Sierra-Cascade Intensive Forest Management Research Cooperative

Series Report No. 18

SCIFMRC

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ANNUAL REPORT 2017

TABLE OF CONTENTS

The year 2017 marked the eighteenth year as an organization for the Sierra Cascade Intensive Forest Management Research Cooperative.

The current membership consists of a mixture of landowners, forestry-related industries, State of California and federal agencies. There are currently seventeen member organizations in the Co-op.

The annual business meeting was held at the Forest Service office March 8, 2017 in Redding (a summary of the meeting can be found in this Annual Report). Seventeen Co-op members and guests attended. The first item of business was a review of the budget. The Co-op ended 2016 with a surplus of $17,450.29. Dues received for 2017 at the time of the annual meeting totaled $40,000, with another $22,000 promised.

In response to concerns, expressed by several Co-op members earlier in the year, about plantation losses in wildfires and what might be done to lessen these losses, Rob York (Blodgett Forest Research Station) presented results of a study published in 2016 in Forest Ecology. The publication was titled: "Damage and Mortality in Young Mixed Conifer Plantations Following Prescribed Fires in the Sierra Nevada, California". The presentation was well received and generated a good discussion.

Following the presentation by Rob York, updates on recently funded Co-op studies were presented: Proposal 12-02 Garden of Eden; Proposal 15-01 Rodeo; Proposal 16-01 Boggs Mountain; Proposal 16-02 Derigo; and Proposal 16-03 Penoxsulam.

The next item of business at the annual meeting was the presentation of new proposals for possible Co-op funding in 2017. Three new proposals were presented. Ed Fredrickson presented a proposal for pre-plant treatments of Telar XP to evaluate conifer tolerance and efficacy. The second new proposal was presented by Jianwei Zhang and its objective was to measure the conifers that were planted on the Agenda 2020 sites (Proposal 03-01). The third new proposal was from Rob York who proposed remeasuring, pruning, and performing maintenance on a giant sequoia spacing study established in 1989 and an incense-cedar spacing study established in 1999. All three proposals were funded by the Co-op. Executive Summaries for four proposals, Boggs (16-01); Derigo (16-02); Penoxsulam (16-03), and Telar (17-03) appear in this Annual Report. Also, two full reports, Agenda 2020 Remeasure (17-02) and Blodgett (17-01) are included in this issue.

One of the last items on the 2017 business meeting agenda was an update on the proposal by a Co-op member to the effect that Co-op members who make presentations at the Forest Vegetation Management Conference should be compensated. This proposal was presented to the Vegetation Management program committee at their 2017 meeting in February. The committee accepted the proposal and a fee of $1,000 was agreed to for each presentation made by a Co-op member.

Treatments for the Telar study were applied on April 3rd at the Oak Run site and April 9th at the Whitmore site. Planting was accomplished on April 14th at Oak Run and May 9th at Whitmore.

The Co-op field trip scheduled for June 7th, with stops located on the Fountain Fire and herbicide trials near Oak Run, had a good turnout with 16 Co-op member and guests attending. The Fountain Fire is now 25 years old. Stops included sites featuring machine and hand planting and precommercial thinning on the Fountain Fire and herbicide trials featuring Cleantraxx, Derigo, Esplanade, Telar XP, and Matrix SG in areas around Round Mountain and Oak Run. Perennial grass issues with Cleantraxx and scotch broom control with Derigo were demonstrated at two sites.

The second year (final) evaluation for the Boggs study was conducted on July 20th. First year evaluations for the Telar study as well as second year (final) evaluations for the Penoxsulam and Derigo studies were conducted in August.

All giant sequoia spacing study plots were resampled at Blodgett during the summer. In addition, pruned trees within the giant sequoia spacing study were resampled and plot maintenance was accomplished on both the giant sequoia and incense-cedar spacing trials. All replicates of one of the spacing treatments in the giant sequoia study were thinned. Resampling of the incense-cedar spacing study is scheduled for summer 2018.

The measurements of the conifers on the Agenda 2020 study were done in November at the Dana site and in December at the Flat Woods site.

The year 2018 should be another busy one for the Co-op. New proposals are currently being submitted to the Co-op for funding consideration. Several funded study sites will have second year measurements taken. Based on the interest shown for field trips featuring Co-op study sites, another trip will be planned for 2018. Results from Co-op studies will continue to be presented at the Forest Vegetation Management Conference. Articles on research funded or partially funded by the Co-op are being featured in peer-reviewed journals on a regular basis.

2017 MEMBERSHIP

Land Manager Membership

- California Department of Forestry
- Fruit Growers Supply Co.
- Roseburg Resources Co.
- Sierra Pacific Industries
- Soper-Wheeler Co.
- Timber Products Co.
- W.M. Beaty & Associates, Inc.

Associate Corporate Membership

- Cal Forest Nurseries & Mountain Gate Gardens

Affiliate Membership

- Bayer CropScience
- Dow AgroSciences
- Silver Butte Timber Co.
- Thunder Road Resources
- Jefferson Resource Company, Inc.

Supporting Members

- California Forestry Association
- PSW Research Station
- University of California
- USDA Forest Service

Sierra Cascade Intensive Forest Management Research Cooperative

Annual Meeting March 8, 2017

The 2017 annual meeting was held at the Bureau of Land Management office in Redding, CA on March 8, 2017. Seventeen Co-op members and guests attended.

The 2016 Annual Report was the first item of business. Membership status was discussed. Membership remained unchanged from 2016. About 65% of the members from 2016 have paid their 2017 dues. Those that have not paid to date indicated that their dues payments are on the way. There are currently seventeen member organizations in the Co-op.

The next item of business was a discussion on the budget. The Co-op ended 2016 with a surplus of $17,450.29. Dues received for 2017 at the time of the annual meeting totaled $40,000, with another $22,000 promised. To supplement the summary of the 2016 budget found in the Annual Report, spread sheets of the proposed budget and annual workload for 2017-2021 were presented to the membership.

Plans for the 2017 field trip were discussed next. The 2016 field trip featured stops on the Day Fire. Stops demonstrating herbicide efficacy trials and treatment options as well as examples of biomass chipping and gopher control were featured on the field trip. The 2017 field trip is scheduled for June 7th. A committee composed of Ed Fredrickson, Mark Gray and Scott Carnegie will develop a list of field trip possibilities. This list will be presented to the membership for final selection of the location. One possibility suggested was the different results from the wildfire found throughout the Fountain Fire which will be 25 years old this year.

The next item on the agenda was in response to a discussion between Co-op members during a break at the Vegetation Management Conference in January. This discussion concerned plantation losses in wildfires and what might be done to lessen these losses. As a follow-up, Eric Knapp of the PSW Research Station in Redding was contacted and he supplied a list of recent publications addressing this subject. This list was shared with the Co-op membership. Rob York, Blodgett Forest Research Station was a coauthor of one of these publications and agreed to present his findings at our Annual Meeting. Rob's publication was published in Forest Ecology and Management in 2016 and is titled: "Damage and Mortality Patterns in Young Mixed Conifer Plantations Following Prescribed Fires in the Sierra Nevada, California". The presentation was well received and generated a lively discussion period.

Following Rob's presentation, updates on funded proposals were presented to the membership. Jianwei Zhang reported on results for Proposal 12-02 Garden of Eden. This study is in its third year. Ed Fredrickson reported on results for Proposal 15-01 Rodeo, Proposal 16-01 Boggs Mountain, Proposal 16-02 Derigo, and

Proposal 16-03 Penoxsulam. Executive summaries for the last four studies are found in the 2016 Annual Report.

Following the funded proposal updates, ideas for possibly three new proposals were discussed by the membership. The first was an update by Mark Gray on the stock type trial of sugar pine and incense cedar which was initially brought before the Co-op in 2015. The proposal is taking shape and hopes are that it will be implemented in 2018. The second idea was presented by Tom Jopson and concerned the possibility of spreading out the planting season to lessen labor supply (tree planters) problems. Tom envisions planting smaller styro-stock and possibly planting all year. Tom will prepare a proposal for funding at our 2018 Annual Meeting. The third idea for a new proposal was a study on assessing the impact of site preparation operations on post-fire sediment delivery and recovery. Joe Wagenbrenner of PSW Research Station sent a draft proposal for the membership's consideration and comments. Joe was unable to attend the Annual Meeting. There were several comments on the draft proposal including applying the study on steep ground as well as more gentle ground, considering less severe mortality classes as well as the severe class, and including members of various water boards during formulation of the study. It was decided to have the membership take the draft proposal home with them and send their comments back to the Co-op after some more thought on the study.

Following the discussion of funded proposals, three new proposals were presented to the membership for possible funding in 2017. Ed Fredrickson presented a proposal for pre-plant treatments with Esplanade F, Telar XP, Matrix SG, Derigo, and Cleantraxx to evaluate conifer tolerance and efficacy. This proposal has an option for the number of sites to be installed. Jianwei Zhang presented a proposal to measure the conifers on the Agenda 2020 study (03-01). And Rob York presented a proposal for giant sequoia and incense cedar levels of growing stock studies. This proposal could be broken down into two parts based on the conifer species being studied.

After questions from members about the new proposals were addressed, it was decided that the voting membership would be canvassed by email to determine how many and at what level the Co-op would fund the proposals. Emails were sent to the voting members on March 9th with a reply due on March 16th.

The next item of business was a report on the status of a suggestion from Bob Amesbury that Co-op members making presentations (using data from Co-op funded studies) at the Forest Vegetation Management Conference should be compensated since the data they were presented was proprietary and paid for by members of the Co-op. During the life of the Co-op, our members average at least one presentation per year at the Conference. This suggestion was presented as a formal proposal to the 2017 Program Committee of the Conference on February 13th with the stipulation that any Co-op member giving a presentation would receive a speaker's fee of $1,000.00 which would go into the Co-op's general fund. The Program Committee agreed and this action will be implemented at the 2018 Vegetation Management Conference.

The last item on the agenda was a discussion on the direction of the Co-op in the future. The year 2017 marks the eighteenth year for the Co-op. Have goals and objectives changed? What areas of intensive forest management should the Co-op research? A list of possible research items was developed by Jeff Webster and presented to the membership for their comments and consideration. The membership was requested to make a timely response to these questions.

The meeting adjourned at this time.

Sierra Cascade Intensive Forest Management Research Cooperative Proposals 16-01
Boggs Mountain State Forest

Principal Investigators: Dave Loveless and Ed Fredrickson

Title: Pre-Plant Site Preparation with Velpar DF and Pindar GT

Year Approved: 2016

Executive Summary
On September 12, 2015, the Valley Fire swept through southern Lake County, California. The fire consumed 76,067 acres. The 3,500 acre Boggs Mountain Demonstration State Forest (BMDSF), located adjacent to the community of Cobb and 10 miles north of Middletown was severely impacted by the fire, with nearly 90% of all vegetation on the forest either consumed or killed. The site is unique in that it lies on the fringe of the timbered region in Lake County. Boggs Mountain is a fairly isolated piece of timberland that has some interesting characteristics. The organic matter content in the soils runs from six to nine percent. This is right on the margin of being too high for hexazinone applications to work effectively. Hexazinone binds tightly to organic matter and can be rendered ineffective when the organic matter content becomes too high.

The Forest is in the process of implementing a salvage and rehabilitation plan to re-establish a successful conifer forest on this highly productive site I and II timberland. Some of the conifer species included in this plan are intolerant to hexazinone. With the introduction of Cleantraxx to forestry, it gives another option for hexazinone intolerant conifers. It has not been tested on sites near Boggs Mountain. The site preparation plan includes the use of herbicides to control competing vegetation with both pre and post reforestation treatments.

While located in the coast range, pre-fire vegetation on BMDSF was composed of inland species including ponderosa pine, Douglas-fir, sugar pine, and a small amount of incense cedar in the overstory. Overstory hardwoods include black oak and live oak. Predominant understory brush species include Sonoma manzanita, Konocti manzanita, and coffeeberry. The soils on Boggs Mountain are moderately deep to very deep, well-drained very gravelly loam and loam derived mainly from the Mountain's lava cap of andesite, basalt, and dacite. Igneous rock derived Aiken and Collayomi are the Forest's most productive soils. A limited amount of timber soils and most of the non-timber soils are derived from Great Valley formation sandstone or shale parent material.

This objective of this study is to evaluate the efficacy of various rates of hexazinone formulated as Velpar DF and Cleantraxx with and without Accord XRT II for

efficacy for pre-plant site preparation to control herbaceous broadleaf weeds and woody plant seedlings in conifer plantations on Boogs Mountain Demonstration State Forest.

The Study: The trial will be installed on the Aiken soil series which comprises the majority of the soil types on the forest. The site will have been recently logged with no further site preparation. The site is approximately 3500 feet elevation with a relatively flat aspect. Herbicide applications will occur in the spring of 2016 prior to the final spring rains.

The trial is a completely randomized block design with four replications per treatment. The plot size will be 10 feet by 25 feet and will be staked at both ends of the centerline with PVC pipe. Plots will be sprayed with a CO2 powered backpack sprayer equipped with a 10 foot boom. All applications will be made at 10 gallons per acre at a consistent pressure of 30 psi. All plots will be sprayed with one timed pass.

Evaluations will occur in the summer and fall of 2016 and consist of ocular estimates of percent bare ground and percent cover by species. Statistical analysis will be conducted by Liz Cole of Oregon State University. All treatment installation, evaluation, and write up will be accomplished by Thunder Road Resources.

Treatments: Will consist of three rates of Velpar DF at 2, 3, and 4 pounds product per acre and Cleentraxx (Pindar GT) at 3 pints and 4.5 pints per acre with and without 2 quarts of Accord XRT II.

2016: The site chosen for this study is on the west side of the forest at approximately 3500 feet elevation on a slight north aspect and zero to five percent slope. The site had burned in the 2015 wildfire and salvaged logged in early 2016. No further site preparation had been done to the site.

Plots were sprayed on April 1st. Evaluations were conducted on July 5th and August 29th.

Data were analyzed using SAS statistical software. Vegetation and seedling data were analyzed using analysis of variance. Treatments were compared using a Tukey's test with adjusted probabilities. Initial seedling size parameters were used as covariates within the ANOVA's for height, caliper, and volume. Analyses for size were weighted by the number of surviving seedlings in each plot. Least squared means for size included adjustments for the covariates, which resulted in some differences for the raw data means. Analyses utilized PROC MEANS, PROC MIXES and PROC GLIMMIX in SAS. PROC GLIMMIX was used when variances were unequal, and either the Poisson or gamma distribution was used.

The entire fire area was clean of vegetation at the time of treatment. Unfortunately, the site where the trial was installed stayed free of vegetation throughout the entire year. No significant differences existed between treatments at either evaluation time during the season (Table 1). Due to lack of vegetation, it was impossible to determine whether either herbicide was effective. The trial was left in place with the hope some value may be gained from it in 2017. Due to the lack of vegetation, only the fall data were presented in this document.

2017: The 2017 evaluation occurred on July 20th. Second year results were not as dramatic as thought. Squaw carpet was 95 percent of the total vegetation on the site. Neither percent bare-ground or squaw carpet cover or control were significantly affected by treatment. Squaw carpet cover was less than the non-treated for all treatments with the exception of the 4.5 pint Pindar GT alone treatment, although differences were not significant (Table 2). This may have already germinated at the time of treatment.

The Boggs trial was disappointing as far as the amount of vegetation that invaded after the trial was installed. The site stayed clean even through the second growing season. No real conclusions can be drawn from the various treatments due to lack of vegetation.

Treatment	% Bare Ground
2 lbs Velpar DF	99.3 (1.0) a
3 lbs Velpar DF	96.8 (2.4) a
4 lbs Velpar DF	98.5 (1.2) a
3 pts Pindar GT	99.3 (0.8) a
4.5 pts Pindar GT	98.8 (0.5) a
3 pts Pindar GT + 2 qts Accord XRT II	97.3 (1.0) a
4.5 pts Pindar GT + 2 qts Accord XRT II	99.8 (0.3) a
Control	97.3 (1.2) a

Table 1. August percent bare ground data for the Boggs Experimental Forest Residual Herbicide Trial. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level.

Treatment	% Bare Ground	% Cover Squaw Carpet
2 lbs Velpar DF	98.3 (1.1)	1.0 (0.4)
3 lbs Velpar DF	96.8 (3.4)	1.0 (0.4)
4 lbs Velpar DF	97.3 (2.5)	1.8 (1.1)
3 pts Pindar GT	98.3 (1.0)	0.8 (0.5)
4.5 pts Pindar GT	94.0 (5.0)	5.8 (3.2)
3 pts Pindar GT + 2 qts Accord XRT II	95.3 (3.2)	2.0 (0.8)
4.5 pts Pindar GT + 2 qts Accord XRT II	97.8 (2.8)	1.8 (1.1)
Control	94.8 (6.7)	4.5 (3.5)

Table 2. August percent bare ground data for the Boggs Experimental Forest Residual Herbicide Trial. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level. If there are no letters, there were no significant main effects.

Sierra Cascade Intensive Forest Management Research Cooperative Proposal 16-02
Pindar GT and Derigo

Principal Investigator: Ed Fredrickson

Title: Improving Post Emergent Herbaceous Control and Conifer Tolerance with Pindar GT, Derigo, and Transline

Year Approved: 2016

Executive Summary:

For the past several years this Co-op and others have been looking at Pindar GT as a new forest site preparation tool. Great results have been shown in California and southwest Oregon regarding pre-emergent herbaceous weed and brush control and conifer tolerance. The one application timing that is proving to be inconsistent is spring post-emergent herbaceous weed control.

There are basically two possible ways to deal with this situation. The first is to tank mix Pindar GT with another herbicide that provides a good foliar knock down of existing vegetation such as glyphosate. This presents a problem however if seedlings have already been planted on the site, due to conifer tolerance issues. The number of herbicides that have foliar activity on existing herbaceous vegetation and adequate conifer tolerance to go over the top of freshly planted seedlings is very limited.

The second option is to add an adjuvant to Pindar GT to try to increase what foliar activity there is using Pindar GT. There are a variety of adjuvants that act as surfactants for herbicides including non-ionic, silicone, petroleum, and seed oil based products. Each may work differently depending on the herbicide used, vegetation being treated, and time of year of the application.

This study will look at several methods to improve knock down of herbaceous vegetation while maintaining conifer tolerance, including evaluating types of surfactants and tank mixes with several other products. A new herbicide that has proven knock down ability and some residual control will be tested.

The adjuvants to be tested will include a methylated seed oil (MSO), silicon surfactant (Sylgard 309), and a non-ionic surfactant (R-11). This study will also look at the potential for the herbicide Transline to assist in improving knock down.

A new product that has been tested extensively in bare ground trials and is currently registered in the United States as a turf herbicide is Derigo. Derigo contains three ALS inhibiting active ingredients, iodosulfuron and foramsulfuron, which are two sulfonylura herbicides, and thiencarbazone which is in the sulfonyl amino carbonyl triazolinone family. All three active ingredients have both foliar and

soil activity. Testing in non-forestry markets in California has shown excellent knock down on a variety of herbaceous broadleaved plants. It is not known at this time whether Derigo has sufficient conifer tolerance to be applied over freshly planted seedlings.

Derigo has an excellent fit for forest landowners. The product has extremely low toxicities for all three active ingredients and very short half-lives in the environment (2 to 55 days). All three active ingredients are fairly mobile in the soil, but the short half-lives make the risk of soil mobility minimal. All three show high degrees of safety toward mammals, birds, and aquatic life.

The objectives of this study are to determine the partial contributions of surfactant and Transline to post-emergent broadleaf weed control with Pindar GT and Derigo, as well as assess the potential benefits of Derigo for forest weed control and conifer tolerance.

The Study: This study is proposed for two sites where normal procedures would include spring herbaceous treatments over freshly planted conifer seedlings. The treatments will occur post-planting and after the majority of herbaceous vegetation has emerged in the spring. Applications need to occur prior to the end of the spring rain season.

The trials are completely randomized block designs with three replications per treatment. Plot size is 10 feet by 25 feet. Plots will be staked at each end of the centerline with PVC pipe and numbered. Planting will occur on Derigo treated plots only and the non-treated controls. Each plot will be planted with ten trees each of two conifer species prior to the application. Planters and seedlings will be provided by the timber companies. Thunder Road Resources will supervise the planting. Conifer species will vary depending on the site. Trees will be measured initially at planting for height and caliper.

