EFFECTS OF SUB-IRRIGATION TUBES AND COVER TYPE ON WOODY PLANT ESTABLISHMENT[1]

Joseph D. Scianna[2], Elizabeth C. Graham, Robert W. Kilian, Darren P. Zentner, and Roger M. Hybner

Abstract. The survival and growth of trees and shrubs in arid regions of the western U.S. is often limited by inadequate soil moisture availability during establishment. This four year study investigated plant growth and water conservation benefits associated with sub-surface water delivery via PVC pipes (sub-irrigation tubes) on two sites. The first test site was maintained fallow, and the second site with a cover of thickspike wheatgrass *Elymus lanceolatus*. Four species of woody plants (bur oak *Quercus macrocarpa*; green ash *Fraxinus pennsylvanica*; ponderosa pine *Pinus ponderosa*; and Rocky Mountain juniper *Juniperus scopulorum*) were tested in randomized complete block designs. The effects of water delivery method (surface-applied versus sub-irrigation tube) and herbaceous competition (fallow versus vegetated) on plant survival, height growth, and vigor rating were compared. In year one, sub-irrigation tubes did not result in significant improvements (ANOVA, LSD Separation, p=0.05) in survival or height growth of any species on either site, but did result in significantly better vigor rating in bur oak on the vegetated site. In year two of the study, only green ash on the fallow site demonstrated significantly better height growth and vigor rating where sub-irrigation tubes were used. In year three on the fallow site, bur oak had significantly greater height growth and green ash had significantly better vigor rating where sub-irrigation tubes were used. Additionally in year three, ponderosa pine on the vegetated site had significantly better height growth where tubes were used. In year four on the fallow site, green ash had significantly better vigor rating where tubes were used. There were no significant differences in survival of any species on either site as a result of water delivery method. With the exception of ponderosa pine in year one, each species by treatment had equal or greater survival, height growth, and vigor rating on the fallow versus the vegetated site. Results strongly support clean cultivation to increase the functional success of tree and shrub conservation plantings. In addition, sub-irrigation tubes may prove effective for some species depending on proximity to the seedling's root system, severity of drought, and other management practices.

Additional Key Words: fallow; vegetated; soil moisture; competing vegetation; PVC pipe; survival; height growth; vigor rating.

---

[1] Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, ***Revitalizing the Environment: Proven Solutions and Innovative Approaches*** May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] Joseph D. Scianna, Research Horticulturist, USDA-NRCS, Bridger, MT 59014, Elizabeth C. Graham, Environmental Engineer & DATR Project Leader, Deer Lodge Valley CD, Bridger, MT 59014, Robert W. Kilian, Area Rangeland Specialist, USDA-NRCS, Miles City, MT, Darren P. Zentner, Biological Technician, USDA-NRCS, Bridger, MT 59014, and Roger M. Hybner, Manager, USDA-NRCS, Bridger, MT 59014.

Proceedings America Society of Mining and Reclamation, 2009 pp 1215-1226
DOI: 10.21000/JASMR09011215
http://dx.doi.org/10.21000/JASMR09011215

Introduction

Evaporative losses and competition for soil moisture, nutrients, and light from competing vegetation contributes significantly to the failure of tree and shrub (woody) plantings in the northern Great Plains and Intermountain West. A lack of adequate site preparation and poor control of sod-forming or rhizomatous grasses and forbs prior to tree and shrub installation frequently results in conservation planting failures. A common misconception is that modest supplemental watering offsets moisture losses from evaporation and competing vegetation. In order to determine the effects of water delivery method and herbaceous plant competition on woody plant survival and growth under a conventional irrigation schedule, two replicated studies were installed at the USDA-NRCS Plant Materials Center in Bridger, Montana, in May 2005.

