GERMINATION AND FIELD ESTABLISHMENT OF JUNIPER IN THE SOUTHWEST

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ABSTRACT: Studies were conducted to determine reliable methods for germinating and establishing Juniperus monosperma. Poor germination is caused by a germination inhibitor in the seed coat and physiological dormancy. Germination rate and value were significantly improved when seeds were leached 48 hours with H_2O, or treated with ethephon or H_2O_2 plus GA_3 before stratification at 4° C.

Establishment studies at three New Mexico sites evaluated the effects of planting date, mulch, drip irrigation, fertilizer and rodent protection on juniper seedling survival. Two years after planting, survival rates for the best treatment combinations ranged from 70 to 99% among sites. July was the superior planting date for the site near Raton, New Mexico. Drip irrigation proved superior to mulch. Plastic mesh was essential and was more effective than animal repellant for rodent protection.

INTRODUCTION

Pinyon-juniper (P-J) woodlands occur extensively in the West and are frequently razed by mining operations, particularly coal stripping. In New Mexico, topography of surface-mined land ranges from flat to rolling hills. Many areas include badlands formed by steep-walled gullies separated by rugged rock ridges. Revegetation can reduce erosion and restore aesthetic values, but restoration is difficult because of low rainfall, wide temperature extremes, animal depredation and rugged topography (Schubert 1977). Because native plants are well adapted to regional conditions, native plant species often can be established more easily than introduced species (Balzar 1975). Establishing native P-J woodlands speeds the progression from early seral stage vegetation (annuals and herbaceous perennials) to longer lived woody species (Wagner and others 1978). Also, it is becoming increasingly apparent that P-J woodlands should be conserved for their renewable products and uses (Jensen 1972; Lanner 1977; Short and McCulloch 1977).

Revegetation programs in the Southwest have rarely included one-seed juniper (Juniperus monosperma) because of unreliable seed germination in nurseries and a lack of information on establishment techniques. Efforts were begun in 1979 in cooperation with the U.S. Forest Service to identify reliable pregermination treatments and subsequently in 1981 to develop revegetation practices. Because greenhouse culture of containerized one-seed juniper varies little from that routinely used to grow other junipers, seedling production was omitted as a research objective. The studies conducted will be highlighted following brief reviews of information available from other sources.

JUNIPER SEED GERMINATION

Seed Production and Germination Properties

One-seed juniper trees produce seed when 10 to 20 years old. Flowering occurs from January to June and the fruit is formed by the fusion of a fleshy female flower into an indehiscent strobilus commonly called a berry (Johnsen and Alexander 1974). Large seed crops are produced every 2 to 5 years and ripen in August or September of their first year within blue or purple berries.

The seed coat consists of an outer fleshy layer of pectic substances, a thick lignified stoney layer and a thin inner membranous and suberized layer. In several juniper species the hard coat interferes with moisture uptake (Johnsen and Alexander 1974). The fleshy white endosperm of these seeds is made up of thick cells with large amounts of cellulose and is surrounded by an outer layer of suberized cells (Pack 1921). Embedded within this is a straight embryo with two to six cotyledons (Johnsen and Alexander 1974).

Paper presented at the Pinyon-Juniper Conference, Reno, Nevada, January 13-16, 1986.

New Mexico Agricultural Experiment Station Scientific Paper No. 253.

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Germination is delayed in most junipers by embryo dormancy and occasionally by impermeable seed coats, immature embryos or the presence of inhibitors (Barton 1951; Djavanshir and Fechner 1976; Pack 1921). Moisture uptake through the hilum of _J. scopulorum_ and _J. virginiana_ seed is apparently obstructed by a covering of vascular tissues from the fruit base. One-seed juniper seeds are reported to have dormant embryos and impermeable seed coats (Johnsen and Alexander 1974).