Herbicide applications will occur immediately after planting. All applications will be applied at 20 gallons per acre at 30 psi with a CO2 powered backpack boom sprayer with a 10 foot boom. Six 80015 nozzles will be utilized for the application. The sprayer will be calibrated prior to application. Plots will be sprayed with one timed pass. Initial vegetation cover will be taken at the time of application for total percent cover and percent cover for the major species present.

Data collected consists of percent bare ground, percent total cover, percent cover and control by species for the dominant species on each site. Vegetation data will be recorded at the end of the first and second growing season. Trees will be measured for caliper and height at planting and will be re-measured at the end of the second growing season. Ocular estimates of survival, percent brown out, needle and bud damage will be measured at the end of the first and second growing season.

All statistics will be run by Liz Cole of Oregon State University. Statistics will consist of analysis of variance with Tukeys tests with adjusted probabilities for multiple comparisons. Initial seedling size will be evaluated for significance and if so will be analyzed using covariate procedures. All layout, evaluations, data interpretation, and annual progress reports will be completed by Thunder Road Resources.

Treatments: Will include: 3 pts. Pindar GT; 3 pts Pindar GT with 1% and 3% MSO, 0.1% Sylgard 309, 0.25% R-11, 3 oz Derigo + 1% MSO and 8 oz Transline + 1% MSO; 3 oz Derigo; 3 oz, 4.5 oz, and 6 oz Derigo with 1% MSO; 3 oz and 6 oz Derigo with 8oz Transline + 1% MSO; 8 oz Transline + 1% MSO; and non-treated controls.

2016: Two sites were chosen for this trial, one near Montgomery Creek, California and the other near Oak Run, California on the west side of the Cascade Range. The Montgomery Creek site is located on property owned and managed by Sierra Pacific Industries. The site is approximately 2,500 feet elevation on a flat aspect. The site was logged as part of a timber harvest plan in 2013. Prior to logging it was pre-harvest sprayed with glyphosate and imazapyr. Following logging, the site was ripped, and planting occurred in 2014. The Oak Run site is on property owned and managed by Roseburg Resources Company. The site is approximately 4,000 feet elevation on a flat aspect. The unit was a clear cut as part of normal logging operations. It was pre-harvest sprayed using imazapyr and glyphosate. The site was logged in 2013 and planted in the spring of 2014. No further site preparation treatments have occurred on the site.

The Montgomery Creek site was planted with styro-4 ponderosa pine and styro-6 Douglas-fir on April 13th and the Oak Run site was planted with styro-5 ponderosa pine and styro-6 Douglas-fir on April 6th. Since abundant conifer tolerance data have already been obtained for Pindar GT, only plots sprayed with Derigo and the non-treated controls were planted.

Spraying occurred on April 15th on the Montgomery Creek site and on April 7th on the Oak Run site.

Evaluations occurred on July 16th for the Montgomery Creek site and July 15th on the Oak Run site.

Data were analyzed using SAS statistical software. Vegetation and seedling data were analyzed using analysis of variance. Treatments were compared using Tukey's test with adjusted probabilities. Initial seedling size parameters were used as covariates within the ANOVA's for height, caliper, and volume. Analyses for size was weighted by the number of surviving seedlings in each plot. Least squared means for size included adjustments for the covariates, which resulted in some difference from the raw data means. Analyses utilized PROC MEANS, PROC MIXES, and PROC GLIMMIX in SAS. PROC GLIMMIX was used when variances were unequal, and either the Poisson or gamma distribution was used. When statements are made regarding statistically significant differences in this document, the alpha level is $P<= 0.05$.

These trials were basically separated into two parts. The first dealt with post emergent applications of Pindar GT with various surfactants to attempt to improve knock down of existing vegetation. The second was a screening trial for vegetation control and conifer tolerance with Derigo.

Montgomery Creek Site: Vegetation control with Pindar GT varied by species (Table 1). The addition of an adjuvant significantly improved control of Spanish clover compared to Pindar GT without (Figure 1). The methylated seed oil adjuvant had better control than Sylgard 309 or R-11 but not significantly. The addition of adjuvant did not make a significant difference with Pindar GT for control of Scotch broom or rattail fescue. Although not significant, it is interesting that the methylated seed oil treatment has the worst control of rattail fescue and Sylgard 309 and R-11 were the best. This is the opposite of what happened with Spanish clover. Percent bare ground did not differ significantly by treatment for Pindar GT, but the highest percent bare ground occurred with either the Derigo or Transline tank mixes.

The addition of a second herbicide significantly improved control on several species. Transline significantly improved control of Spanish clover over the Pindar GT with no adjuvant and the treatments with Sylgard 309 and R-11. The addition of Derigo improved control of Scotch broom and rattail fescue, but due to higher variability, not significantly over the other Pindar GT treatments.

Derigo treatments initially provided very good knock down of the vegetation that was present on the site. By the time of the first evaluation, vegetation had started to re-invade the plots as Derigo has a very short residual life. Adding an MSO to Derigo increased percent bare ground over the no adjuvant treatment but not significsntly. Increasing the Derogo rate to 6 ounces per acre did have a significant increase in bare ground over the three ounce treatment with no adjuvant and the non-treated control. Bare ground increased with six ounces plus an MSO over the three and four and half ounce rate with an MSO, but not significantly. The highest percent bare ground was achieved with the Derigo plus Transline tank mix. Both tank mix treatments had significantly more bare ground than the three ounce rate of Derigo with no MSO and the non-treated control.

Scotch broom control was variable with Derigo, but it definitely inhibited growth and suppressed some germination. However, Scotch broom control was not significantly affected by treatment. Most of this can be attributed to variability of Scotch broom cover among plots. Although treatment differences were not significant, there were less Scotch broom and smaller plants in the Derigo treated plots compared to Pindar GT, Transline alone or in the untreated controls.

All rates of Derigo provided significantly better control of rattail fescue than non-treated control or the treatment with Transline alone except for the three ounce rate of Derigo with MSO. Control of rattail fescue was slightly better with Derigo compared to Pindar GT treatments, but not significantly. Spanish clover was initially knocked down very well shortly after treatment, but recovered as the season went on. Best control was achieved with the Derogo plus Transline tank mixes. The six ounce rate of Derigo with MSO, Transline alone, and the two Derigo plus Transline tank mixes had significantly better control of Spanish clover than the three ounce Derigo treatment with no MSO, the 4.5 ounce Derigo treatment with MSO and the non-treated control. Transline controlled Spanish clover very well on its own.

Both ponderosa pine and Douglas-fir were significantly affected by treatment (Table 2, Figure 2). Bud damage was significantly increased for both species with Derigo at any rate compared to the no-treated control. Needle damage was significantly increased with Derigo at all rates on Douglas-fir compared to the non-treated control. Needle damage was higher with Derigo treatments for ponderosa pine, but not significantly. Survival and percent brownout were not significantly affected by treatment for either species.

Oak Run Site: The Oak Run site was comprised of a good mix of weeds to evaluate the two herbicides. For the Pindar GT treatments, percent bare ground was significantly influenced by treatment (Table 3). All treatments with Pindar GT except for the three pint rate with no adjuvant and the three pint with Transline had significantly more bare ground than the non-treated control. Percent bare ground did not differ significantly among Pindar GT treatments. However, there were some apparent trends. The addition of an adjuvant did increase the percent bare ground but not significantly. Little difference existed between adjuvants but R-II provided the most bare ground of the ones tested. The most bare ground was achieved with the tank mix with Derigo while Transline added little on this site.

This site was dominated by a fairly rare weed in forestry, but one that is starting to invade forestry sites. Rush skeleton weed was abundantly present here. All Pindar GT treatments provided significantly more control than the non-treated control. Treatments did not differ significantly among Pindar GT treatments, but the addition of an adjuvant definitely increased control over the three pints of Pindar GT without an adjuvant. All Pindar GT treatments with an adjuvant controlled rush skeleton weed fairly well. Control was increased more when Derigo or Transline was tank mixed with three pints of Pindar GT.

All Pindar GT treatments provided significantly more annual grass control than the non-treated control, but again, did not differ significantly from one another. All treatments provided good control except the Pindar GT plus Transline tank mix. Squirrel tail is a commom perennial grass common to this area that was also abundant on this site. Pindar GT is inherently weak on perennial grasses and this was apparent on this site. Control of squirrel tail was poor and no

Pindar GT treatment differed significantly from the non-treated control.

All treatments with Derigo except the three ounce rate with no adjuvant and the four and a half ounce rate with MSO had significantly more bare ground than the non-treated control or the treatment with Transline alone. No treatment with Derigo significantly differed from each other regarding bare ground and no obvious trends were present.

Control of rush skeleton weed was poor with Derigo alone at any rate, even with MSO. All treatments with Derigo alone had significantly poorer control than either Derigo tank mix with Transline or Transline alone. Transline alone at eight ounces per acre controlled rush skeleton weed one hundred percent.

Annual grass control with Derigo was excellent, but the addition of MSO significantly improved control of the three ounce rate. All treatments containing Derigo had significantly more annual grass control than the non-treated control and Transline alone with the exception of the three ounce Derigo rate with no MSO which was only significantly different from the non-treated control. No Derigo treatments with MSO were significantly different from each other.

Control of squirrel tail was sporadic at best. The six ounce rate of Derigo with MSO provided significantly more control of squirrel tail than either the three ounce rate without MSO or Transline alone, but not the untreated control. This may be an artifact. No other differences existed between Derigo treatments

Similar to the Montgomery Creek site, ponderosa pine nor Douglas-fir survival or percent brownout were significantly affected by treatment (Table 4). However, all treatments with Derigo had significantly more bud and needle damage on ponderosa pine and significantly more bud damage on Douglas-fir compared to the non-treated control. Needle damage was also higher with Derigo treatments for Douglas-fir, but not significantly.

Overall, both of these sites showed that adjuvants increased control for both Pindar GT and Derigo. The type of adjuvant that provided the best control varied by species for Pindar GT. Only an MSO was tested with Derigo. The most consistent and largest gains were achieved by tank mixing Pindar GT or Derigo with an additional herbicide. This was similar to results observed in the analogous two trials conducted by the Certified Forest Research Group. Pindar GT and Derigo both exhibited weaknesses when perennial grasses were present.

Both sites showed unacceptable levels of conifer injury from over-the-top applications to freshly planted conifers from Derigo. It was not determined whether pre-plant applications had an acceptable level of conifer safety. While survival and brownout were not affected, the applications caused significant levels of leader and needle stunting resulting in growth loss. From these data it does not appear that over-the-top applications with Derigo are a feasible option for forestry applications.

2017: Montgomery Creek Site
Vegetation for the Pindar GT portion of the trial had mostly fully recovered by the end of the second growing season which is typical for Pindar GT applications. Percent bare-ground did not significantly differ from the non-treated controls by the end of the second growing season (Table 5). Rat tail fescue control was still significantly affected by treatment at the end of the second growing season. The 3 pint per acre rate of Pindar GT with 1 percent MSO and the 3 pint Pindar GT plus 3 ounces of Derigo per acre treatment were significantly different from the non-treated controls. Rat tail fescue control did not significantly differ within herbicide treatments for Pindar GT but the general trend showed much better fescue control with an adjuvant, especially MSO.

Needle grass, Scotch broom nor Spanish clover were significantly affected by Pindar GT treatment at the end of the second growing season. Pindar GT had little if any effect on needle grass or Scotch broom. Spanish clover was moderately controlled in the first growing season but was recovering by the second.

Percent bare-ground did not significantly differ by treatment for the Derigo portion of the trial. Rat tail fescue control did not significantly differ within Derigo treatments, but 4.5 and 6 ounces of Derigo alone and both combinations with 8 ounces of Transline per acre did provide significantly more fescue control than the non-treated controls. Derigo did provide fairly decent control of needle grass at rates of 4.5 ounces per acre or higher, but results were not significantly different within Derigo treatments or from the non-treated controls. Spanish clover which was controlled very well in the first growing season had totally recovered by the end of the second. Spanish clover control was not significantly affected by treatment at the end of the second growing season.

The greatest find of Derigo in this study was its ability to control Scotch broom. At rates of 3 ounces per acre and higher with MSO, Scotch broom was controlled very well. Scotch broom was controlled significantly better than most of the Pindar GT treatments, Transline alone and the non-treated controls. Control did not significantly differ within Derigo treatments, however there was an obvious trend regarding the addition of MSO. While not significantly different, control increased with 3 ounces of Derigo per acre from 31.7 to 91.7 percent when 1 percent MSO was added. All other Derigo treatments with MSO exceeded 90 percent control at the end of the second year. While Derigo may not be a feasible tool in forestry due to conifer tolerance issues, it is available as a non-crop herbicide for roadside or industrial use and could be a valuable tool controlling broom.

Conifer tolerance was poor with Derigo for both ponderosa pine and Douglas-fir (Table 6). Severe bud and needle damage as well as growth reduction occurred. Douglas-fir survival was so poor in the second season, measurement variables could not be analyzed. The non-treated controls had almost 100 percent mortality and no treatments with Derigo were significantly different from the controls. Bud damage was also very severe in the non-treated controls due to the mortality and again the Derigo treatments were not significantly different. Within the Derigo treatments the 3 ounce rate in combination with 8 ounces of Transline had the least damage and best survival but it was still poor.

Survival was better in ponderosa pine but not by much. Poor survival confounded some of the analyses. Survival did not significantly differ among treatments. Survival was poor overall but was best again in the combinations with Transline although not significantly. Most treatments still had better survival than the non-treated controls due to less competition. The 3 ounce per acre Derigo treatment with 8 ounces of Transline has significantly less bud damage than the 3 ounce Derigo treatment with 1 percent MSO, but no other treatments were significantly different from each other or the non-treated control. Bud damage was severe across all treatments.

Stem volume for ponderosa pine was not significantly affected by treatment. Even though survival in the non-treated control was poor and stem volume was not significantly affected, the volume in the non-treated controls averaged 2 to 5 times greater than any of the Derigo treatments.

Overall, surfactant effects with Pindar GT were marginal in the first or second year. MSO may be slightly more effective than other products tested here but all were very close. This site demonstrated the weakness of Pindar GT on perennials and its effectiveness on annuals such as rat tail fescue.

Derigo does not appear to be an appropriate tool in forestry from this or other studies due to significant conifer injury. It does have a fit for forestry roadside applications or industrial use and is labeled for those uses. Scotch broom control on roadsides would have a major fit.

Oak Run Site

By the end of the second growing season on the Oak Run site, it had become totally dominated by the perennial grass, squirrel tail. Neither percent bare-ground or percent control of squirrel tail were significantly affected by treatment (Table 7). Neither Pindar GT or Derigo were effective treatments for squirrel tail.

The combination of conifer tolerance issues with Derigo and competition from squirrel tail led to almost complete mortality of the Douglas-fir and very poor survival for ponderosa pine on this site. Neither species had great enough survival to evaluate growth data. Douglas-fir survival ranged from 0 to 6 percent and ponderosa pine ranged from 10 to 25 percent. Survival and bud damage were not significantly affected by treatment. Bud damage was severe for all Derigo treatments and the non-treated controls.

This site drives home the point that land managers must know what type of vegetation will be expected on a site. Neither Pindar GT or Derigo are effective on squirrel tail. Therefore, treatments released squirrel tail and caused severe mortality. While we know Pindar GT normally has great conifer tolerance, it does not appear that Derigo does. Ponderosa pine that did survive had significant bud damage and growth loss.

The 2017 measurements/analysis are the final work on this proposal. The complete report and all supporting data are available at the Co-op office in Redding.

Treatment	% Bare Ground	% Cov Scotch Broom	% Cont Scotch Broom	% Cov Spanish Clover	% Cont Spanish Clover	% Cov RT Fescue	% Cont RT Fescue
3 pt Pind GT	15.0 (7.6) abc	19.3 (15.3) a	0.0 (0.0) a	63.3 (21.9) abc	16.7 (16.7) f	13.3 (13.3) abc	70.0 (30.0) ab
3 pt Pind GT + 1% MSO	31.7 (19.2) abc	2.3 (1.5) a	33.3 (33.3) a	35.0 (23.6) bcd	63.3 (23.3) abcd	20.0 (15.3) abc	60.0 (30.6) abc
3 pt Pind GT + 3% MSO	38.3 (15.9) abc	14.3 (8.1) a	3.3 (3.3) a	27.3 (13.9) abcd	61.7 (18.8) abcd	2.3 (1.5) abc	50.0 (28.9) abc
3 pt Pind GT + 0.1% Sylgard	18.3 (10.9) abc	5.0 (2.5) a	0.0 (0.0) a	33.3 (28.3) bcd	35.0 (15.0) bcde	6.0 (4.6) abc	80.0 (15.3) a
3 pt Pind GT + 0.25% R-11	15.0 (7.6) abc	4.3 (3.0) a	33.3 (33.3) a	39.0 (26.4) abcd	40.0 (20.8) cdef	6.0 (4.5) abc	73.3 (12.0) a
3 pt Pind GT + 3 oz Derigo + 1% MSO	66.6 (4.4) a	2.0 (1.0) a	63.3 (18.6) a	16.6 (3.3) bcd	70.0 (0.0) abc	3.3 (1.6) abc	90.0 (5.8) a
3 pt Pind GT + 8 oz Transline + 1% MSO	78.3 (9.3) a	5.7 (2.3) a	10.0 (10.0) a	1.0 (0.6) e	96.7 (1.7) a	3.3 (3.3) bc	76.7 (23.3) a
3 oz Derigo	6.7 (4.4) bc	5.0 (2.9) a	33.3 (33.3) a	71.6 (18.6) ab	13.3 (8.3) ef	3.3 (1.6) abc	76.7 (14.5) a
3 oz Derigo + 1% MSO	33.3 (15.9) abc	1.7 (1.7) a	66.7 (33.3) a	36.7 (14.5) abcd	53.3 (6.7) abcd	23.3 (18.3) abc	43.3 (21.9) abc
4.5 oz Derigo + 1% MSO	35.0 (17.6) abc	2.0 (0.0) a	51.7 (26.8) a	63.3 (16.9) ab	26.7 (21.9) def	1.7 (1.7) c	93.3 (6.7) a
6 oz Derigo + 1% MSO	76.7 (13.6) a	0.7 (0.3) a	50.0 (28.9) a	21.7 (14.8) cd	76.7 (14.5) abc	0.7 (0.7) c	96.7 (3.3) a
6 oz Derigo + 8 oz Transline + 1% MSO	86.7 (6.0) a	0.7 (0.7) a	66.7 (33.3) a	9.0 (3.8) de	88.3 (4.4) ab	0.7 (0.7) c	98.3 (1.7) a
3 oz Derigo + 8 oz Transline + 1% MSO	93.3 (1.7) a	1.0 (1.0) a	66.7 (33.3) a	1.7 (0.3) e	95.0 (0.0) a	1.7 (1.7) c	95.0 (5.0) a
8 oz Transline + 1% MSO	53.3 (20.5) ab	7.3 (3.9) a	0.0 (0.0) a	0.0 (0.0) e	100.0 (0.0) a	26.7 (12.0) ab	13.3 (13.3) bc
Control	3.3 (1.7) c	9.0 (5.6) a	0.0 (0.0) a	81.7 (6.0) a	0.0 (0.0) f	33.3 (14.8) a	0.0 (0.0) c

Table 1. Montgomery Creek Pindar GT/Derigo vegetation assessments. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level.