Materials and Methods

Two deciduous species (bur oak *Quercus macrocarpa* Michx. and green ash *Fraxinus pennsylvanica* Marsh.) and two coniferous species (ponderosa pine *Pinus ponderosa* C. Lawson var. *scopulorum* Engelm. and Rocky Mountain juniper *Juniperus scopulorum* Sarg.) were tested on two sites in this study. All seedlings were 2-0 stock originating from northern plains seed sources and propagated at the Montana State Forest Tree Nursery, Missoula, Montana, and the Plant Materials Center, Bridger, Montana. These species were selected for their varied leaf retention characteristics and rooting patterns, two traits that may influence plant survival and growth relative to water delivery method. One test site was maintained fallow over the 2004 - 2008 growing seasons by a combination of mechanical and chemical weed control. The second site was maintained under a cover of established thickspike wheatgrass *Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould ssp. *lanceolatus*, with intermittent patches of bluebunch wheatgrass *Pseudoroegneria spicata* (Pursh) A. Löve, 'Bozoisky-Select' Russian wildrye *Psathyrostachys juncea* (Fisch.) Nevski, and sainfoin *Onobrychis viciifolia* Scop. Although planting directly into sites with established sod-forming grass is not a recommended practice, testing under these conditions is necessary to determine the ability of sub-irrigation tubes and subsurface watering to offset moisture loss from herbaceous competition.

The experimental designs were randomized complete block with three replicated blocks. Each block contained twenty seedlings of each of the four species, ten seedlings with sub-irrigation tubes, ten seedlings without sub-irrigation tubes. All seedlings were randomized within an individual block. Statistical analysis by Analysis of Variance (ANOVA), all pair-wise comparison, p=0.05 level.

In April 2005, planting holes were dug with a 20.3 cm (8-in) tractor-powered auger. Two hundred and forty seedlings were planted in the fallow site on April 25, 2005, and each watered with approximately 3.8 l (1 gal) of water. On April 26, 2005, 240 seedlings were planted in the vegetated site and watered with approximately 3.8 l (1 gal) of water. Seedlings at both planting sites were spaced 1.8 m (6 ft) within-row and 3.6 m (12 ft) between-row. On May 4 and 5, 2005, rigid seedling protectors were installed on all bur oak and green ash seedlings to prevent animal damage.

Irrigation tubes were installed in the fallow and vegetated sites on May 5 and May 6, 2005, respectively. Irrigation tubes consisted of 10.2-cm (4-in) inside-diameter non-perforated, polyvinylchloride (PVC) sewer pipe. Each pipe measured 91.4 cm (36 in) long, with 5.1-cm (2-in) wide, horizontal openings every 5.1 cm (2 in) along the length of the pipe, beginning 15.2 cm (6 in) from the top of the pipe. The width of each horizontal opening was approximately 3.2 mm (0.12 in). A 76- to 81-cm (30- to 32-in) deep hole was augured for each tube with a 10.2-cm (4-in) Giddings® soil probe. Tube holes were located approximately 25.4 cm ± 10.2 cm (10 in ± 4 in) upslope from the seedling with the tube openings facing the seedling. Each tube was inserted in the hole until approximately 76.2 cm (30 in) of the pipe was below ground and 15.2 cm (6 in) was above ground. Residual soil inside the tube was then removed with a hand auger. The inside base of each tube was sealed with a pre-moistened, baseball-size sphere of bentonite clay.

All seedlings in each site were watered on May 9 and 10, 2005. Trees with tubes received approximately 7.2 l (1.9 gal) in the tube plus 3.8 l (1 gal) on the soil surface around each plant. Trees without tubes received approximately 11.0 l (2.9 gal) on the soil surface only. This initial protocol was used to guarantee that some supplemental water reached the root systems of all trees during early establishment. Berms were constructed and irrigation systems designed at both sites to ensure that supplemental moisture applied to adjacent crops and fields did not become available to the test plants. All plants in the fallow site were given a second irrigation on May 27, 28, and 31, 2005, using the same method as previously described. All plants in the vegetated site were given a second irrigation on June 2, 2005, as previously described. The final irrigation of both sites occurred on July 22, 2005. No fall irrigation water was applied. Weeds were controlled in the fallow site each year by a combination of hand rouging, mechanical cultivation, and spot spraying with a 2 to 3 percent glyphosate solution. Tall competing plants in the vegetated site were controlled by mowing between-rows on May 26 and then again on June 23 and 24, 2005. Plant evaluations were conducted on September 27, 2005.

