AERIAL SPRAYING FOR JUNIPER CONTROL IN CENTRAL WEST TEXAS

A Thesis

Presented to the

Faculty of the Graduate School of

Angelo State University

In Partial Fulfillment of the

Requirements for the Degree

MASTER OF SCIENCE

by

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December 2013

Major: Animal Science

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ABSTRACT

Juniper (*Juniperus* sp.) invasion lowers forage and animal production. The objectives of the study are (1) to compare of four different Picloram (Trooper 22K) and Edict 2SC mixtures through aerial spraying during the spring, (2) to compare of understory vegetation before aerial spraying and after aerial spraying, and (3) evaluate cost effectiveness of the aerial spraying method. The herbicides were applied at either 946 ml. recommended or 1890 ml. double of Picloram along with 59 ml. or 88 ml. of Edict. Canopy cover of all woody species and forage production were similar among treatments (P>0.05). Mortality rates of juniper varied from 63 to 95% on treated plots with no mortality of juniper noted on the control plots. Aerial spraying increased mortality of juniper when compared to the control plots. Inclusion of higher rates of Edict did not affect mortality rates.

ACKNOWLEDGMENTS

I wish to thank various people for their contribution to this project; John Quinn, owner of the ranch, for allowing this project to be conducted on his ranch; North Star Helicopters, for their donation and assistance in the aerial application of chemicals; Nufarm Americas, for the donations of the chemicals for this project. Special thanks should be given to Dr. Scott, my research project supervisor, for his professional guidance and valuable support and my committee of Dr. Salisbury, Dr. Branham, Dr. Taylor, for their useful and constructive recommendations on this project. I would like to thank Professor Owens, Grant Rogers, and Zach Borrom for the assistance in collecting canopy cover, forage production, and mortality data.

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INTRODUCTION

The encroachment of both ashe (*Juniperus ashei Buchh.*) and redberry (*Juniperus pinchotti Sudw.*) juniper species was estimated to have started in the 1800s and spread to deeper soiled clay flats, bottomlands and valleys as grazing increased and fire frequency declined. Adams and Zanoni's (1979) reported a spread of juniper from Amarillo to San Angelo predominately redberry juniper (Ansley et al. 1995). Ashe juniper typically dominates areas south of San Angelo, throughout the Edwards Plateau vegetation type (Smeins et al. 1997). The encroachment of both species has resulted in degradation of the grass communities, beneficial woody species, and biological diversity. Mature juniper stands have a dense canopy cover that reduces sunlight from penetrating (Ueckert 1997). In addition, the canopy of juniper trees intercepts precipitation resulting in increased water evaporation (Thurow et al. 1997). Without sufficient amounts of sunlight and precipitation, forage production steadily declines. Monoterpenes that are produced on the leaves of juniper plants further prohibit forage production once leaf senescence occurs, because the monoterpenes reduce soil bacterial degradation of organic material. Gerolini (1996) reported that forage production decreased at an increasing rate until the juniper canopy cover reached 34%. At that point, very little herbaceous production remains.

The control options for juniper are mechanical, chemical, and fire. Mechanical controls include chaining, grubbing, and root plowing. The cost

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of mechanical controls has risen in the last several years reducing the economic feasibility of the method (Johnson et al.1999). The high price of fuel has further limited the amount of mechanical control in the past five years. In addition, mechanical control techniques have limitations because of the site characteristics. If the area with a large juniper stand is on a rocky site, increased labor and equipment costs reduce the economic feasibility of mechanical brush control options.

The density of juniper also affects the cost of control. Mechanical control may exceed $400/ha when density is a high number of juniper trees per acre. Chemical control of juniper is typically not feasible because of low mortality rates and cost for controlling large stands of juniper trees. Picloram and Hexazonine can be used to chemically treat and kill small juniper (e.g., under 4 ft), but the volume of herbicide to treat large trees results in costs exceeding feasibility.