Treatment	PP Surv	PP % Br Out	PP Bud Dam	PP Needle Dam	DF Surv	DF % Br Out	DF Bud Dam	DF Needle Dam
3 pt Pind GT + 3 oz Derigo + 1% MSO	93.3 (6.7) a	13.3 (8.8) a	5.0 (1.1) a	2.7 (0.9) a	86.7 (6.7) a	18.3 (4.4) a	7.3 (0.3) ab	7.3 (0.3) a
3 oz Derigo	93.3 (3.3) a	21.7 (7.3) a	4.7 (1.7) a	4.0 (2.0) a	86.7 (13.3) a	25.0 (12.6) a	5.7 (1.7) b	7.0 (1.2) a
3 oz Derigo + 1% MSO	100.0 (0.0) a	8.3 (1.7) a	5.3 (0.3) a	3.3 (0.9) a	90.0 (5.8) a	21.7 (6.7) a	7.0 (0.6) ab	7.3 (0.3) a
4.5 oz Derigo + 1% MSO	86.7 (13.3) a	20.0 (15.0) a	6.3 (0.9) a	4.3 (2.3) a	83.3 (8.8) a	25.0 (10.4) a	7.7 (0.3) a	8.0 (0.6) a
6 oz Derigo + 1% MSO	96.7 (3.3) a	13.3 (3.3) a	6.0 (0.6) a	3.7 (0.7) a	93.3 (6.7) a	16.7 (9.3) a	7.3 (0.3) ab	7.3 (0.3) a
6 oz Derigo + 8 oz Transline + 1% MSO	93.3 (3.3) a	13.3 (3.3) a	6.0 (0.6) a	3.3 (1.3) a	83.3 (8.8) a	26.7 (7.3) a	7.7 (0.3) a	7.3 (0.3) a
3 oz Derigo + 8 oz Transline + 1% MSO	100.0 (0.0) a	8.3 (1.6) a	5.0 (0.6) a	4.7 (1.2) a	96.7 (3.3) a	11.7 (4.4) a	7.0 (0.0) ab	7.0 (0.0) a
Control	93.3 (6.7) a	13.3 (8.8) a	0.7 (0.3) b	1.7 (0.9) a	100.0 (0.0) a	3.3 (1.7) a	0.0 (0.0) c	1.7 (0.9) b

Table 2. Montgomery Creek Pindar GT/Derigo conifer tolerance data. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level.

Treatment	% Bare Ground	% Cov Squirrel Tail	% Cont Squirrel Tail	% Cov Ann. Grass	% Cont Ann. Grass	% Cov Rush Skeleton Weed	% Cont Rush Skeleton Weed
3 pt Pind GT	23.3 (13.3) abc	60.0 (15.3) a	6.7 (6.7) bc	1.7 (1.7) bc	93.3 (6.7) a	2.3 (1.5) bc	50.0 (28.9) ab
3 pt Pind GT + 1% MSO	40.0 (10.0) ab	51.7 (15.9) a	3.3 (3.3) bc	7.3 (6.4) ab	80.0 (15.3) ab	0.7 (0.7) c	86.7 (13.3) a
3 pt Pind GT + 3% MSO	46.7 (14.5) ab	41.7 (8.3) a	20.0 (15.3) abc	1.7 (1.7) bc	88.3 (11.7) a	1.0 (0.6) c	88.3 (9.3) a
3 pt Pind GT + 0.1% Sylgard	40.0 (0.0) ab	46.7 (8.8) a	21.7 (21.7) abc	0.0 (0.0) c	100.0 (0.0) a	0.3 (0.3) c	90.0 (10.0) a
3 pt Pind GT + 0.25% R-11	56.7 (8.8) a	31.7 (10.1) ab	0.0 (0.0) c	1.7 (1.7) bc	96.7 (3.3) a	1.0 (0.0) c	93.3 (6.7) a
3 pt Pind GT + 3 oz Derigo + 1% MSO	68.3 (6.0) a	31.7(6.0) ab	46.7 (6.7) abc	0.0 (0.0) c	100.0 (0.0) a	0.0 (0.0) c	100.0 (0.0) a
3 pt Pind GT + 8 oz Transline + 1% MSO	40.0 (18.0) abc	46.7 (21.9) ab	36.7 (18.6) abc	13.3 (8.8) a	58.3 (22.0) abc	0.0 (0.0) c	100.0 (0.0) a
3 oz Derigo	23.3 (3.3) abc	46.7 (14.5) a	10.0 (10.0) bc	10.0 (5.0) a	33.3 (24.0) c	11.0 (4.9) a	16.7 (16.7) bc
3 oz Derigo + 1% MSO	55.0 (13.2) a	33.3 (8.8) ab	53.3 (6.7) ab	0.7 (0.7) bc	96.7 (3.3) a	6.0 (4.6) ab	33.3 (33.3) bc
4.5 oz Derigo + 1% MSO	35.0 (17.6) abc	36.7 (14.5) ab	36.7 (6.7) abc	0.0 (0.0) c	100.0 (0.0) a	3.7 (1.3) bc	26.7 (26.7) bc
6 oz Derigo + 1% MSO	65.0 (7.6) a	8.3 (1.7) b	81.7 (6.0) a	0.0 (0.0) c	100.0 (0.0) a	1.3 (0.7) c	33.3 (33.3) bc
6 oz Derigo + 8 oz Transline + 1% MSO	53.3 (16.9) ab	38.3 (22.1) ab	43.3 (26.0) abc	0.0 (0.0) c	100.0 (0.0) a	0.0 (0.0) c	100.0 (0.0) a
3 oz Derigo + 8 oz Transline + 1% MSO	43.3 (6.7) ab	43.3 (12.0) a	26.7 (12.0) abc	1.7 (1.7) bc	93.3 (6.7) a	0.0 (0.0) c	100.0 (0.0) a
8 oz Transline + 1% MSO	11.7 (4.4) bc	70.0 (15.3) a	0.0 (0.0) c	4.0 (1.0) ab	53.3 (27.3) bc	0.0 (0.0) c	100.0 (0.0) a
Control	6.7 (1.7) c	35.0 (7.6) ab	16.7 (16.7) abc	13.3 (3.3) a	0.0 (0.0) d	10.3 (5.5) a	0.0 (0.0) c

Table 3. Oak Run Pindar GT/Derigo vegetation assessments. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the p <= 0.05 level.

Treatment	PP Surv	PP % Br Out	PP Bud Dam	PP Needle Dam	DF Surv	DF % Br Out	DF Bud Dam	DF Needle Dam
3 pt Pind GT + 3 oz Derigo + 1% MSO	80.0 (15.3) a	30.0 (15.3) a	7.7 (0.7) a	6.7 (1.2) a	86.7 (3.3) a	21.7 (1.7) a	7.3 (0.3) a	7.3 (0.3) a
3 oz Derigo	70.0 (20.0) a	41.7 (16.9) a	8.0 (0.6) a	7.7 (0.6) a	83.3 (12.0) a	40.0 (10.0) a	7.7 (0.3) a	7.7 (0.3) a
3 oz Derigo + 1% MSO	83.3 (3.3) a	25.0 (5.0) a	7.0 (1.0) a	6.7 (0.7) a	63.3 (8.8) a	48.3 (10.1) a	8.0 (0.6) a	8.0 (0.6) a
4.5 oz Derigo + 1% MSO	63.3 (6.7) a	46.7 (6.7) a	8.0 (0.0) a	8.3 (0.3) a	60.0 (5.8) a	53.3 (3.3) a	8.3 (0.3) a	9.0 (0.0) a
6 oz Derigo + 1% MSO	83.3 (3.3) a	33.3 (4.4) a	8.3 (0.3) a	7.0 (0.6) a	83.3 (12.0) a	28.3 (8.3) a	8.0 (0.6) a	7.6 (0.3) a
6 oz Derigo + 8 oz Transline + 1% MSO	60.0 (25.2) a	50.0 (22.9) a	8.0 (0.6) a	7.0 (1.5) a	60.0 (30.6) a	46.7 (27.3) a	8.3 (0.9) a	8.0 (1.0) a
3 oz Derigo + 8 oz Transline + 1% MSO	90.0 (10.0) a	25.0 (7.6) a	7.3 (0.7) a	7.3 (0.3) a	76.6 (6.7) a	30.0 (7.6) a	7.7 (0.7) a	8.0 (0.6) a
Control	86.7 (3.3) a	25.0 (2.9) a	1.0 (0.0) b	3.3 (0.7) b	73.3 (3.33) a	33.3 (4.4) a	1.0 (0.0) b	6.3 (1.7) a

Table 4. Oak Run Pindar GT/Derigo conifer tolerance data. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the p <= 0.05 level.

Treatment	% Bare Ground	% Control Rat Tail Fescue	% Control Needle Grass	% Control Spanish Clover	% Control Scotch Broom
3 pt Pind GT	5.0 (2.9)	63.3 (31.8) ab	16.7 (16.7)	36.7 (18.6)	0.0 (0.0) b
3 pt Pind GT + 1% MSO	13.3 (8.3)	90.0 (10.0) a	0.0 (0.0)	36.7 (18.5)	26.7 (26.7) ab
3 pt Pind GT + 3% MSO	10.0 (10.0)	76.7 (14.5) ab	0.0 (0.0)	50.0 (28.9)	0.0 (0.0) b
3 pt Pind GT + 0.1% Sylgard	11.7 (9.3)	60.0 (30.6) ab	0.0 (0.0)	58.3 (30.1)	0.0 (0.0) b
3 pt Pind GT + 0.25% R-11	8.3 (4.4)	73.3 (26.7) ab	26.7 (26.7)	55.0 (27.5)	33.3 (33.3) ab
3 pt Pind GT + 3 oz Derigo + 1% MSO	28.3 (13.0)	90.0 (5.8) a	23.3 (23.3)	60.0 (5.8)	50.0 (26.5) ab
3 pt Pind GT + 8 oz Transline + 1% MSO	20.0 (11.6)	66.7 (33.3) ab	6.7 (6.7)	65.0 (7.6)	0.0 (0.0) b
3 oz Derigo	8.3 (1.7)	85.0 (10.4) ab	28.3 (28.3)	16.7 (16.7)	31.7 (18.8) ab
3 oz Derigo + 1% MSO	6.7 (3.3)	60.0 (5.8) ab	36.7 (18.6)	6.7 (6.7)	91.7 (4.4) a
4.5 oz Derigo + 1% MSO	13.3 (8.3)	86.7 (13.3) a	80.0 (20.0)	16.7 (16.7)	93.3 (4.4) a
6 oz Derigo + 1% MSO	21.7 (14.2)	86.7 (8.8) a	70.0 (15.3)	3.3 (3.3)	96.7 (3.3) a
6 oz Derigo + 8 oz Transline + 1% MSO	21.7 (14.2)	100.0 (0.0) a	61.7 (31.1)	6.7 (3.3)	95.0 (5.0) a
3 oz Derigo + 8 oz Transline + 1% MSO	18.3 (6.0)	88.3 (6.0) a	50.0 (28.9)	28.3 (21.3)	93.3 (6.7) a
8 oz Transline + 1% MSO	20.0 (15.3)	30.0 (30.0) ab	0.0 (0.0)	21.7 (21.7)	0.0 (0.0) b
Control	0.0 (0.0)	0.0 (0.0) b	0.0 (0.0)	0.0 (0.0)	0.0 (0.0) b

Table 5. Montgomery Creek Pindar GT/Derigo vegetation assessments. All rates are per acre. Standard errors are in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level.

Treatment	PP % Survival	PP Bud Dam	PP Stem Volume cm^3	DF Surv	DF Bud Dam
3 pt Pind GT + 3 oz Derigo + 1% MSO	40.0 (15.3)	6.7 (1.2) ab	6.5 (3.7)	3.3 (3.3) ab	9.7 (0.3) a
3 oz Derigo	6.7 (6.7)	9.7 (0.3) a	6.1 (0.0)	0.0 (0.0) b	10.0 (0.0) a
3 oz Derigo + 1% MSO	46.7 (18.6)	6.0 (2.1) ab	2.6 (1.0)	6.7 (3.3) ab	9.3 (0.3) ab
4.5 oz Derigo + 1% MSO	36.7 (26.7)	6.3 (2.7) ab	9.2 (3.4)	16.7 (16.7) ab	8.0 (1.2) ab
6 oz Derigo + 1% MSO	46.7 (26.0)	6.3 (2.3) ab	3.2 (0.3)	23.3 (12.0) ab	9.0 (0.6) ab
6 oz Derigo + 8 oz Transline + 1% MSO	70.0 (11.6)	4.7 (1.5) ab	5.4 (0.8)	30.0 (10.0) ab	8.0 (0.6) ab
3 oz Derigo + 8 oz Transline + 1% MSO	86.7 (8.8)	3.3 (1.2) b	7.6 (1.4)	46.7 (13.3) a	6.3 (1.3) b
Control	10.0 (0.0)	9.0 (0.0) ab	25.4 (13.9)	3.3 (3.3) ab	9.7 (0.3) a

Table 6. Montgomery Creek Pindar GT/Derigo conifer tolerance data. All rates are per acre. Standard errors in parenthesis. Values with the same letter are not significantly different at the p <= 0.05 level.

Treatment	% Bare Ground	% Control Squirrel Tail	PP % Survival	PP Bud Damage
3 pt Pind GT	11.7 (6.0)	0.0 (0.0)		
3 pt Pind GT + 1% MSO	8.3 (1.7)	0.0 (0.0)		
3 pt Pind GT + 3% MSO	16.7 (6.7)	40.0 (20.8)		
3 pt Pind GT + 0.1% Sylgard	10.0 (0.0)	0.0 (0.0)		
3 pt Pind GT + 0.25% R-11	15.0 (2.9)	0.0 (0.0)		
3 pt Pind GT + 3 oz Derigo + 1% MSO	16.7 (1.7)	23.3 (14.5)	26.7 (17.6)	8.0 (1.5)
3 pt Pind GT + 8 oz Transline + 1% MSO	16.7 (6.7)	20.0 (20.0)		
3 oz Derigo	3.3 (3.3)	13.3 (13.3)	13.3 (8.8)	9.3 (0.3)
3 oz Derigo + 1% MSO	18.3 (10.1)	16.7 (16.7)	23.3 (6.7)	8.3 (0.7)
4.5 oz Derigo + 1% MSO	6.6 (4.4)	20.0 (20.0)	23.3 (12.0)	8.3 (1.2)
6 oz Derigo + 1% MSO	11.7 (4.4)	40.0 (20.8)	23.3 (8.8)	8.3 (0.7)
6 oz Derigo + 8 oz Transline + 1% MSO	11.7 (4.4)	15.0 (10.4)	10.0 (0.0)	9.0 (0.0)
3 oz Derigo + 8 oz Transline + 1% MSO	10.0 (5.8)	0.0 (0.0)	20.0 (11.6)	9.0 (0.6)
8 oz Transline + 1% MSO	6.7 (1.7)	0.0 (0.0)		
Control	1.7 (1.7)	10.0 (10.0)	20.0 (11.6)	8.7 (0.9)

Table 7. Oak Run Pindar GT/Derigo vegetation and conifer assessments. All rates are per acre. Standard errors are in parenthesis. Values with the same letter are not significantly different at the p <= 0.05 level.

Figure 1. Control of Spanish Clover with 6 oz of Derigo five months after treatment.

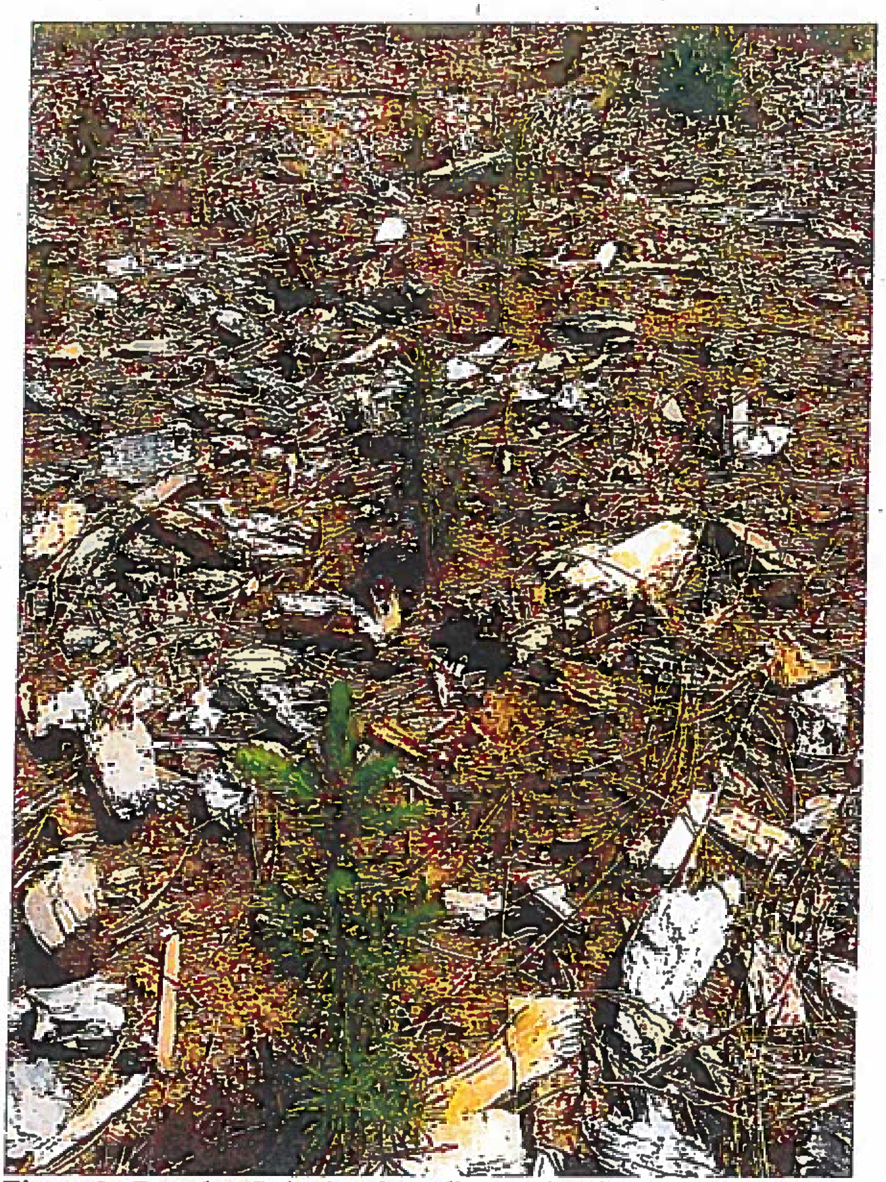

Figure 2. Douglas-fir bud and needle stunting from Derigo applications.

Sierra Cascade Intensive Forest Management Research Cooperative Proposal 16-03
Penoxsulam With and Without Surfactant

Principal Investigator: Ed Fredrickson

Title: Weed Control with Directed Spray of Penoxsulam with and without Surfactant at Two Timings

Year Funded: 2016

Executive Summary:
For the past several years, the Sierra Cascade Intensive Forest Management Research Cooperative has been evaluating Pindar GT (oxyfluorfen + penoxsulam) as a pre or post plant herbaceous site preparation treatment. Dow AgroScience recently changed the name of Pindar GT to Cleantraxx. Over the course of many studies, it was determined that penoxsulam had the ability to inhibit seed germination of some woody brush species, mainly Ceanothus. Penoxsulam is an ALS inhibitor much like imazapyr and sulfometuron. Immazapyr has excellent activity on woody brush whereas sulfometuron has none. The amount of activity penoxsulam alone has on brush species is unknown. Previous testing has shown penoxsulam to be extremely tolerant to conifers and is used at unprecedented low use rates. It was also observed in several operational applications, once the product had been registered, that Cleantraxx had at least some foliar activity on herbaceous and woody plants. Due to superior control of woody brush seedlings with Cleantraxx compared to GoalTender (oxyfluorfen only), a mid-summer broadcast foliar trial on bracken fern was conducted by Dow AgroSciences with Cleantraxx. Early results showed excellent foliar knock down of bracken fern compared to glyphosate, but also significant foliar activity on snow berry. Since oxyfluorfen has no activity on woody brush, the interest in penoxsulam rapidly grew.

Broadcast foliar applications of a herbicide usually provide somewhat lesser control than directed applications. To date, penoxsulam has not been formally evaluated for its ability to control woody brush or difficult to control herbaceous plants with directed applications. There would be several benefits if directed penoxsulam applications were feasible. The treatments would provide a very low use rate application, reducing the amounts of overall herbicides used. It would also provide the landowner with a product that had very high margins of conifer safety, reducing the risk of accidental damage and the time required to protect seedlings, hence reducing application costs. In the long-term, it is Dow AgroSciences goal to replace the oxyfluorfen in Cleantraxx with a new environmentally sound and conifer safe soil active herbicide.