In late 2005 wetting front tests were conducted. This involved the application of water via sub-irrigation tubes, followed by excavation of the adjacent soil in order to visually determine where the water had moved in the soil profile. As a result of these trials, it was concluded that water applied through the tubes was not adequately reaching the root systems of trees with sub-irrigation tubes. In an attempt to remedy the situation, 76-cm (30-in) extensions were added to the top of each sub-irrigation tube in 2006, increasing storage capacity to approximately 13.2 l (3.5 gal) per tube. The initial watering protocol was also changed in 2006. Trees without tubes received 11.4 l (3 gal) directly on the plant, whereas trees with sub-irrigation tubes only received supplemental water via the tubes. Table 1 lists quantities of early growing season supplemental irrigation and natural precipitation over the course of the study. The influence of environmental factors (climatic trends, edaphic conditions, frequency and duration of rain events, etc.) on the availability of natural precipitation to plants must be considered when interpreting this data. It is worth noting that plant growth patterns did emerge in response to relative amounts of total growing season moisture.

Table 1. Supplemental irrigation and natural precipitation, 2005 through 2008.

Year	Amount of Supplemental Irrigation (April 1 – July 31) (in)	Amount of Natural Precipitation. (April 1 – July 31) (in)
2005	9.62	8.22
2006	9.62	2.32
2007	9.62	6.31
2008	4.81	5.20

RESULTS

	Cover	2005 Survival %	2006 Survival %	2007 Survival %	2008 Survival %	2005 Height Growth cm	2006 Height Growth cm	2007 Height Growth cm	2008 Height Growth cm	2005 Vigor Rating (1-9) 1=best	2006 Vigor Rating (1-9) 1=best	2007 Vigor Rating (1-9) 1=best	2008 Vigor Rating (1-9) 1=best
Field 3													
Oak-NT	fallow	100	100	100	97	24.5	27.3	8.6	5.0	3.8	3.6	3.1	4.3
Oak-T	fallow	100	100	100	97	20.6	18.8	17.2	0.1	4.2	3.9	3.5	4.0
Ash-NT	fallow	100	100	100	100	34.0	60.8	65.7	42.0	3.7	4.2	4.3	4.9
Ash-T	fallow	100	100	100	100	33.7	75.9	74.3	67.1	3.4	3.4	3.6	4.0
Pine-NT	fallow	100	100	100	100	6.3	18.2	19.9	39.1	3.9	3.2	2.6	3.4
Pine-T	fallow	100	100	100	100	6.3	10.7	21.9	34.4	4.2	4.0	3.3	3.8
RMJ-NT	fallow	100	100	100	100	14.9	38.2	38.9	36.7	3.5	2.7	2.2	2.7
RMJ-T	fallow	100	100	100	100	13.3	32.8	40.6	35.0	3.5	2.9	2.2	2.6
Field 14													
Oak-NT	veget.	100	90	90	80	15.4	-3.3	-18.4	-6.0	5.1	6.1	7.7	7.5
Oak-T	veget.	100	90	90	87	16.8	-2.3	-17.9	-2.2	4.6	6.0	7.2	6.9
Ash-NT	veget.	100	100	100	97	7.8	-2.4	-7.9	3.1	5.4	6.4	7.2	7.1
Ash-T	veget.	100	93	93	90	7.2	-2.1	-6.2	1.6	5.5	6.8	7.3	7.3
Pine-NT	veget.	100	100	97	90	10.0	5.1	-4.5	12.1	4.6	5.1	5.9	6.9
Pine-T	veget.	100	93	93	90	6.8	6.6	2.9	10.3	4.6	4.9	5.4	6.6
RMj-NT	veget.	100	100	100	100	8.0	3.0	-0.2	12.1	5.4	5.8	6.5	6.6
RMj-T	veget.	100	100	100	100	6.9	3.0	1.1	6.2	5.5	6.2	6.5	7.2

NT=No Tube
T=Tube
negative growth indicates tip dieback

Table 2. Sub-irrigation tube study results, Bridger PMC, 2005 through 2008.

Blue indicates a statistically significant positive effect when sub-irrigation tube is used ($p \leq 0.05$).
Red indicates a statistically negative effect when sub-irrigation is used or conversely, a positive effect when water is applied atop the seedling ($p \leq 0.05$).