Johnsen (1962) reported that _J. monosperma_ germination improved following a 48-hour soak in several changes of distilled water. He attributed this to the leaching of seed germination inhibitors. High temperature stratification (cyclic 20-30° C) or H_2O_2 was used to improve permeability while chilling was required to break embryo dormancy (Barton 1951; Djavanshir and Fechner 1976; Van Haverbeke and Read 1976). High temperature or H_2SO_4 without chilling, H_2O_2, removal of seed coats, dilute acids and increased oxygen pressure, light and carbon dioxide were ineffective in promoting germination of unstratified seeds (Pack 1921).

The most common treatment for breaking seed dormancy, particularly physiological dormancy, is stratification of fully imbibed seeds at low temperatures (0.5°-5° C) for up to six months. This generally improves germination percent and rate, and widens the temperature range over which germination will occur. For one-seed juniper, stratification at 5° C for 30 to 120 days has been recommended (Johnsen 1962), but may be unnecessary for some seedlots (Johnsen 1962; Riffle and Springfield 1968). However, cold stratification reduces the nurseryman's flexibility and exposes seed to microfloral degradation.

NMSU Cooperative Studies on Seed Treatments

Tests were conducted with seeds harvested in north central New Mexico in October 1979 to evaluate the effects of several pregermination treatments on _J. monosperma_ seed germination (table 1). Cones were depulped by a procedure described by Van Haverbeke and Barnhart (1978). Debris and void seed were removed by flotation and a South Dakota seed blower. Seeds were X-rayed and subjected to a tetrazolium salt test at the National Tree Seed Laboratory to determine percent viable seed per lot.

Tests evaluated germination percent after a 40-day period, germination rate and germination value. The highest daily rate (peak value) was used as an index of germination rate. Germination percent and the sum of the daily germination rates were used to compute germination value as described by Djavanshir and Pourbeik (1976).

Table 1.--Pregermination experiments conducted at New Mexico State University (O'Brien 1980)

1. Leaching (48 hrs)
   A. w/ or w/o leaching , no strat.
   B. Leach before 0, 30, 60, 90 dy strat.

2. GA_3 (48 hr soak)
   A. 0, 100, 150, 200, 250, 300, 350, 400 ppm _before_ 90 dy strat.
   B. 125, 250, 500, 1000 ppm _after_ 90 dy strat.

3. Ethepon (Ethrel)
   A. 48 hrs 0, 200, 400, 800, 1600 ppm _after_ 90 dy strat.
   B. 48 hrs 300, 600, 1200, 2400 ppm or 24 hrs ethephon (same rates) + 24 hrs 250 ppm GA_3 _before_ 0, 30 or 90 dy strat.

4. Trts applied _before_ 0, 30, 60, 90 dy strat.
   A. GA_3 (48. hr soak in 250 ppm)
   B. Kinetin (" " " " 25 ")
   C. H_2O_2 (" " " " 5 % soln.)
   D. 24 hr kinetin (25 ppm) + 24 hr GA_3 (250 ppm)
   E. 24 hr kinetin (25 ppm) + 24 hr H_2O_2 (5%)
   F. 24 hr H_2O_2 (5%) + 24 hr GA_3 (250 ppm)
   G. 24 hr H_2O_2

Preliminary tests determined: the time required to complete water imbibition at 24° C; the effect of imbibition temperature (4° C vs. 24° C) before a 90-day stratification on germination; and effects of germination chamber photoperiod (8 hr light vs. no light) and temperature (20-30° C vs. 20-35° C). Studies showed that seed were fully imbibed after 16 hrs, that germination percent, rate and value were significantly higher after warm imbibition (24° C), and that seed germinated best when subjected to an 8-hr photoperiod, 16 hrs at 20° C and 8 hrs at 30° C. Results of these studies were applied to pregermination tests.

Chemical induction tests involved placing seeds in 20-ml solutions containing the respective chemical. Seeds were maintained at 24° C for the times indicated in table 1.

