4
$50,001-$100,000	5 %	1
More than $100,000	21 %	4
Other	5 %	1
Total	99 %	19

Other responses Q4:
1. Sorry, no way to track in transportation projects.

Q5. In 2006, how much native seed did your organization or agency unit you represent purchase for the following seed practices? Please specify amount in POUNDS.

Ecological Restoration Pounds:

	Valid Percent	Frequency (*n*)
0-100 lbs	27 %	3
101-500 lbs	27 %	3
501-1,000 lbs	18 %	2
1,001-5,000 lbs	18 %	2
5,001-10,000 lbs	9 %	1
Total	99 %	11

Burn Area Rehabilitation Pounds:

	Valid Percent	Frequency (*n*)
0-100 lbs	20 %	2
101-500 lbs	30 %	3
501-1,000 lbs	0 %	0
1,001-5,000 lbs	30 %	3
5,001-10,000 lbs	20 %	2
Total	100 %	10

Roadside Mitigation Pounds:

	Valid Percent	Frequency (*n*)
0-100 lbs	67 %	2
101-500 lbs	33 %	1
501-1,000 lbs	0	0
1,001-5,000 lbs	0	0
5,001-10,000 lbs	0	0
Total	100 %	3

Flood Abatement Pounds:

	Valid Percent	Frequency (*n*)
0-100 lbs	0	0
101-500 lbs	0	0
501-1,000 lbs	0	0
1,001-5,000 lbs	0	0
5,001-10,000 lbs	0	0
Total	0	0

Wildlife habitat improvement Pounds:

	Valid Percent	Frequency (*n*)
0-100 lbs	33 %	2
101-500 lbs	50 %	3
501-1,000 lbs	0 %	0
1,001-5,000 lbs	17 %	1
5,001-10,000 lbs	0 %	0
Total	100 %	6

Range Rehabilitation Pounds:

	Valid Percent	Frequency (*n*)
0-100 lbs	0 %	0
101-500 lbs	0 %	0
501-1,000 lbs	0 %	0
1,001-5,000 lbs	0 %	0
5,001-10,000 lbs	0 %	0
Total	0 %	0

Other responses Q5:
1. All in cuttings
2. 10 lbs. for timber operations mitigation
3. Federal Lands Highway Project seeding

Q6. In 2006, how much money did your organization or agency unit you represent spend on native seed for the following practices? Please specify amount in DOLLARS.

Ecological Restoration Dollars:

	Valid Percent	Frequency (*n*)
$0-$1,000	27 %	3
$1,001-$5000	27 %	3
$5,001-$10,000	9 %	1
$10,001-$50,000	18 %	2
$50,001-$100,000	18%	2
More than $100,000	0 %	0
Total	99 %	11

Burn Area Rehabilitation Dollars:

	Valid Percent	Frequency (*n*)
$0-$1,000	30 %	3
$1,001-$5000	20 %	2
$5,001-$10,000	0 %	0
$10,001-$50,000	20 %	2
$50,001-$100,000	20 %	2
More than $100,000	10 %	1
Total	100 %	10

Roadside Mitigation Dollars:

	Valid Percent	Frequency (*n*)
$0-$1,000	0 %	0
$1,001-$5000	67 %	2
$5,001-$10,000	0 %	0
$10,001-$50,000	33 %	1
$50,001-$100,000	0 %	0
More than $100,000	0 %	0
Total	100 %	3

Flood Abatement Dollars:

	Valid Percent	Frequency (*n*)
$0-$1,000	0 %	0
$1,001-$5000	0 %	0
$5,001-$10,000	0 %	0
$10,001-$50,000	0 %	0
$50,001-$100,000	0 %	0
More than $100,000	0 %	0
Total	0 %	0

Wildlife Habitat Improvement Dollars:

	Valid Percent	Frequency (*n*)
$0-$1,000	67 %	4
$1,001-$5000	0 %	0
$5,001-$10,000	17 %	1
$10,001-$50,000	0 %	0
$50,001-$100,000	0 %	0
More than $100,000	17 %	1
Total	101 %	6

Range Rehabilitation Dollars:

	Valid Percent	Frequency (*n*)
$0-$1,000	0 %	0
$1,001-$5000	0 %	0
$5,001-$10,000	0 %	0
$10,001-$50,000	0 %	0
$50,001-$100,000	0 %	0
More than $100,000	0 %	0
Total	0 %	0

Other responses Q6:
1. $50 for timber operation mitigation

Q7. Realistically, how many pounds of native seed would your organization/agency need in the next 5 years, if your program grew at an optimal rate? (Provide amount in POUNDS)

	Valid Percent	Frequency (*n*)
0-100 lbs	23 %	5
101-500 lbs	18 %	4
501-1,000 lbs	14%	3
1,001-5,000 lbs	18 %	4
5,001-10,000 lbs	9 %	2
10,001-25,000 lbs	9 %	2
25,001-50,000 lbs	5 %	1
50,001-75,000 lbs	5 %	1
Total	101 %	22

Other response Q7:
1. It would depend on the size of fires.
2. It would dependent on the fire frequency.
3. Future seeding needs for the projects I am involved in are hard to predict. The demand is dependent on 1) Large Fires 2) Values at risk from those fires 3) The funding available to the Forest and Region for fire rehabilitation.

Q8. In 2006, where did you purchase most of the native seed supply?

	Valid Percent	Frequency (*n*)
Locally In-state	12 %	3
Regionally In-state	12 %	3
Regionally Out-of-state	44 %	11
Out-of-state (not within the region)	4 %	1
Other	28 %	7
Total	100 %	25

Other responses Q8:

1. Any native seed purchased was done through Arizona Game & Fish Department
2. The seed came through the consolidated seed buy for Bureau of Land Management and came from vendors throughout the west
3. States are asked to use as local as possible seed sources within region at most.
4. Mixture of Locally In-state, and Out of State
5. None purchased
6. About equal amounts in state (Mesa) and out of state (Utah)
7. Field collect some natives. Purchase seed locally, and out of state.

Q9. What is the principle method of acquiring the seed/plant materials for your organization or agency unit you represent needs? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Request for bid	40 %	17
Advertisement	2 %	1
Purchase order/catalog	23 %	10
Long-term contract	9 %	4
Auction	0 %	0
Requisition from internal source	0 %	0
Grow it	9 %	4
Other	16 %	7
Total	99 %	43

Other responses Q9:

1. Collect Regionally-In state
2. The local unit tries to determine what seed they need then what seed might be available by consulting.
3. Collect by hand on site
4. Usually purchase of seeds is done in conjunction with construction project contract
5. Wildland collecting

6. Collect seed; have seed grown at National Resource Conservation Service Los Lunas PlantMaterials Center from National Park seed stock
7. Field collect, phone and internet orders

Q10. Please name the principle sources from which you acquire native seed?

Principle source 1

1. Granite Seed (5)
2. Collect ourselves
3. Maple Leaf Seed
4. Various seed companies normally through competitive bid
5. On-site at Hart Prairie Preserve
6. S and S seed company
7. Collect seed from within Grand Canyon National Park
8. Various sources in Colorado & Utah
9. Field Collection off of public and private lands

Principle source 2

1. Lawyer Nursery (2)
2. Curtis and Curtis Seed (2)
3. Flagstaff Native Plant and Seed
4. Seed grown by Natural Resource Conservation Service Los Lunas Plant Materials Center
5. Grasslands West
6. Wildlands Seed Company
7. Southwest Seed
8. Sharp Brothers Seed

Principle source 3

1. Flagstaff Native Plant and Seed (2)
2. Southwest Seed
3. Sharp Brothers Seed
4. Los Lunas Plant Material Center
5. Post-fire seeding by Burned Area Emergency Rehabilitation team

Principle source 4

1. Forest Service (Coconino and Kaibab National Forests)

Principle source 5: No one answered

Q11. Does your organization or agency unit you represent choose to use non-native plant materials for seeding practices?

	Valid Percent	Frequency (*n*)
Yes	41 %	9
No	59 %	13
Total	100 %	22

Q12. What factors within your organization or agency unit you represent ultimately decide IF NATIVE SEEDS are purchased? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Organization/agency policy	25 %	19
Organization/agency Environmental ethics	10 %	8
Availability of native seed	21%	16
Availability of certified noxious weed-free seed	17 %	13
Success of germination	9 %	7
Cost of native seed	13 %	10
Other	5 %	4
Total	100 %	77

Other responses Q12:

1. Type of project
2. Availability and cost at State level limit use. Lack of technical expertise within the Department of Transportation also.
3. We always prefer to use seed collected on site. Purchasing of seeds is only a last resort solution.
4. Seed from outside Grand Canyon National Park has been applied by US Forest Service Burn Area Emergency Rehabilitation team

Q13. What factors within your organization or agency unit you represent ultimately decide how much native seed is purchased? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Amount of money allocated for this purpose	26 %	14
Project acreage	31 %	17
Availability of native seed	24 %	13
Availability of certified noxious weed-free native seed	17 %	9
Other	2 %	1
Total	100 %	54

Other responses Q13:

1. How much seed can be grown at Natural Resource Conservation Service Plant Material Center for a specific (funded) project.

Q14. Does your organization or agency unit you represent currently require the use of certified noxious weed-free native seed?

	Valid Percent	**Frequency (*n*)**
Yes	80 %	16
No	20 %	4
Total	100 %	20

Q15. In the next 5 years, does your organization or agency unit you represent anticipate requirements to use certified noxious weed-free native seed?

	Valid Percent	**Frequency (*n*)**
Yes	67 %	4
No	33 %	2
Total	100 %	6

Q16. Is your organization or agency unit you represent concerned about the genetic source of native seed?

	Valid Percent	**Frequency (*n*)**
Yes	93 %	26
No	7 %	2
Total	100 %	28

Q17. How would your organization or agency unit you represent define local genotype?

	Valid Percent	Frequency (*n*)
From a Local source (within a 50 mile radius)	29 %	8
From a source within the County	4 %	1
From a source within the Region	25 %	7
From a source within the State	4 %	1
Other	39 %	11
Total	101 %	28

Other responses Q17:

1. Local source desired, however depends somewhat on species.
2. Within a 200 mile radius has been practical. We are a long way from 50 mile radius supplies.
3. Local genotype would depend on the species, we would prefer a local source, but this has never been possible.
4. Within a 25 mile radius
5. Within Ecological Basin
6. From a local source at the same elevation within the same general vicinity
7. From seed collected in Grand Canyon National Park; in addition, we have seed zones within the park we adhere to.
8. Biotic Community
9. It depends on the plant species
10. Depends on the species in question. Some are more important to have "local" than others
11. Elevation, soil type and precipitation

Q18. In the next 5 years, does your organization or agency unit you represent foresee a need for local genotype native plant materials for seeding practices?

	Valid Percent	Frequency (*n*)
Yes	87 %	20
No	9 %	2
Other	4 %	1
Total	100 %	23

Other responses Q18:

1. Only if not enough is collected on site

Q19. Are there any limiting factors keeping your organization or agency unit you represent from buying seed locally?

