Proceedings
THIRD ANNUAL CONFERENCE

Terre Haute, Indiana June 2-3, 1983

Sponsored by: Amax Coal Company, Purdue University, Southern Illinois University, Madisonville Community College

Proceedings

of the Third Annual

BETTER RECLAMATION WITH TREES CONFERENCE

Edited by

P. E. Pope
Department of Forestry and Natural Resources
Purdue University

Terre Haute, Indiana

June 2-3, 1983

1983 THEME: ESTABLISHMENT PRACTICES

Hosted by:

Meadowlark Farms, Inc. and AMAX Coal Company

Department of Forestry and Natural Resources, Purdue University

Sponsored by:

AMAX Coal Company

Purdue University

Southern Illinois University

Madisonville Community College

METHODS FOR ESTABLISHING CONTAINERIZED NATIVE JUNIPER ON SURFACE DISTURBED SITES IN THE SOUTHWEST.

James T. Fisher

and

John B. McRae
New Mexico State University
Box 3530, Dept. of Horticulture
Las Cruces, New Mexico 88003

and

Earl F. Aldon
Rocky Mountain Forest & Range Experiment Station
2205 Columbus, S.E.
Albuquerque, New Mexico 87106

Abstract. In the Southwest, revegetation methods must mitigate alkaline soils, low rainfall, wide temperature fluctuations and heavy rodent browsing. Methods contributing to woody plant establishment are reviewed and results from current research are discussed. In separate studies, containerized native juniper (*Juniperus monosperma* (Engelm.) Sarg.) were planted on three northern New Mexico mine spoils with good to excellent success depending on treatment. Preliminary results show drip irrigation and the addition of triple superphosphate (0-46-0) to be beneficial for seedling survival, whereas slow release fertilizer (Osmocote 18-6-9) caused mortality. Rodent protection is absolutely necessary on some sites. The importance of time of planting is discussed.

INTRODUCTION

This paper will review western woody plant revegetation and will report results obtained thus far from New Mexico research begun in 1981. Compared to the East, western states have devoted minor attention to tree and shrub planting on surface-disturbed land. It will become apparent that some revegetation site problems are more severe in the Southwest than East, while others can be negotiated with less effort.

---

*1 cm = 10 mm = 2.54 in
1 m = 1.09 yd = 3.27 ft.
1 g = 0.03 oz; 1000 gm = 1 kg
1 ha = 2.47 ac
1 kg/ha x 0.89 = lb/ac

Coal strip-mining by the year 2000 will alter more than 81,000 ha west of the 100th meridian. In New Mexico, topography of surface mined land ranges from flat to rolling hills, and many areas include "badlands", formed by steep-walled gullies separated by rugged rock ridges. Revegetation is necessary to reduce erosion and to restore aesthetic values.

Natural pinyon-juniper woodlands occur extensively among the almost 14,580 ha impacted by mining operations in New Mexico (Nat. Acad. Sci., 1973). Pinyon-juniper woodlands occur extensively in Nevada, Utah, Colorado and Arizona and are commonly disturbed by mining. Woodlands occupy 24.3 million ha in the five-state area. Although the pinyon-juniper type was once frequently destroyed to increase forage production, most land managers now want the woodlands conserved and managed for multiple products and uses (Jensen, 1972; Lanner, 1977). It follows that pinyon-juniper woodlands should be restored following surface mining to produce wood products, Christmas trees and wildlife, especially large mammals (Short and McCullock, 1977).

Regeneration of mined sites in the Southwest is especially difficult due to low rainfall, wide temperature extremes, animal depredation and rugged topography (Schubert, 1977). On disturbed sites, revegetation with native plant species frequently results in better establishment and more rapid growth than can be achieved with introduced species. For example, in a 1974 evaluation of the Navajo Mine revegetation program, the Westinghouse Environmental Systems Department concluded that native species became established sooner and grew better than introduced species (Balzer, 1975). Successful establishment of native pinyon-juniper woodland will speed the progression from early seral stage vegetation (annuals and herbaceous perennials) to longer lived woody species. In northwestern New Mexico, mined sites were still in a very early seral stage 13 years after disturbance as shown by low species diversity and a preponderance of short-lived taxa (Wagner, Martin and Aldon, 1978).