It is the objective of this trial to test applications of penoxsulam, formulated as Sapphire, on a variety of woody brush species on several sites.

The Study: There will be three sites for this study. Each site should contain two vegetative species of interest to evaluate. Brush should not be greater than three feet tall. Good access and flat to moderate slopes are beneficial. The sites should be located on the east or west side of the Cascade Range but no further south than Lake Almanor, or further east than Bieber, CA.

The experimental design is a completely randomized block with ten replications per treatment. Each brush clump is considered one replication. Each clump will be tagged and numbered prior to application. Each timing will be installed as a separate trial on each site. The timings utilized for this trial will be June and August.

Clumps will be sprayed with a CO2 powered backpack sprayer equipped with a wand and fitted with an 8003 tapered flat fan nozzle. Target volume per acre will be 25 gallons. Clumps will be sprayed to obtain complete coverage, but not to runoff.

Evaluations will be completed at the end of the first and second growing season and will consist of ocular estimates of percent control by species.

All layout, application, evaluation, statistical interpretation, write up, and annual reporting will be completed by Thunder Road Resources. All statistical evaluation will completed by Liz Cole of Oregon State University. Statistical analysis will consist of analysis of variance and Tukeys tests with adjusted probabilities for multiple comparisons.

Treatments: Will include three rates of Sapphire at 0.25, 0.5, and 0.75 percent as a volume per volume solution with no adjuvant and with one percent methylated seed oil. All treatments will be compared to an operational standard which is two percent Chopper plus two percent Accord XRT II with five percent methylated seed oil and a non-treated control.

2016: Three sites were chosen for this trial with two brush species per site. The first site is located on property owned and managed by Fruit Growers Supply Company near Burney, California. The site is a fuel break that had been thinned to a wide spacing approximately ten years prior to this study. The site is approximately 3,500 feet elevation on a slight south slope with five to ten percent slope. Deerbrush and Greenleaf manzanita are the two woody brush species on the site. The second site is located on property owned and managed by Roseburg Resources Company near Montgomery Creek, California. The site is approximately 5,000 feet in elevation in a timber stand that was chip thinned in the late 1900's. Golden chinquapin and snowberry are the two species on this site. The final site is also located on property owned and managed by Fruit Growers Supply Company. It is located in the 2014 Eiler Fire near Burney, California. The site was logged and chipped after the fire with no further site preparation. The site is approximately 5,000 feet elevation on a slight south aspect and a ten to fifteen percent slope. Squaw carpet and snowbrush are the two woody brush species on this site.

The Fruit Growers manzanita and deerbrush site was sprayed on June 10th and August 24th. The Fruit Growers squaw carpet and snowbrush site was sprayed on June 11th and August 24th. The Roseburg snowberry and chinquapin site was sprayed on June 18th and August 25th.

All sites were evaluated between September 20th and 21st.

Data were analyzed using SAS statistical software. Vegetation and seedling data were analyzed using analysis of variance. Treatments were compared using a Tukey's test with adjusted probabilities. Initial seedling size parameters were used as covariates within the ANOVA's for height, caliper, and volume. Analyses for size was weighted by the number of surviving seedlings in each plot. Least squared means for size included adjustments for the covariates, which resulted in some difference from the raw data means. Analyses utilized PROC MEANS, PROC MIXES, and PROC GLIMMIX in SAS. PROC GLIMMIX was used when variances were unequal, and either the Poisson or gamma distribution was used. June and August treatments were compared using a standard T-test. When statements are made regarding statistically significant differences in this document, the alpha level is $P <= 0.05$.

Timing played a significant role for snowbrush and deerbrush, but had no significant effect for any other brush species. June treatments had better control compared to August treatments for snowbrush and deerbrush, but part of that may be due to the fact that there was only about one month between the August application and the evaluation periods because evaluations had to take place before fall senescence occurred (Tables 1 & 2). Second year evaluations will most likely give a better indication of timing effects.

Snowberry was the most sensitive woody brush species to Sapphire tested in this trial (Figure 1).There was no significant difference between June and August spray timings and rate played no significant role in efficacy. The addition of a methylated seed oil significantly increased percent control for both June and August applications. All treatments with an MSO were significantly different from all treatments without an MSO and the non-treated controls for either timing. The adjuvant effects regarding the snowberry were very apparent. The operational standard had better control than all the Sapphire without an MSO, but was only significantly different from the low rate of Sapphire with an MSO in June. The operational standard was not significantly different from any Sapphire treatments with an MSO in August, although control was slightly better. Treatments without an MSO were not significantly different from the non-treated control.

Sapphire treatments had no significant effect on golden chinquapin at either timing compared to the non-treated control. Surfactant effects were slight and mostly not significant with the exception of the comparison of the low rate of Sapphire without an MSO to both the low and high rate of Sapphire with an MSO which were significantly different in the August timing. The operational standard was significantly different from all the other treatments in August, but not different from any in June.

Sapphire treatments were not significantly different from the non-treated controls for squaw carpet regardless of MSO or timing. The operational standard provided significantly better control than all other treatments in June, but only the non-

MSO treatments and the high rate of Sapphire with an MSO were significantly different from the operational standard in August.

Sapphire treatments had no significant effect on snowbrush in August compared to the non-treated control, but did show some significant differences in June. In June, all treatments provided significantly better control than the non-treated controls with the exception of the two lowest rates of Sapphire without an MSO. The highest rate of Sapphire with an MSO provided significantly better control than all other Sapphire treatments and the non-treated control, but significantly less control than the operational standard.

Similar to snowbrush, Sapphire treatments had no significant effect on deerbrush in August and were not significantly different from the non-treated control with the exception of the high rate of Sapphire with an MSO but this appears to be an artifact. The operational standard provided significantly better control than all Sapphire treatments and the non-treated control in August with the exception of the one Sapphire treatment that appears to be an artifact. June treatments were significantly affected by treatment. Sapphire had no effect on control, but the addition of MSO did. All Sapphire treatments with MSO had significantly better deerbrush control than treatments without MSO with the exception of the lowest rate of Sapphire with no MSO. Non MSO Sapphire treatments were not significantly different from the non-treated controls, but all of the treatments with an MSO were. The operational standard provided significantly better control than all Sapphire treatments and the non-treated control.

Greenleaf manzanita was not significantly affected by treatment at all in August, even compared to the operational standard. No Sapphire treatment was significantly different from the non-treated controls in June. The operational standard was significantly different from all other treatments in June.

While some decent effects on woody brush were observed, it does not appear that Sapphire alone is an adequate control treatment, at last based on the first year data. The trials did provide some important information in regards to Cleantraxx applications in that it definitively showed the importance of adding an MSO to maximize control on established vegetation.

2017: Brush control with penoxsulam at the end of the second growing season was poor with all species evaluated (Table 3). The only species that penoxsulam had any effect on in year two was snowberry. Snowberry control did not significantly differ among penoxsulam treatments. Snowberry control increased with the addition of MSO at both timings, but not significantly. August treatments were better than June treatments but only the high rate of penoxsulam with no MSO was significantly better in August. In June only the 0.5 and 0.75 percent treatments with MSO provided significantly more control than the non-treated controls and in August, only the 0.75 percent treatment with MSO did. The Chopper plus Accord XRT II operational standard has significantly better control than all treatments in June with the exception of the highest two rates of penoxsulam with MSO. In August, the Chopper plus Accord XRT II treatment only provided significantly better control than the two lowest rates of penoxsulam with no MSO and the non-treated control.

Control of golden chinquapin, Greenleaf manzanita, snowbrush, deerbrush, and squaw carpet with penoxsulam treatments did not significantly differ from the non-treated controls within either timing and the addition of MSO had no effect. Timing also did not have a significant effect on control with penoxsulam. For these species, the Chopper plus Accord XRT II treatments has significantly greater control than all treatments and did not significantly differ by timing.

Overall, it appears that penoxsulam does have some foliar activity on deciduous species and it is somewhat enhanced with the addition of MSO. The overall efficacy is weak but the data do suggest that applications with Pindar GT (Cleantraxx) may benefit from the addition of MSO.

The 2017 measurements/analysis are the final work on this proposal. The complete report and all supporting data are available at the Co-op office in Redding.

Treatment	% Cont Snow Berry	% Cont G. Chinq	% Cont Squaw Carpet	% Cont Snowbrush	% Cont Deerbrush	% Cont GL Manz
0.25% Sapphire	17.0 (3.2) c	19.0 (9.1) a	2.0 (1.0) c	8.5 (0.7) cd	24.5 (8.8) bc	9.0 (1.6) b
0.5% Sapphire	15.0 (1.7) c	10.5 (1.4) a	7.5 (3.3) bc	12.0 (1.3) cd	14.0 (1.9) c	13.0 (1.9) b
0.75% Sapphire	20.5 (4.9) c	20.0 (9.1) a	6.0 (2.1) bc	17.0 (3.7) c	13.5 (2.0) c	10.0 (1.5) b
0.25% Sapphire + 1% MSO	51.5 (9.3) b	13.5 (1.5) a	8.0 (1.5) bc	17.0 (1.3) c	36.5 (5.6) b	12.0 (2.1) b
0.5% Sapphire + 1% MSO	57.0 (8.1) ab	17.5 (8.7) a	7.0 (1.9) bc	18.5 (1.5) c	34.0 (5.5) b	10.5 (1.4) b
0.75% Sapphire + 1% MSO	67.0 (6.0) ab	10.5 (1.7) a	11.0 (1.6) b	44.0 (7.0) b	33.0 (4.8) b	12.5 (1.3) b
2% Chop +2% Acc XRT II + 5% MSO	96.0 (3.1) a	52.5 (14.9) a	55.5 (8.8) a	98.3 (0.74) a	95.5 (3.0) a	85.5 (6.8) a
Control	19.5 (5.1) c	26.5 (12.3) a	4.0 (1.0) bc	6.5 (1.1) d	13.0 (1.7) c	12.0 (1.3) b

Table 1. June efficacy data for the directed penoxsulam (Sapphire) trial. All rates expressed as percent solution v/v. Standard errors in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level.

Treatment	% Cont Snow Berry	% Cont G. Chinq	% Cont Squaw Carpet	% Cont Snowbrush	% Cont Deerbrush	% Cont GL Manz
0.25% Sapphire	9.0 (2.2) b	6.5 (1.1) c	5.0 (1.7) bc	6.5 (1.1) b	13.5 (1.3) b	11.5 (1.5) a
0.5% Sapphire	8.0 (2.3) b	8.5 (1.3) bc	1.5 (0.8) b	6.5 (1.3) b	15.0 (1.8) b	13.0 (2.4) a
0.75% Sapphire	6.5 (1.8) b	8.5 (1.5) bc	5.0 (1.8) bc	7.5 (1.1) b	15.0 (1.5) b	11.5 (1.5) a
0.25% Sapphire + 1% MSO	63.5 (7.3) a	14.0 (1.8) b	5.5 (1.2) abc	6.5 (0.8) b	16.5 (1.3) b	16.0 (3.1) a
0.5% Sapphire + 1% MSO	63.0 (5.7) a	13.5 (2.8) bc	8.5 (2.2) ab	9.5 (1.9) b	18.5 (1.7) b	13.0 (1.3) a
0.75% Sapphire + 1% MSO	72.0 (4.5) a	16.0 (1.6) b	4.5 (1.2) bc	8.0 (1.1) b	17.5 (1.3) a	11.0 (1.3) a
2% Chop +2% Acc XRT II + 5% MSO	75.5 (2.4) a	39.0 (3.8) a	18.0 (2.8) a	34.0 (4.2) a	72.5 (6.0) a	20.5 (5.4) a
Control	8.5 (1.3) b	9.5 (2.0) bc	7.5 (2.7) abc	12.0 (6.5) b	16.0 (2.3) b	15.0 (2.7) a

Table 2. August efficacy data for the directed penoxsulam (Sapphire) trial. All rates expressed as percent solution v/v. Standard errors in parenthesis. Values with the same letter are not significantly different at the p <= 0.05 level.

Treatment	% Control Snow Berry June	% Control Snow Berry August	% Control Squaw Carpet June	% Control Squaw Carpet August
0.25% Sapphire	34.0 (13.7) bc	36.5 (12.9) bc	1.5 (1.1) b	4.0 (1.6) b
0.5% Sapphire	10.0 (5.2) bc	21.0 (4.6) bc	7.0 (2.5) b	7.0 (2.5) b
0.75% Sapphire	9.5 (6.9) bc	53.5 (14.5) abc	7.0 (2.1) b	5.5 (1.7) b
0.25% Sapphire + 1% MSO	25.0 (11.9) bc	43.0 (10.0) abc	6.0 (1.9) b	7.5 (2.8) b
0.5% Sapphire + 1% MSO	44.0 (12.6) ab	63.0 (11.5) abc	4.5 (2.4) b	5.5 (2.3) b
0.75% Sapphire + 1% MSO	56.5 (13.8) ab	67.0 (8.5) ab	6.5 (4.0) b	8.5 (4.0) b
2% Chop +2% Acc XRT II + 5% MSO	100.0 (0.0) a	100.0 (0.0) a	39.0 (10.4) a	61.5 (7.6) a
Control	5.5 (3.4) c	20.0 (9.6) c	4.5 (1.4) b	3.0 (1.3) b

Table 3. June and August efficacy data for the directed penoxsulam (Sapphire) trial. All rates expressed as percent solution v/v. Standard errors in parenthesis. Values with the same letter are not significantly different at the $p <= 0.05$ level.

Figure 1. Snowberry control with 0.75% Sapphire plus 1% MSO.

Sierra Cascade Intensive Forest Management Research Cooperative Proposal 17-03
Pre-Plant Telar XP Treatments

Principal Investigator: Ed Fredrickson

Title: Pre-Plant Treatments with Esplanade F, Telar XP, Matrix SG, Derigo and Cleantraxx to Evaluate Conifer Tolerance and Efficacy

Year Funded: 2017

Executive Summary:
For the past several years, the Sierra Cascade Intensive Forest Management Research Cooperative has been looking at a variety of new site preparation products. Unfortunately, the climate has not cooperated and the majority of those trials were conducted under drought conditions. The products tested also showed a significant lack of post-emergent knock down of existing vegetation. Several trials were installed in 2016 to test the new product Derigo to aid with post-emergent applications. All tests were conducted over the top of existing conifers and tolerance to post-plant applications was poor, although post-emergent knock down of herbaceous vegetation was excellent. Pre-plant applications to this point have remained untested.

Esplanade F was extensively tested during the drought and performed sporadically at best on forestry sites. However, with the return of normal weather patterns, Esplanade F has shown a remarkable ability to control herbaceous vegetation into the second growing season following treatment. Excellent conifer tolerance, low use rates and long residual activity potentially make it a very useful tool in forestry. Since it appears this year will also continue under normal precipitation conditions, this trial would re-evaluate Esplanade F in combination with various new products for forestry to aid in post-emergent knock down of existing herbaceous vegetation. The trial would also include two treatments with Cleantraxx with glyphosate for comparison.

Two other products from Bayer Crop Science show excellent potential to aid with post-emergent knock down. Telar XP (chlorsulfuron) is a well-known non-crop product that has historically shown great post-emergent activity on herbaceous broadleaves at very low rates (1 to 2 ounces). Conifer tolerance has not been tested. The second product is Matrix SG (rimsulfuron) which also has excellent post-emergent knock down of herbaceous broadleaves and annual grasses. Matrix SG has been previously tested by the Co-op and others but only in pre-emergent, pre-plant applications with glyphosate in the tank mix so any post-emergent knock down from Matrix SG was masked by the glyphosate. Conifer tolerance was excellent, and this product should be evaluated to aid with post-emergent applications.

In 2017, a series of trials was proposed for the Sierra Cascade Intensive Forest Management Research Cooperative and the Certified Forest Research Group to evaluate pre-plant application of Derigo in combination with Esplanade F to evaluate conifer tolerance and efficacy. It was also proposed to evaluate several other herbicides that may have potential

in forestry as tank mix partners to aid post-emergent knockdown of established vegetation. Several treatments with Cleantraxx were added to the trial just to evaluate operational treatments in a year where weather patterns returned to normal after several years of severe drought. The Cleantraxx treatments cannot be fairly compared to any of the Esplanade combinations regarding vegetation control as the Cleantraxx treatments have Accord XRT II added for knockdown and the Esplanade F combinations do not. The Cleantraxx treatments are strictly anecdotal.

The objective of this trial is to evaluate the conifer tolerance and efficacy of these product as a pre-plant application. For products that have not been previously tested in forestry and exhibit good conifer tolerance and efficacy, it is the hope that they may be tested in the future as post-plant applications.

The Study: This trial is proposed for two or three sites on the west side of the Sierra or Cascade crest for the Sierra Cascade cooperative. This protocol will also be replicated on several sites through the Certified Forest Research Group (CFRG) as well to expand the scope of the data. The sites chosen should have an abundance of emerged herbaceous vegetation at the time of treatment and have not been previously treated with herbicides. This proposal is for spring application sites.

The trial will be a randomized complete block design with three replications. Plot size will be 10 feet by 25 feet (0.05 acre). Application volume will be at 20 gallons per acre. All plots will be sprayed with a calibrated CO2 powered backpack boom sprayer with one timed pass. All plots will be marked with PVC pipe at each end of centerline. Plots will be sprayed and planted the following day with 10 trees each of two conifer species. Seedlings and planters will be provided by the Co-op member and planting will be supervised by Thunder Road Resources.

Evaluations will consist of initial caliper and height along with stem volume calculations of the conifer seedlings at planting time and at the end of year two. Ocular evaluations of percent bare ground, percent cover and control by species, conifer survival, conifer percent brownout, bud and needle damage ratings will occur at the end of year one and year two.

All statistics will be run by Liz Cole of Oregon State University. Statistics will consist of analysis of variance with Tukey tests with adjusted probabilities for multiple comparisons. Initial seedling size will be evaluated for significance and if appropriate will be analyzed using covariant procedures. All layout, evaluations, data interpretation and annual progress reports will be completed by Thunder Road Resources.

Treatments: Will include two rates of IAF plus RIS; two rates of Esplanade F; two rates of Esplanade F plus Telar XP; one rate of Telar XP; two rates of Derigo; one rate of Esplanade F plus Derigo; two rates of Cleantraxx plus Accord XRT II; one rate of Matrix SG; and a non-treated control.

2017: Two sites were chosen for this trial. The first site is located on property owned and managed by Roseburg Resource Company and is located approximately 10 miles east of Oak Run, California. The site is a clearcut that was logged in 2014 and planted in 2015. The site had received an initial chemical site preparation treatment with no further herbicide work. By 2017, vegetation had completely reoccupied the site. The site is approximately 4000 feet elevation on a slight west aspect with 0 to 5 percent slope.

The second site is located on property owned and managed by W.M. Beaty and Associates. It is located approximately 5 miles east of Whitmore, California. The site is a shaded fuel break that was pre-harvest sprayed in 2015 and masticated in 2016. No further herbicide work was done. The site is approximately 4000 feet elevation on a flat aspect with 0 to 5 percent slope.

The Oak Run site was sprayed on April 3, 2017 and the Whitmore site on April 9th.

The Oak Run site was planted on April 14th with ponderosa pine and white fir. The Whitmore site was planted on May 9th with ponderosa pine and Douglas-fir.

Visual evaluations took place at the end of the first growing season. Vegetation was evaluated for percent bare ground and percent cover and control by weeds. Conifers were visually assessed for survival, percent brownout, bud and needle damage and root number and length. The same evaluations will be repeated at the end of 2018 in addition to the seedlings being remeasured.

Data were analyzed using SAS statistical software. Vegetation and seedling data were analyzed using analysis of variance. Treatments were compared using a Tukey's test with adjusted probabilities. Initial seedling size parameters were used as covariates within the ANOVA's for height, caliper and volume. Analyses for size were weighted by the number of surviving seedlings in each plot. Least squared means for size included adjustments for the covariates, which resulted in some differences from the raw data means. Analyses utilized PROC MEANS, PROC MIXED and PROC GLIMMIX in SAS. PROC GLIMMIX was used when variances were unequal, and either the Poisson or gamma distribution was used. Where statements are made regarding statistically significant differences, the alpha level is $P <= 0.05$.