Leaching significantly improved germination percent, rate and value. Leached seeds germinated rapidly to a high percent while control seeds germinated more slowly (fig. 1). In addition, there was a positive linear response as stratification after leaching increased from 0 to 90 days (fig. 2). Applied before or after a 90-day stratification, GA_3 had no detectable influence on germination. However, H_2O_2 plus GA_3 (250 ppm) resulted in almost total germination of viable seeds. Germination percent, rate and value increased in a linear manner as ethephon concentration

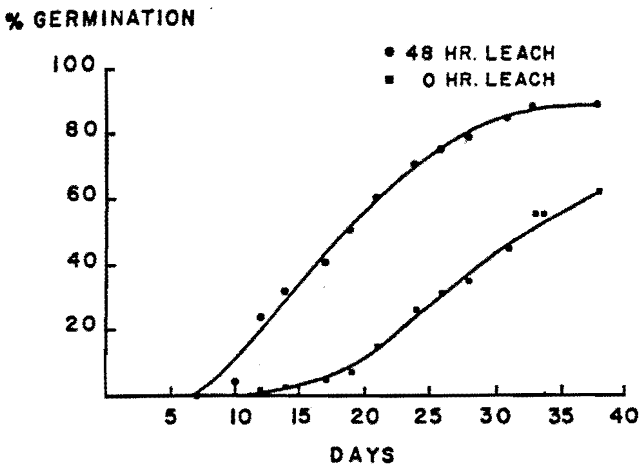

Figure 1--Cumulative germination rates of non-stratified J. monosperma seed leached for 0 and 48 hours.

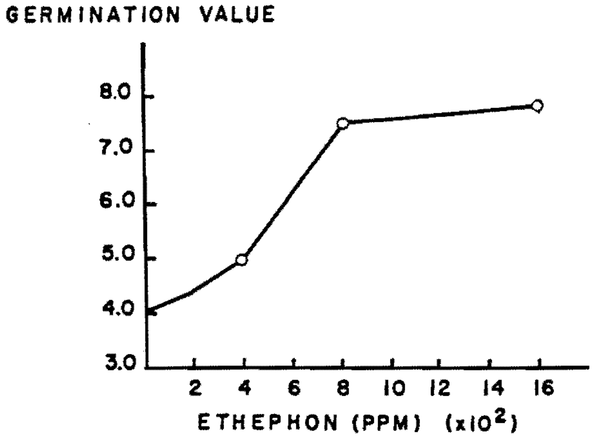

Figure 3--Ethephon effects on germination value of J. monosperma seed stratified 90 days before treatment.

increased (fig. 3). The combination of ethephon and GA_3 was ineffective. The germination percent of chemically treated seeds was not improved by cold stratification. However, value was highest when the H_2O_2 plus GA_3 and ethephon-only treatments were applied in conjunction with 30 days of cold stratification, as shown for the former in figure 4. Kinetin plus H_2O_2 improved percent germination only and, overall, was less effective than GA_3 plus H_2O_2.

Results indicated that poor germination may result from the presence of a germination inhibitor in the seed coat and physiological dormancy. Gibberellic acid-only treatments probably failed because the thick seed coat disallowed uptake. Apparently H_2O_2 sufficiently scarified seed to permit GA_3 uptake, or oxidized inhibitory substances to the extent that GA_3 could function effectively. The treatment combining 24 hr exposures to ethephon and GA_3 apparently did not allow sufficient time for ethephon uptake. Among ethephon-only treatments, high concentrations apparently gave best results because of greater absorption.

Recommendations drawn from these studies are that seed should be leached with water at 20-24° C and cold stratified for 90 days or, for a shortcut treatment, be subjected to H_2O_2 plus GA_3 or ethephon-only applied before 30 days cold stratification. The method chosen will therefore depend upon circumstances and available materials.

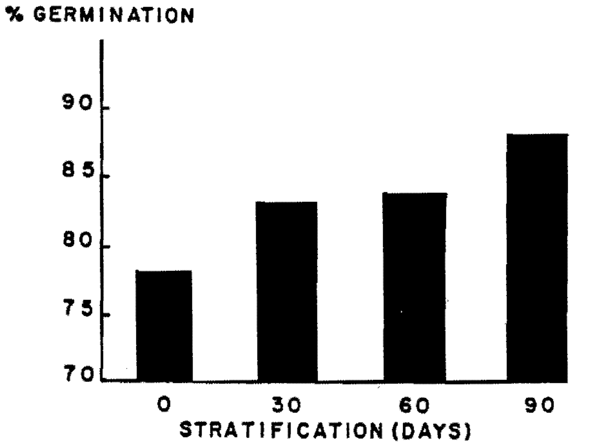

Figure 2--Germination percent of J. monosperma seed leached for 48 hours and cold stratified for 0, 30, 60 and 90 days.