RESULTS

Percentage Survival

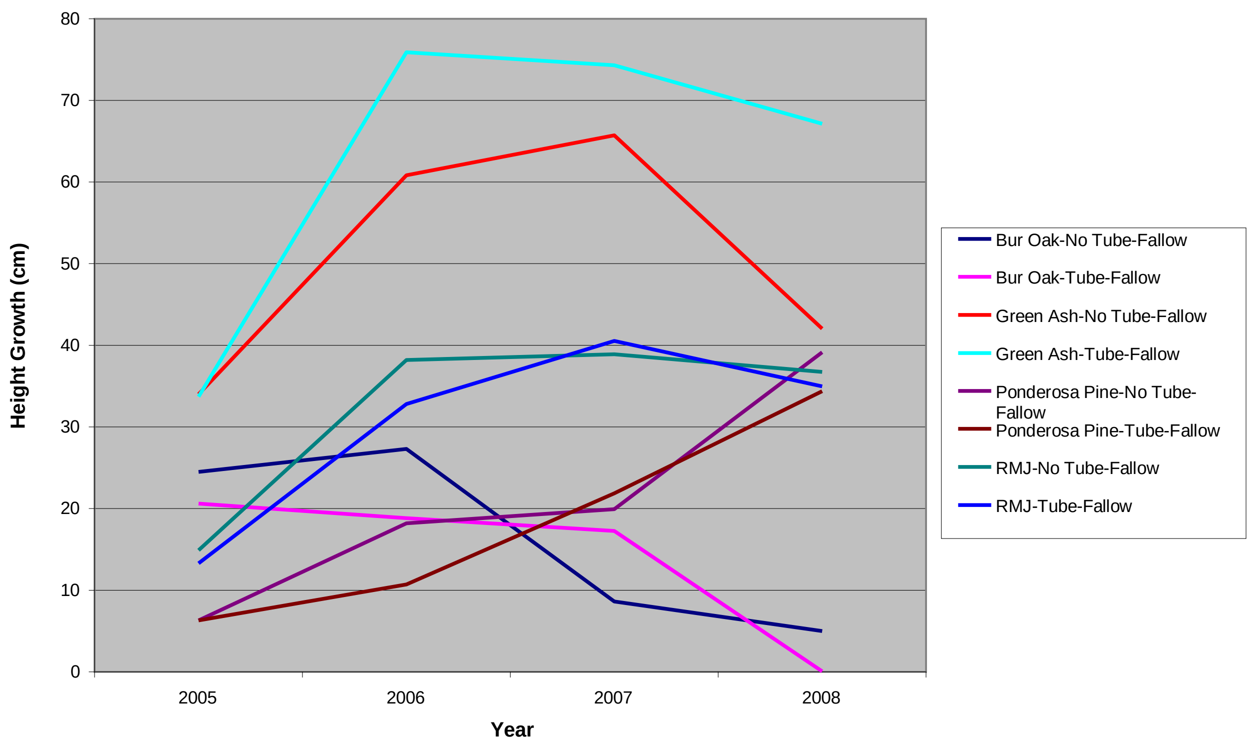
Percentage survival results appear in Table 2. There were no statistical differences in seedling survival in any given year within a species between irrigation methods ($p \geq 0.05$). By 2008, the overall mean survival on the fallow site was 99.2 percent as compared to 91.8 percent on the vegetated site. Of the four species tested on the vegetated site, only Rocky Mountain juniper maintained 100 percent survival over the course of the study.