Whitmore Site: The Whitmore site was primarily dominated by perennial grass. Percent bare ground did not significantly differ by treatment although herbicides tank mixed with Esplanade F did increase bare ground to some degree (Table 1). Esplanade F alone had virtually the same amount of bare ground as the non-treated controls on a perennial dominated site.

Needle grass control was significantly affected by treatment. The addition of Matrix SG to Esplanade F significantly increased control of needle grass over Esplanade F alone. The only other treatments that provided significantly more control than the Esplanade F alone were the Cleantraxx treatments with Accord XRT II, but again this was not a fair comparison due to the addition of the Accord XRT II. Most of the other products added to Esplanade F increased needle grass control somewhat, but not significantly.

Ponderosa pine survival, bud damage and root length were not significantly affected by treatment, but root number was (Table 2). Both Esplanade F combinations with Telar XP and the low rate of Derigo alone had significantly fewer roots than the non-treated controls. Bud damage was also highest with the Esplanade F plus Telar XP combinations, but not significantly.

Douglas-fir survival, bud damage, root number and length were not significantly affected by treatment (Table 3). Root number was again lowest with the Esplanade F plus Telar XP treatments, but not significantly. Root length followed a similar pattern. Cleantraxx treatments had the best conifer tolerance for both ponderosa pine and Douglas-fir but not significantly.

Oak Run Site: The Oak Run site on Roseburg Resources Company lands was a very tough site with a heavily established herbaceous vegetation complex at the time of treatment. It was not expected that Esplanade F alone treatments would knock down established vegetation, the purpose was to evaluate the tank mix partners for their knock down ability.

Only the Cleantraxx treatments with Accord XRT II provided significantly more bare ground than the non-treated controls, and these treatments cannot be compared fairly to any of the Esplanade F or other herbicide treatments (Table 4). The lack of bare ground with Esplanade F, Derigo, Telar XP and Matrix SG alone or in combination was mainly because they did not have the ability to knock down the established perennial grass which was mainly squirrel tail. No herbicide treatments except the Cleantraxx with Accord XRT II provided significantly more squirrel tail control than the non-treated controls.

In regard to the annual grasses, percent control was significantly affected by treatment. All herbicide treatments except the Esplanade F at either rate alone provided significantly more control of rat tail fescue than the non-treated controls, but no herbicide treatments were significantly different from each other. Derigo, Matrix SG and Telar XP all increased control of rat tail fescue alone or in combination with Esplanade F. Derigo and Matrix SG provided the best control of rat tail fescue in combination with Esplanade F.

Due to the heavy competition on this site with most treatments, survival of ponderosa pine was poor and white fir was virtually a total loss. Due to this, only percent survival was analyzed (Table 5). Only the Cleantraxx treatments that had the Accord XRT II reduced competition enough to have good survival. These were the only treatments that had significantly better white fir and ponderosa pine survival than the non-treated controls. White fir survival ranged from 80 to 87 percent and ponderosa pine from 87 to 93 percent with the Cleantraxx treatments whereas white fir ranged from 0 to 20 percent and ponderosa pine from 7 to 47 percent in the remaining treatments.

A significant amount of conifer injury ratings were confounded by the heavy amount of competition induced mortality. Hence, the data were not analyzed. That said, there was bud and needle damage from both the Derigo and Telar XP treatments that is not readily apparent from the data due to the mortality.

Overall, between the two sites tested within this cooperative and the multitude of sites tested by the Certified Forest Research Group, it does not appear that Derigo or Telar XP will be suitable for forestry uses due to poor conifer tolerance. While both products succeeded in controlling certain vegetation and enhancing knock down with Esplanade F, they also contributed to increased bud and needle damage, reduced growth and affected root development. Matrix SG does appear that it may have a fit for forestry applications. In combination with Esplanade F, it increased control of annual and perennial grasses as well as several other broadleaved species. It also appears to have relatively good conifer tolerance on the majority of the sites tested.

Treatment	% Bare Ground	% Control Needle Grass
4.5 oz IAF + RIS + 1% MSO	61.7 (6.0)	81.7 (15.9) a
6 oz IAF + RIS + 1 MSO	58.3 (4.4)	80.0 (3.2) a
5 oz Esplanade F + 1% MSO	25.0 (7.6)	0.0 (0.0) b
7 oz Esplanade F + 1% MSO	25.0 (12.6)	0.0 (0.0) b
5 oz Esplanade F + 1 oz Telar XP + 1% MSO	40.0 (18.0)	13.3 (13.3) ab
7 oz Esplanade F + 1 oz Telar XP + 1% MSO	63.3 (6.7)	43.3 (14.5) ab
1 oz Telar XP + 1% MSO	53.3 (19.7)	43.3 (21.9) ab
3 oz Derigo + 1% MSO	68.3 (6.0)	41.7 (9.3) ab
6 oz Derigo + 1% MSO	60.0 (15.3)	48.3 (13.0) ab
7 oz Esplanade F + 3 oz Derigo + 1% MSO	71.7 (7.3)	66.7 (17.6) ab
3 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	66.7 (3.3)	90.0 (5.8) a
4.5 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	80.0 (5.0)	88.3 (7.3) a
4 oz Matrix SG + 1% MSO	40.0 (15.3)	45.0 (29.3) ab
Non Treated Control	26.7 (8.8)	13.3 (13.3) ab

Table 1. Visual vegetation assessments for the 2017 Whitmore, California site preparation trial. Standard errors are in parenthesis. Values with the same letter are not statistically different at the $p <= 0.05$ level. If there are no letters, there were no significant main effects. IAF + RIS is a blend of Esplanade F and Matrix SG.

Treatment	% Survival PP	Bud Damage PP	Root Number PP	Root Length PP
4.5 oz IAF + RIS + 1% MSO	60.0 (25.1)	3.3 (0.3)	5.0 (0.6) ab	6.3 (1.8)
6 oz IAF + RIS + 1 MSO	93.3 (3.3)	2.0 (1.0)	5.0 (0.6) ab	7.0 (1.2)
5 oz Esplanade F + 1% MSO	90.0 (10.0)	2.0 (0.6)	4.3 (0.3) ab	6.3 (1.5)
7 oz Esplanade F + 1% MSO	76.7 (14.5)	2.3 (1.5)	4.0 (1.0) ab	4.0 (1.2)
5 oz Esplanade F + 1 oz Telar XP + 1% MSO	73.3 (17.6)	3.6 (2.2)	3.3 (0.3) b	5.7 (1.9)
7 oz Esplanade F + 1 oz Telar XP + 1% MSO	83.3 (12.0)	3.7 (0.9)	3.3 (0.9) b	2.7 (0.3)
1 oz Telar XP + 1% MSO	83.3 (6.7)	2.0 (1.2)	4.3 (0.7) ab	6.7 (1.5)
3 oz Derigo + 1% MSO	96.7 (3.3)	2.3 (1.2)	3.7 (0.7) b	5.3 (0.3)
6 oz Derigo + 1% MSO	96.7 (3.3)	2.7 (0.9)	5.0 (0.6) ab	5.7 (1.5)
7 oz Esplanade F + 3 oz Derigo + 1% MSO	86.7 (6.7)	3.0 (0.6)	4.7 (0.3) ab	4.3 (0.9)
3 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	96.7 (3.3)	0.3 (0.3)	6.0 (1.0) ab	5.7 (0.9)
4.5 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	96.7 (3.3)	1.3 (0.7)	5.7 (0.3) ab	9.0 (0.6)
4 oz Matrix SG + 1% MSO	100.0 (0.0)	1.3 (0.7)	4.7 (1.2) ab	5.7 (2.2)
Non Treated Control	96.7 (3.3)	1.0 (0.0)	8.0 (1.2) a	6.0 (0.6)

Table 2. Visual ponderosa pine assessments for the 2017 Whitmore, California site preparation trial. Standard errors are in parenthesis. Values with the same letter are not statistically different at the $p <= 0.05$ level. If there are no letters, there were no significant main effects. IAF + RIS is a blend of Esplanade F and Matrix SG.

Treatment	% Survival DF	Bud Damage DF	Root Number DF	Root Length DF
4.5 oz IAF + RIS + 1% MSO	73.3 (17.6)	4.3 (0.9)	8.7 (0.9)	6.7 (1.8)
6 oz IAF + RIS + 1 MSO	83.3 (8.8)	3.3 (1.2)	9.0 (0.0)	5.3 (0.3)
5 oz Esplanade F + 1% MSO	66.7 (12.0)	5.0 (2.1)	8.7 (0.3)	5.3 (0.9)
7 oz Esplanade F + 1% MSO	66.7 (20.3)	4.0 (2.6)	7.0 (0.6)	4.3 (0.7)
5 oz Esplanade F + 1 oz Telar XP + 1% MSO	63.3 (31.8)	4.0 (3.0)	6.0 (1.2)	3.7 (0.7)
7 oz Esplanade F + 1 oz Telar XP + 1% MSO	70.0 (15.3)	4.7 (1.8)	5.0 (2.0)	3.0 (1.0)
1 oz Telar XP + 1% MSO	83.3 (12.0)	3.7 (2.0)	8.3 (0.9)	6.0 (1.0)
3 oz Derigo + 1% MSO	66.7 (14.5)	5.3 (1.3)	7.0 (1.2)	5.0 (1.0)
6 oz Derigo + 1% MSO	70.0 (15.3)	7.0 (0.6)	6.7 (1.2)	2.7 (0.3)
7 oz Esplanade F + 3 oz Derigo + 1% MSO	46.7 (14.5)	6.3 (1.3)	7.5 (0.5)	4.5 (0.5)
3 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	96.7 (3.3)	2.7 (2.7)	7.3 (1.2)	4.7 (0.9)
4.5 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	93.3 (3.3)	1.7 (0.9)	9.0 (0.0)	7.0 (0.6)
4 oz Matrix SG + 1% MSO	83.3 (8.8)	2.7 (1.5)	8.0 (0.0)	4.3 (0.3)
Non Treated Control	76.7 (3.3)	2.7 (0.3)	8.3 (1.2)	4.7 (0.9)

Table 3. Visual Douglas-fir assessments for the 2017 Whitmore, California site preparation trial. Standard errors are in parenthesis. Values with the same letter are not statistically different at the $p <= 0.05$ level. If there are no letters, there were no significant main effects. IAF + RIS is a blend of Esplanade F and Matrix SG.

Treatment	% Bare Ground	% Control Squirrel Tail	% Control Rat Tail Fescue
4.5 oz IAF + RIS + 1% MSO	31.7 (11.7) ab	16.7 (12.0) ab	100.0 (0.0) a
6 oz IAF + RIS + 1 MSO	43.3 (16.4) ab	23.3 (8.8) ab	100.0 (0.0) a
5 oz Esplanade F + 1% MSO	36.7 (16.7) ab	36.7 (18.6) ab	63.3 (31.8) ab
7 oz Esplanade F + 1% MSO	18.3 (3.3) ab	33.3 (16.7) ab	50.0 (28.9) ab
5 oz Esplanade F + 1 oz Telar XP + 1% MSO	20.0 (7.6) ab	3.3 (3.3) ab	100.0 (0.0) a
7 oz Esplanade F + 1 oz Telar XP + 1% MSO	26.7 (13.0) ab	13.3 (13.3) ab	100.0 (0.0) a
1 oz Telar XP + 1% MSO	40.0 (17.3) ab	20.0 (11.5) ab	70.0 (30.0) a
3 oz Derigo + 1% MSO	51.7 (8.3) ab	75.0 (7.6) ab	100.0 (0.0) a
6 oz Derigo + 1% MSO	35.0 (7.6) ab	60.0 (10.0) ab	98.3 (1.7) a
7 oz Esplanade F + 3 oz Derigo + 1% MSO	55.0 (23.6) ab	65.0 (32.5) ab	81.7 (15.9) a
3 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	91.7 (1.7) a	100.0 (0.0) a	100.0 (0.0) a
4.5 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	94.0 (2.1) a	100.0 (0.0) a	100.0 (0.0) a
4 oz Matrix SG + 1% MSO	50.0 (11.5) ab	46.7 (23.3) ab	93.0 (6.7) a
Non Treated Control	15.0 (10.4) b	0.0 (0.0) b	0.0 (0.0) b

Table 4. Visual vegetation assessments for the 2017 Oak Run, California site preparation trial. Standard errors are in parenthesis. Values with the same letter are not statistically different at the $p <= 0.05$ level. If there are no letters, there were no significant main effects. IAF + RIS is a blend of Esplanade F and Matrix SG.

Treatment	% Survival PP	% Survival WF
4.5 oz IAF + RIS + 1% MSO	4.3 (2.9) c	0.0 (0.0) c
6 oz IAF + RIS + 1 MSO	46.7 (8.8) abc	10.0 (5.8) bc
5 oz Esplanade F + 1% MSO	46.7 (20.3) abc	16.7 (16.7) c
7 oz Esplanade F + 1% MSO	23.3 (23.3) bc	6.7 (3.3) c
5 oz Esplanade F + 1 oz Telar XP + 1% MSO	6.7 (6.7) c	0.0 (0.0) c
7 oz Esplanade F + 1 oz Telar XP + 1% MSO	13.3 (8.8) c	0.0 (0.0) c
1 oz Telar XP + 1% MSO	6.7 (6.7) c	3.3 (3.3) c
3 oz Derigo + 1% MSO	46.7 (8.8) abc	0.0 (0.0) c
6 oz Derigo + 1% MSO	23.3 (6.7) bc	0.0 (0.0) c
7 oz Esplanade F + 3 oz Derigo + 1% MSO	83.3 (6.7) abc	30.0 (17.3) abc
3 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	93.3 (3.3) a	80.0 (0.0) ab
4.5 pts Cleantraxx + 2 qts Accord XRT II + 1% MSO	86.7 (6.7) ab	86.7 (6.7) a
4 oz Matrix SG + 1% MSO	50.0 (25.2) abc	20.0 (15.3) abc
Non Treated Control	16.7 (12.0) c	0.0 (0.0) c

Table 5. Visual ponderosa pine and white fir assessments for the 2017 Oak Run, California site preparation trial. Standard errors are in parenthesis. Values with the same letter are not statistically different at the $p <= 0.05$ level. If there are no letters, there were no significant main effects. IAF + RIS is a blend of Esplanade F and Matrix SG.

Giant sequoia and incense-cedar level of growing stock studies

Proposal 17-01

Lauren Cox and Robert York

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Executive summary of progress

Blodgett Forest Research station established a replicated giant sequoia spacing trial in 1989 and an incense-cedar spacing trial in 1999. During summer 2017, we resampled all plots of the giant sequoia spacing study, resampled pruned trees within the giant sequoia spacing study, and conducted plot maintenance on both the giant sequoia and incense-cedar spacing trials. Additionally, we thinned all replicates of one of the spacing treatments in the giant sequoia study. The thinning increased the spacing of a high density treatment to match the spacing of a low density treatment. The thinning will provide information on the effect of thinning on overall stand productivity in the future. Because maintenance of the incense-cedar spacing trial (removing competing species and relocating row/tree markers) took longer than anticipated, the measurement did not occur in 2017. Resampling of the incense-cedar spacing study is scheduled for summer 2018. Preliminary results of the giant sequoia spacing study as well as the pruning study are provided below.

Giant sequoia spacing study

Giant sequoia survival

Since 2010, only 1% of trees (27 of 2352) within the giant sequoia spacing study were reported dead or missing. This extremely low level of mortality has been consistent throughout the life of this study, despite what has clearly been competition-related growth effects occurring since year 4. From field observations and preliminary data observations of tree size distributions, it is clear that growth differentiation in the denser stands is not yet occurring. This does not appear to be leading to stagnation, however, because stand-level growth in the high density stands is still similar to low density stands as described below. Rather, it appears that growing space is being spread evenly among individuals. While this pattern cannot continue indefinitely, the persistence of high survival and a lack of differentiation is noteworthy. While no volume is being "lost" from mortality, the tradeoff is an overall suppression of sawlog development. In upcoming analyses, we plan to quantify tree size distributions to provide further insight on the lack of growth differentiation.

Giant sequoia density effects on diameter and height growth

Across all sampling periods, mean diameter and height increased with increasing spacing (Fig. 1). Following the most recent sampling, only the two widest spacing treatments had diameters greater than 14" whereas stems spaced 12' or wider reached average diameters greater than 10" (Fig. 1, bottom). After 28 years, average diameter of stems at the widest spacing was 132% larger than stems at the tightest spacing, whereas mean stem height was

74% taller at the 20' spacing compared to the 7' spacing. Interestingly, the rate of height growth increased from 22 to 28 years, deviating from the height growth trend from the previous sampling periods (Fig. 2). This latest growth period included the severe 4-year drought from 2012 to 2016. We speculate that the increased height growth is either from a carbon allocation effect or possibly from roots tapping into deep water sources.

Density effects on stem and stand volume production

The 2017 resampling indicated higher individual tree volumes with wider spacing treatments. This general trend has been present throughout all sampling periods, although the degree of difference between average tree volume has increased over time (Fig. 3). During the 16th growing season, individual tree volume at the widest spacing was 690% greater than volume of trees at the tightest spacing. This difference was 760% during the 28th growing season. Repeated measures analysis of variance indicated significant differences among spacing treatments and sampling periods for dbh, height, and individual tree volume. This confirms that the different spacings are growing along non-parallel paths. Stand volume was similar across all spacings during the 28th growing season (Fig. 4) and exhibited a 38% increase since the last sampling period (22nd growing season). Although stand volumes have increased over time, there was no difference between different spacing treatments. Typically, lower density stands are expected to have relatively low stand volume and relatively high individual tree volume. However, our results indicate that there is no a tradeoff between stand volume and individual tree size for giant sequoia on this site. Rather, it appears that even at very wide spacings, growing space is efficiently converted to stemwood because of the rapid growth of giant sequoia.

Management implications

These results demonstrate the relatively high sensitivity that giant sequoia has to density. Height growth continues to be sensitive to density, even at relatively low density ranges. Maintaining low densities clearly benefits sawlog production. The lack of relationship between density and stand volume suggests that giant sequoia occupy available growing space very quickly and maintain high resource use efficiency for producing stemwood. Using 14" as a minimum for the average dbh necessary for a profitable commercial thin, the majority of the two widest spacings (18 and 20 feet hexagonal spacing) had attained thinning viability at age 28. Using a lower threshold of 10" dbh, the majority of spacings greater than 12' hexagonal had achieved commercial viability. The results suggest either planting at relatively low densities and maintaining low competition, or thinning early to wide spacings, would be appropriate for giant sequoia.

From a carbon sequestration perspective, we have not observed any benefit from maintaining high densities. Rather, low densities appear to achieve both high stand carbon accumulation as well as sawlog development. Small diameter forest products, such as poles or biomass chips, could be grown viably with tight spacing.

A comparison of giant sequoia with other mixed conifer species could put these results into a broader context and provide information about mixed species plantations. Other mixed species growth studies that include giant sequoia, as well as integration of this study with pruning studies at Blodgett would also likely provide information on mixed species plantations that include giant sequoia.

Pruning intensity effects on stem form and growth

In 2000, "guard trees" (trees on the edges of spacing treatments) were pruned to three different heights: 6.6, 11.5, and 18 feet. Randomly chosen unpruned trees from the spacing study were used as controls. At the time of pruning, trees were 11 years old and averaged 22 feet tall. This was a "green pruning;" lower branches were removed while they still had live foliage. Heights of trees were somewhat variable, resulting in corresponding variability in the percent of live crown that was removed. The majority (interquartile range) of trees had between 33 and 62% of the live crown removed, as a percent of height.

A total of 529 study trees were measured at 1, 3, 9, and 16 years after pruning. Measurements of total height and stem diameter occurred each time. Stem diameter measurements on all trees took place at 1, 4.5, 6.6, 11.5, and 18 feet above ground, with the upper three heights corresponding to the different prune heights. Early measurements were collected with tapes and a combination of ladders and climbing. The 16 year measurement used a Jim-Gem pentaprism dendrometer for diameters at heights above 6.6 feet. This method, while not as precise (12% error compared to remeasurement of the same trees with tapes), had no clear bias in accuracy and was confirmed to be a viable measure of stem form given the large sample sizes in this study. The 18 and 4.5 feet stem height measurements were used to estimate Girard Form Class (DIB at top of the butt log / DBH) at the end of the 17 year period. Diameter inside bark was estimated by multiplying outside bark by 0.9472, a correction factor based on a previous analysis of bark thickness in a destructive sampling of giant sequoia.