Fire was the primary control of juniper before settlement by Europeans. Wildfires controlled the spread of juniper to mainly rocky outcrops, dry hills, and any-where protected from wildfires. Prescribed burning effectively controls ashe juniper when sufficient grass production provides sufficient fuel for fire conditions that result in topkill. In addition, prescribed burning results in mortality of redberry juniper seedlings but mature redberry juniper plants usually re-sprout following fire. Redberry juniper possesses a basal bud zone that results in resprouting after fire. The bud zone is typically exposed above the soil surface in seedlings resulting in plant mortality. Unfortunately, fire is not an option in many locations characterized by dense stands of juniper because of a lack of grass cover to provide the necessary fuel for a fire resulting in juniper topkill and seedling mortality.

Aerial spraying of mesquite is an effective and economically feasible method of control (Ames 2006). Unfortunately, aerial spraying of juniper has not been successful. However, recent development of new herbicide mixtures may offer some promise of juniper control through aerial application.

The purpose of this project was to determine the feasibility of aerial spraying to control junipers. The herbicide mixtures of this project were Picloram (Trooper 22K) with Edict 2SC. The herbicide products are Nufarm Americas brands (Alsip, IL). Trooper 22K is a Picloram: 4-amino-3, 5, 6-trichloropicolinic acid, potassium salt. This herbicide has shown sporadic results on juniper control during the fall application. There is some indication that the kill rates from Picloram applications can be improved when the mixture is doubled and applied during the spring. In addition, there is some indication that the addition of Edict 2SC with Picloram may increase mortality rates. Edict 2SC is a pyraflufen ethyl: ethyl-2-chloro-5-(4-chloro-5-difluoromethoxy-1-methy-1-H-pyrazol-3-yl)-4-fluorophenoxyacetate. Nufarm tested the fall application of this Picloram and Edict 2SC mixture which resulted in little to no control of juniper. This study included the comparison of four different Picloram and Edict 2SC mixtures through aerial spraying during the spring, the comparison of understory vegetation on sprayed and unsprayed, and the cost effectiveness of aerial spraying for ashe juniper control.

OBJECTIVES

The objectives of this study were to:

1. compare the efficacy of Picloram and Edict 2SC mixture for juniper control,
2. compare herbaceous forage production on treated and non-treated locations, and
3. compare the cost effectiveness of the aerial spraying method.

LITERATURE REVIEW

Removal of juniper has shown to increase water yield from rangelands in Edwards Plateau by decreasing interception and evapo-transpiration losses (Hester 1996). Thus, the presence of an over-story canopy of juniper reduces the amount of water reaching the ground, decreases herbaceous forage production, and decreases stocking rates (Dye et al.1995). Increases in juniper also reduce overall plant diversity thereby decreasing wildlife habitat as well (Engle et al. 1987; Armentrout and Pieper 1988; McPherson and Wright 1990).

Redberry and ashe juniper can both be controlled with high volume foliar sprays containing 1 % Picloram (sold under the trade names of Tordon or Trooper 22K) or soil treatments of undiluted Velpar (Hexazinone) applied at 3 ml/1m of juniper height or diameter, beneath the juniper canopy (Welch 1995; McGinty and Ueckert 1996, 1997). Costs of labor and herbicides escalate rapidly in dense or mature junipers (Ueckert 1997). Nevertheless, chemical control may be more cost-effective in many situations. Young et al. (1982) reported a lower investment in time and cost when applying picloram by hand compared to mechanical clearing of western juniper (*Juniperus occidentalis spp. occidentalis Hook.*).

Historically, junipers were probably limited to shallow soils and rocky outcrops (Bray 1904). These areas typically would not produce sufficient herbaceous cover to provide the necessary fuel for wildfires, which probably limited juniper cover on more productive sites when wildfires were common. In the 1800's, the increase of grazing pressure for domestic livestock reduced forage production and fire fuel loads on the majority of the Edwards Plateau resulting in a dramatic decrease in wildfire frequency (Ueckert 1997). The ecological site went from a fire climax community to suppressed fire grasslands with increased woody species (Archer et al. 1995; Van Auken and Bush 1997; Van Auken 2000). Fire suppression perpetuates the dominance of woody species over more palatable grasses and forbs (Smein et al. 1997). Today, juniper dominates the majority of rangelands in the Edwards Plateau, with little grass cover remaining.