Revegetation programs have not included native western junipers due to unreliable seed germination in nurseries. However, research conducted recently through SEAM sponsorship (O'Brien and Fisher, 1980) demonstrated the feasibility of large-scale production of containerized juniper seedlings. The step presently receiving attention is establishment of seedlings under the challenging conditions imposed by mined woodland sites.

Silvics of *Juniperus monosperma* (Engelm.) Sarg.

One-seed juniper is a dioecious species and reproduces through seed production which begins when trees are 10 to 20 years old. It extends from central Colorado to central Arizona, is widely distributed throughout most of New Mexico and reaches into western Texas and Mexico. The pinyon-juniper type is found throughout New Mexico with the exception of southeastern and south central regions.

The entire distribution of pinyon-juniper falls within the semi-arid classification. Mean annual temperature of woodlands is 11°C (52°F) (Randles, 1949) and the frost-free period is about 120 days (Woodbury, 1947). Annual precipitation varies from 310 to 520 mm. In eastern New Mexico, 75% of the yearly precipitation falls from April through September, compared with only 45% in western Arizona (Springfield, 1976). In addition, growing season precipitation becomes more concentrated in the period July to September from east to west, and very little spring moisture is received (Paulsen, 1975). This summer monsoon pattern becomes less pronounced in northern Arizona where much of the precipitation comes from cold winter storms, and the vegetation shows affinities for the Great Basin region (Paulsen, 1975; Springfield, 1976).

The pinyon-juniper type is found at elevations from 1,400 to 2,300 m in New Mexico. Generally, the lower altitudinal limit of the type is restricted by deficient moisture and the upper by cold temperatures (Pearson, 1931). Meagher (1943) underscored the role of moisture when he found that one-seed juniper had a higher survival when both water and shade were provided. In a similar vein, Jameson (1965) found small one-seed juniper growing as understory to larger trees and deemed this arrangement necessary for new tree establishment.

Soils vary considerably over the range of the pinyon-juniper type due to variation in parent materials, topography, microclimate and time of pedogenesis. The limited supply of moisture available for plant growth, rock weathering and soil leaching appear to determine the genesis and resulting morphology of pinyon-juniper soils (Paulsen, 1975). Site quality is mainly a function of soil depth, profile development and precipitation. O'Rourke and Ogden (1969) found that sites with low pinyon-juniper crown cover generally had high calcium carbonate (13%), high pH (7.8) and high phosphorus. They believed these characteristics reflected the long-term meager precipitation received at the sites and could be used as site indicators.

Junipers are characterized by slow growth (Tueller and Clark, 1975; Jameson, 1965). In Meagher's study (1943), two-year-old pinyon seedlings averaged 5.6 cm in height and one-seed junipers, 3.1 cm. Similarly, Howell (1940) reported that pinyons of all sizes grew faster than one-seed juniper.

Methods for Woody Plant Revegetation in the Southwest

Due to soil disturbance and scant precipitation, woodland revegetation may be more difficult than conventional reforestation. Methods are mostly directed toward avoidance of irreversible seedling water stress because moisture is the most limiting factor on southwestern mined sites. Soil toxicity problems are generally manageable because most of the New Mexico coals are low in sulfur and iron and high concentrations of acid water are not produced (Kottlowski and Beaumont, 1971).

Moisture stress develops when plant water loss exceeds absorption. Establishment methods attempt to reduce this imbalance through supplemental irrigation, maximization of precipitation effectiveness and acceleration of first year root extension. Supplemental irrigation can be applied through sprinkler or drip systems. Precipitation can be utilized more efficiently through water harvesting, improved infiltration and retardation of evapotranspiration. Correction of site nutrient deficiencies, seedling containerizeration and properly scheduled planting can provide further assurance that site precipitation is fully utilized for establishment. Each of these areas will be reviewed.