The repeated measures at each stem height were analyzed with a multivariate repeated measures approach (MANOVA-R). This tested for overall differences in growth among pruning treatments for the entire time period and also tested for differences in growth trends. Post-hoc differences between treatments in average growth across the entire period were assessed with Tukey's Honestly Significant Difference (HSD) tests. This tested whether or not individual pairs of pruning treatments were different than each other.

Results

Diameter growth at all stem heights were different among pruning treatments across the entire 17 years ($p<0.001$) and were also different in terms of the trend in growth over time ($p<0.001$). Given the large sample size in this study, this was not surprising. Controls grew more than pruned trees at stem base (Fig. 5). Pruning reduced basal stem growth, with effect size related to prune height. Trees pruned to the 11.5 and 18' prune heights grew considerably less at stem base in the first two years following pruning, increasing at an average rate of 1.9% per year. This compares to a 4.4% rate per year for controls and trees pruned to 6.6' height. Growth rate at the stem base, however, converged during the 10 to 17 year period following pruning. This occurred primarily through a decline in growth in controls and 6.6' prune height trees. The decline correlates with the trend in natural crown recession, where live crown bases increased via lower branch mortality. Across the whole study period, growth at stem base was greatest for controls, followed by 6.6', 11.5', then 18' prune heights (Fig. 6).

At 6.6' prune height, the significant patterns ($p<0.001$ for both overall differences among treatments and for different trends among treatments) were similar to the patterns at stem base (Fig. 7). The difference between controls and trees pruned to 6.6 feet, however, was not as large. All pruned trees were growing at roughly half the rate as they were at the end of the study period, while controls had a similar growth rate at the end of the study compared to shortly after pruning. Across the whole study period (Fig. 8), growth rate was similar between controls and trees pruned to 6.6' height. Trees pruned to 11.5 and 18' grew considerably less. Across all trees, growth rate at 6.6' height was greater (4.5%) than at stem base (2.9%).

Further up the stems at 11.5 feet, there were differences in overall growth rates and the trends in growth rate among the pruning treatments ($p<0.001$). Trees pruned to 11.5 feet and lower had similar patterns, while trees pruned to 18 feet had a much slower growth rate in the first period (Fig. 9). As with lower stem heights, the growth rates of all trees converged by the end of the study period. The early reduction in growth rate for those trees pruned to 18 feet caused an overall reduction in growth rate compared to the lower prune heights, which were also similar to the controls (Fig. 10).

At the highest stem height of 18 feet, there were detectable differences in overall growth rates and trends among pruning treatments ($p<0.001$). However, the differences were subtle compared to growth at lower stem heights (Fig. 11). Trees pruned to 18 feet had the lowest growth rate at the beginning of the growth period, but had the highest growth rate by the end of the period. The average growth rate at 18' stem height for the whole study period was similar among all pruning treatments (Fig. 12; $p=0.28$).

There was a difference in Girard Form class among pruning treatments ($p=0.005$), with a general increase in form class as prune height increased (Fig. 13). Pairwise comparisons indicated that controls were similar to trees pruned to 6.6 feet, while all pruned trees were similar to each other.

There was a clear effect of pruning treatment on height growth ($p<0.001$), with height growth declining with prune height. Additionally, each comparison between pairs of pruning treatments was significant (p values <0.05; Fig. 14).

Management implications

Pruning of giant sequoia caused a reduction in stem taper, but it was not through an increase in growth at the base of the live crown. Rather, it was from decreases in radial growth along the stem below pruning. Pruning high and early in giant sequoia led to detectable differences in Girard Form class, a common method for assessing log form and value. Small differences in form class can lead to larger differences in merchantable log volume. An increase in 1 unit of Girard form class results in a 3% increase in merchantable volume. Hence, between controls and those trees pruned to 18', which is the entire length of the butt log, merchantable volume increased by 27%. However, there was a loss in overall stem growth from pruning. The reduction in taper was traded off with a reduction in height growth.

For giant sequoia, one can expect to gain the typical benefits expected of pruning: clear wood production and a reduction of stem taper. Its rapid growth compared to other studies (when low density is maintained) suggests considerable clear wood production beyond the defect core following pruning. However, aggressive pruning early on should also be expected to lead to a reduction in height growth. Whether pruning is cost-effective will depend upon objectives and the timber products that are ultimately produced. Even aggressive early pruning followed by a height growth reduction may be cost effective if there is a premium on clear wood.

The results suggest that sequential lift pruning, while more costly than pruning the entire butt log at once, may avoid negative growth effects. Lift pruning in ~6 foot increments can be expected to have only small, if any, negative effects on growth followed by a recovery after two to three years. A pilot study at Blodgett Forest suggested no difference in stem growth between lifted giant sequoia and pruned trees as of the installation of the third lift. Even one pruning lift can be costly, however. In a different pilot study, giant sequoia had an average of over 50 branches below 7 feet of stem height. This compared to less than 20 branches for ponderosa pine. Even though branch size was much smaller for giant sequoia (1.2") compared to ponderosa pine (2.2"), the extreme number of branches in giant sequoia could make it a relatively costly species to prune. On the other hand, wood density of giant sequoia is relatively low, thus likely requiring less pruning effort per branch of a given size. An ergonomic study of pruning giant sequoia versus other mixed conifer species could reveal differences in pruning effort in mixed species stands to help prioritize pruning effort.

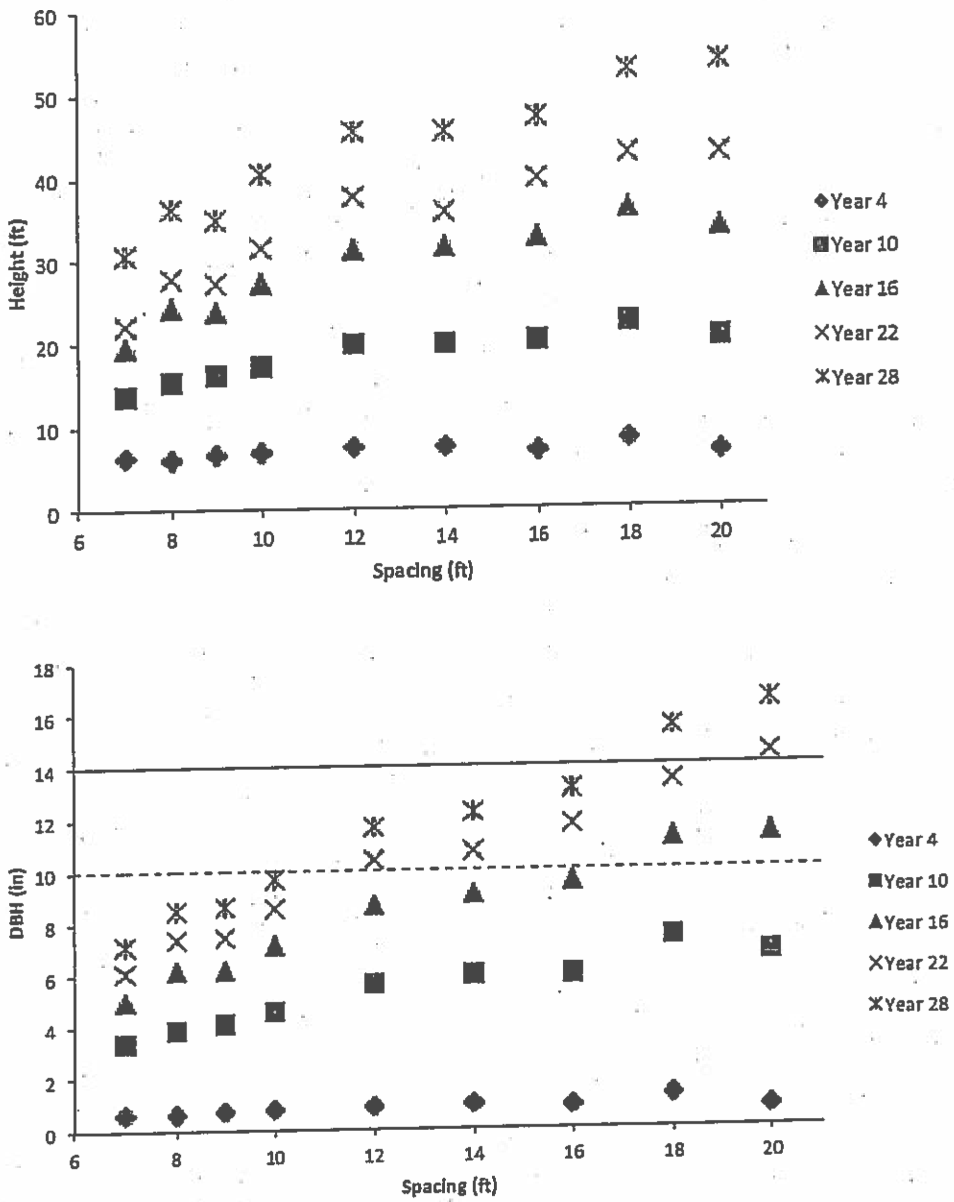

Fig. 1 Mean height (top) and dbh (bottom) over time of planted giant sequoia at Blodgett Forest Research Station. Values shown are averaged across three replicates. The solid red line shows the typical minimum dbh for sawlog production, while the dashed line shows what may be considered to be a threshold for operational feasibility for conducting a commercial thin.

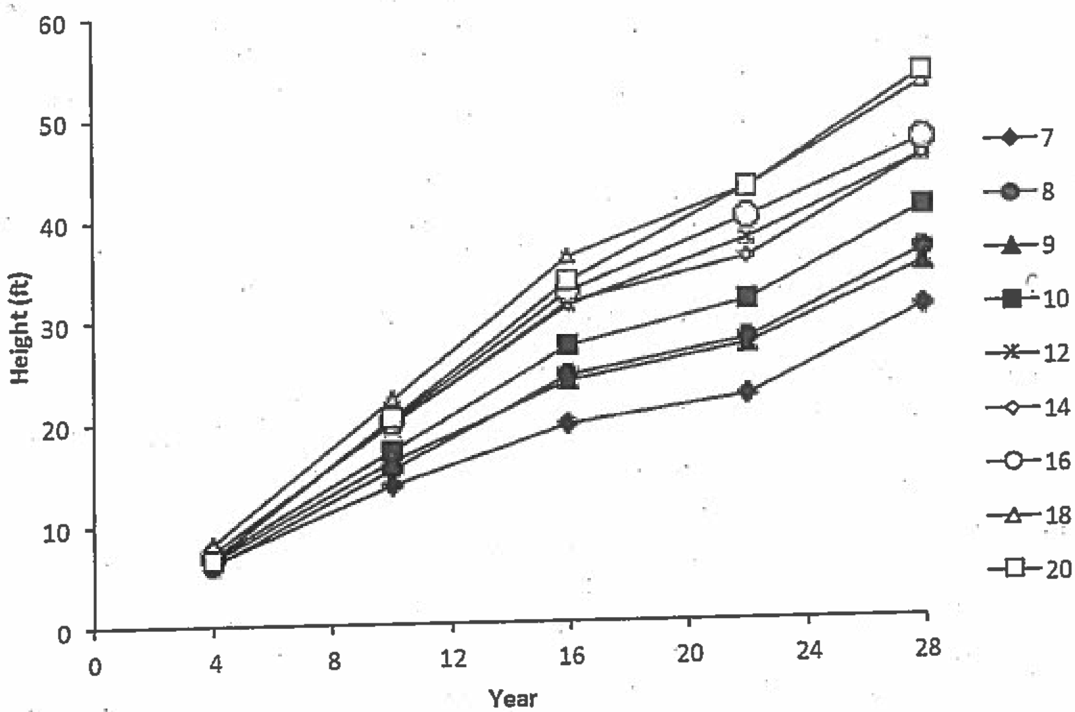

Fig. 2. Density effects on stem height over 28 years for giant sequoia at Blodgett Forest Research Station. Lines represent different spacing treatments (ft). Values are averaged over three replicates.

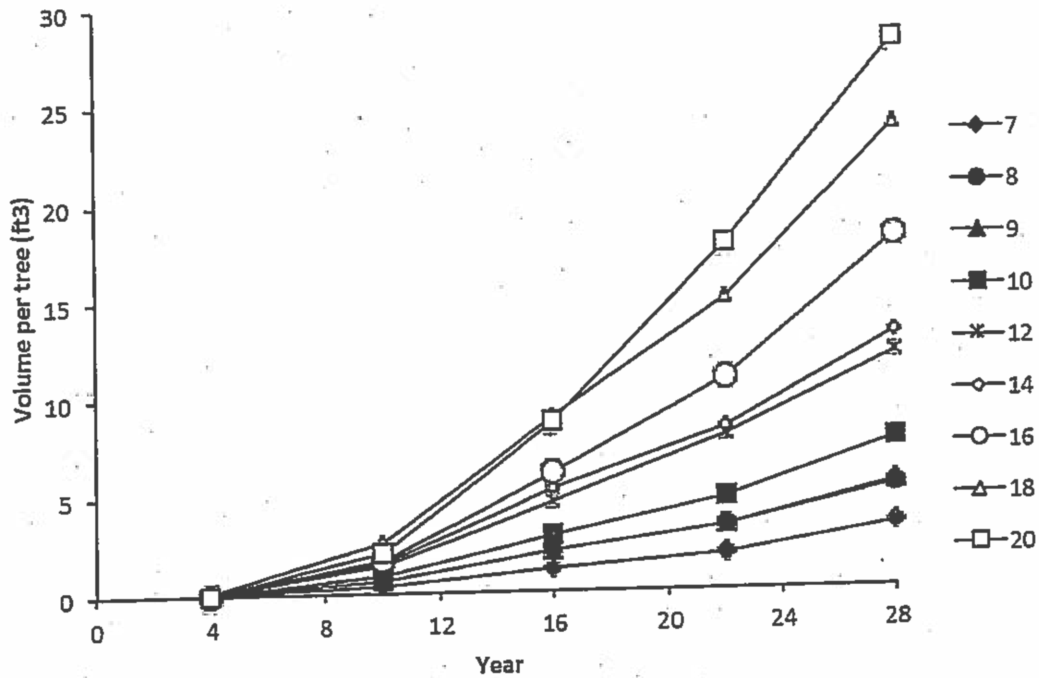

Fig. 3. Density effects on stem volume over 28 years for giant sequoia at Blodgett Forest Research Station. Lines represent different spacing treatments (ft). Values are averaged over three replicates.

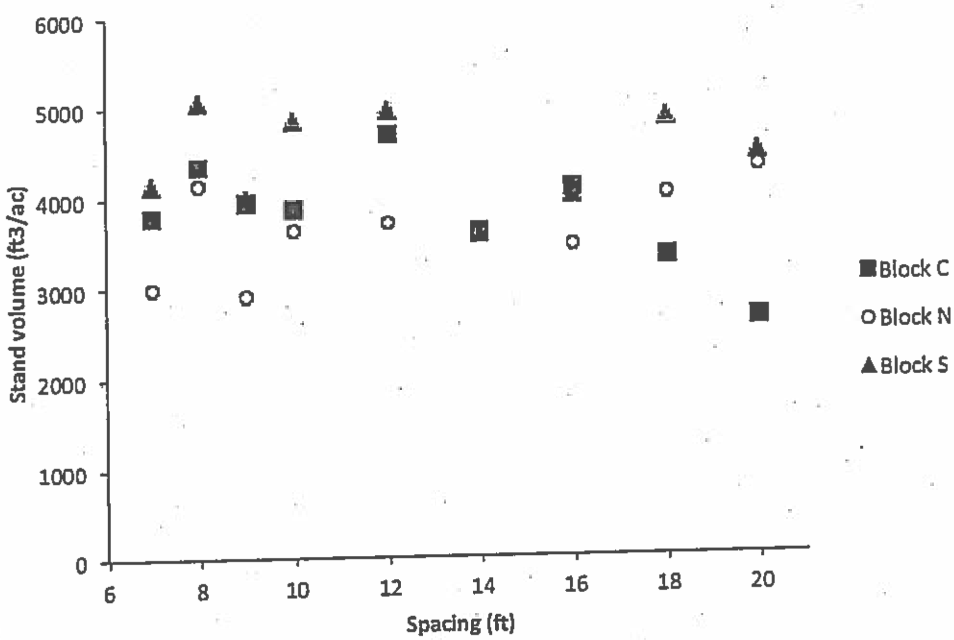

Fig. 4. Stand volume (ft^3 ac^{-1}) for giant sequoia across increasing spacing treatments after 28 years.

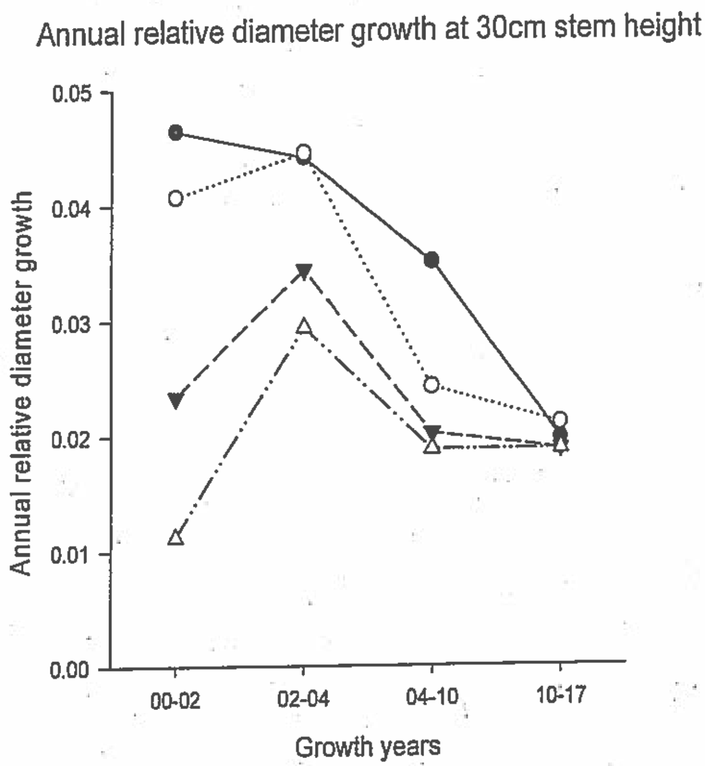

Fig. 5. Stem diameter growth at 1 foot above the ground. Growth is expressed relative to the size of the tree at time of pruning, annualized by the number of years between measurement periods.

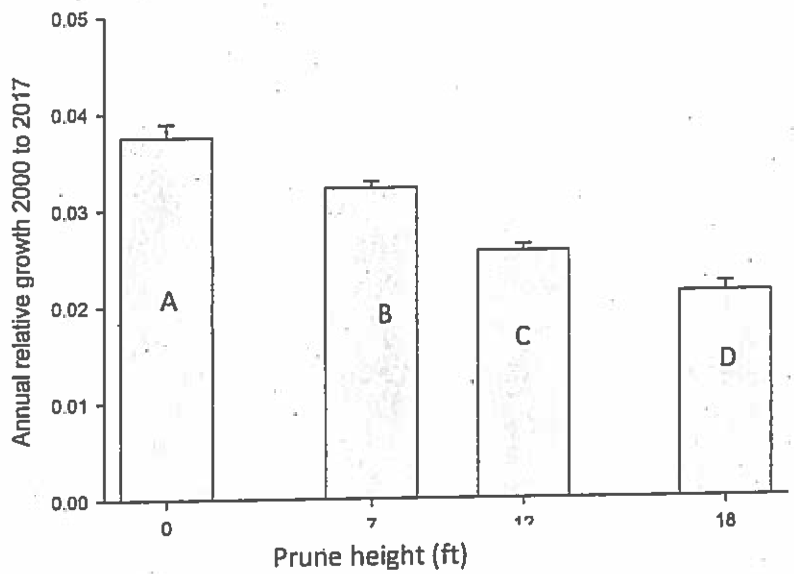

Fig. 6. Means and standard errors for annual relative diameter growth at the base of trees pruned to different heights. Letters indicate different means, as indicated with Tukey HSD.