	Valid Percent	**Frequency (*n*)**
Yes	75 %	21
No	25 %	7
Total	100 %	28

Q20. What limiting factors are keeping your organization or agency unit you represent from buying seed locally? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Cost of local native seed	24 %	10
Availability of local native seed	50 %	21
Lack of certified noxious weed-free seed	12 %	5
Other	14 %	6
Total	100 %	42

Other responses Q20:

1. Lack of availability and knowledge of seed mix information within some Department of Transportations. We are working on that.
2. The purchase of our seed harvester will help with our local seed needs, but we will not be able collect all we need.
3. Procurement requirements
4. Quantity clients needed are not readily available
5. Seed use restricted to in-park genetic material. Growers have to agree not to sell any seed or plants from park material to anyone other than Grand Canyon National Park.
6. No place to buy amounts needed.

Q21. In the next 5 years, SEEDS from what native plant species would your organization or agency unit you represent like to have brought into local commercial seed production for use in large-scale seeding projects (25 acres or more)? Please list in order from your 1st choice to your 5th choice (1st choice being the most ideal).

1st Choice Seed

Native grasses (2)
Populus tremuloides (Aspen)
Achnatherum hymenoides (Indian ricegrass)
Coleogyne ramosissima (Blackbrush)
Festuca arizonica (Arizona fescue)
Atriplex confertifolia (Shadscale saltbush)
Poa fendleriana (Muttongrass) (2)

Distichlis spicata (Inland saltgrass) (2)
Bouteloua gracilis (Blue grama) (3)
Purshia spp. (Cliffrose)
Digitaria californica (Arizona cottontop)
Pinus ponderosa (Ponderosa pine) (2)
Elymus elymoides (Squirreltail)
Larrea tridentata (Creosote Bush)
Seed type dependent on site specific need gramas
Legumes
Atriplex canescens (Fourwing saltbush)

2nd Choice Seed

Native forbs
Pinus ponderosa (Ponderosa pine)
Elymus elymoides (Squirreltail)
Bouteloua gracilis (Blue grama) (2)
Ambrosia spp. (Bursage)
Native cool season grass for quick cover crop
Atriplex canescens (Fourwing saltbush)
Sporobolus interruptus (Black dropseed)
Sporobolus airoides (Alkali sacaton)
Festuca arizonica (Arizona fescue)
Artemisia tridentata var. wyomingensis (Wyoming Big Sagebrush)
Prosopis glandulosa (Honey mesquite)
Bothriochloa barbinodis (Cane bluestem)
Poa fendleriana (Muttongrass)
Pascopyrum smithii (Western wheatgrass)
Yucca brevifolia (Joshua tree)
Muhlenbergia montana (Mountain muhly)
Krascheninnikovia lanata (Winterfat)
Pinus edulis (Pinyon pine)
Bouteloua eriopoda (Black grama)

3rd Choice Seed

Festuca arizonica (Arizona fescue) (3)
Purshia spp. (Cliffrose)
Atriplex canescens (Fourwing saltbush)
Larrea tridentata (Creosote bush)
Native showy forb seeds
Bouteloua gracilis (Blue grama)
Indigenous grasses
Koeleria macrantha (Prairie junegrass)
Sesuvium verrucosum (Western sea purslane)
Muhlenbergia montana (Mountain muhly)
Krascheninnikovia lanata (Winterfat)

Baccharis spp. (Baccharis)
Pappophorum vaginatum (Pima pappusgrass)
Hilaria jamesii (James' galleta)
Achnatherum hymenoides (Indian ricegrass)
Agropyron cristatum (Crested wheatgrass)
Ambrosia spp. (Bursage)
Populus tremuloides (Aspen)

4th Choice Seed
Bouteloua gracilis (Blue grama) (3)
Eriogonum spp. (Buckwheat)
Penstemon palmeri (Palmer's penstemon)
Bouteloua curtipendula (Sideoats grama)
Native mid successional seeds
Elymus elymoides (Squirreltail) (2)
Fallugia paradoxa (Apache plume)
Festuca arizonica (Arizona fescue)
Heliotropium curassavicum (Salt heliotrope)
Pleuraphis spp. (Galleta grass)
Atriplex canescens (Fourwing saltbush)
Atriplex spp. (saltbush)
Muhlenbergia porteri (Bush muhly)
Sporobolus airoides (Alkali sacaton)
Oenothera spp. (Evening primrose)

5th Choice Seed
Pinus flexilis (Limber pine)
Penstemon spp. (Penstemon)
Sphaeralcea parvifolia (Globemallow)
Pleuraphis spp. (Galleta grass)
Native seed mixes
Pascopyrum smithii (Western wheatgrass)
Populus fremontii (Fremont cottonwood)
Elymus elymoides (Squirreltail)
Anemopsis californica (Yerba mansa)
Bromus marginatus (Mountain brome)
Eragrostis intermedia (Plains lovegrass)
Atriplex canescens (Fourwing saltbush)
Bouteloua curtipendula (Sideoats grama) (2)
Lupinus spp. (Lupine)
Artemisia spp. (Sagebrush)
Festuca arizonica (Arizona fescue)
Muhlenbergia montana (Mountain muhly)

6th Choice Seed

Pinus leiophylla var. chihuahuana (Chihuahua pine)
Artemisia bigelovii (Bigelow sagebrush)
Achnatherum hymenoides (Indian ricegrass)
Muhlenbergia wrightii (Spike muhley)
Cercocarpus ledifolius var. ledifolius (Curl-leaf mountain mahogany)
Purshia stansburiana (Stansbury cliffrose)
Geraea canescens (Desert sunflower)
Muhlenbergia straminea (Screwleaf muhly)
Bouteloua curtipendula (Sideoats grama)
Atriplex confertifolia (Shadscale saltbush)
Artemisia tridentata (Big sagebrush)
Penstemon strictus (Rocky mountian penstemen)
Various forbs within the Pinyon-Juniper woodland
Pinus engelmannii (Apache pine)

7th Choice Seed

Native shrubs
Elymus elymoides (Squirreltail)
Shepherdia argentea (Silver buffaloberry)
Kraschennikovia lanata (Winterfat)
Schoenoplectus americanus (Olney threesquare)
Carex nebrascensis (Nebraska sedge)
Muhlenbergia asperifolia (Alkali muhly)
Artemisia tridentata (Big sagebrush)
Muhlenbergia montana (Mountain muhly)
Penstemon eatonii (Firecraker penstemen)
Ephedra spp. (Ephedra)
Pinus leiophylla var. chihuahuana (Chihauhau pine)

8th Choice Seed

Poa fendleriana (Muttongrass)
Native grasses
Atriplex canescens (Fourwing saltbush)
Scirpus californicus (California bulrush)
Deschampsia caespitosa (Tufted hairgrass)
Pleuraphis mutica (Tabosa grass)
Purshia stansburiana (Stansbury cliffrose)
Blepharoneuron tricholepis (Pine dropseed)
Panicum obtusum (Vine mesquite)
Picea engelmannii (Englemann Spruce)

9th Choice Seed

Yucca brevifolia (Joshua tree)
Penstemon spp. (Penstemon)
Sphaeralcea parvifolia (Globemallow)

Festuca thurberi (Thurber fescue)
Pleuraphis rigida (Big galleta)
Rhus aromatic (Fragrant sumac)
Hilaria jamesii (James' galleta)
Pseudotsuga menziesii (Douglas fir)

10th Choice Seed

Koeleria spp. (Junegrass)
Bouteloua gracilis (Blue grama)
Sporobolus airoides (Alkali sacaton)
Cercocarpus intricatus (Littleleaf mountain mahogany)
Penstemon spp. (Penstemon)
Misc riparian, grass and woodland

Q22. In the next 5 years, GRASSES from what native plant species would your organization or agency unit you represent like to have brought into local commercial seed production for use in large-scale seeding projects (25 acres or more)? Please list in order from your 1st choice to your 5th choice (1st choice being the most ideal).

1st Choice Grass

Festuca arizonica (Arizona fescue) (4)
Bouteloua curtipendula (Sideoats grama) (2)
Elymus canadensis (Canada wildrye)
Poa fendleriana (Muttongrass) (2)
Distichlis spicata (Inland saltgrass)(2)
Sporobolus contractus (Spike dropseed)
Bouteloua gracilis (Blue grama) (4)
Elymus elymoides (Squirreltail)
Achnatherum hymenoides (Indian ricegrass)(2)

2nd Choice Grass

Bouteloua gracilis (Blue grama) (4)
Elymus elymoides (Squirreltail)
Pleuraphis spp. (Galleta grass) (2)
Smith's native wheat grass for the west
Koeleria macrantha (Prairie junegrass)(2)
Sporobolus airoides (Alkali sacaton)
Bothriochloa barbinodis (Cane bluestem)
Sporobolus airoides (Alkali sacaton)
Poa fendleriana (Muttongrass)(2)
Pascopyrum smithii (Western wheatgrass)
Muhlenbergia porter (Bush muhly)
Achnatherum hymenoides (Indian ricegrass)
Festuca arizonica (Arizona fescue)

3rd Choice Grass

Bouteloua curtipendula (Sideoats grama) (2)
Hesperostipa comata (Needle and thread)(2)
Achnatherum hymenoides (Indian ricegrass) (2)
Bouteloua spp. (Grama grass)
Festuca arizonica (Arizona fescue)
Muhlenbergia montana (Mountain muhly)
Muhlenbergia porter (Bush muhly)
Bouteloua gracilis (Blue grama)
Agropyron cristatum (Crested wheatgrass)
Bouteloua rothrockii (Rothrock grama)
Koeleria macrantha (Prairie junegrass)

4th Choice Grass

Sporobolus cryptandrus (Sand dropseed) (2)
Sporobolus contractus (Spike dropseed)
Elymus elymoides (Squirreltail) (2)
Native cord grass and other wetland natives
Pleuraphis spp. (Galleta grass)
Sporobolus airoides (Alkali sacaton)
Hilaria jamesii (James' galleta)
Bouteloua curtipendula (Sideoats grama) (3)
Bouteloua gracilis (Blue grama)
Blepharoneuron tricholepis (Pine dropseed)

5th Choice Grass

Hilaria jamesii (James' galleta)
Poa fendleriana (Muttongrass)
Schizachyrium scoparium (Little bluestem)
Bouteloua gracilis (Blue grama)
Sporobolus flexuosus (Mesa dropseed)
Achnatherum hymenoides (Indian ricegrass)(2)
Aristida purpurea (Purple threeawn)

Q23. In the next 5 years, FORBS from what native plant species would your organization or agency unit you represent like to have brought into local commercial seed production for use in large-scale seeding projects (25 acres or more)? Please list in order from your 1st choice to your 5th choice (1st choice being the most ideal).