In New Mexico, the biggest problem with spoil materials may be getting moisture into them (Aldon and Springfield, 1973). Cultivation, certain types of mulches and drip irrigation can improve infiltration. Cultivation also incorporates organic matter, breaks the surface crust, promotes aeration and enables roots to penetrate heavy soils (U.S.D.A. Forest Service, 1979).

Many types of mulches have been used in plant establishment (Springfield, 1972; Carpenter et al., 1978). The ideal mulch in arid and semi-arid climates should: (1) facilitate infiltration while preventing evaporation; (2) decrease soil temperature extremes; (3) control wind and water erosion; and (4) be long lasting, inexpensive and easy to apply. Because no single material universally meets these criteria, it is important to tailor the material to site and species. Grass hay or straw is commonly applied at a rate of about 3,360 kg/ha and is a common standard against which other materials are evaluated (Berg, 1972). The effective life of straw and hay mulches will vary with climatic conditions, but may be usually about one year. Soil incorporation to a depth of 5 cm with a disc will retard wind removal. Properly applied, straw mulch has been shown to increase soil moisture. Applied too heavily, a thick cover of organic mulch causes considerable loss of water by interception of precipitation and subsequent evaporation (Hodder, 1974). Incorporation of straw mulch greatly increases the organic matter content of relatively sterile spoil material. This supplies carbon, energy and minerals for microbes and CO_2, NO_3, SO_4 and organic acids to help dissolve materials and supply other plant nutrients. Organic matter also increases soil aggregation and protects the aggregates from destruction by water. It also increases porosity, aeration and water infiltration (Hodder, 1974).

Soil reactions following incorporation of crop and wood residues are similar in many respects. However, wood residues are longer lasting, easier to apply, carry no weed seeds, and wood chips resist wind movement (U.S.D.A. Forest Service, 1979). Wood chips are frequently applied to steep slopes (e.g., 20%) where straw mulches are less effective in preventing erosion.

Supplemental irrigation has significantly increased the survival of woody plants in western revegetation plots (Lang, 1971; Orr, 1977). Drip irrigation resulted in excellent first year survival of J. scopulorum (Williamson and Wangerud, 1980) and reduced mortality of fourwing saltbush (Aldon, 1978). Drip systems are being used more frequently as emitters and fixtures are improved to minimize salt clogging. Drip irrigation is highly appropriate for woody plants due to spacing and can place the water directly where it is needed. Directed watering reduces weed problems, soil erosion and the total volume of water used. Portable systems can be designed to meet the needs of remote sites (Garcia, 1979).

The two elements most commonly deficient on disturbed land are nitrogen (N) and phosphorus (P) (Berg, 1972). Phosphorus deficiencies can limit or prevent seedling establishment. Planting failure is often attributed to insufficient moisture when in fact, soil is so deficient in P that plants do not extend their roots to an adequate moisture supply (U.S.D.A. Forest Service, 1979). Nitrogen deficiency is often a limiting factor in plant productivity, rather than seedling establishment. Top soils may contain adequate N but subsoils and geologic materials are generally deficient (U.S.D.A. Forest Service, 1979).

Fertilization with soluble fertilizer at the time of tree planting is generally discouraged due to the likelihood of plant injury. Slow release fertilizers can be applied without injury and adequate nutrients can be provided for many months. Because release is temperature sensitive, more nutrients are available when higher soil temperatures are conducive to root growth. According to Whitcomb (1977), root growth of woody plants following transplanting can be greatly increased by providing slow-release fertilizer and superphosphate. Similar responses have been reported for conventional fertilizers but results have been erratic. Addition of conventional fertilizers nearly doubled the yield of shrubs planted on a Montana mine spoil (Hodder, 1974). A major benefit was increased root production.

Containerization has gained considerable support over the last decade because many of the problems associated with production and outplanting of bare root nursery stock have been eliminated. Critical to outplanting success in the Southwest is avoidance of transplant shock, greatly reduced because the root plug remains intact during planting. Equally important is that container seedlings can be planted during the time when summer rains fall in the Southwest. More information is needed to determine optimal planting times in the mountainous regions. Preliminary studies in northern New Mexico indicate that planting container seedlings in late August and September results in less survival and growth than July planting (Fisher and Montano, unpublished). For some conifer species, planting in late summer and fall apparently does not allow adequate root development before soil temperatures become too low for extension.