Recent efforts have shown that both sheep and goats consume juniper after conditioning a preference for the plant (George et al. 2010; Anderson et al. 2013). Both species can be fed juniper at weaning, increasing an acceptance of the plant. Once released on pasture, they continue to consume juniper, especially during periods when herbaceous quality is reduced. Dietz et al. (2010) showed that goats consumed juniper throughout the year on juniper-dominated rangelands, with juniper making up 30% of the diet in some months.

Although goats may be effective in reducing cover and removing juniper seedlings, goat browsing rarely results in plant mortality. In addition, fire is effective in controlling redberry juniper seedlings, but rarely kills mature trees. With sufficient grass cover, fire may be an option for ashe juniper control as well. Given the high cost of mechanical control, other cost-effective methods of controlling mature juniper are needed. This study hopes to identify a cost-effective method of controlling mature juniper trees using aerial spraying during the spring.

METHOD AND MATERIALS

The effects of chemical control with different rates of application on ashe juniper were evaluated three years after the initial application. The location of the chemical control test plots were located on the Quinn Ranch, which is 10.07 km southwest of Brady, TX (lat. 31° 2' 14.17", long. 99° 23' 14.66"). The pasture provided a consistence in soil type and vegetative representatives of the target species. The soil type for all the test plots was Tarrent soils (USDA-NRCS 2013). The characteristics of Tarrent soil are a clay loam with limestone outcrops. The limestone outcrops were found in eight percent slopes and created a stoney shallow soil for the area.

The vegetation prior to initial application of the test plots consisted primarily of ashe juniper and live oak (*Quercus virginiana, Mill.*). The interspaces had small clumps of mixed vegetation of prickly pear (Opuntia sp. Mill.), algerita (*Berberis trifoliolata, Moric.*), and Texas persimmon (*Biospyros texana, Scheele.*). The grasses were three awns (*Aristidea sp.*) and buffalo grass (*Buchloe dactyloides, Nutt.*). The test plots and surrounding pasture had rapidly moved into a closed canopy oak/juniper woodlands. The lack of ground cover diminished the control options of fire and further lowering the animal production.

Experimental units were placed into a block form on the same soil type with similar juniper densities. Two main blocks were created within the high density juniper and live oak. The two main blocks were further divided into eight plots in the first block and two in the remaining block. The eight plots were created to compare the mixture rates.

The size of the test plots were 1.34 ha. Test plots were large enough to allow the placement of transects in any angle and not have chemical overlap. Each plot was treated with one of four chemical mixtures. The chemicals were Picloram (Trooper 22K) and Edict 2SC (Pyraflufen ethyl). The application amounts were either 946 ml. or 1890 ml. of Picloram along with 59 ml. or 88 ml. of Edict 2SC. All plots were sprayed at the same time in May 2011. Targeted wind speeds were between 8 -16 kph and targeted air temperatures were between 29 and 35^{o}C.The canopy cover was collected from 30 randomly placed 30-m transects (n=30) along with juniper canopy cover and herbage production estimated using 10 randomly placed .33m^2 quadrats/plot.

Juniper canopy cover was determined by the line intercept method (Bonham 1989). The line intercept method included 3 (30m long) line transects in a random direction within each of the plots. The canopy cover was determined for all woody species and recorded as live or dead. Herbage production was estimated by 10 clipping 0.33-m^2 quadrats located randomly within each plot (Bonham 1989). All samples were hand-clipped by species and weighed separately after drying. The clip samples were dried at 16^{o}C for 48 hours, weighed and converted to kg $\cdot$ ha^{-1} to estimate aboveground biomass. Data was collected three years after treatment.

Data was analyzed using analysis of variance with chemical treatment as the main effect. Plots nested within treatments served as replications. Data was analyzed using the statistical package JMP (SAS 2007). Means were separated using Tukey's Protected LSD when $P \leq 0.05$.

RESULTS

Plant species present in the plots include ashe juniper, live oak. Plots had small clumps of mixed vegetation of prickly pear, algerita, and Texas persimmon. The grasses were three awns and buffalo grass.

Plots had moderate canopy cover of juniper on non-treated plots and on treated plots prior to treatment (Initial canopy cover was not measured). Treatment with herbicides did not differ ($P>0.05$) in canopy cover of juniper compared to the control treatment (Table 1). Treatment with herbicides did not affect cover of other shrubs or total canopy cover of woody plants. There was no difference ($P>0.05$) in the mean forage production between treatments and treated plots versus control plots (Table 2).