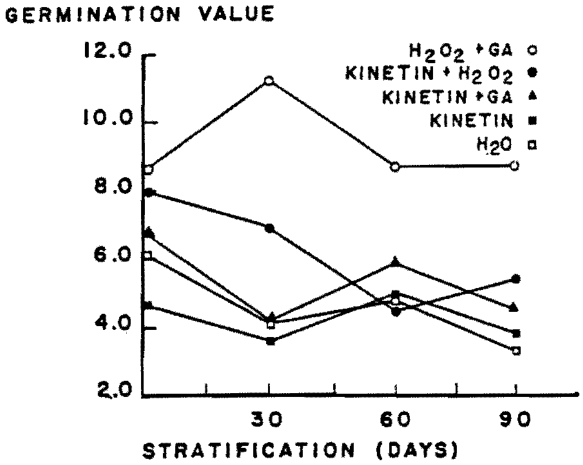

Figure 4--Chemical and cold stratification treatment effects on germination value of J. monosperma seed.

FIELD ESTABLISHMENT OF JUNIPER

Woody Plant Revegetation in the Southwest

In New Mexico, transplant survival is determined largely by moisture availability (Aldon and Springfield 1973). Cultivation, certain types of mulches and drip irrigation can improve infiltration. Cultivation also incorporates organic matter, promotes aeration and helps roots penetrate heavy soils (USDA 1979). Mulches often improve tree and shrub survival (Springfield 1972; Carpenter and others 1978) because moisture is conserved. Mulches routinely used are wood chips or straw applied at a rate of about 3,360 kg/ha. Straw is a common standard against which other materials can be evaluated (Berg 1972). The effective life of straw and hay mulches varies with climatic conditions, but is usually about 1 year. Wood residues last longer, are easier to apply, carry no weed seeds and resist wind movement (USDA 1979). Wood chips are often applied to steep slopes (20% or more) where straw mulches are less effective in preventing erosion.

Incorporating straw into soil to a depth of 5 cm retards wind removal. Applied too heavily, a thick cover of organic mulch causes considerable water loss by intercepting precipitation and subsequent evaporation (Hodder 1974). Straw mulch greatly increases the organic matter content of relatively sterile spoil material. Organic matter also increases soil porosity and aggregation (Hodder 1974).

Supplemental irrigation has significantly increased woody plant survival in western revegetation plots (Lang 1971). Drip irrigation increased survival of *Juniperus scopulorum* (Williamson and Wangerud 1980), and *Atriplex canescens* (Aldon 1978). 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). Transplants often fail because soil is so deficient in P that plants do not extend their roots enough to exploit an adequate moisture supply (USDA 1979). Topsoils may contain adequate N, but subsoils and geologic materials are usually deficient (USDA 1979). Conventional fertilizers have given erratic results in arid regions because their salts often injure transplants. Slow release formulations may be less injurious and provide nutrients for many months. Because release rate is temperature dependent, more nutrients are available when higher soil temperatures are also conducive to root growth. Transplant root growth can be greatly increased by providing slow-release fertilizer and superphosphate (Whitcomb 1977).

Seedling containerization reduces transplant shock and permits planting when summer rains occur in the Southwest. Preliminary studies in northern New Mexico indicate that planting container seedlings in late August and September results in less survival and growth than in July plantings (Fisher and Neumann, unpublished data). For some conifer species, planting in late summer and fall apparently does not allow adequate root development before low soil temperatures reduce further root extension.