Height Growth

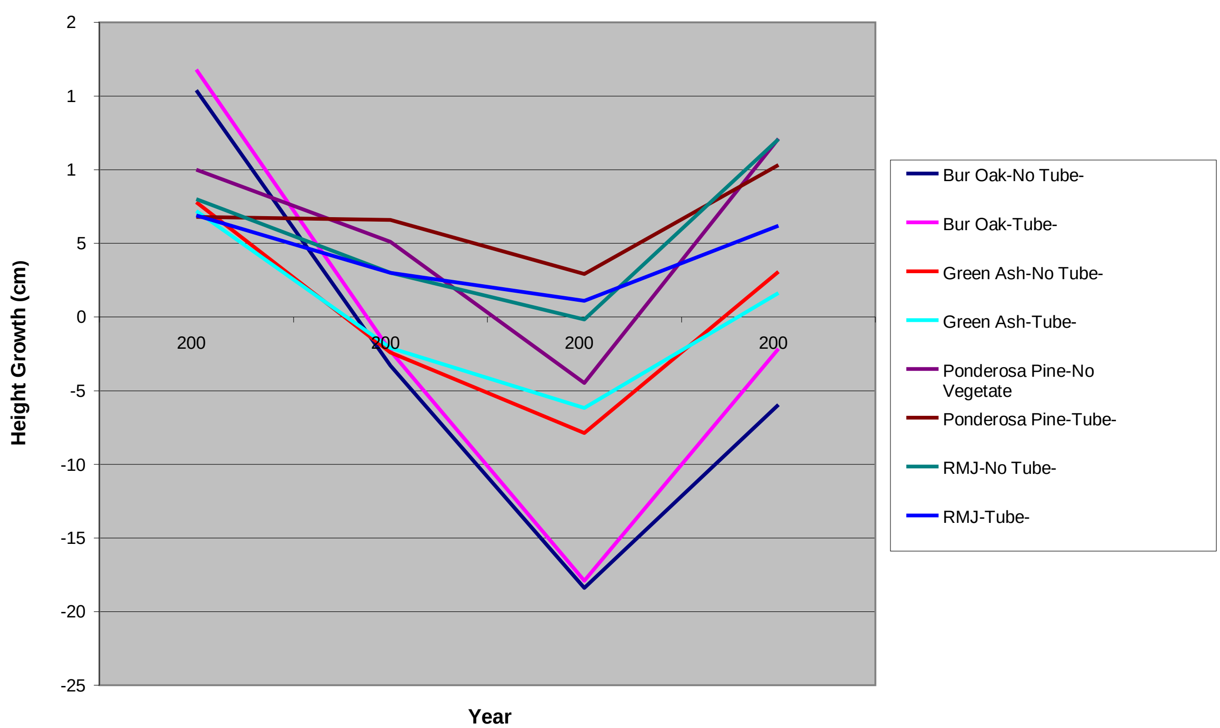
Height growth results appear in Table 2 and Graphs 1 and 2. In 2005, the only statistical difference in height growth resulting from irrigation method occurred on the vegetated site, whereas ponderosa pine without tubes had greater growth than ponderosa pine with tubes. In 2006 on the fallow site, green ash with tubes grew significantly greater than green ash without tubes, whereas bur oak without tubes grew significantly greater than bur oak with tubes. In 2007, bur oak with tubes on the fallow site and ponderosa pine with tubes on the vegetated site had greater growth than their respective counterparts without tubes. Although not statistically significant, green ash with tubes on the fallow site grew 8.6 cm (3.4 in) more in 2007 than trees without tubes. In 2008, bur oak without tubes on the fallow site and Rocky Mountain juniper without tubes on the vegetated site grew significantly greater than their counterparts with tubes. Once again, there was a large but not statistically significant difference in height growth on the fallow site between the irrigation methods with green ash, where trees with tubes grew 25.1 cm (9.9 in) taller than tree without tubes.

On the fallow site, there was a general pattern of increasing annual height growth from 2005 to 2006, mixed trends from 2006 to 2007, and a decreasing trend for most species from 2007 to 2008. The yearly pattern was quite consistent regardless of irrigation method. Exceptions included ponderosa pine that increased in height growth each successive year, and, in contrast, bur oak that tended to decrease in annual height growth over time. On the vegetated site, annual height growth decreased for all species and irrigation methods from 2005 to 2007. Growth rate increased for all species, however, from 2007 to 2008 for both irrigation methods, but remained well below annual growth rates on the fallow site. With the exception of ponderosa pine in 2005, height growth each year on the fallow site was greater than the vegetated site for a given species by irrigation method.