1st Choice Forb

Eriogonum spp. (Buckwheat) (2)
Sphaeralcea parvifolia (Globemallow) (4)
Baileya multiradiata (Desert marigold)
Schoenoplectus americanus (Olney threesquare)
Penstemon spp. (Penstemon) (3)

Oenothera spp. (Evening primrose)
Plantago spp. (Common plantain)
Atriplex canescens (Fourwing saltbush)

2nd Choice Forb

Penstemon spp. (Penstemon) (2)
Penstemon ambiguous (Bush penstemon)
Sphaeralcea parviflora (Globemallow)
Symphyotrichum leave (Smooth aster)
Artemisia frigida (Fringed sage)
Scirpus californicus (California bulrush)
Penstemon eatonii (Firecracker penstemen)
Senna covesii (Desert senna)
Krascheninnikovia lanata (Winterfat)

3rd Choice Forb

Oenothera spp. (Evening primrose)
Malacothrix glabrata (Desert dandelion)
Plantago ovata (Indian wheat)
Solidago speciosa (Showy goldenrod)
Sesuvium verrucosum (Western sea purslane)
Sphaeralcea parvifolia (Globemallow)
Penstemon palmeri (Palmer's penstemon)
Lupinus spp. (Lupine)
Eschscholtzia mexicana (Mexican gold poppy)

4th Choice Forb

Penstemon palmeri (Palmer's penstemon)
Phlox spp. (Phlox)
Iris versicolor (Blue flag iris)
Heliotropium curassavicum (Salt heliotrope)
Astragalus spp. (Milkvetch)
Lesquerella spp. (Bladderpod)

5th Choice Forb

Asclepias spp. (Milkweed)
Asclepias tuberosa (Butterfly milkweed)
Lupinus spp. (Lupine)

Q24. In the next 5 years, TREES/SHRUBS from what native plant species would your organization or agency unit you represent like to have brought into local commercial seed production for use in large-scale seeding projects (25 acres or more)? Please list in order from your 1st choice to your 5th choice (1st choice being the most ideal).

1st Choice Tree/Shrub

Pinus ponderosa (Ponderosa pine) (4)
Purshia spp. (Cliffrose) (2)
Salix exigua (Narrowleaf willow)
Coleogyne ramosissima (Blackbrush)
Quercus gambelii (Gambel oak)
Cercocarpus montanus (Mountain mahongany)
Purshia stansburiana (Stansbury cliffrose)
Pseudotsuga menziesii (Douglas fir)
Prosopis gandulosa (Honey mesquite)
Salix arizonica (Arizona willow)
Atriplex canescens (Fourwing saltbush)
Artemisia tridentata (Big sagebrush)
Populus tremuloides (Aspen)
Larrea tridentata (Creostote bush)
Prosopis velutina (Velvet mesquite)
Artemisia spp. (Sagebrush)
Juniperus spp. (Juniper)

2nd Choice Tree/Shrub

Populus tremuloides (Aspen) (3)
Artemisia bigelovii (Bigelow sagebrush)
Atriplex canescens (Fourwing saltbush)(2)
Ambrosia spp. (Bursage) (2)
Purshia subintegra (Arizona cliffrose)
Fraxinus velutina (Velvet ash)
Kraschennikovia lanata (Winterfat)(3)
Prosopis pubescens (Screwbean mesquite)
Salix bebbiana (Bebb's willow)
Artemisia tridentata var. wyomingenisis (Wyoming big sagebrush)
Pinus edulis (Pinyon pine) (3)
Fallugia paradoxa (Apache plume)
Pinus ponderosa (Ponderosa pine)
Encilia farinosa (Brittlebush)

3rd Choice Tree/Shrub

Pinus leiophylla var. chihuahuana (Chihuahua pine) (2)
Kraschenіnnikovia lanata (Winterfat)
Atriplex confertifolia (Shadscale saltbrush)
*Larrea tridentata (*Creosote bush)
Rhus glabra (Smooth sumac)

Atriplex canescens (Fourwing saltbush) (2)
Lycium spp. (Wolfberry)
Populus spp. (Cottonwood)
Purshia spp. (Cliffrose) (2)
Juniperus monosperma (Oneseed juniper)
Purshia mexicana (Mexican cliffrose)
Picea pungens (Blue spruce)
Yucca brevifolia (Joshua tree)
Ambrosia deltoidea (Triangle-leaf bursage)

4th Choice Tree/Shrub
Juniperus osteosperma (Utah juniper)(2)
Ephedra spp. (Ephedra)
Baccharis salicina (Willow baccharis)
Baccharis emoryi (Emoryi baccharis)
Rosa spp. (Wild rose)
Krascheninnikovia lanata (Winterfat)
Artemisia tridentata (Big sagebrush)
Atriplex canescens (Fourwing saltbush) (3)
Lycium spp. (Wolfberry)
Purshia tridentata (Antelope bitterbrush)
Pinus engelmannii (Apache pine)
Acacia berlandieri (Guajillo)
Amorpha fruticosa (Indigo bush)

5th Choice Tree/Shrub
Quercus gambelii (Gambel's oak)(2)
Populus fremontii (Fremont cottonwood)
Yucca brevifolia (Joshua tree)
Menodora spp. (Menodora)
Artemisia tridentata (Big sagebrush)
Pinus edulis (Pinyon pine)
Atriplex canescens (Fourwing saltbush)
Cercocarpus montanus (Mountain mahogany)

Q25. What factors ultimately decide what native plant materials are needed for large-scale seeding practices (25 acres or more)? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Maintaining plant species diversity	30 %	24
Probability of success	34 %	27
Wildlife forage/habitat objectives	29 %	23
Other	8 %	6
Total	101 %	80

Other responses Q25:
1. Project objectives
2. Probability of success and cost, along with ability to compete with cheatgrass and noxious weeds
3. Cost will always be a factor in highway corridors as well as ease of maintenance
4. Habitat migration due to climate change
5. Cost (2)

Q26. Does your organization or agency unit you represent currently collect native seed to be used for seeding projects?

	Valid Percent	Frequency (*n*)
Yes	53 %	16
No	47 %	14
Total	100 %	30

Q27. How much native seed has your organization or agency unit you represent collected within the last year?

	Valid Percent	Frequency (*n*)
None of our seeding need	0 %	0
Less than 10 pounds	33 %	6
10-50 pounds	28 %	5
51-100 pounds	17 %	3
101-500 pounds	6 %	1
501-1000 pounds	0 %	0
1,001-5,000 pounds	6 %	1
Greater than 5,000 pounds	0 %	0
Other	11 %	2
Total	101 %	18

Other responses Q27:
1. Each State handles differently...a couple seed for production, others for priority projects in natural areas
2. Limited collection of native seeds for Jacket Fire Project and Native Seed Grant. Both were special contracts and not typical of most projects we do. Seed for Jacket Fire was collected in 2005.

Q28. Currently, what mechanisms or facilities does your organization or agency unit you represent have to collect, store, and/or propagate native plant seed? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
None	27 %	14
Greenhouse(s)	10 %	5
Storage facilities	18 %	9
Seed collecting machines	8 %	4
Seed processing equipment	8 %	4
Irrigation capabilities	10 %	5
Land available to grow seed	8 %	4
Other	12 %	6
Total	101 %	51

Other responses Q28:
1. Currently setting up cone processing equipment
2. Center for Plant Conservation (CPC) Seed Collection Storage
3. Whatever it takes....but prefer all to be available from the private sector
4. Pick and process by hand
5. We have a Natural Resource Conservation Service Tucson Plant Materials Center
6. Hand seed cleaning equipment and seed refrigerators at Grand Canyon National Park nursery; seed fields, seed cleaning and mixing for large projects and seed storage at Natural Resource Conservation Los Lunas Plant Materials Center.

Q29. Does your organization/agency currently want to become a supplier of native seed for seeding practices?

	Valid Percent	**Frequency (*n*)**
Yes	22 %	5
No	74 %	17
Already am a supplier	4 %	1
Total	100 %	23

Q30. What type of organization/agency do you work for?

	Valid Percent	Frequency (*n*)
Federal	47 %	14
State	27 %	8
County	0 %	0
Tribal	7 %	2
Private (Based Locally)	7 %	2
Private (Not Locally Based)	3 %	1
Not for Profit	10 %	3
Other	0 %	0
Total	101 %	30

Q31. What other organizations/agencies do you currently collaborate with on native plant projects? Select all that apply. (multiple response answer)

	Valid Percent	Frequency (*n*)
No other organizations/agencies	0 %	0
Federal	22 %	22
State	20 %	20
County	10 %	10
Tribal	15 %	15
Private (Based Locally)	9 %	9
Private (Not Locally Based)	2 %	2
Not for Profit	15 %	15
None	0 %	0
Other	5 %	5
Total	98 %	98

Other responses Q31:
1. Conservation groups
2. Local Weed Management Area - just getting started
3. University
4. We only serve in an advisory role for restoration projects on the Navajo Nation
5. American Conservation Experience and other volunteer groups aid in seed collection

Q32. What organizations/agencies would you like work with in the future on native plant projects? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
No other organizations/agencies	2 %	2
Federal	17 %	18
State	17 %	18
County	14 %	15
Tribal	14 %	15
Private (Based Locally)	12 %	13
Private (Not Locally Based)	8 %	8
Not for Profit	11 %	12
None	1 %	1
Other	3 %	3
Total	99 %	105

Other responses Q32:

1. Local ecotype producing seed growers....or at least small regional suppliers
2. We are working with our regional headquarters on technical assistance on how to address needs while adhering to National Park Service policy
3. Depends on land status where our projects may be located

Q33. Does your organization or agency unit you represent currently receive federal or state monies or incentives to assist with seeding practices?

	Valid Percent	Frequency (*n*)
Yes	57 %	16
No	43 %	12
Total	100 %	28

Q34. What is the primary funding source for your organization/agencies seeding practices coming from? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Federal dollars (excluding federal incentive programs)	52 %	14
State dollars (excluding state incentive programs)	15 %	4
Federal incentive programs	11 %	3
State incentive programs	4 %	1
County dollars	0 %	0
Tribal dollars	0 %	0
Internal dollars	11 %	3
Private dollars	7 %	2
Total	100 %	27

Q35. In order to initiate a successful native plant materials market in northern Arizona, what are the greatest obstacles to overcome? Select all that apply. (multiple response answer)

	Valid Percent	**Frequency (*n*)**
Availability of labor	7 %	7
Cost of seed	22 %	21
Availability of seed	27 %	26
Cost of facilities	14 %	14
Fostering partnerships with other agencies	5 %	5
Funding from other agencies	10 %	10
Knowledge on the use of native plant materials	10 %	10
Other	4 %	4
Total	99 %	97

Other responses Q35:

1. Business expertise; start-up capital; dedicated full-time organizational structure
2. Demand (2)
3. Consistent availability, supply and demand. These three factors are difficult to control to predict and could lead to failure of program.