Mortality was observed in all treatments. Juniper mortality did not differ ($P>0.05$) among treated plots. Juniper mortality was 95% in 946 ml. of Picloram with 59 ml. of Edict and lowest 62.67% in 1891 ml. of Picloram with 88 ml. of Edict 2SC (Table 3). However, juniper mortality was higher ($P<0.05$) when each 946 and 1891 ml of Trooper were applied with 59 ml of Edict when compared to the control treatment. Increasing the amount of Edict from 59 ml to 88 ml, did not improve ($P>0.05$) mortality rates of juniper. None of the herbicide mixtures used in the study affected mortality rates of other shrubs in the plots.

Increasing the amount of Trooper from 946 ml to 1891 ml increased the cost of application by $20/ha (Table 4). Increasing the amount of Edict from 59 to 88 ml increased the cost of application by $3/ha.

Table 1. Canopy cover (%) for juniper, live oak, and other shrubs by treatment

Treatment ($ml \cdot ha^{-1}$)		Canopy Cover (%)			
Picloram	Edict	Juniper	Live Oak	Other Cover[b]	Total Cover
1890	59	6.5	1.9	0.1	8.9
946	59	8.5	2.1	0.0	10.5
1890	88	5.7	1.6	0.3	7.8
946	88	4.7	1.2	0.1	6.1
Control[a]		6.2	1.6	0.5	7.9

[a] Control received neither Picloram or Edict
[b] Other Cover included persimmon, algerita

Table 2. Mean forage production by treatment as warm season grasses (WSG), cool season grasses (CSG), forbs, and total forage production

Treatment (ml · ha^{-1})		Forage Production (kg · ha^{-1})			
Picloram	Edict	WSG	CSG	Forbs	Total
1890	59	149.7	725.3	365.3	1240.3
946	59	366.6	589.5	188.4	1156.5
1890	88	339.9	649.3	99.1	1088.3
946	88	455.7	477.4	128.1	1070.8
Control[a]		657.5	391.8	193.4	1242.6

[a]Control received neither Picloram nor Edict

Table 3. Mean Mortality (%) for juniper, live oak, and other shrubs by treatment

Treatment ($ml \cdot ha^{-1}$)		Mortality (%)		
Picloram	Edict	Juniper	Live Oak	Other Shrubs
1890	59	90.5[a]	0.0	1.0
946	59	95.0 [a]	20.0	0.0
1890	88	62.7 [ab]	5.0	33.3
946	88	70.0 [a]	56.7	0.0
Control[c]		0.0 [b]	8.3	33.3

[a-b]Means with different superscripts differ ($P<0.05$).
[c]Control received neither Picloram nor Edict

Table 4. Cost of juniper aerial spraying by treatment (\$ per ha^{-1})

Treatment ($ml \cdot ha^{-1}$)		Cost ($\$ \cdot ha^{-1}$)
Picloram	Edict	
1890	59	85.40
946	59	65.40
1890	88	87.40
946	88	67.40
Control[a]		---

[a]Control received neither Picloram nor Edict

DISCUSSION

Based on assessment of canopy cover and forage production, aerial spraying with Picloram and Edict had little impact on forage dynamics. Canopy cover of all woody species, including juniper, were similar among treatments. Forage production was also similar among treatments. Based on an initial visual inspection of the plots, aerial spraying with Picloram and Edict appeared to increase juniper mortality. Indeed, preliminary assessment of the results (Table 3) appears to support this assumption. Mortality rates of juniper varied from 95 to 63% on treated plots with no mortality of juniper noted on the control plots. Treatment with picloram increased mortality of juniper when compared to the control treatment. However, inclusion of higher rates of Edict had no apparent impact on juniper mortality. Similarly, doubling the recommended rate of Picloram did not increase mortality of juniper.

For this study, there were only two replications per treatment, limiting the degrees of freedom and the likelihood of showing a statistical difference. Including more replications of each treatment would have increased the statistical power of the study and the likelihood of illustrating a statistical difference. Other experimental design flaws were also evident. For instance, to assess the potential benefit of including Edict, the study should have included two other treatments, 946 ml of Picloram and 1891 ml of Picloram without Edict. In addition, baseline data should have been collected on all plots, prior to treatment allocation. Baseline data on canopy cover and herbaceous forage production would have been useful in assessing the benefits of aerial spraying for juniper control.