The ultimate benefit of planting containerized rather than bareroot seedlings appears to vary somewhat by site and the type of material tested. Generally, containerized seedlings perform progressively better as the planting site becomes more harsh. In addition, the deeper containers 15 to 25 cm raise considerably the odds that roots will be planted in a favorable soil moisture zone. The zone of adequate soil moisture can rapidly recede below shallow roots.

Tree seedlings planted in the Southwest are exposed to high soil and air temperatures, and artificial shade may be used to reduce seedling moisture stress. Animal protection may be needed to avoid planting failure on some sites. Poisons may be hazardous to health and non-target species, and trapping is impractical. Light weight polypropylene mesh tubes are now mass produced and may offer a safe protective method (Campbell, 1969) in addition to shade. Tubes are photo-degradable in 3 to 5 years.

CURRENT RESEARCH AND PRELIMINARY RESULTS

RESEARCH OBJECTIVES

In 1981, research was begun in cooperation with the U.S. Forest Service to determine methods for routine restoration of junipers on mined sites. Overall objectives were to relate planting date to growth and survival and to determine benefits from drip irrigation, mulch, protective "Vexar" tubes and slow release and superphosphate fertilizers. Specific research objectives were tailored to each of three test sites in compliance with the most urgent needs and available resources. Physical descriptions and results obtained thus far from each site follow.

York Canyon Mine, Raton, New Mexico

The study site is located within the Raton Coal Field which lies on the edge of the Great Plains in rugged, dissected plateau country. It is 98 km west of Raton, and the elevation is 2,194 m. The landscape is characterized by mountain topography that ranges from gently to strongly sloping ridge tops to very steep slopes. Many west to northwest-trending canyons reach into the plateau and provide access to coal. Mineable lenses in the Plateau formation range from 1 to 4 m thick. Coal is extracted by Kaiser Steel through underground and surface mining.

Soils are developing generally in parent material weathered from sedimentary rocks dominated by sandstone and shale. Good stands of native vegetation occur on all but the sites with very shallow soil. White fir, Douglas fir, limber pine and pinyon-juniper woodlands are found over much of the area.

The Raton Coal Field area generally receives 360 to 460 mm of precipitation annually (Gould et al., 1975). The winter months are rather dry with an average of about 20 mm for November and March. July and August are the wettest months, averaging 76 mm, and the remaining months receive slightly more than 25 mm. According to the Kaiser Steel weather records, 28 cm of precipitation were received in 1980 at the mine site. Temperatures averaged -5°C (23°F) in December and January and 17°C (63°F) in July. Summer maximum temperatures may reach 35°C (95°F).

The experimental site is level to moderately sloping with 31 to 51 cm of top soil covering spoil material. Soil pH is 8.2 to 8.8 according to Kaiser Steel personnel.

The study compares 12 treatments (3 planting dates (mid July, August and May), drip irrigation versus straw mulch and no fertilizer versus the addition of slow release (18-6-12) and triple superphosphate (0-46-0) added to the planting hole). Applied were 20 kg of Osmocote and 11 kg triple superphosphate per cubic meter of planting hole fill.

A split plot randomized block design with 6 replications was used. Main plots are drip irrigation and straw mulch. Six subplots (3 planting dates x 2 fertilizer regimes) were randomly assigned within each main plot. Each subplot contains 38 seedlings spaced 0.5 m apart within rows spaced 0.9 m apart. Junipers were grown in 160 cm^3 Ray Leach tubes for 10 months.

Enclosed by a 2.5 m chain-linked fence, the study site was roto-tilled prior to planting to improve infiltration and remove weeds. Seedlings were auger planted. Straw mulch was spread by hand and incorporated within the top 5 to 10 cm of soil to avoid wind displacement. The drip system involved a surge tank, a portable centrifugal pump and enough 1.3 cm bi-wall tubing to supply each seedling with two tubes, each within 20 cm of the main stem. Seedlings were irrigated bi-monthly, May through September, with enough moisture to wet the soil to a depth of 30.5 cm. Weeds were controlled by hand cultivation.