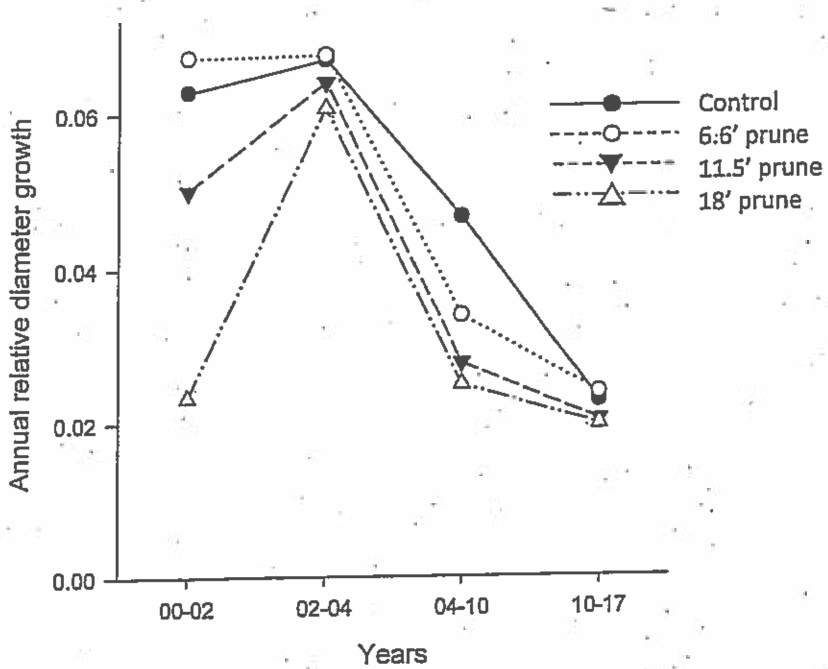

Fig. 7. Stem diameter growth at 6.6' above the ground.

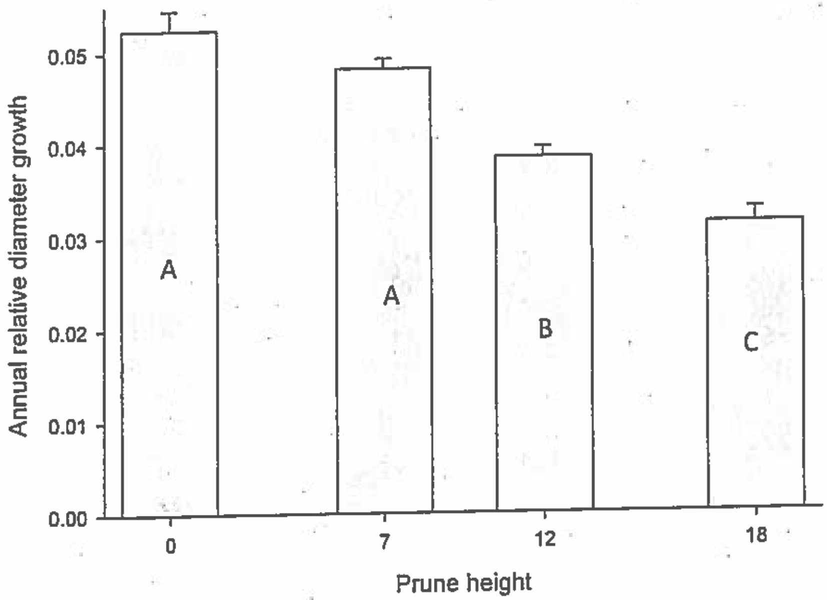

Fig. 8. Means and standard errors for annual relative diameter growth at a stem height of 6.6 feet on trees pruned to different heights. Letters indicate different means, as indicated with Tukey HSD.

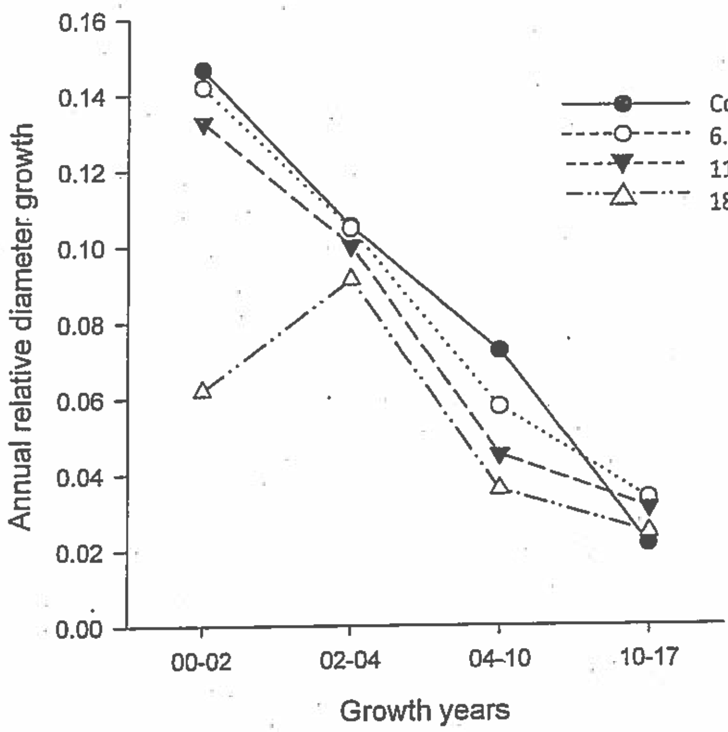

Fig. 9. Stem diameter growth at 11.5' above the ground.

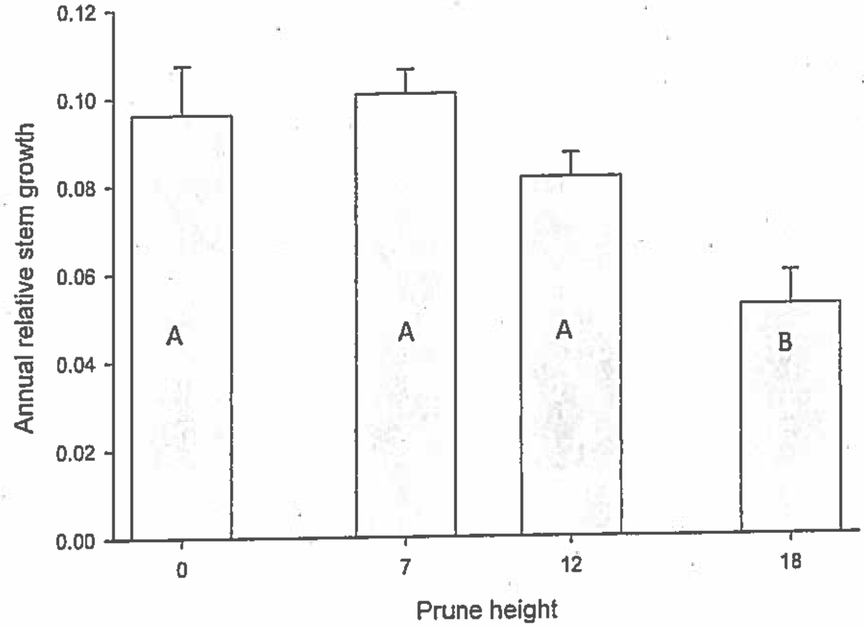

Fig. 10. Means and standard errors for annual relative diameter growth at a stem height of 11.5 feet on trees pruned to different heights. Letters indicate different means, as indicated with Tukey HSD.

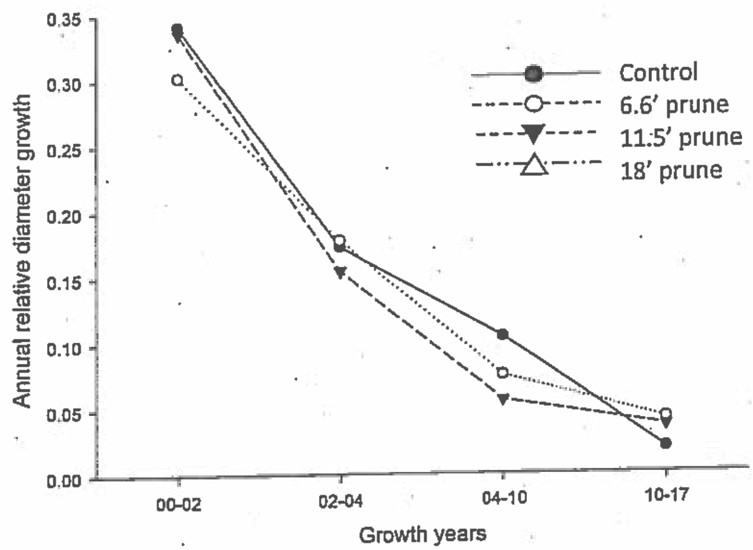

Fig. 11. Stem diameter growth at 18' above the ground.

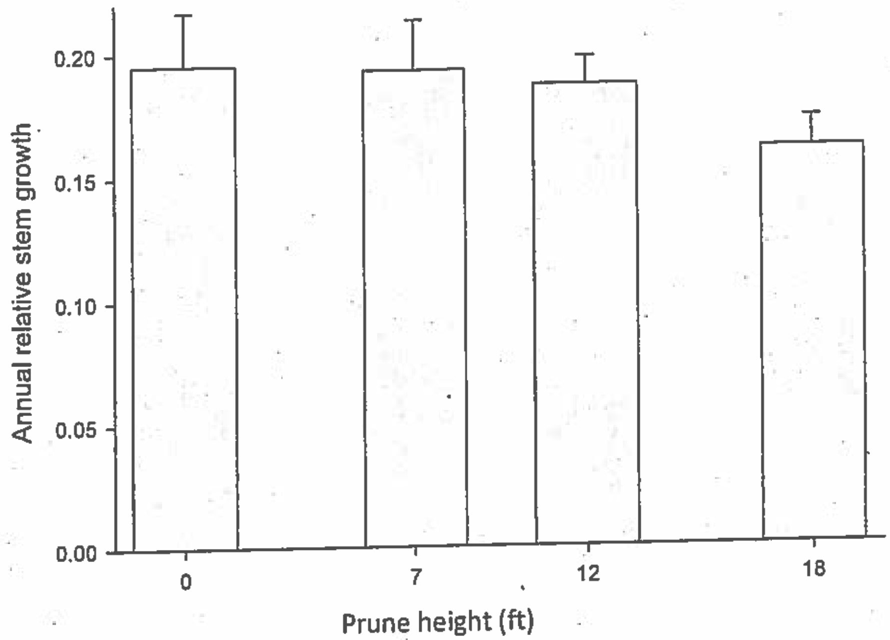

Fig. 12. Means and standard errors for annual relative diameter growth at a stem height of 18 feet on trees pruned to different heights. There were no differences detected among prune treatments (p=0.27)

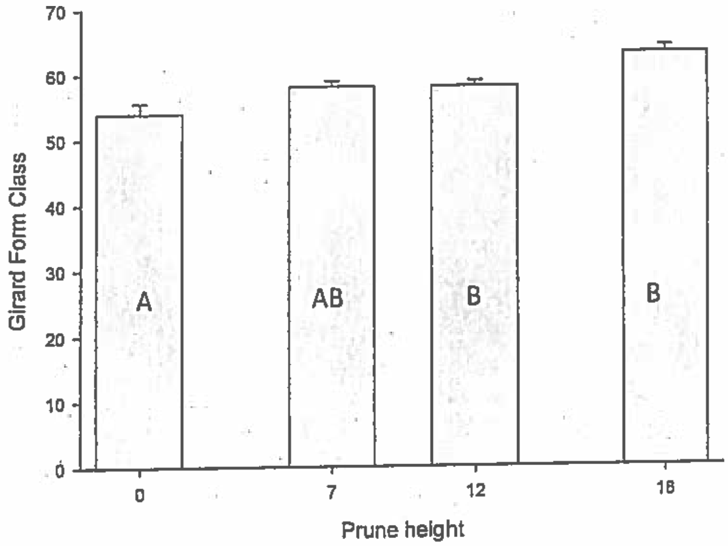

Figure 13. Girard form class (ratio of diameter inside bark at 18′ stem height / dbh) 17 years after pruning giant sequoia to different heights at age 11.

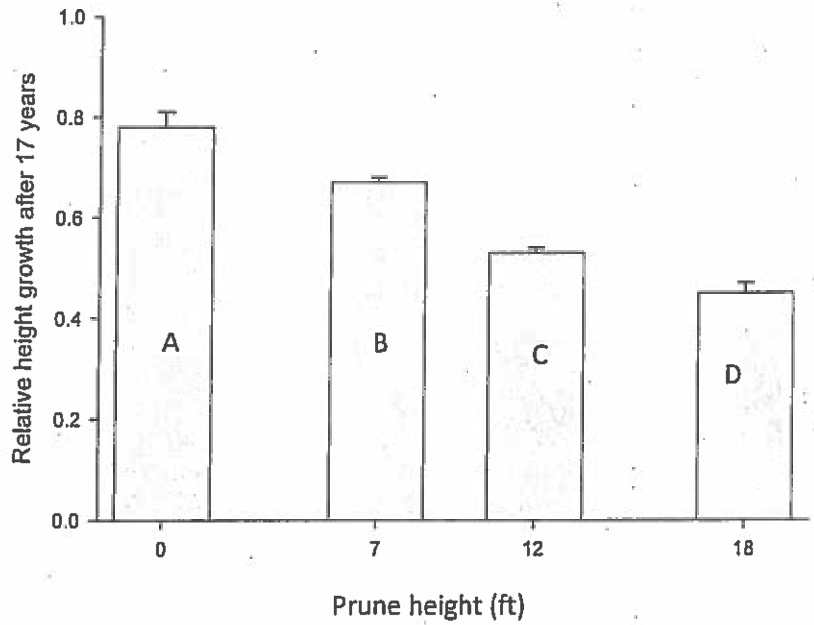

Fig. 14. Relative height growth 17 years after pruning giant sequoia to different heights at age 11.

Sierra Cascade Intensive Forest Management Research Cooperative Proposal 17-02

Agenda 2020 Flatwoods and Dana Tree Measurement

Principal Investigator: Jianwei Zhang

Title: Effect of dominant shrub cover and species on growth of young ponderosa pine plantations

Year Approved: 2017

Summary: Thirteen-year growth response of ponderosa pine to various manipulations of understory vegetation was studied to determine if a threshold of understory cover can be established and whether nitrogen-fixing *Ceanothus* species provide benefit to plantation growth compared to non N-fixing *Arctostaphylos* species, given their ability to improve site fertility. Results showed that completely controlling competing vegetation increased plantation growth, as was universally expected. But effect of partial shrub control on plantation performance varied. Not only did we not find a benefit of nitrogen-fixing shrubs on tree growth, young plantation growth was slightly better in the non N-fixing plots compared to the N-fixing plots, which had heavier shrub densities. An understory density threshold for tree growth was not observed. Due to the overriding effect of shrub competition, neither controlling herbaceous species nor fertilization showed a significant effect on these young plantation's growth. A long-term value of N-fixing shrubs, if there is one, must be balanced by successful plantation establishment and rapid early growth.

Introduction

Early productivity of ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) plantations declines as understory competition increases (McDonald and Fiddler 2010; Zhang et al. 2013). Growth drops as ground cover of woody shrubs approaches as little as 20% (Shainsky & Radosevich 1986, White & Newton 1989), with the effect persisting well after trees have overtopped the brush. This relationship was unrelated to site quality (Oliver 1984) although the trends may change after overstory crown closure (Zhang et al. 2006; 2013). Fiske (1982) concluded that pine plantations undergoing average competition from manzanita ultimately would fail. Therefore, forest managers have tried to keep understory cover well below the 20 to 30% threshold in young pine plantations.

The previous shrub control research conducted in California ponderosa pine plantations yielded some site specific conclusions. By summarizing 32 of their own studies established in northern and central California during 25 years, McDonald and Fiddler (2010) concluded that survival and growth of several species of conifers, mainly ponderosa pine, "were correlated to the density, foliar cover, and height of various combinations of over 235 species of hardwoods, shrubs, forbs, and graminoids." Effect of controlling competing vegetation on plantation growth varied with site quality. Reporting findings for 30 years from a low productivity site in the Cascades, McDonald and Powers (2003) showed that trees growing with dense shrub cover produced less than one percent of the volume of trees growing free of shrub competition. Oliver (1990) found that 20-year old stands with dense shrubs achieved only about half the volume of brush-free stands on a much more productive Sierra Nevada site. After crown closure, the effect of vegetation control on plantation growth dissipates, especially with the onset of self-thinning, although it takes many years for a stand to reach this stage at poor sites (Zhang et al. 2006; 2013). Therefore, these long-term studies raise questions about the universality of shrub control prescriptions and how site quality influences long-term silvicultural response.

Plantation responses may also vary due to different understory communities (McDonald and Fiddler 2010). Previous reviews have stated that nitrogen fixed by *Ceanothus* could be important to conifer forests (Johnson & Cole 2005). For example, annual rates of fixation by full stocking of *C. velutinus* could be as high as 100 kg N ha^{-1} yr^{-1} on the western slopes of the Cascade (Binkley et al. 1982, McNabb & Cromack 1983, Youngberg & Wollum 1976). It was much lower with 10 kg N ha^{-1} yr^{-1} under mature ponderosa pine stand (Busse 2000). Soil quality was better on non-vegetation control plots than on the vegetation control plots as measured by soil carbon, nitrogen, and microbial biomass (Busse et al. 1996). However, the long-term value of N-fixing species and their early competitive effect to plantations were never simultaneously studied. The benefit arguments largely are from soil nitrogen accumulation, because critical experiments have not been designed to test the concept.

In this study, we analyzed data collected from plantations established at two sites in 2005 to determine (1) the effect of varying degrees of shrub competition on plantation performance and (2) whether nitrogen-fixing shrubs (*Ceanothus*) show benefits to plantation growth compared to non N-fixing shrubs (*Arctostaphylos*).

Materials and methods

The study was established at two sites in northern California, Dana (Lat. 41.1416, long. 121.6385, Elev. 1259 m) being a low to moderately productive site, and Flatwoods (Lat. 40.9665, Long. 121.9495, Elev. 889 m) being a highly productive site. Although the two sites are only 30 km apart, it is cooler and much drier at Dana than at Flatwoods, with mean annual temperature 11.2°C and 14.6°C and annual precipitation 775 mm and 1880 mm, respectively from 2004 to 2016. Soil is the Jimmerson loam-Jimmerson stony sandy loam complex at Dana and Cohasset-Aiken stony loams at Flatwoods, with similar soil depth about 200 cm. Twelve treatments and control (13 experimental units) were randomly replicated four times at each site. These included the following vegetation targets at year 5 after tree planting:

- No vegetation control
- Full vegetation control
- Manzanita cover: 5, 15, 30, or 50%
- *Ceanothus* cover: 5, 15, 30, or 50%
- Herbaceous vegetation release once (herbs 1) following woody plant removal
- Herbaceous vegetation no release (herbs 0) with woody plant removal

- Fertilization, (**Wil-Gro 9-9-4**) one briquette at planting

Each plot (0.25 ac) was split, and one-half plot was planted with ponderosa pine seedlings and the other half was planted with Douglas-fir seedlings in spring of 2005. Spacing for both species was 8 by 8 feet. The four manzanita treatments were accomplished by planting greenhouse-raised seedlings. *Ceanothus* cover developed from native seed cache and sprouting of live shrubs. Manzanita survival was generally poor and required two unsuccessful, separate plantings of greenhouse seedlings plus transplanting shrubs from the adjacent forests. The entire Douglas-fir split plots showed very low survival and therefore were eliminated from the study. The activities include (1) field sites harvested and prepared for planting in 2004 and 2005, (2) 104 plots were installed including planting Douglas-fir and ponderosa pine in 2005, (3) herbicide treatments applied 5% Accord XRT II plus 5% MSO at label rates to full vegetation control plots and only woody plants on both herbaceous manipulation plots in 2005 and herbaceous species (herbs 1) in 2006, (4) manzanita seedlings were planted in 2006 and 2007, (5) shrub cover was measured in 2008, (6) shrub densities adjusted by both manual and Garlon 3A at full strength to original cover percentage targets for manzanita and *Ceanothus* treatments in 2009, (7) shrub cover was re-measured in 2014, and (8) ponderosa pine trees were measured in 2017.