Steps are often required to protect transplants from animal browsing. Because poisons, repellents and trapping are either hazardous or unreliable, lightweight polypropylene netting or meshed tubes that physically protect each tree have been developed and appear effective (Campbell 1969). Tubes are marketed in a variety of gauges and dimensions, and they photodegrade in the field in 3 to 5 years.

NMSU Cooperative Studies on Revegetation Practices

Experiments were begun in 1981 to determine reliable methods for routine revegetation of juniper on mined sites. Specific objectives were to relate establishment success to planting date and treatments including drip irrigation, mulch, protective polypropylene mesh (50 mil) tubes and fertilization. Research objectives were tailored to each of three test sites in compliance with the most urgent needs and the available resources. Site descriptions, methods and results are fully described elsewhere (Fisher and others, in press). This paper will summarize two of the three studies.

The Raton site (2,194 m elev.) is 98 km west of Raton, New Mexico. It occurs within a major coal field occupying dissected plateau country. Mineable lenses ranging from 1 to 4 m thick are extracted by underground and surface mining. Good stands of native vegetation occur on all sites except those with shallow soil. Douglas-fir and ponderosa pine are located on north-facing slopes; P-J woodlands reside on the more xeric sites. Mean annual rainfall is 360-460 mm. Soils are derived from sandstone and shale and have a pH of 8.2-8.8. The experimental site is level to moderately sloping with 31 to 51 cm of topsoil covering spoil material.

The Grants site (2,194 m elev.) is on La Jora Mesa within the Cibola National Forest. The test site is surrounded by P-J woodlands and is an abandoned uranium spoil. Annual precipitation is 130 to 230 mm, and soil pH is about 8. The soil is derived from Dakota sandstone, a prominent mesa soil in the area (Griswold 1971).

At the Raton site, a split-plot randomized block design with six replications was used. Main plots were drip irrigation and straw mulch. Six subplots (three planting dates X two fertilizer regimes) were randomly assigned within each main plot. Planting dates were July and August 1981, and May 1982. Fertilizer treatments were 20 kg/m^3 Osmocote (18-6-12) slow-release fertilizer plus 11 kg/m^3 triple-superphosphate (0-46-0) mixed with soil in the planting hole versus no supplemental fertilizer. Each subplot contained 38 seedlings spaced 0.5 m X 0.9 m. The 13-month-old seedlings were grown in 160-cm^3 Ray Leach tubes according to procedures described by Tinus and McDonald (1979).

The study site was roto-tilled before planting to improve moisture infiltration and remove weeds. Seedlings were auger-planted. Straw mulch was spread by hand and incorporated into the top 5 to 10 cm of soil to avoid wind displacement. The drip system supplied each seedling with enough moisture to wet the soil around it to a depth of 30 cm. Drip plots were irrigated bi-monthly from May through September. Weeds were controlled by hand cultivation.

The Grants test evaluated Osmocote (18-6-12) and 0-46-0 triple-superphosphate (TSP) fertilizers along with wood chip mulch or the lack of it. Specific treatments are identified in table 2. Fertilizers were applied in shallow pockets--about 6 cm deep and 10 cm to each side of the trees. All seedlings, except those in one of the controls, were protected from rodents with a lightweight polypropylene mesh (6 mil) that was much less rigid than the 50 mil mesh tubes used at Raton and which could be cut to the desired length and attached to the trees before planting.

Results were as follows: At the Raton site, July planting resulted in the highest survival (73%) and was statistically superior ($p<0.05$) to May at 55% and August at 48%. The drip/no fertilizer subtreatment was significantly better than all other subtreatments for each planting date, except August where it was equivalent to mulch/no fertilizer (fig.5). Drip-irrigated