Juniper survival at 5 and 15 months (except May 1982 planting) following planting is found in Table 1. Survival decreased very little between 5 and 15 months, and this suggests that planting success or failure may be determined in less than one year. Averaged over treatments, July planting resulted in highest survival. May averaged 65% and August 48%. Across planting dates, drip irrigation and no fertilizer gave uniformly high survival (95-98%). However, mulched plots without fertilizer showed comparable success during August and May plantings. Fertilizer depressed survival and apparently caused less damage when diluted with supplemental irrigation. Fertilizer was particularly damaging during August, possibly due to the intolerance of seedlings to night-time freezing temperatures. Since seedlings are more vulnerable to freeze damage when growing, nutrient additions in the late growing season have produced negative results in woody plant nurseries.

McKinley Mine

Operated by Pittsburg and Midway Coal Company, the McKinley Mine is located in northwestern New Mexico near Gallup. Most of the area is composed of sandstone of the Mesa Verde group of the upper Cretaceous period (Wagner, Martin and Aldon, 1978). The mine is at an elevation of 2,010 to 2,070 m and receives 280 to 380 mm of annual precipitation.

Table 1. Percent survival for 8 treatment combinations and 3 planting dates after 5 and 15 months from planting - Raton Test.

Planting Date	July 15, 1981		Aug. 21, 1981		May 5, 1982	
Months from Planting	5	15	5	15	5	15
Treatment						
Drip & No Fertilizer	98	93	100	96	95	-
Mulch & No Fertilizer	85	78	99	94	91	-
Drip & Fertilizer	88	74	10	4	45	-
Mulch & Fertilizer	51	49	7	1	29	-
Drip	93	84	55	50	70	-
Mulch	68	64	53	48	60	-
No Fertilizer	92	86	99	95	93	-
Fertilizer	70	62	9	3	37	-

Table 2. Percent survival for 4 treatments and 3 planting dates 3 months from planting - Gallup Test.

Planting Date	Aug. 17, 1982	Sept. 23, 1982	Nov. 3, 1982
Treatment			
Control	94	88	78
Osmocote & T.S.P.	98	88	74
Vexar	100	97	83
Vexar, Osmocote & T.S.P., Shade	98	93	88
AVERAGE	98	92	81

The general area is found within the southeastern end of the Great Basin desert shrub region, dominated mostly by big sagebrush. Pinyon and one-seed juniper are co-dominants of slopes and ridges.

Study sites are found on level land within the confines of North McKinley mine. Sites have 31 to 41 cm of top soil and have been successfully reseeded with grasses within 3 to 5 years.

This study includes three 1982 planting dates (Aug. 17, Sept. 23 and Nov. 3), slow release and superphosphate fertilizers, and protective tubes. The experiment therefore involves 12 treatments (3 planting dates x 2 fertilizer regimes x 2 (protective tube and none)). A completely randomized block experimental design with 6 replications was used. The experimental unit is 20 juniper seedlings planted 0.5 m apart within rows on contours separated by 1 m.

Seedlings used in this study were grown in 1456 cm^3 (90 cu.in) paraffin-coated containers. Osmocote (18-6-12) and triple-superphosphate (0-46-0) were applied to the planting hole at 3.6 kg and 7.1 kg per cubic meter, respectively. A feature unique to this study was the addition of a fine-meshed nylon sleeve to "Vexar" tubes to determine the benefit of added shade.

At the McKinley Mine, August planting resulted in excellent survival across treatments (Table 2). Noteworthy is the decline across planting dates indicating that fall planting may reduce survival considerably. Animal damage was not severe during the three month period; survival of unprotected seedlings was only 5 to 10 % less than those surrounded by Vexar.

Zia Mine

Located within the Cibola National Forest near Grants, New Mexico, the Zia Mine is at an elevation of 2,194 m. Found on La Jora Mesa, the test site is surrounded by pinyon-juniper woodland and is an abandoned uranium spoil operated by the Zia Mine. Annual precipitation is 130 to 230 mm. Soil pH is about 8, and the texture is derived from Dakota sandstone, a prominent mesa former in the area (Griswold, 1971).