Graph 1 - Fallow Site - Height Growth Over



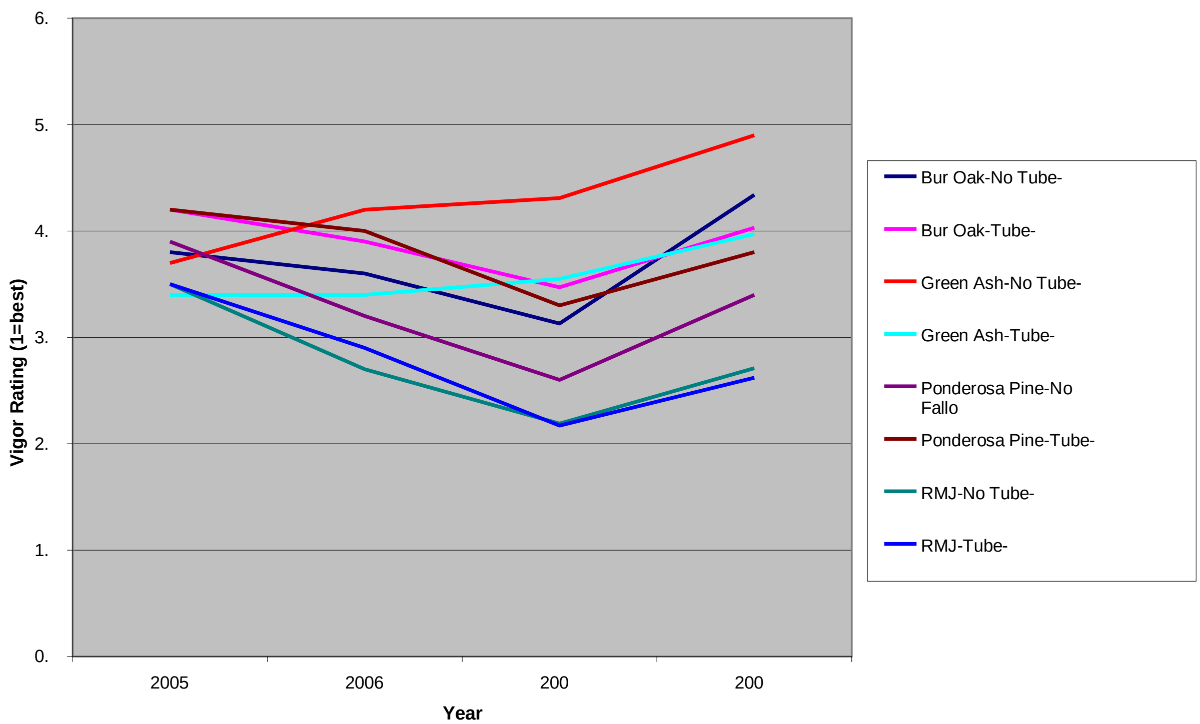
Graph 2 - Vegetated Site - Height Growth Over