Q36. Currently, what programs are available to your organization/agency that encourage increases in local native seed production? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Native plant programs	21 %	12
Seed increaser programs	4 %	2
Fire rehabilitation programs	23 %	13
Restoration programs	28 %	16
Wildlife habitat improvement programs (i.e. WHIP, LIP, etc.)	19 %	11
Other	5 %	3
Total	100 %	57

Other responses Q36:
1. None
2. Federal Lands Highway Project; Natural Resource Conservation Service/National Park Service collaboration
3. Environmental Quality Incentive Program

Q37. Please list and describe three native plant programs that would be useful to your organization/agency. Please list as 1st through 3rd choice (1st choice being the most useful).

1st choice program

1. Seed collection in volume
2. Local greenhouse growing native plants
3. Native plant establishment training
4. Native seed program
5. Locally grown seed available all year round
6. Native Plant Initiative - National Fire Plan
7. Local reliable seed source
8. Natural Resource Conservation Service Plant Materials Program
9. Seed fields from park obtained plants with storage for revegetation and post-fire needs
10. Burn Area Emergency Rehabilitation
11. A funding program would be nice
12. Uncompahgre Plateau Project
13. Field Collection of Native Seed
14. Native Seed Search

2nd choice program

1. Seed growing
2. Regional Natural Resource Conservation Service greenhouse/seed source
3. Native plant site specific selection training
4. Fire rehabilitation program
5. Local Weed Boards
6. Noxious weed mitigation
7. Great Basin Project3rd choice program
1. Seed cleaning and storage
2. Non-government organization plant propagation
3. How to write native seed mix specifications/contracts
4. Wildlife habitat improvement program
5. Forest restoration
6. USDA Forest Service projects

Q38. Do you strongly agree, somewhat agree, somewhat disagree, or strongly disagree with this statement? "Availability of ecosystem seed mixes (i.e. ponderosa pine forest, pinyon/juniper, grassland, foraging habitat seed mixes) is of great value to our organization/agency."

	Valid Percent	**Frequency (*n*)**
Strongly Agree	68 %	19
Somewhat Agree	18 %	5
Somewhat Disagree	11 %	3
Strongly Disagree	4 %	1
Total	101 %	28

Comments Q38:

1. Not only plant community seed mixes, but xeric, mesic, and wet site mixes within a project.
2. This would be preferred for post-fire seeding; most likely Burned Area Emergency Rehabilitation rather than National Park Service would be purchasing this seed.
3. It depends on too many factors to have a simple answer.
4. Again, it depends on the relevance of the species to that area
5. Depends on the state of the "ecosystem"

Q39. Our organization/agency would be willing to enter into a 5 year contract with a certified native seed company?

	Valid Percent	**Frequency (*n*)**
Yes	20 %	3
No	80 %	12
Total	100 %	15

Comments Q39:
1. As a federal agency, we are not allowed to do so...but will support in other ways.
2. If they produce the seed we need when we need it.
3. Contracting and procurement policy would limit long-term contracts
4. Would depend on the project and duration
5. Many factors to consider here

Q40. Are there any general comments that you would like to add regarding the topics of this survey?

1. We are an interstate natural gas transmission company which adheres to federal, state and local regulations pertaining to reseeding and restoration
2. We do not use large quantities of seed like those amounts necessary for large seedling project. We produce plants/seedlings for research, wildlife habitat improvement, and fire rehabilitation/restoration projects. A lot of our propagation is also from cuttings. We have produced over 250,000 plants which have been put into the field over the last 3 years. Almost 50,000 Fremont cottonwoods and native willows in the last two years strictly from cuttings. Besides seed local gardens which hold different genotypes of Fremont cottonwood and willows would be useful as a source for cuttings. Local gardens with different local genotypes of aspen would also be useful for cuttings for future project.
3. Seed pound/cost only an estimate
4. Before the market is developed, there needs to be a concerted effort to determine the feasibility of planting the various native seeds through existing equipment as well as what the seeding and germination requirements of the species are. For example there seems to be very little information on how deep Needle and Thread grass seeds need to be seeded not to mention how breaking the awns off the seed (as is currently done0 during processing affects it's ability to germinate. Not to mention if it can be effectively seeded in combination with other seed with different requirements. Other unanswered questions are how to effectively seed into established mediterranean annual stands. Until we can understand some of these issues, we will waste most of our time and money trying.
5. I am sure your results will underscore the NEED for more native plant material production. How will you use the results???
6. Our new seed collector is new and untested. We are not sure how the whole process will work from harvesting to processing to storage. So, this is a big unknown factor on how much seed we will need from out-side sources.
7. My answers are only relevant to Hart Prairie Preserve, not the entire Nature Conservancy.
8. Our work is mainly on the lower Colorado River; however the seed companies that we obtain seed from are in San Diego and Utah. It would be great to have a local grower. Some seed is hard to propagate in field conditions and the plants are better planted as plugs.
9. NRCS has a plant materials program that is developing native plant species for use in the region. We would like to see these better utilized by growers for use in their adapted ranges.

10. Development of seed sources of regional ecotypes of native species is critical for use post-fire, for revegetation, for weed and erosion control and for general revegetation needs. Thanks for working on this project.
11. We will utilize local native seed whenever possible. If we had a reliable source, and costs, quality, supply, etc were conducive to our procurement regulations, we would utilize local sources as a priority.
12. Most of our activities have been in southern Arizona or along the Central Arizona Project alignment through Sonoran desert biome
13. Is there a separation between small scale and large scale markets?
14. Because the topic of this survey is so complicated, having a comment section associated each question would be helpful. That way you could explain "yes" or "no" if needed.
15. There needs to be a local outlet to be available to us here in Northern Arizona, possible in Flagstaff.
16. I cannot speak for my agency as a whole. I can only answer questions that relate to my direct experience including as few fire rehabilitation projects (BAER). I cannot address the willingness of the Forest Service to enter into long-term contracts
17. We did have a seedling program for a number of years. It was disbanded and I am not aware of any plans for us to reinstate any of these programs.

Appendix IV: Annotated Questionnaire - Supply

A total of 37 questions were administered to 33 suppliers of native seed in the Native Plant Materials Market Feasibility Survey. Answer frequencies (*n*) and valid percents of survey results for each question are summarized in an Annotated Questionnaire below.

In cases where respondents answered "Don't Know" and "Decline to Answer," these responses were counted as "missing" and were omitted in calculating valid percent. In addition, valid percents were rounded which may cause total percents to equal slightly more or less than 100. For the multiple response questions, where respondents were able to select more than one answer, the total n may be higher than the number of respondents. In these cases, valid percents were calculated by the number (*n*) in each response category divided by the total number of responses for the question. Where respondent answers where duplicated in the open response questions/sections, the total (*n*) duplicated responses is represented in parenthesis after the stated response. See Appendix V for a full list of scientific names and authorities used in this questionnaire.

Q1. How would you define local genotype?

	Valid Percent	**Frequency (*n*)**
From a Local source (within a 50 mile radius)	32 %	10
From a source within the County	16 %	5
From a source within the Region	19 %	6
From a source within the State	7 %	2
From a source Out-of-State	0 %	0
Other	26 %	8
Total	100 %	31

Other responses s Q1:

1. It depends on the species. For some it would be a watershed or a specific ridge, for others it might be a part of several states.
2. It depends, some things change drastically in 50 miles in Utah. A 50 mile radius would be a good start although on occasion out of state is possible.
3. Within similar habitat, but it depends on species
4. Same species growing in similar climate, (rainfall, temperature ranges, soil types) can be at any distance.
5. A community of species covering similar topography, elevation.
6. Collection of material is within a 5th order HUC (Hydrologic Unit Code, as defined by US Geological Survey), used within a third order HUC; mid-range elevational bands of 500'

7. 300 miles south & west -150 miles north & east- Maximum elevation increase 2000 ft.- elevation decrease 1000 ft.
8. 200 mile radius

Q2. How important is producing and/or using local genotype plants and seeds to your organization/agency?

	Valid Percent	Frequency (*n*)
Very Important	33 %	10
Somewhat Important	47 %	14
Somewhat Unimportant	17 %	5
Very Unimportant	3 %	1
Total	100 %	30

Comments Q2:
1. Problems using local genotype plants or seeds that we run into is that they don't fit a large enough area and you can run into collectors charging huge prices if the demand is great. There is never enough of the types that you are looking for to seed large areas and it takes along time to grow enough to be of use. We run into this problem all the time. The best approach is to have the plant materials centers select viable varieties that fit larger areas. A lot of the times the local genotype varieties have a difficult time become established and competing.
2. The variability of fire makes difficult to inventory quantities of local genotypes that may or may not be sold.
3. The majority of our seed sales not influenced by local genotype
4. It is not always practical. There is a chicken and egg problem with localized material.
5. Very important for woody species (as required by federal law); very important for forbs
6. The answer to this question can vary dramatically from species to species. In other words, some species are more adaptable than others.
7. It is important to us if it is important to our customers
8. It is dependent upon customer requests - we sell a lot of native grass seeds for reclamation and maintenance.

Q3. Is there a current market to sell local genotype plants and seeds that will be used for large-scale restoration projects (25 acres or more)?

	Valid Percent	Frequency (*n*)
Yes	70 %	19
No	30 %	8
Total	100 %	27

Comments Q3:
1. In some places
2. The problem is that we can't get good seed stock to grow enough seed to fit any project of any size quick enough. Example is if you have a project that required a collected variety. The cost at the time of bid was $100.00 per pls lb. By the time the project was seeded the price had gone up to $1,000.00 per Pure Live Seed pound because of the weather and availability of the seed and the person who had tied up all the seed and raised the price. If it is not available in the commercial market place by many players the price of the seed will be huge
3. A very small market
4. Very limited
5. Yes, along the Sierra front where most of my business is.
6. Hard to answer, both yes and no, unpredictable.
7. This depends on the species and is typically more true for seed
8. As long as the production is kept private.
9. It varies depending on the location of the restoration project and the adaptability of the species being replaced. If widely adapted species are being replaced then the importance of using locally adapted species diminishes.
10. There may be on occasion but enough to create a stable market.
11. In my opinion this is beginning to grow to the size of large scale.

Q4. Does your organization/agency currently sell native plant materials (plants and/or seeds)?

	Valid Percent	**Frequency (*n*)**
Yes	94 %	29
No	7 %	2
Total	101 %	31

Q5. What would it take for your organization/agency to start selling native species?