The Zia Mine test is a factorial comparison of fertilizer, seedling protection and mulch treatments (respectively, 3 x 2 x 2). Fertilizer treatments include: Osmocote (18-6-12) at 3.6 kg/m^3 triple-superphosphate (0-46-0) at 7.1 kg/m^3. Seedling protection was provided by "MGK Big Game Repellent" or 46 cm x 7.5 cm dia. "Vexar" tubes. Plots received wood and bark chips (1.5 to 3.0 cm x 6.0 to 10 cm) or no mulch.

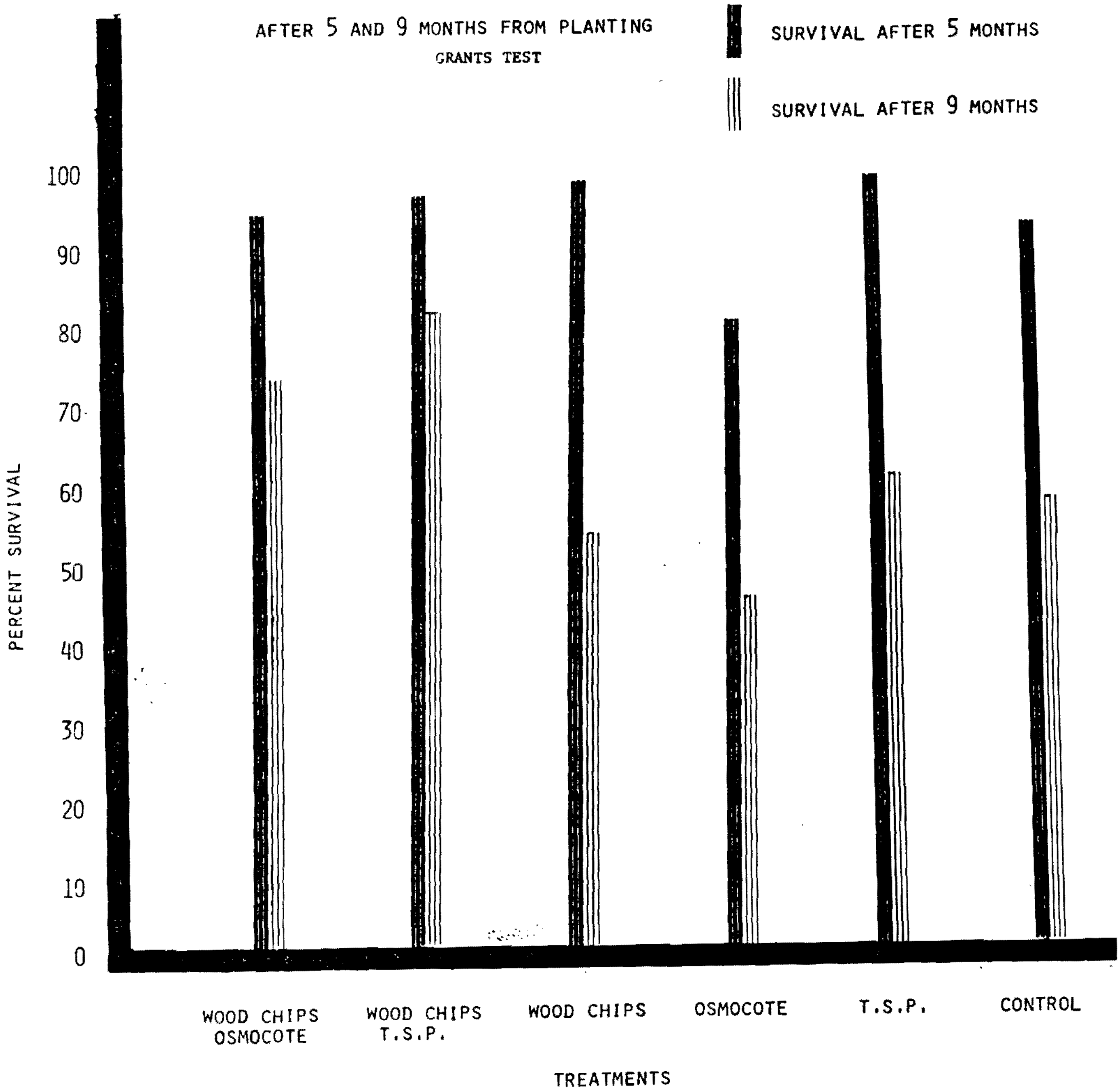
Survival on the uranium spoil site is lowest among sites (Fig. 1). Small rodent pressure has been extremely damaging, even among seedlings protected with "Vexar". Browsing did not erase the negative influence of fertilizers, apparent before rodent browsing began. The combination of wood chips and total superphosphate appears beneficial in this study. Game repellent did not provide lasting benefit; almost all (98%) seedlings were browsed after nine months.