The juniper control method of aerial spraying was applied in May. Most attempts to control juniper with aerial applications have been applied in the summer or fall. These efforts have shown little to no mortality of juniper from aerial spraying. Given the apparent increased mortality rates observed in this study, future studies should compare seasonality of aerial applications on control of juniper.

Control of juniper benefits the biodiversity of the rangelands (Whitson et al. 1975). Even with the lack of statistical differences and questionable experimental design, there is a trend toward reduced cover of juniper. Many landowners would like to initiate a prescribed burning program to reduce both prickly pear and juniper cover but existing juniper densities often limit grass production that is essential fuel for fire. Regardless of the control method used, a reduction in juniper cover may be necessary to produce sufficient grass cover for future prescribed burning efforts.

Cost data for this study illustrate that aerial spraying for juniper control is relatively expensive with questionable increases in forage production. Based on the cost of application, aerial spraying for juniper does not appear to be an economically feasible control option. Mechanical brush control options, like grubbing, are effective in resulting in juniper mortality and increases in herbaceous forage production for similar costs at moderate densities.

Picloram is a restricted use herbicide. Application of restricted use herbicides are closely regulated by the Texas Department of Agriculture (TDA) and the Environmental Protection Agency (EPA). Picloram is classified as a restricted use herbicide because it is hydrophilic and has shown up in underground water supplies, especially when higher concentrations are applied. It seems highly unlikely that TDA and (or) the EPA would approve concentrations above 946 ml/ha (recommended rate). The western half of the Edwards Plateau is dominated by juniper on fractured limestone soils. The region is the primary recharge zone for the Edwards Aquifer. Given its hydrophilic nature, it seems highly unlikely that higher treatment rates would be approved for use in the Edwards Plateau vegetation type.

CONCLUSION

Few conclusions can be drawn from the current study given the limitations of the experimental design. Based on the observations of the study, the following study is proposed for future graduate student efforts. Initially, each treatment should be applied to individual trees. A minimum of 3 replications per treatment with a minimum of 10 trees per treatment should be utilized. The same design is commonly used in evaluation of different herbicides for mesquite control and provides sufficient statistical power. Treatments should consist of (1) control, (2) Picloram alone, (3) Picloram with 59 ml of Edict, and Picloram with 88 ml of Edict. These treatments should be applied to different trees in spring, summer, fall, and winter using the approved recommended rates of Picloram (946 ml/ha). In addition, treatments and seasons should be applied to different soil types/locations. Baseline data of cover and herbaceous forage production should be collected. Vegetation response to treatments should be monitored for 3 years. If differences are observed, then treatments could be re-applied using aerial application procedures.

LITERATURE CITED

Adams, R. P., and T. A. Zanoni. 1979. The distribution, synonymy, and taxonomy of three junipers of southwestern United States and Northern Mexico. *Southwestern Naturalist* 24:323-329.

Ames, C. R. 2006. Mesquite Control on the Coronado National Forest. *Journal of Range Management* 19:148-150.

Anderson, J. R., C. B. Scott, C. A. Taylor, Jr., C. J. Owens, J. R. Jackson, D. K. Steele, and R. Brantley. 2013. Using experience and supplementation to increase juniper consumption by three breeds of sheep. *Rangeland Ecology and Management* 66:204-208.

Ansley, R. J., W. E. Pinchak, and D. N. Ueckert. 1995. Changes in Redberry Juniper Distribution in Northwest Texas (1948 to1982). *Rangelands* 17:49-53.

Archer, J., D. S. Schimel, and E. A. Holland. 1995. Mechanisms of shrubland expansion: land use, climate, or CO_2. *Climate Change* 29:91-99.

Armentrout, S. M., and R. D. Pieper. 1988. Plant distribution surrounding Rocky Mountain pinyon pine and oneseed juniper in south-central New Mexico. *Journal of Range Management* 41:139-143.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley & Sons, Inc., New York, N.Y. p.19-47.