	Valid Percent	**Frequency (*n*)**
Guarantee of demand	0 %	0
Contract with an organization/agency	0 %	0
Starting seed stock	0 %	0
Collecting, propagation, and planting procedures	0 %	0
Training on proven seed techniques	0 %	0
Other	100 %	2
Total	100 %	2

Other responses Q5:
1. We are not in the business of trying to sell seed and we do not want to
2. We are a government agency; we do not sell material

Q6. What kinds of native plant materials does your organization/agency sell? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Trees	11 %	10
Shrubs	16 %	15
Grasses	20 %	18
Forbs	18 %	16
Seeds	32 %	29
Other	3 %	3
Total	100 %	91

Other responses Q6:
1. All seed is owned by the National Forests; the USFS Lucky Peak Nursery will produce the native plants/seed and provide that material to the appropriate NF at the cost-of-production.
2. Native collected and production.
3. Cacti, agaves, succulents

Q7. How do you obtain the plant materials/seed that you propagate for sale? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Commercial source	28 %	20
Government agency	10 %	7
Field collect our own	31 %	22
Subcontract for field collection	19 %	14
Don’t propagate-field collect directly for sale	8 %	6
Other	4 %	3
Total	100 %	72

Other responses Q7:
1. National Forest will provide the seed from which US Forest Service Lucky Peak Nursery will produce the plants/seed to that National Forest at the cost-of-production
2. Some species of shrubs, grasses and forbs to develop a local ecotype
3. Most native plant materials are produced in our greenhouses

Q8. Where does your organization/agency acquire the native plant materials that you sell? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Locally In-state	30 %	22
Regionally In-state	25 %	18
Regionally Out-of-state	21 %	15
Out-of-state (not within the region)	18 %	13
Other	7 %	5
Total	101 %	73

Other responses Q8:
1. Western United States
2. Seed is provided by the National Forests to the US Forest Service Lucky Peak Nursery from which native plants/seed is provided to the appropriate National Forests at cost-of-production.
3. All of the above
4. In our business native seeds are seeds that are native to the United States, they are not necessarily grown in the United States
5. We coordinate with 100 plus small producers and then market the seed throughout this large multi-state area

Q9. What facilities/machines does your organization/agency have to support the production/supply of native plant materials (plants and/or seeds)? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
No Facilities	2 %	2
Greenhouse	9 %	10
Storage facilities	21 %	24
Land	16 %	19
Seed cleaning machines	19 %	22
Seed collection tools	16 %	19
Labor	16 %	19
Other	2 %	2
Total	101 %	117

Other responses Q9:
1. We currently do not do any increases in greenhouses but our business plan is to have these available at a later date.
2. All plant material is field grown and marketed bare-root

Q10. How many acres are currently used by your organization/agency for native plant materials (plants and/or seeds) production?

	Valid Percent	Frequency (*n*)
None	15 %	4
Less than 1 acre	4 %	1
1-5 acres	8 %	2
6-20 acres	12 %	3
21-50 acres	8 %	2
51-75 acres	15 %	4
76-100 acres	0 %	0
Over 100 acres	39 %	10
Total	101 %	26

Q11. Who buys the majority of your native plants and seeds? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Federal agencies	24 %	15
State agencies	22 %	14
Private local organizations	24 %	15
Private non-local organizations	14 %	9
Do not have a major purchaser – use onsite only	2 %	1
Other	14 %	9
Total	100 %	63

Other responses Q11:
1. Individual nurseries
2. Local individuals for home use as well as landscapers and restoration crews
3. Single largest is the federal and or related programs.
4. Homeowners
5. Farmers and Ranchers
6. Wholesale nurseries / mostly in southern Arizona & southern California
7. Individual homeowners
8. Other wholesalers (greenhouses) and individual land owners
9. Energy Industry

Q12. What is the most significant limitation to a business involved in the production of native plant materials (plants and/or seeds)?

	Valid Percent	**Frequency (*n*)**
Cost of facilities	4 %	1
Trained labor	4 %	1
Availability of labor	4 %	1
Land available for native plant materials production	4 %	1
Consistent and reliable demand	38 %	9
Lack of knowledge about native plant materials production	21 %	5
Supply of seed	8 %	2
Supply of certified noxious weed-free seed	0 %	0
Other	17 %	4
Total	100 %	24

Other responses Q12:

1. You should have "All of the Above", if you are talking about local genotype or all native seeds. It makes a great deal of difference. Local genotype is a huge amount of time and labor finding varieties that you can grow. It is extremely expensive and time consuming.
2. Weed control
3. For the past few years it would be available land for production. Currently, the price of wheat and corn, have impacted the available acres for production of native species.
4. Reliable seed production of native seed species. Private increase of native seed species is unreliable and varies too dramatically to make it financially worth-while. Native collection of locally adapted species is more reliable and cost effective.

Q13. Does your organization/agency sell native seeds?

	Valid Percent	**Frequency (*n*)**
Yes	97 %	28
No	3 %	1
Total	100 %	29

Q14. Does your organization/agency collect native plant seeds?

	Valid Percent	**Frequency (*n*)**
Yes	82 %	23
No	18 %	5
Total	100 %	28

Q15. Where are the native plant seeds collected? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Field plots	34 %	13
Wildland collections	61 %	23
Other	5 %	2
Total	100 %	38

Other responses Q15:
1. Urban landscape plantings
2. Farming

Q16. How are the seeds collected? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Mechanically	28 %	13
Hand-picked	47 %	22
Hand seed-harvesters	23 %	11
Other	2 %	1
Total	100 %	47

Other responses Q16:
1. Knocked off shrubs & onto tarps

Q17. Does your organization/agency currently subcontract the collection of your native plant seeds?

	Valid Percent	**Frequency (*n*)**
Yes, subcontract all	12 %	3
Yes, subcontract some	65 %	17
No, do not subcontract	23 %	6
Total	100 %	26

Q18. Are your seeds certified noxious weed-free seeds?

	Valid Percent	**Frequency (*n*)**
Yes, all are	29 %	8
Yes, some are	46 %	13
No	25 %	7
Total	100 %	28

Q19. Why has your organization/agency decided to sell certified noxious weed-free seeds? Select all that apply. (multiple response question)

	Valid Percent	**Frequency (*n*)**
Federal regulations	22 %	10
State regulations	27 %	12
Ecological ethics	27 %	12
Sellable market value is increased	16 %	7
Other	9 %	4
Total	101 %	45

Other responses Q19:

1. Please explain what that statement means. By Federal standards it means Noxious Weed Free for the State where it is going. Some people believe that it means there are no noxious weeds, but by regulation it is something else. I talk to so many people that don't have a clue what that statement means.
2. We haven't decided to do so
3. All of the above
4. Most noxious weeds are NOT a problem in restorations, most are only problems in traditional agriculture. I have many more concerns with other crops such as Sweet Clover and CrownVetch

Q20. In 2006, what percentage of production costs was spent on seed collection?

	Valid Percent	Frequency (*n*)
None, 0%	13 %	3
1-5%	21 %	5
6-10%	25 %	6
11-20%	0 %	0
21-30%	21 %	5
31-40%	0 %	0
41-50%	8 %	2
51-75%	8 %	2
76-100%	4 %	1
Total	100 %	24

Q21. In 2006, what percentage of production cost was spent on native seed propagation (including pots, greenhouse, fertilizer, water, etc.)?

	Valid Percent	Frequency (*n*)
None, 0%	32 %	7
1-5%	23 %	5
6-10%	14 %	3
11-20%	5 %	1
21-30%	14 %	3
31-40%	5 %	1
41-50%	5 %	1
51-75%	5 %	1
76-100%	0 %	0
Total	103 %	22

Q22. In 2006, what percentage of production cost was spent on storage facilities for native seeds?

	Valid Percent	Frequency (*n*)
None, 0%	8 %	2
1-5%	40 %	10
6-10%	28 %	7
11-20%	16 %	4
21-30%	0 %	0
31-40%	0 %	0
41-50%	4 %	1
51-75%	4 %	1
76-100%	0 %	0
Total	100 %	25

Q23. In 2006, what percentage of production cost was spent on labor for native seed production?

	Valid Percent	Frequency (*n*)
None, 0%	13 %	3
1-5%	13 %	3
6-10%	17 %	4
11-20%	13 %	3
21-30%	17 %	4
31-40%	13 %	3
41-50%	9%	2
51-75%	0 %	0
76-100%	4 %	1
Total	99 %	23

Q24. In thinking about all of your organization/agencies native plant materials production, in 2006, what percentage of production cost was spent on labor for native plant material production?

	Valid Percent	Frequency (*n*)
None, 0%	0 %	0
1-5%	10 %	2
6-10%	24 %	5
11-20%	14 %	3
21-30%	24 %	5
31-40%	5 %	1
41-50%	10 %	2
51-75%	10 %	2
76-100%	5 %	1
Total	102 %	21

Q25. Is your organization/agency’s native plant operations currently supported by external funding, internal funding, or both?

	Valid Percent	Frequency (*n*)
Internal	62 %	13
External	5 %	1
Both	33 %	7
Total	100 %	21

Q26. Currently, which entities provide funding for your organization/agencies native plant materials operations? Select all that apply. (multiple response question)

	Valid Percent	Frequency (*n*)
Internal	33 %	7
Federal	10 %	2
State	43 %	9
Private	5 %	1
Other	10 %	2
Total	101 %	21

Other responses Q26:
1. Not sure what is meant by internal
2. None

Q27. What percentage of your organization/agencies native plant operations is funded by the following entities? Percentage should total 100%. (Broad categories combined)

	Total Valid Percent	Total Frequency (*n*)	Detailed Responses of Percentages Selected
Federal	13 %	4	0-5% (2), 26-50% (1), Exactly 100% (1)
State	9 %	3	0-5% (1), 6-15% (1), Exactly 100% (1)
Private	25 %	8	0-5% (2), 26-50% (1), 51-75% (2), 76-99% (1), Exactly 100% (2)
Internal	41 %	13	26-50% (4), 76-99% (1), Exactly 100% (8)
Other	13 %	4	Exactly 100% (4)
Total	101 %	32	

Q28. Are you familiar with the revenue accrued by your organization/agency from selling native trees, shrubs, grass, forbs, and/or seeds?

	Valid Percent	Frequency (*n*)
Yes	87 %	20
No	13 %	3
Total	100 %	23

Q29. In 2006, what percent revenue did you accrue from selling the following native plants/seed? For each type, please specify percentage of total sales. Percentages should total 100%. (Broad response categories combined)

	Total Valid Percent	Total Frequency (*n*)	Detailed Responses of Percentages Selected
Trees	14 %	7	1% (1), 5% (1), 12% (1), 20% (1), 30% (1), 40% (1), 45% (1),
Shrubs	16 %	8	2% (1), 15% (2), 30% (2), 40% (2), 45% (1)
Grasses	18 %	9	1% (1), 2% (1), 5% (1), 20% (1), 60% (1), 70% (1) 75% (2), 80% (1),
Forbs	16 %	8	5% (5), 20% (1), 25% (1), 40% (1)
Seeds	35 %	17	9% (1), 20% (1), 25% (1), 60% (1), 90% (1), 100% (12),
Total	99 %	49	

Q30. In 2006, seeds from what plant species did you sell the most of? How much of seed from each species was sold in 2006? Please specify species and amount sold in Pounds in same box and list in order of largest amount sold first.