SUMMARY

Although these results are preliminary and await complete statistical analysis, some generalities can be drawn on a cautionary basis. It is clear that containerized junipers can be planted with satisfactory to excellent success depending on treatments provided. Most apparent is the negative impact of slow-release fertilizer, even at a relatively low rate

FIGURE 1. PERCENT SURVIVAL FOR 6 TREATMENTS UNDER VEXAR PROTECTION AFTER 5 AND 9 MONTHS FROM PLANTING

GRANTS TEST



(3.6 kg/m^3). Conversely, triple superphosphate appears beneficial at one site. Drip irrigation provided uniformly high survival and reduced fertilizer induced mortality. It is probable that during dry years differences between drip and non-irrigated plots would be greater. Summer rainfall was above average at the Raton site during the summer months of 1981. Organic mulching produces excellent survival under some conditions and apparently can be favorably combined with phosphate fertilization.

It is probable that November planting will be unfavorable in northwestern New Mexico. August may be a favorable month for planting juniper in the Raton Coal Field.

Rodent protection is absolutely essential on some sites, and it is doubtful that egg solid-based repellent will be adequate for lasting protection. Admittingly, short term benefits were not determined.

Treatment influences on juniper early growth will be addressed due to the importance of meeting performance contracts with trees of established trees no less than 30 cm. It is entirely possible that growth responses will differ substantially during years two and three following planting.

LITERATURE CITED

Aldon, E. F. 1978. Reclamation of coal-mined land in the Southwest. J. Soil Water Conservation 33:75-79.

Aldon, E. F. and H. W. Springfield. 1973. Revegetation of coal mine spoils in New Mexico: a laboratory study. USDA For. Serv. Res. Note RM-245, 4 p.

Balzer, J. L. 1975. A venture into reclamation. Mining Congr. J. 64:24-29.

Berg, W. A. 1972. Use of soil laboratory analysis in revegetation of mined lands. Mining Congr. J. 61(4):32-35.

Campbell, D. L. 1969. Plastic fabric to protect seedlings from animal damage. pp.87-88. In Wildl. Refor. Pacific Northwest Symp. Proc. 1968. Oreg. State Univ., Corvallis.

Carpenter, S. B., D. H. Graves and R. R. Kruspe. 1978. Individual tree mulching as an aid to the establishment of trees on surface mine spoil. Reclam. Rev. 1:139-142.

Garcia, G. 1979. A portable irrigation system for remote sites. USDA For. Serv. Res. Note RM-374, 2 p.

Gould, W. L., D. Rai and P. J. Wierenga. 1975. Problems in reclamation of coal mine spoils in New Mexico. pp.107-121. In M. K. Wali (ed.), Practices and Problems of Land Reclamation in Western North America, Univ. North Dakota Press.

Griswold, G. B. 1971. Open-pit uranium mining in New Mexico, pp.8-10. In Survey of Surface Mining in New Mexico, Circ. 114, State Bur. Mines Min. Res.8-10.

Hodder, R. L. 1974. Surface-mined land reclamation research at Colstrip, Montana. Montana Agric. Exp. Stn. Res. Rept. 69.

Howell, Joseph Jr. 1940. Pinyon and juniper -- a preliminary study of volume, growth and yield. USDA Soil Conserv. Serv., Reg. 8, Bull. 71, Forest Serv. 12, 90 p.