Bray, W. L. 1904. The timber of the Edward Plateau of Texas: Its relation to climate, water supply, and soil. *In:* U.S. Department of Agriculture, Bureau of Forestry Bulletin 49.

Dietz, T. H., C. B. Scott, E. J. Campbell, C. J. Owens, C. A. Taylor Jr., and R. Brantely .2010. Feeding Redberry Juniper (Juniperus pinchotii) at Weaning Increases Juniper Consumption by Goats on Pasture. *Rangeland Ecology & Management* 63:366-372.

Dye, K. L., D. N. Ueckert, and S. G. Whisenant. 1995. Redberry juniper-herbaceous understory interactions. *Journal of Range Management* 48:100-107.

Engle, D. M., J. F. Stritzke, and P. L. Claypool. 1987. Herbage standing crop around eastern redcedar tree. *Journal of Range Management* 40:237-239.

George, C. H., C. B. Scott, T. R. Whitney, C. J. Owens, B. J. Mays, and R. Brantley. 2010. Supplements containing escape protein improve redberry juniper consumption by goats. *Rangeland Ecology and Management* 63:655-661.

Gerbolini, A. J. 1996. Economics evaluation of redberry juniper control in Texas Rolling Plains. H.S. Thesis Dept. of Agricultural and Applied Economics., Texas Tech University. Lubbock, TX.

Hester, J. 1996. Influence of woody dominated rangelands on site hydrology and herbaceous production[thesis]. Edwards Plateau, Texas. Texas A&M University.

Johnson, P., A. Gerbolini, D. Ethridge, C. Britton, and D. Ueckert. 1999. Economics of redberry juniper control in the Texas Rolling Plains. *Journal of Range Management* 52:569-574.

McGinty, A., and D. Ueckert. 1996. Brush Busters how to master cedar. Three Safe and effective ways to control small cedar (juniper). *In:*Texas Agricultural Extension Service and Texas Agricultural Experiment Station Leaflet L-5160.

McGinty, A., and D. Ueckert. 1997. Brush Busters: a program to market tactical brush management technology to landowners. *In Proc*: 1997 Juniper Symposium. San Angelo, Texas. Texas Agricultural Experiment Station.

McPherson, G. R., and H. A. Wright. 1990. Establishment of Juniperus pinchottii in Western Texas: environmental effects. *Journal of Arid Environment* 19:283-287.

SAS Institute. 2007. JMP User's guide, Version 3.1 *SAS Institute Inc*., North Carolina 487 p.

Smeins, F. E., M. K. Owens, and S. D. Fuhlendorf. 1997. Biology and ecology of Ashe (Blueberry) juniper. P. 9-24. *TX.* A&M University Research Station at Sonora, Juniper Symposium 1994. Tech Rep. 94-2.

Thurow, T., A. Thurow, R. Conner, and C. Taylor. 1997. Trade-offs on landscapes dominated by juniper . *In Proc*: Juniper Symposium. San Angelo, Texas. Texas Agricultural Experiment Station.

Ueckert, D. N. 1997. Juniper Control and Management. In: Proc. Juniper Symposium. San Angelo, TX. Texas Agricultural Experiment Station.

USDA-NRCS. 2013. Ecological Site Description. Available at: http://esis.sc.egov.usda.gov. Accessed 29 October 2012.

Van Auken, O. W. 2000. Shrub invasions of North American semi-arid grasslands. *Annual Review of Ecology and Systematics* 31:197-215.

Van Auken, O. W., and J. K. Bush. 1997. Growth of Prosopis glandulosa in response to changes in aboveground and belowground intergerence. *Ecology* 78:1222-1229.

Welch, T. G. 1995. Chemical weed and brush control suggestions for rangelands. *In:*Texas Agricultural Extension Service Bulletin B-1466 27p.

Whitson, R. E., C. J. Scrifes, and D. B. Polk, Jr. 1975. Economic efficiency of ash juniper control in the Edwards Plateau. *In:* Rangeland Resources Research 1971-1974. Texas Agricultural Experiment Station College Station, TX PR-3341.

Young, J. A., R. A. Evans, J. D. Budy, and A. Torell. 1982. Cost of controlling maturing western juniper trees. *Journal of Range Management* 35: 437-442.