Plant Species 1

Penstemon palmerii (Palmer's penstemon)
Agropyron cristatum (Crested Wheatgrass) 350,000 lbs

Bouteloua gracilis (Blue grama) 3,000 lbs
Bouteloua curtipendula (Sideoats grama) 28,000 lbs
Agropyron spp. (Wheatgrass)
Pseudoroegneria spicata (Bluebunch wheatgrass) (2)
Eriogonum spp. (Buckwheat)
Bouteloua gracilis (Blue grama) 258 Pure Live Seed
Agave 5
Thinopyrum intermedium (Intermediate wheatgrass) 80,000 lbs
Grasses
Bromus carinatus (Califormia Brome) 15,000
Elymus glaucus (Blue wildrye), 9,000
Pascopyrum smithii (Western wheatgrass) 40,000 lbs

Plant Species 2
Penstemon humilis (Low beardtongue)
Agropyron fragile (Siberian wheatgrass) 122,000 lbs
Buchloe dactyloides (Buffalograss) 2,500 lbs
Bouteloua gracilis (Blue grama) 15,000 lbs
Achnatherum hymenoides (Indian ricegrass) (2) – 1 said 241 Pure Live Seed
Pascopyrum smithii (Western wheatgrass)
Achillea spp. (Yarrow)
Mammillaria spp. (Globe cactus) 2 lbs
Elytrigia intermedia spp. *trichophora* (Pubescent wheatgrass) 60,000 lbs
Forbs
Festuca rubra (Red fescue) 8000
Pseudoroegneria spicata (Bluebunch wheatgrass) 23,000 lbs

Plant Species 3
Epilobium canum ssp. *latifolium* (Hummingbird trumpet)
Thinopyrum intermedium (Intermediate wheatgrass) 100,000 lbs
Festuca ovina (Sheep fescue) 750 lbs.
Pascopyrum smithii (Western wheatgrass) 15,000 lbs
Elymus cinereus (Great basin wildrye)
Poa spp. (Bluegrass)
Festuca arizonica (Arizona fescue)
Bouteloua curtipendula (Sideoats grama) 225 Pure Live Seed
Echinocereus spp. (Hedgehog cactus) (2)
Agropyron cristatum (Crested wheatgrass) 40,000 lbs
Hordeum brachyantherum (Meadow barley) 8,000 lbs
Bromus carinatus (Califormia brome) 8,000 lbs
Elymus lanceolatus (Thickspike wheatgrass) 17,000 lbs

Plant Species 4
Eriogonum heracleoides (Parsnipflower buckwheat)
Schedonorus phoenix (Tall Fescue) 95,000 lbs
Eschscholzia californica (California poppy) 200 lbs

Sporobolus cryptandrus (Sand dropseed) 7,000 lbs
Atriplex canescens (Fourwing saltbush)
Festuca idahoensis (Idaho fescue)
Sporobolus airoides (Alkali sacaton) 135 Pure Live Seed
Yucca spp. (Yucca) 2 lbs
Bassia prostrata(Forage kochia) 15,000 lbs
Nassella pulchra (Purple needlegrass) 4,000
Horedeum brachyantherum (Meadow barley) 2,500
Elymus trachycaulus (Slender wheatgrass) 17,000 lbs

Plant Species 5

Lupinus polyphyllus (Bigleaf lupine)
Dactylis glomerata (Orchardgrass) 95,000 lbs
Linum perenne (Blue flax) 200 lbs.
Hedysarum boreale (Utah sweetvetch) 3,000 lbs
Purshia spp. (Bitterbrush)
Pleuraphis spp. (Galleta grass) 130 Pure Live Seed
Sclerocactus spp. (Fishhook cactus) 1
Nassella cernua (Nodding needlegrass) 1,500
Carex obnupta (Slough sedge) 1,500
Nassella viridula (Green needlegrass) 15,000

Q31. In the next 5 years, what species of native seeds would your organization/agency predict to be the highest in demand for large-scale seeding projects (25 acres or more)? Please list in order from your 1st choice to your 5th choice (1st choice being the highest in demand).

1st Choice Seed

Hesperostipa comata (Needle and thread)
Pseudoroegneria spicata (Bluebunch wheatgrass) (2)
Achnatherum hymenoides (Indian ricegrass)
Elymus elymoides (Squirreltail)
Agropyron spp. (Wheatgrass)
Agave spp. (Agave)
Eragrostis intermedia (Plains lovegrass)
Bromus carinatus (California brome)
Elymus glaucus (Blue wildrye)
Pascopyrum smithii (Western wheatgrass)
Grass species

2nd Choice Seed

Bouteluoa gracilis (Blue grama)
Achnatherum hymenoides (Indian ricegrass) (3)
Pascopyrum smithii (Western wheatgrass)
Artemisia tridentata spp. wyomingenisis (Wyoming big sage)

Yucca spp. (Yucca)
Pseudoroegneria spicata (Bluebunch wheatgrass) (2)
Muhlenbergia porteri (Bush muhly)
Nasella pulchra (Purple needlegrass)
Bromus carnatius (California brome)

3rd Choice Seed

Atreplex confertifolia (Shadscale saltbush)
Elymus cinereus (Great Basin wildrye)
Pseudoroegneria spicata (Bluebunch wheatgrass)
Poa spp. (Bluegrass)
Sporobolus airoides (Alkali sacaton)
Echinocereus spp. (Hedgehog cactus)
Pascopyrum smithii (Western wheatgrass)
Pleuraphis mutica (Tobosa grass)
Vulpia microstachys (Small fescue)
Festuca idahoensis spp. romerii (Roemer's fescue)
Elymus lanceolatus (Thickspike wheatgrass)

4th Choice Seed

Purshia spp. (Bitterbrush)
Bouteloua curtipendula (Sideoats grama)
Pascopyrum smithii (Western wheatgrass)
Pleuraphis spp. (Galleta grass)
Elymus lanceolatus (Thickspike wheatgrass)
Hilaria belangeri (Curly mesquite)
Eschscholzia californica (California poppy)
Carex obnupta (Slough sedge)
Elymus trachycaulus (Slender wheatgrass)

5th Choice Seed

Linum perenne (Blue flax)
Elymus elymoides (Squirreltail)
Elymus lanceolatus (Thickspike wheatgrass)
Sporobolus cryptandrus (Sand dropseed)
Achnatherum hymenoides (Indian ricegrass)
Panicum obtusum (Vine mesquite)
Lupinus succulentus (Hollowleaf annual lupine)
Carex spp. (Sedge)
Nassella viridula (Green needlegrass)

Q32. In the next 5 years, what species of native grasses would your organization/ agency predict to be the highest in demand for large-scale seeding projects (25 acres or more)? Please list in order from your 1st choice to your 5th choice (lst choice being the highest in demand).

1st Choice Grass

Achnatherum spp. (Needlegrass)
Elymus wawawaiensis (Snake River wheatgrass)(2)
Pseudoroegneria spicata (Bluebunch wheatgrass)
Bouteloua gracilis (Blue grama)
Achnatherum hymenoides (Indian ricegrass)
Festuca idahoensis (Idaho fescue)
Elymus elymoides (Squirreltail)
Eragrostis intermedia (Plains lovegrass)
Buchloe dactyloides (Buffalograss)
Nasella pulchra (Purple needlegrass)
Pascopyrum smithii (Western wheatgrass)

2nd Choice Grass

Elymus cinereus (Great Basin wildrye)
Elymus trachycaulus (Slender wheatgrass)
Bouteloua curtipendula (Sideoats grama)
Pascopyrum smithii (Western wheatgrass) (2)
Pseudoroegneria spicata (Bluebunch wheatgrass)(2)
Muhlenbergia porteri (Bush muhly)
Bouteloua spp. (Grama grass)
Vulpia microstachys (Small fescue)

3rd Choice Grass

Bromus marginatus (Mountain brome)
Hilaria jamesii (James' galleta)
Pseudoroegneria spicata (Bluebunch wheatgrass)
Achnatherum hymenoides (Indian ricegrass)
Sporobolus airoides (Alkali sacaton)
Pascopyrum smithii (Western wheatgrass)
Panicum virgatum (Switchgrass)
Poa secunda (Sandberg bluegrass)
Elymus lanceolatus (Thickspike wheatgrass)

4th Choice Grass

Elymus cinereus (Great Basin wildrye)
Sporobolus cryptandrus (Sand dropseed)
Bouteloua curtipendula (Sideoats grama)
Bromus marginatus (Mountain brome)
Pleuraphis spp. (Galleta grass)
Achnatherum hymenoides (Indian ricegrass)

Sorghastrum nutans (Indiangrass)
Agostis pallens (Bentgrass)
Elymus trachycaulus (Slender wheatgrass)

5th Choice Grass
Pascopyrum smithii (Western wheatgrass)
Schizachyrium scoparium (Little bluestem)
Elymus hystrix (Bottlebrush grass)
Carex garberi (Elk sedge)
Sporobolus cryptandrus (Sand dropseed)
Elymus lanceolatus (Thickspike wheatgrass)
Andropogon spp. (Bluestem)
Nassella viridula (Green needlegrass)

Q33. In the next 5 years, what species of native trees/shrubs would your organization/agency predict to be the highest in demand for large-scale seeding projects? Please list in order from your 1st choice to your 5th choice (1st choice being the highest in demand).

1st Choice Forb
Linum perenne (Blue flax) (4)
Eriogonum spp. (Buckwheat)
Agave spp. (Agave)
Achillea millefolium var. occidentalis (Western yarrow)
Zinnia acerosa (Desert zinnia)
Plantago erecta (Dotseed plantain)
Lupinus spp. (Lupine)
Sphaeralcea parvifolia (Globemallow)

2nd Choice Forb
Sphaeralcea parvifolia (Globemallow)
Hedysarum boreale (Utah sweetvetch)
Achillea spp. (Yarrow)
Yucca spp. (Yucca)
Linum perenne (Blue flax) (2)
Zinnia grandifolia (Rocky mountain zinnia)

3rd Choice Forb
Achillea spp. (Yarrow) (3)
Penstemon spp. (Penstemon)
Castilleja spp. (Indian paintbrush)
Echinocereus spp. (Hedgehog cactus)
Penstemon palmeri (Palmer penstemon)
Sphaeralcea parvifolia (Globemallow)

4th Choice Forb

Penstemon spp. (Penstemon)
Onobrychis vicifolia (Sainfoin)
Sphaeralcea parviflora (Globemallow)

5th Choice Forb

Helianthus spp. (Sunflower)
Sanguisorba minor (Small burnett)
Primula spp. (Primrose)

Q34. In the next 5 years, what species of native trees/shrubs would your organization/agency predict to be the highest in demand for large-scale seeding projects? Please list in order from your 1st choice to your 5th choice (1st choice being the highest in demand).