We measured diameter at 1.37 m (DBH) for the inner 20 ponderosa pine trees in all plots at the end of the 2017 growing season (November and December). Tree height and height to live crown were measured for every other tree within these measurement plots. As previously stated, shrub cover was measured during the 2008 and 2014 growing seasons. The former one was used for adjusting the targeted cover percentage. Understory vegetation was sampled using a line-intercept method on four parallel 10 m transects. Species were identified and grouped as *Arctostaphylos* sp., *Ceanothus* sp. (*Ceanothus prostrate* was separately recorded), other shrubs, and naturally regenerated hardwoods and conifers.

Data analyses: We analyzed tree DBH, height, basal area (BA) and woody plant cover using analysis of variance in SAS PROC MIXED with location and plot as random effects and treatment with fixed effect. Because of large variation in tree survival rate among treatments, we fit tree growth models (DBH, height, and BA) with survival rate as a covariant first. If the effect of survival rate was non-significant, we would not include it in the model. A general model was:

$$y_{ijk} = \mu + \alpha_i + \gamma_j + \alpha\gamma_{ij} + \varepsilon_{ijk}$$

Where y_{ijk} is the dependent variable measured for the i^{th} treatment, the j^{th} location, and k^{th} replication, μ is the overall mean, α_i is the fixed effect of the i^{th} treatment (i=1, 2, ...), γ_j is the random effect of the j^{th} location (j=1 and 2) , $\gamma_j \sim N(0, \sigma_L^2)$, $\alpha\gamma_{ij}$ is the location by treatment interactions, and ε_{ijk} is an experimental error, $\varepsilon_{ijk} \sim iid\ N(0, \sigma_e^2)$. Treatment differences were tested with Tukey adjust comparisons with α=0.1. All regressions were also fitted with SAS PROC REG.

Results and Discussion

Treatment effect was significant for all variables ($P<0.01$, Table 1). For trees, the differences were mainly caused by no vegetation control and full vegetation control. Apparently, survival rate contributed a great deal to growth variation. The no vegetation control plots and no herbaceous control plots showed a lower survival rate than other treatment plots at both sites. However, fewer trees in the plots did not yield larger trees as we expected, although these plots carry less basal area. The two sites differed significantly in DBH, height, BA, and survival ($P<0.043$), with average DBH 12.2 cm and 11.4 cm, height 4.9 m and 5.2 m, BA 13.8 m^2 ha^{-1} and 16.2 m^2 ha^{-1}, and survival rate 0.64 and 0.79 at Dana and Flatwoods, respectively. Apparently, larger tree DBH was due to lower survival rate at Dana than at Flatwoods. Trees grew better on manzanita dominant plots than on *Ceanothus* dominant plots, especially at Flatwoods, which might be due to a heavier cover of *Ceanothus* than manzanita. For understory shrubs, manzanita grew better at Dana than Flatwoods. But, the trends were reversed for the *Ceanothus*. Four species of *Ceanothus* species were found, *C. cordulatus, integerimus, prostratus*, and *velutinus. C. cordulatus* was not found at Dana, but it was thick at Flatwoods. Even though we had purposely manipulated shrub cover in 2009, the targeted cover percentage and even the trends were not achieved; for example, the 15% cover was the highest cover percentage at Dana. In general, DBH, height, and BA were higher in full vegetation control than in no vegetation control treatments; both were supposed to be two extremes of the treatments. There were some exceptions at both sites. For example, controlling shrubs but not herbaceous species showed not only lower survival rate, but also smaller tree size or BA. We cannot explain this phenomena.

The threshold of shrub density for both manzanita and *Ceanothus* could not be found from our manipulated percentage. However, we found weak and non-significant relationships between growth variables (height and BA) and shrub cover (Fig. 1). The results were not expected because previous studies always found the strong negative relationships between shrub cover and tree growth. There are two potential explanations. One was low tree survival rate on some plots, mainly on non-vegetation control and both with and without herbaceous release treatments. After we eliminated the plots with survival rate ≤ 0.5, the relationship would have significantly improved (Fig. 2). Another explanation was the non-uniform shrub development prior to 2009 and shrub cover manipulation in 2009, which might have interrupted the stand development, at least for understory vegetation. Thus, the relationships between plantation growth and understory cover percentage might have been changed and affected. In addition, Zhang et al. (2006) failed to find the differences in ponderosa pine plantation grown under full shrub cover from that under 50% shrub cover. The main reason was difficulty in controlling understory cover in a targeted percentage year after year; understory canopy would occupy the spaces rapidly. Therefore, the threshold of shrub cover percentage was often confounded with plantation age when tree seedlings and competing vegetation developed together. However, plantation growth will significantly increase when competing vegetation is completely controlled.

In this young ponderosa pine plantation, not only did nitrogen-fixing shrubs (*Ceanothus*) not show the benefits to plantation growth compared to non N-fixing shrubs (*Arctostaphylos*), but trees were considerably smaller on the *Ceanothus* plots than on the manzanita plots (Table 1). As we suggested earlier, shrub cover was much higher on *Ceanothus* plots than on manzanita plots at both sites, which may explain the results. Based on 6-year results from the Garden of Eden study, Powers and Ferrell (1996) concluded that shrub control was essential for satisfactory plantation performance on poor, droughty sites. Moisture availability is the most common factor limiting plant growth in temperate regions of Mediterranean climate. Consequently, competition for soil moisture is considered the main mechanism of interaction between ponderosa pine and other vegetation. McDonald & Fiddler (1990) reported that predawn plant water potentials were 0.7 MPa higher in pine plots kept shrub-free with herbicides. Because soil moisture was such an overriding factor, fertilizer application after shrub control offered no further advantage beyond shrub control alone at low quality site (Powers and Ferrell 1996). They hypothesized that shrubs block uptake of fertilizer nutrients by pine. If this is true, it may explain a lack of tree growth enhancement by nitrogen-fixing shrubs in this study.

An effect of controlling herbaceous species was non-significant (Table 1). Yet, tree growth responded to the treatment positively, especially at Dana. This suggests that at droughty sites, any soil water availability will help tree performance. In fact, White & Newton (1989) have shown that herbs can extract moisture as deeply as 0.9 m.

In summary, our results showed that completely controlling competing vegetation increased plantation growth, as was universally expected. However, relationships between partial control and the performance of trees was more complicated. We did not find that nitrogen-fixing shrubs provided benefits to plantation growth. On the contrary, young plantation growth on non N-fixing species plots was slightly better than on N-fixing species plots due to its heavier woody plant densities. Neither did we find an understory density threshold for tree growth. Due to the overriding effect of shrub competition, neither controlling herbaceous species nor fertilization showed a significant effect on these young plantation's growth. A long-term value of N-fixing shrubs must be balanced by successful plantation establishment and rapid early growth.

Acknowledgements

Our late colleague Dr. Robert F. Powers designed the study and oversaw the installation and earlier data collection. Thanks to Roseburg Forest Resources for installing the study at both their sites. Alice Ratcliff for measuring the shrub covers and Ed Fredrickson for measuring trees. The comments from Dr. Smith and anonymous reviewers for improving the manuscript are greatly appreciated. Use of trade names in this paper does not constitute endorsement by the United States Forest Service.

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Table 1. Means, standard errors, and p-values for testing treatment effects for DBH, height (HT), basal area (BA), and survival rate for ponderosa pine and shrub covers for manzanita, *Ceanothus*, and total woody shrubs at Dana and Flatwoods in northern California.

Site	Treatment	Trees				Shrubs cover (%)		
		DBH (cm)	HT (m)	BA (m^2 ha^{-1})	Survival rate	Manzanita	*Ceanothus*	Total shrub
Dana	No veg control	8.0 (1.0)b	3.6 (0.3)c	9.7 (1.7)a	0.29 (0.08)b	4.4 (2.7)cd	21.1 (14.1)a	35.1 (21.7)a
	Full veg control	13.5 (0.9)a	6.0 (0.3)a	16.4 (1.5)a	0.73 (0.10)ab	1.5 (1.5)d	3.4 (1.6)a	5.3 (2.8)a
	Manzanita 5%	12.9 (0.9)a	5.2 (0.3)ab	15.3 (1.6)a	0.88 (0.06)a	4.7 (1.9)cd	0.0 (0.0)a	9.7 (2.7)a
	Manzanita 15%	12.0 (0.9)ab	5.0 (0.3)ab	12.6 (1.5)a	0.74 (0.08)ab	27.8 (4.2)a	1.8 (1.8)a	29.7 (5.4)a
	Manzanita 30%	11.6 (0.9)ab	5.2 (0.3)ab	11.7 (1.5)a	0.73 (0.10)ab	17.8 (3.5)ab	4.8 (2.0)a	26.7 (3.8)a
	Manzanita 50%	13.5 (0.9)a	5.5 (0.3)ab	15.5 (1.5)a	0.71 (0.13)ab	13.7 (2.7)bc	2.7 (2.2)a	17.4 (3.6)a
	Ceanothus 5%	12.9 (0.9)a	5.1 (0.3)ab	13.4 (1.5)a	0.55 (0.12)ab	2.5 (1.9)cd	13.5 (7.5)a	24.5 (7.3)a
	Ceanothus 15%	11.7 (0.9)ab	4.8 (0.3)ab	13.7 (1.5)a	0.68 (0.20)ab	0.5 (0.5)d	5.3 (2.2)a	20.0 (7.8)a
	Ceanothus 30%	12.4 (0.9)ab	4.6 (0.3)b	14.0 (1.6)a	0.81 (0.07)ab	0.3 (0.3)d	10.1 (6.8)a	22.7 (8.0)a
	Ceanothus 50%	12.0 (0.9)ab	4.6 (0.3)b	12.7 (1.5)a	0.70 (0.15)ab	0.3 (0.3)d	24.0 (6.9)a	36.4 (10.1)a
	Herbs 1	13.9 (0.9)a	5.2 (0.3)ab	17.3 (1.5)a	0.65 (0.13)ab	0.2 (0.2)d	0.8 (0.8)a	3.2 (1.4)a
	Herbs 0	11.3 (1.0)ab	4.4 (0.3)bc	12.5 (1.7)a	0.30 (0.12)b	0.9 (0.9)cd	0.0 (0.0)a	2.9 (1.3)a
	Fert_	13.2 (0.9)a	5.0 (0.3)ab	15.0 (1.5)a	0.59 (0.12)ab	6.5 (5.7)cd	9.0 (6.9)a	19.1 (7.7)a
Flatwoods	No veg control	9.5 (1.2)b	4.2 (0.6)bc	13.5 (3.2)ab	0.39 (0.17)b	3.0 (1.2)ab	45.3 (9.7)a	56.3 (11.4)ab
	Full veg control	15.0 (0.9)a	6.7 (0.4)a	26.7 (2.5)a	0.86 (0.03)a	0.0 (0.0)b	7.0 (3.6)cd	7.2 (3.5)c
	Manzanita 5%	11.4 (1.0)ab	5.3 (0.4)ab	16.5 (2.6)ab	0.91 (0.01)a	8.7 (5.7)ab	4.4 (2.3)cd	13.4 (5.0)c
	Manzanita 15%	12.5 (0.9)ab	5.4 (0.4)ab	17.9 (2.5)ab	0.85 (0.04)a	12.5 (8.8)ab	1.7 (1.0)d	14.2 (9.7)c
	Manzanita 30%	12.6 (1.0)ab	5.8 (0.4)ab	19.2 (2.5)ab	0.88 (0.03)a	13.3 (3.6)ab	5.2 (2.1)cd	18.9 (4.2)c
	Manzanita 50%	12.8 (0.9)ab	6.2 (0.5)ab	18.4 (2.5)ab	0.78 (0.03)a	17.8 (6.5)a	2.9 (2.1)cd	20.7 (6.5)c
	Ceanothus 5%	10.5 (1.0)b	4.8 (0.4)ab	13.3 (2.5)bc	0.90 (0.04)a	0.2 (0.2)b	32.9 (2.6)bc	37.4 (6.4)bc
	Ceanothus 15%	11.1 (0.9)ab	5.2 (0.4)ab	14.8 (2.5)bc	0.78 (0.06)a	0.0 (0.0)b	44.9 (5.9)ab	61.2 (7.3)abc
	Ceanothus 30%	9.3 (0.9)b	4.7 (0.4)bc	11.2 (2.5)bc	0.78 (0.10)a	0.0 (0.0)b	41.2 (13.0)ab	56.5 (16.3)ab
	Ceanothus 50%	9.4 (0.9)b	4.4 (0.4)bc	11.3 (2.5)bc	0.85 (0.06)a	0.0 (0.0)b	63.9 (12.2)a	78.9 (14.1)a
	Herbs 1	11.8 (1.0)ab	5.3 (0.4)ab	16.9 (2.5)ab	0.88 (0.03)a	0.0 (0.0)b	1.3 (1.3)d	1.3 (1.3)c
	Herbs 0	12.0 (1.0)ab	5.2 (0.5)ab	16.3 (2.7)ab	0.59 (0.17)b	1.3 (1.3)ab	0.7 (0.6)d	2.8 (1.1)c
	Fert_	10.7 (0.9)bc	4.8 (0.4)ab	14.3 (2.5)bc	0.84 (0.05)a	0.1 (0.1)b	49.2 (8.5)a	67.2 (15.3)ab
P-values	Site	0.042	0.001	0.042	<0.001	0.137	<0.001	<0.001
	Trtmt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Site*Trtmt	0.260	0.419	0.368	0.870	0.274	<0.001	0.003

The different letters at each site indicate P<0.10.

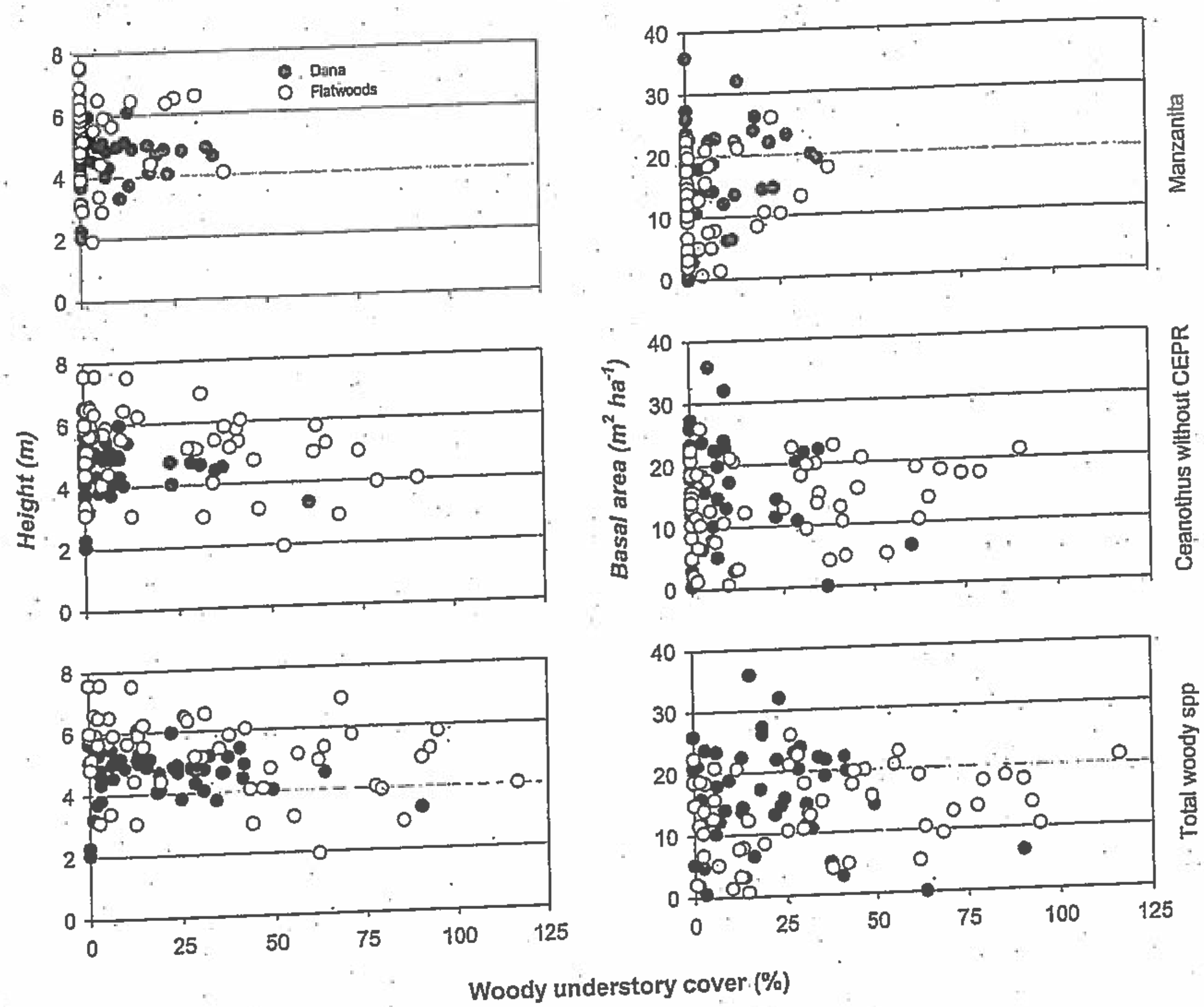

Figure 1. Relationships between woody understory cover (%) and 13th-year height and total basal area for ponderosa pine grown on various understory manipulation treatments and control on the Agenda 2020 sites at Dana and Flatwoods in northern California.

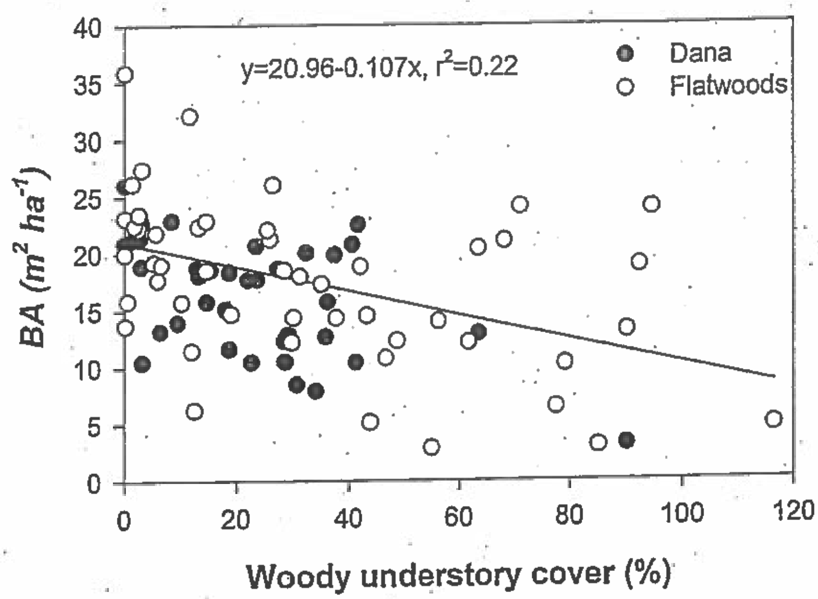

Figure 2. Relationship between woody understory cover (%) and 13th-year total basal area with tree survival rate greater than and equal to 50% for ponderosa pine grown on various understory manipulation treatments and control on the Agenda 2020 sites at Dana and Flatwoods in northern California.

Sierra Cascade Intensive Forest Management Research Cooperative
Income/Expense Statement
Calendar Year Report for the Period Jan. 1 to Dec. 31, 2017

Beginning Balance on January 1, 2017	$17,451.00
Total Income (Membership Dues)	$62,000.00
Expenses	
Boggs Remeasurement	$1,000.00
New Proposals	$26,037.00
Co-op Manager Expenses	$35,000.00
Storage Shed	$780.00
Total Expenses	$62,817.00
Year End Balance as of December 31, 2017	$16,634.00

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