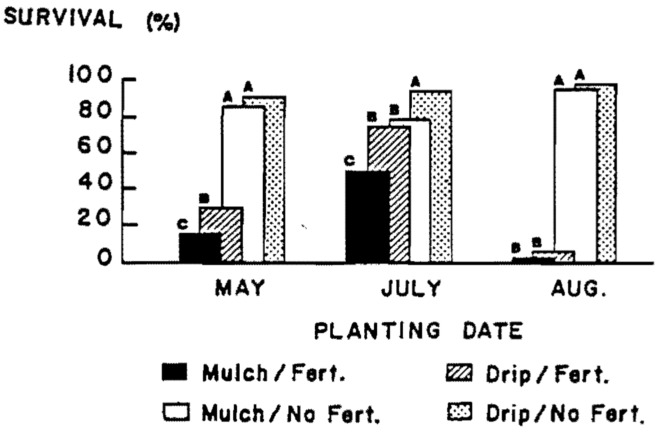

Figure 5--Survival percent for J. monosperma seedlings planted at Raton. For each planting date, treatment values with the same letter are not significantly different ($p<0.5$).

Table 2.--Treatment effects on one-year survival of one-seed juniper seedlings planted near Grants, New Mexico

Treatment: Mulch	Treatment: Fertilizer	Survival (%)
Wood Chips	21 g/tree TSP[1]	98.8 A[2]
	10.1g Os.[3] + TSP	97.5 A
	20.2 g Os.+ TSP	93.9 AB
	none	92.5 AB
No Mulch	21 g/tree TSP	83.8 B
	10.1g Os. + TSP	88.8 AB
	20.2 g Os.+ TSP	95.0 AB
	none	88.8 AB
	none/no protection[4]	85.0 B

[1] Triple-superphosphate (0-46-0)
[2] Values with the same letter are not significantly different at $p<0.05$.
[3] Osmocote (18-6-12)
[4] Treatment lacked rodent protection.

plots (84% survival) were superior to mulched plots (64% survival) for the July planting. Fertilization significantly decreased seedling survival within each planting date. Respective survivals for fertilized versus unfertilized plots were 22% versus 88% for May, 62% versus 86% for July, and 3% versus 95% for August.

At the Grants site, the TSP-only or 10.1 g Osmocote + TSP treatments applied with mulch were superior ($p<0.01$) to TSP-only plots not mulched. Mulched plots showed significantly higher ($p<0.05$) survival (96%) than the non-mulched plots (89%). Although survival was 85% for seedlings without protection, nearly all had been severely browsed by rodents. The plastic mesh used in all other treatments protected the trees from serious animal damage.

Revegetation studies showed that containerized seedlings can be planted with satisfactory to excellent success on spoil banks. Planting date was significant at Raton indicating that seedlings should be planted in time for root growth before ground freeze. In a similar study conducted near Gallup, New Mexico at a lower elevation (2,070 m) and latitude, August planting was superior to September and November (Fisher and others, in press). Although the optimum planting time will vary with site, Raton and Gallup results clearly show that high survival can be achieved if the June drought is avoided.

Dryland plantings in arid regions require some method, like organic mulching, to conserve soil moisture. Mulch clearly improves survival and without severe drought may produce results equivalent to irrigation.

Fertilization can provide a benefit, especially if combined with irrigation. Fertilizer should be applied in shallow pockets near the tree, not directly into the planting hole.

Seedling protectors are essential for success on sites where rodent populations are substantial. The lighter weight, smaller guage (6 mil) mesh used at the Grants site is recommended over rigid 50 mil tubes because the mesh is less expensive, can be attached before going to the field, stays in place longer and photodegrades in about 1 year. Twelve mil mesh is available and would extend protection beyond 1 year.

In summary, we are confident that use of the germination and revegetation practices developed can be joined with existing seedling production technology to successfully restore disturbed or over-exploited juniper woodlands. In addition, it is probable that denuded and severely eroded juniper lands in other countries (for example Pakistan) could be restored through similar techniques.

ACKNOWLEDGMENTS

We gratefully acknowledge technical and financial assistance provided by Dr. Earl F. Aldon and the Rocky Mountain Forest and Range Experiment Station. Funds were received through USDA Forest Service Cooperative Agreement No. RM-81-173-CA. We are also grateful for the cooperation and support of Kaiser Steel Corporation and Pittsburg and Midway Coal Company. Special thanks go to John B. McRae, formerly of NMSU, for his dedication and conscientious hard work.

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