1st Choice Tree/Shrub

Purshia spp. (Cliffrose)
Artemisia filifolia (Sand sagebrush)
Artemisia tridentata var. tridentata (Basin big sage)
Atriplex canescens (Fourwing saltbush)(2)
Artemisia tridentata (Big sagebrush)
Artemisia tridentata var. wyomingenisis (Wyoming big sagebrush) (2)
Populus spp. (Cottonwood)
Artemisia californica (Coastal sagebrush)
Alnus rubra (Red alder)

2nd Choice Tree/Shrub

Atriplex canescens (Fourwing saltbush)(2)
Artemisia tridentata var. wyomingenisis (Wyoming big sagebrush)
Purshia spp. (Bitterbrush)
Kraschininnikovia lanata (Winterfat)
Artemisia tridentata (Big sagebrush) (2)
Salix goodingii (Gooding's Willow)
Eriogonum fasciculatum (Eastern Mojave buckwheat)
Mahonia nervosa (Cascade barberry)
Chrysothamnus spp. (Rabbitbrush)

3rd Choice Tree/Shrub

Purshia tridentata (Antelope bitterbrush)
Cercocarpus montanus (Mountain mahogany)
Atriplex canescens (Fourwing saltbrush) (3)
Purshia spp. (Bitterbrush)
Pinus ponderosa (Ponderosa pine)
Artemisia tridentata (Big sagebrush)
Platanus wrightii (Arizona sycamore)
Encelia californica (California brittlebrush)

4th Choice Tree/Shrub

Fallugia paradoxa (Apache plume)
Purshia spp. (Bitterbrush)
Pinus contorta (Lodgepole pine)
Prosopis pubescens (Screwbean mesquite)
Purshia tridentata (Antelope bitterbrush)
Atriplex gardneri (Gardner saltbush)

5th Choice Tree/Shrub

Rhus trilobata (Skunkbush sumac)
Krascheninnikovia lanata (Winterfat)
Pseudotsuga menziesii (Douglas fir)
Purshia spp. (Bitterbrush)

Q35. Are there any general comments that you would like to add regarding the topics of this survey?

1. Going through your questions, I can't think of all the problems that we have run into with regard to native seed. You talk about 25 acre areas, what about when you have wildfires, floods, or other major events. How do you provide the genotype for the area to cover these events, and if you plant seed from outside the area that you are talking about don't you contaminate what you are trying to accomplish. There is no way a present where you can grow enough genotype seed to fit all the needs out there. As each region wants more and more species only the cost is going to put all out of reach for any project. I would have to see genotype and other native species of the same type planted in test plots side by side in every area that shows planting genotypes grown only within a small local area are better. And I haven't seen it done yet
2. For me, it seems geared for larger operators, not small timers like myself doing this mostly for xeriscaping of small properties.
3. Location of each person answering the survey will make a big difference on the kind of native business they do. For example land managers in low precip zones are happy when anything, native or not, grows. Where a land manager in a high precip Zone >14 inches has the luxury of being selective as there are far more species to choose from in that location.

4. It is a little difficult to decide what the top sellers will be since it depends on what area you are talking about. Restoration projects tend to be very species specific and changes for each location. Our success has come from trying to educate the public and we deal more with individuals than agencies.
5. Species supply and demand are highly volatile and change monthly
6. Market dynamics/volatility defy rational decision making.
7. I would recommend you review the Bureau of Land Management (BLM) purchases over the previous 5 years. Using that information you could get an excellent idea of which species are in demand. Visit www.fedbizops.gov for that info or contact the BLM out of Boise, Idaho.
8. Many of the questions did not apply to my small business. Though a high percentage of my seeds are from native plants, my customers are wholesale nursery growers for the landscape & retail nursery trades. I've worked to encourage the use of true native material, rather than merely drought tolerant exotics, in the urban landscape.
9. The most difficult aspect of supplying locally adapted species for our business is the red tape and long delays related to the governing land agencies and the ability of the seed purchaser to acquire funds. For example, the long drawn out process of the federal agencies procuring money often outlasts the plants growing season and the plants often blossom, produce seed and then shed their production before the agencies can get funding in place. This often delays the agency's ability to purchase seed until the following season and the seed needs to go on the ground now. The fact that federal agencies work on a fiscal year system that does not coincide with the growing/harvest season does not help, either. Another problem is the following example: the Fish and Game needs seed to plant a recent fire. The closest locally adapted seed stand is located just over the next ridge from the planting site but is growing on US Forest Service (USFS) land and the USFS won't let you collect seed in that area.
10. We are a small non-profit foundation and we do not do large scale projects.
11. As I stated in my answers, the selection of the seeds and plants that will be in demand are very customer and site specific. We feel that there is not one grass or plant that works well in all locations and situations. Another thing to take into consideration is the constant development of new viable types of native plants that are being researched and will be available in the next 5-10 years.
12. Most of the questions on this survey do not fit our company. We distribute wildflower seeds, some of which are native types -- we do not offer specific eco-types, seed grown in certain areas, do native collection. Seed native to the United States is not just grown in the United States. Your survey is more suited to companies that grow in their location for application in their region or are involved in hand collection.
13. If there is a market then you can damn well bet there will be someone there to produce what is needed.

Appendix V: Species list of native and non-native species used throughout the Native Plant Material Market Feasibility Survey

Common Name	Scientific Name	Growth Habit
Agave	*Agave spp.* L.	Shrub
Alkali muhly	*Muhlenbergia asperifolia* (Nees & Meyen ex Trin.) Parodi	Graminoid
Alkali sacaton	*Sporobolus airoides* (Torr.) Torr.	Graminoid
American bird's-foot trefoil	*Lotus purshianus* Clem. & E.G. Clem.	Forb
Antelope bitterbrush	*Purshia tridentata* (Pursh) DC.	Shrub
Apache pine	*Pinus engelmannii* Carrière	Tree
Apache plume	*Fallugia paradoxa* (D. Don) Endl. ex Torr.	Shrub
Arizona cliffrose	*Purshia subintegra* (Kearney) Henrickson	Shrub
Arizona cottontop	*Digitaria californica* (Benth.) Henr.	Graminoid
Arizona fescue	*Festuca arizonica* Vasey	Graminoid
Arizona sycamore	*Platanus wrightii* S. Watson	Tree
Arizona willow	*Salix arizonica* Dorn	Shrub
Aspen	*Populus tremuloides* Michx.	Tree
Baccharis	*Baccharis spp.* L.	Shrub
Basin wildrye	*Leymus cinereus* (Scribn. & Merr.) A. Löve	Graminoid
Basin big sage	*Artemisia tridentata* Nutt. ssp. *tridentata*	Tree/Shrub
Bebb's willow	*Salix bebbiana* Sarg.	Tree/Shrub
Bent grass	*Agrostis pallens* Trin.	Graminoid
Big galleta	*Pleuraphis rigida* Thurb.	Graminoid
Big sagebrush	*Artemisia tridentata* Nutt.	Tree/Shrub
Bigelow sagebrush	*Artemisia bigelovii* A. Gray	Shrub
Bigleaf lupine	*Lupinus polyphyllus* Lindl.	Forb
Bitterbrush	*Purshia spp.* (DC.) ex Poir.	Shrub
Black dropseed	*Sporobolus interruptus* Vasey	Graminoid
Black grama	*Bouteloua eriopoda* (Torr.) Torr.	Graminoid
Blackbrush	*Coleogyne ramosissima* Torr.	Shrub
Bladderpod	*Lesquerella spp.* S. Watson	Forb
Blue flag iris	*Iris veriscolor* L.	Forb
Blue flax	*Linum perenne* L.	Forb
Blue grama	*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths	Graminoid
Blue spruce	*Picea pungens* Engelm.	Tree
Blue wildrye	*Elymus glaucus* Buckley	Graminoid
Bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) A. Löve	Graminoid
Bluegrass	*Poa spp.* L.	Graminoid
Bluestem	*Andropogon spp.* L.	Graminoid
Bottlebrush grass	*Elymus hystrix* L.	Graminoid
Brittlebush	*Encelia spp.* Adans.	Shrub
Buckwheat	*Eriogonum spp.* Michx.	Forb
Buffalograss	*Buchloe dactyloides* (Nutt.) J.T. Columbus	Graminoid
Bursage	*Ambrosia spp.* L.	Forb
Bush penstemon	*Penstemon fruticosus* (Pursh) Greene	Forb
Butterfly milkweed	*Asclepias tuberosa* L.	Forb

Common Name	Scientific Name	Growth Habit
California brittlebrush	*Encelia californica* Nutt.	Shrub
California brome	*Bromus carinatus* Hook. & Arn.	Graminoid
California bulrush	*Scirpus californicus* (C.A. Mey.) Palla	Graminoid
California poppy	*Eschscholzia californica* Cham.	Forb
Canada wildrye	*Elymus canadensis* L.	Graminoid
Cane bluestem	*Bothriochloa barbinodis* (Lag.) Herter	Graminoid
Cascade barberry	*Mahonia nervosa* (Pursh) Nutt.	Shrub
Checkerbloom	*Sidalcea* A. Gray	Forb
Chihuahua pine	*Pinus leiophylla* Schiede & Deppe var. *chihuahuana* (Engelm.) Shaw	Tree
Cliffrose	*Purshia spp.* L.	Tree/Shrub
Coastal sagebrush	*Artemisia californica* Less.	Shrub
Common plantain	*Plantago spp.* L.	Forb
Coneflower	*Bracopis* Cass.	Forb
Cordgrass	*Spartina spp.* Schreb.	Graminoid
Cottonwood	*Populus spp.* L.	Tree
Creosote bush	*Larrea tridentata* (DC.) Coville	Shrub
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.	Graminoid
Curl-leaf mountain mahogany	*Cercocarpus ledifolius* Nutt. var. *ledifolius*	Tree/Shrub
Curly mesquite	*Hilaria belangeri* (Steud.) Nash	Graminoid
Desert dandelion	*Malacothrix glabrata* (A. Gray ex D.C. Eaton) A. Gray	Forb
Desert marigold	*Baileya multiradiata* Harv. & A. Gray ex A. Gray	Forb
Desert senna	*Senna covesii* (A. Gray) Irwin & Barneby	Forb
Desert sunflower	*Geraea canescens* Torr. & A. Gray	Forb
Desert zinnia	*Zinnia acerosa* (DC.) A. Gray	Forb
Dotseed plantain	*Plantago erecta* Morris	Forb
Douglas fir	*Pseudotsuga menziesii* (Mirb.) Franco	Tree
Dropseed	*Sporobolus spp.* R. Br.	Graminoid
Eastern Mojave buckwheat	*Eriogonum fasciculatum* Benth.	Shrub
Elk sedge	*Carex garberi* Fernald	Graminoid
Emoryi baccharis	*Baccharis emoryi* A. Gray	Shrub
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.	Tree
Ephedra	*Ephedra spp.* L.	Shrub
Firecraker penstemon	*Penstemon eatonii* A. Gray	Forb
Fishhook cactus	*Sclerocactus spp.* Britton & Rose	Shrub
Flax	*Linum spp.* L.	Forb
Forage kochia	*Bassia prostrata* (L.) A.J. Scott	Subshrub
Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.	Shrub
Fragrant sumac	*Rhus aromatica* Aiton	Shrub
Fremont cottonwood	*Populus fremontii* S. Watson	Tree