Vigor Rating

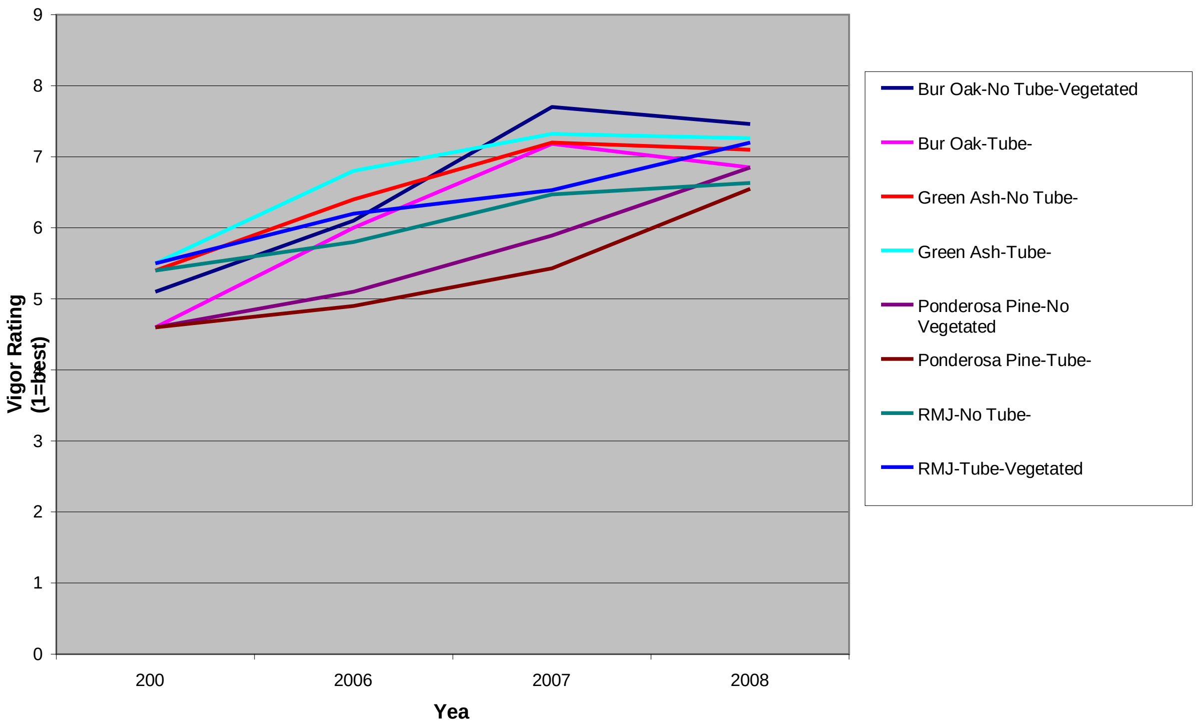
Vigor rating results appear in Table 2 and Graphs 3 and 4. A rating of "1" is best and "9" is worst. Vigor rating is a visual estimation of the health and vitality of the plant based on characteristics such as leaf or needle color and condition, overall plant form, rates of growth, and general plant condition in response to stress. In 2005, bur oak with tubes had significantly better (lower value) vigor rating than trees without tubes on the vegetated site. In 2006, green ash with tubes had significantly better vigor rating on the fallow site than trees without tubes. In contrast, both green ash and Rocky Mountain juniper on the vegetated site had significantly better vigor rating when sub-irrigation tubes were not used. In 2007, green ash with tubes and ponderosa pine without tubes had significantly better vigor rating than their irrigation treatment counterparts on the fallow site. No differences in vigor rating based on irrigation method emerged in 2007 on the vegetated site. In 2008, green ash with tubes on the fallow site had significantly better vigor rating than green ash without tubes. Similarly, Rocky Mountain juniper without tubes on the vegetated site had significantly better vigor rating than juniper with tubes.

Graph 3 - Fallow Site - Vigor Rating Over Time



The overall mean vigor rating on the fallow site was 3.7 in 2008, whereas the overall mean vigor rating on the vegetated site was 7.0. For a given species, mean vigor rating on the fallow site was always better than on the vegetated site.