Jameson, D. A. 1965. Arrangement and growth of pinyon and one-seed juniper trees. Plateau 37:121-127.

Jensen, N. E. 1972. Pinyon-juniper woodland management for multiple use benefits. J. Range Manage., 25:231-234.

Kottlowski, F. E. and E. C. Beaumont. 1965. Strip mining of coal in New Mexico, pp. 16-17. In Survey of surface mining in New Mexico, Circ. 114, State Bur. Mines Min. Res..

Lang, R. 1971. Reclamation of strip mine spoil banks in Wyoming. Agric. Expt. Sta. Res. J. 71, Univ. of Wyoming, 32 p.

Lanner, R. M. 1977. The eradication of pinyon-juniper woodland. Has the program a legitimate purpose? Wes. Wildl. 3:12-17.

Meagher, G. S. 1943. Reaction of pinon and juniper seedlings to artificial shade and supplemental watering. J. For. 41:480-482.

National Academy of Sciences, Environmental Studies Board. 1973. Rehabilitation potential of western coal lands. Nat. Acad. Sci./Nat. Acad. Eng. Washington, D.C., 206 p.

O'Brien, J. V. and J. T. Fisher. 1980. Seed handling and germination of New Mexico native junipers. HortScience 15(3):159 (Abstract)

O'Rourke, J. T. and P. R. Ogden. 1969. Vegetative response following pinyon-juniper control in Arizona. J. Range Manage. 22:416-418.

Orr, H. K. 1977. Reestablishment of wooded waterways and associated upland shrub communities in surface mining areas of the north-western Great Plains, pp. In Proc. Fifth Symp. Surface Mining and Reclam. NCA/BCR Coal Conf. and Expo. IV, Louisville, Ky.

Paulsen, H. A. 1975. Range management in the central and southern Rocky Mountains: A summary of the status of our knowledge by range ecosystem. USDA For. Serv. Res. Paper RM-154, 34 pp.

Pearson, G. A. 1931. Forest types in the Southwest as determined by climate and soil. USDA Tech. Bull. 247, 144 p.

Randles, A. 1949. Pinyon-juniper in the Southwest. USDA Yearb. pp.342-347.

Schubert, G. H. 1977. Forest regeneration of arid lands, pp.82-87. In Proc. Soc. Amer. Foresters, 1977 Nat. Conv.

Short, H. L. and C. Y. McCulloch. 1977. Managing pinyon-juniper ranges for wildlife. USDA For. Serv. Gen. Tech. Rept. RM-47, 10 p.

Springfield, H. W. 1972. Mulching improves survival and growth of Cercocarpus transplants. USDA For. Serv. Res. Note RM-200, p.

Springfield, H. W. 1976. Characteristics and management of southwestern pinyon-juniper ranges: The status of our knowledge. USDA For. Serv. Res. Pap. RM-106, 32 p.

Tueller, P. T. and James Clark. 1975. Autecology of pinyon-juniper species of the Great Basin, pp.27-40. In The Pinyon-Juniper Ecosystem: A Symposium. Utah Agr. Exp. Sta.

U.S.D.A. Forest Service. 1979. User guide to vegetation, mining and reclamation in the West. USDA For. Serv. Gen. Tech. Rept. INT-64, 85 p.

Wagner, W. L., W. C. Martin and E. F. Aldon. 1978. Natural succession on stripmined lands in northwestern New Mexico. Reclam. Rev. 1:67-73.

Whitcomb, C. E. 1977. Effects of nutrition on propagation and rate of establishment of purpleleaf Japanese honeysuckle, (Lonicera japonica 'Purpurea') Agric. Expt. Sta. Res. Rept., P-760, p.66-68.

Williamson, R. L. and K. W. Wangerud. 1980. Reestablishing woody draws on the northern Great Plains after mining the first steps, pp. In Proc. of adequate reclamation of mined lands. Soil Cons. Soc. of Amer. and WRCC-21, Billings, Mont., Mont.

Woodbury, A. M. 1947. Distribution of pigmy conifers in Utah and northeastern Arizona. Ecology 28:113-126.