Common Name	Scientific Name	Growth Habit
Fringed sage	*Artemisia frigida* Willd.	Subshrub
Galleta grass	*Pleuraphis spp.* Torr.	Graminoid
Gambel oak	*Quercus gambelii* Nutt.	Tree/Shrub
Gardner's saltbush	*Atriplex gardneri* (Moq.) D. Dietr.	Shrub
Globe cactus	*Mammillaria spp.* Haw.	Shrub
Globemallow	*Sphaeralcea parvifolia* A. Nelson	Forb
Goldfields	*Lasthenia* Cass.	Forb
Gooding's willow	*Salix gooddingii* C.R. Ball	Tree
Grama	*Bouteloua spp.* Lag.	Graminoid
Great Basin wildrye	*Elymus cinereus* (Scribn. & Merr.) A. Löve	Graminoid
Green needlegrass	*Nassella viridula* (Trin.) Barkworth	Graminoid
Guajillo	*Acacia berlandieri* Benth.	Tree/Shrub
Hedgehog cactus	*Echinocereus spp.* Engelm.	Shrub
Hollowleaf annual lupine	*Lupinus succulentus* Douglas ex K. Koch	Forb
Honey mesquite	*Prosopis glandulosa* Torr.	Tree/Shrub
Hummingbird trumpet	*Epilobium canum* (Greene) P.H. Raven ssp. *latifolium* (Hook.) P.H. Raven	Forb
Idaho fescue	*Festuca idahoensis* Elmer	Graminoid
Indian paintbrush	*Castilleja spp.* Mutis ex L. f.	Forb
Indian ricegrass	*Achnatherum hymenoides* (Roem. & Schult.) Barkworth	Graminoid
Indian wheat	*Plantago ovata* Forssk.	Forb
Indiangrass	*Sorghastrum nutans* (L.) Nash	Graminoid
Indigo bush	*Amorpha fruticosa* L.	Shrub
Inland saltgrass	*Distichlis spicata* (L.) Greene	Graminoid
Intermediate wheatgrass	*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey	Graminoid
James' galleta	*Hilaria jamesii* (Torr.) Benth.	Graminoid
Joshua Tree	*Yucca brevifolia* Engelm.	Tree/Shrub
Junegrass	*Koeleria spp.* Pers.	Graminoid
Juniper	*Juniperus spp.* L.	Tree/Shrub
Lewis flax	*Linum lewisii* Pursh	Forb
Limber Pine	*Pinus flexilis* James	Tree
Little bluestem	*Schizachyrium scoparium* (Michx.) Nash	Graminoid
Littleleaf mountain mahogany	*Cercocarpus intricatus* S. Watson	Shrub
Lodgepole pine	*Pinus contorta* Douglas ex Louden	Tree
Low beardtongue	*Penstemon humilis* Nutt. ex A. Gray	Forb
Lupine	*Lupinus spp.* L.	Forb
Meadow barley	*Hordeum brachyantherum* Nevski	Graminoid
Menodora	*Menodora spp.* Bonpl.	Shrub/subshrub
Mesa dropseed	*Sporobolus flexuosus* (Thurb. ex Vasey) Rydb.	Graminoid
Mexican cliffrose	*Purshia mexicana* (D. Don) Henrickson	Tree/Shrub
Mexican gold poppy	*Eschscholtzia mexicana* Cham.	Forb
Milkvetch	*Astragalus spp.* L.	Forb

Common Name	Scientific Name	Growth Habit
Milkweed	*Asclepias spp.* L.	Forb
Mountain brome	*Bromus marginatus* Nees ex Steud.	Graminoid
Mountain mahogany	*Cercocarpus montanus* Raf.	Tree/Shrub
Mountain muhly	*Muhlenbergia montana* (Nutt.) Hitchc.	Graminoid
Muttongrass	*Poa fendleriana* (Steud.) Vasey	Graminoid
Narrowleaf willow	*Salix exigua* Nutt.	Tree/Shrub
Nebraska sedge	*Carex nebrascensis* Dewey	Graminoid
Needle and thread	*Hesperostipa comata* (Trin. & Rupr.) Barkworth	Graminoid
Needlegrass	*Achnatherum spp.* P. Beauv.	Graminoid
Nodding needlegrass	*Nassella cernua* (Stebbins & R.M. Love) Barkworth	Graminoid
Olney threesquare	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R.	Graminoid
Oneseed juniper	*Juniperus monosperma* (Engelm.) Sarg.	Tree/Shrub
Orchardgrass	*Dactylis glomerata* L.	Graminoidx
Palmer's penstemon	*Penstemon palmeri* A. Gray	Forb
Parsnipflower buckwheat	*Eriogonum heracleoides* Nutt.	Forb
Penstemon	*Penstemon spp.* L.	Forb
Phlox	*Phlox spp.* L.	Forb
Pima pappusgrass	*Pappophorum vaginatum* Buckley	Graminoid
Pine dropseed	*Blepharoneuron tricholepis* (Torr.) Nash	Graminoid
Pinyon pine	*Pinus edulis* Engelm.	Tree
Plains lovegrass	*Eragrostis intermedia* Hitchc.	Graminoid
Ponderosa pine	*Pinus ponderosa* C. Lawson	Tree
Popcornflower	*Plagiobothrys* Fisch. & C.A. Mey	Forb
Prairie coneflower	*Ratibida pinnata* (Vent.) Barnhart	Forb
Prairie junegrass	*Koeleria macrantha* (Ledeb.) Schult.	Graminoid
Primrose	*Primula* L.	Forb
Pubescent wheatgrass	*Elytrigia intermedia* (Host) Nevski ssp. *trichophora* (Link) Tvzel	Graminoid
Purple needlegrass	*Nassella pulchra* (Hitchc.) Barkworth	Graminoid
Purple threeawn	*Aristida purpurea* Nutt.	Graminoid
Rabbitbrush	*Chrysothamnus* Nutt.	Shrub
Red alder	*Alnus rubra* Bong.	Tree
Red fescue	*Festuca rubra* L.	Graminoid
Rocky mountain penstemen	*Penstemon strictus* Benth.	Forb
Rocky mountain zinnia	*Zinnia grandiflora* Nutt.	Forb
Roemer's fescue	*Festuca idahoensis* Elmer ssp. *roemeri* (Pavlick) S. Aiken	Graminoid
Rothrock grama	*Bouteloua rothrockii* Vasey	Graminoid
Sagebrush	*Artemisia spp.* L.	Shrub
Sainfoin	*Onobrychis viciifolia* Scop.	Forb
Saltbush	*Atriplex spp.* L.	Shrub
Salt heliotrope	*Heliotropium curassavicum* L.	Forb
Sand dropseed	*Sporobolus cryptandrus* Hitchc.	Graminoid
Sand sagebrush	*Artemisia filifolia* Torr.	Shrub

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Sandberg bluegrass	*Poa secunda* J. Presl	Graminoid
Screwbean mesquite	*Prosopis pubescens* Benth.	Tree/Shrub
Screwleaf muhly	*Muhlenbergia straminea* Hitchc.	Graminoid
Seashore bentgrass	*Agrostis pallens* Trin.	Graminoid
Sedge	*Carex spp.* L.	Graminoid
Selfheal	*Prunella* L.	Forb
Shadscale saltbush	*Atriplex confertifolia* (Torr. & Frém.) S. Watson	Shrub
Sheep fescue	*Festuca ovina* L.	Graminoid
Showy goldenrod	*Solidago speciosa* Pursh	Forb
Siberian wheatgrass	*Agropyron fragile* (Roth) P. Candargy	Graminoid
Sideoats grama	*Bouteloua curtipendula* (Michx.) Torr.	Graminoid
Silver buffaloberry	*Shepherdia argentea* (Pursh) Nutt.	Tree/Shrub
Skunkbush sumac	*Rhus trilobata* Nutt.	Shrub
Slender hairgrass	*Deschampsia elongate* (Hook.) Munro	Graminoid
Slender wheatgrass	*Elymus trachycaulus* (Link) Gould ex Shinners	Graminoid
Slough sedge	*Carex obnupta* L.H. Bailey	Graminoid
Small burnet	*Sanguisorba minor* Scop.	Forb
Small fescue	*Vulpia microstachys* (Nutt.) Munro	Graminoid
Smooth aster	*Symphyotrichum laeve* (L.) A. Löve & D. Löve	Forb
Smooth sumac	*Rhus glabra* L.	Tree/Shrub
Snake River wheatgrass	*Elymus wawawaiensis* J. Carlson & Barkworth	Graminoid
Spanish clover	*Trifolium gemellum* (Pourr. Ex Willd.	Forb
Spike bentgrass	*Agrostis exarata* Trin.	Graminoid
Spike dropseed	*Sporobolus contractus* Hitchc.	Graminoid
Spike muhly	*Muhlenbergia wrightii Vasey ex J.M. Coult.*	Graminoid
Squirreltail	*Elymus elymoides* (Raf.) Swezey	Graminoid
Stansbury cliffrose	*Purshia stansburiana* (Torr.) Henrickson	Tree/Shrub
Sunflower	*Helianthus spp.* L.	Forb
Switchgrass	*Panicum virgatum* L.	Graminoid
Tall fescue	*Schedonorus phoenix* (Scop.) Holub	Graminoid
Thickspike wheatgrass	*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould	Graminoid
Thurber fescue	*Festuca thurberi* Vasey	Graminoid
Tobosa grass	*Pleuraphis mutica* Buckley	Graminoid
Tomcat clover	*Trifolium willdenovii* Spreng	Forb
Triangle-leaf bursage	*Ambrosia deltoidea* (Torr.) Payne	Shrub
Tufted hairgrass	*Deschampsia cespitosa* (L.) P. Beauv.	Graminoid
Utah juniper	*Juniperus osteosperma* (Torr.) Little	Tree
Utah sweetvetch	*Hedysarum boreale* Nutt.	Forb
Velvet ash	*Fraxinus velutina* Torr.	Tree
Velvet mesquite	*Prosopis velutina* Woot.	Tree/Shrub
Vine mesquite	*Panicum obtusum* Kunth	Graminoid

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Western sea-purslane	*Sesuvium verrucosum* Raf.	Forb
Western wheatgrass	*Pascopyrum smithii* (Rydb.) A. Löve	Graminoid
Western yarrow	*Achillea millefolium* L. var. *occidentalis* DC.	Forb
Wheatgrass	*Agropyron* Gaertn.	Graminoid
Wild rose	*Rosa spp.* L.	Shrub
Willow baccharis	*Baccharis salicina* Torr. & A. Gray	Shrub
Winterfat	*Krascheninnikovia lanata* (Pursh) A. Meeuse & Smit	Shrub
Wolfberry	*Lycium spp.* L.	Shrub
Wyoming big sagebrush	*Artemisia tridentata* Nutt. var. *wyomingensis* (Beetle & Young) S.L. Welsh	Tree/Shrub
Yarrow	*Achillea spp.* L.	Forb
Yerba mansa	*Anemopsis californica* (Nutt.) Hook. & Arn.	Forb
Yucca	*Yucca* L.	Shrub