Graph 4 - Vegetated Site - Vigor Rating Over Time

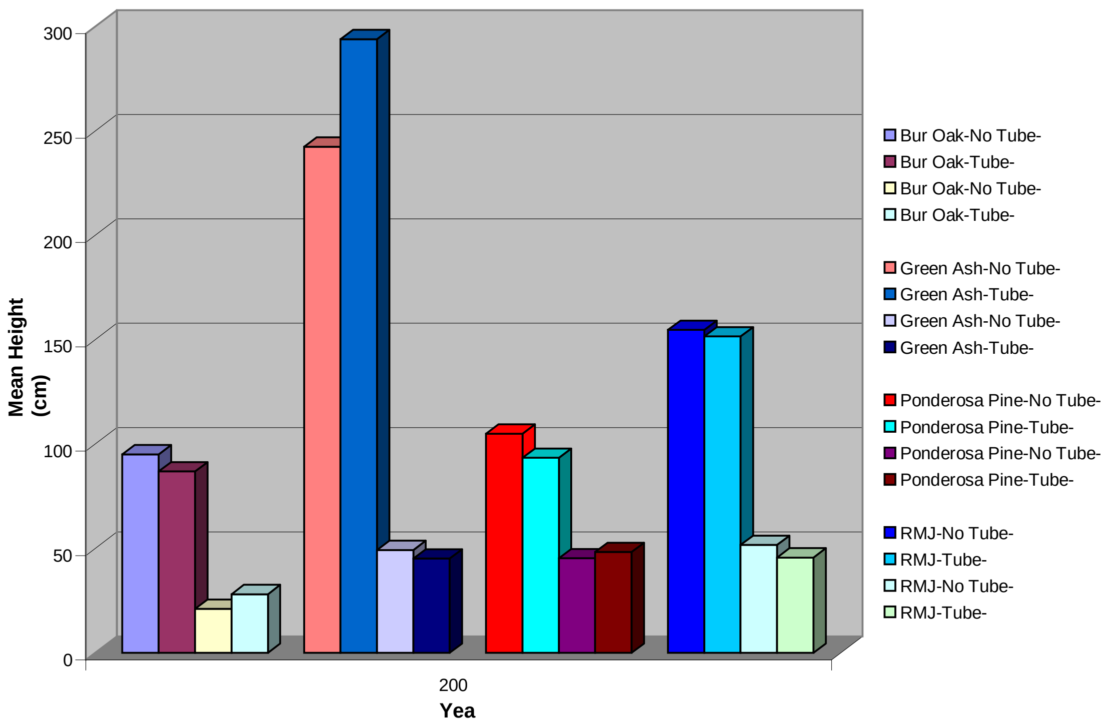


With the exception of green ash, there was improved vigor rating (decreasing value) from 2005 to 2007 on the fallow site. From 2007 to 2008, all species, regardless of irrigation method, declined modestly in vigor rating on the fallow site. On the vegetated site, there was a uniform trend of decreasing vigor rating over time, although bur oak improved modestly from 2007 to 2008, especially trees with tubes.

<u>Mean Height</u>

Mean height results in 2008 appear in Chart 1. Although this parameter was not used for statistical comparison, it is interesting to compare height as a function of irrigation method and cover type. Images of green ash on the fallow and vegetated sites in 2008 appear in Fig. 1 and 2, respectively.

Chart 1 - Mean Height All Species



CONCLUSIONS

Seedling survival remained relatively high on both sites over the course of the study, although plant height growth and vigor decreased substantially over time on the vegetated site. Decreasing annual height growth on the fallow site with green ash and bur oak largely reflects deer browse and injury in 2006 and 2007, as well as below average precipitation in 2006. A dry 2006 growing season had a much more pronounced effect on growth on the vegetated site in 2007 than on the fallow site. Consistently superior growth and vigor on the fallow versus the vegetated site of green ash with sub-irrigation tubes probably resulted from roots of this fast growing species accessing soil moisture near tubes quicker than other species. Positive effects of surface watering alone on the vegetated site reflect placement of supplemental water in closer proximity to the root zone of establishing seedlings, primarily shallow-rooted Rocky Mountain juniper. Vegetative cover was more competitive for deep soil moisture than juniper seedlings, thereby negating any positive effects of subsurface supplemental moisture. If it is possible for supplemental irrigation to offset competition from herbaceous cover, the quantity and/or placement of water will have to be adjusted. All species demonstrated stress-induced dormancy on the vegetated site which may limit growth potential on any given year.

Figure 1 – Green ash on fallow site 2008 Figure 2 - Green ash on vegetated site 2008

Based on these results, the initial distance between sub-irrigation tubes and seedlings ~25 cm (~10 in) was too great. It is likely that deep placement of sub-irrigation tubes will only prove effective during early establishment if seedlings have sufficiently long root systems to be placed directly along a substantial length of the tubes. Additional studies are needed in which the distances between tubes and seedlings are minimized, and tubes are only buried 15.25 to 25.4 cm (6 to 10 in) below the surface of the soil. This configuration may reduce the time and cost of tube installation, improve water delivery to the seedling, facilitate retrofitting of established plantings with tubes, and allow easy removal and re-use of tubes. It may also be possible to utilize the above ground portion of tubes as anchors for animal protection devices and windscreens.

Results from this study strongly support the practice of controlling herbaceous competition to improve seedling height growth and vigor rating during early tree and shrub establishment. This recommendation is based on the species, irrigation schedule, and methods used in this study. Subsurface delivery of water did not generally offset competition from herbaceous vegetation given the amount and frequency of supplemental watering used in this experiment. Attainment of functional plant size and desired stage of development for various conservation practices will be impossible or substantially delayed if herbaceous competition is not minimized.

Acknowledgements

This study supports on-going field research funded in part by a Grazing Lands Conservation Initiative grant sponsored by the Little Beaver County Conservation District. This study is conducted in cooperation with the Montana Department of Natural Resources and Conservation and the Montana Conservation Seedling Nursery in Missoula, Montana.