CHRISTMAS TREE SPECIES TRIALS IN ARIZONA'S EAST-CENTRAL MOUNTAINS

by

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ABSTRACT

During the summer of 1975, the seedling survival and height growth rates of brutia pine (*Pinus brutia* Tenn.), Arizona cypress (*Cupressus arizonica* Greene), Douglas fir (*Pseudotsuga menziesii* var. *glauca* ((Beissn.)) Franco), pinyon pine (*Pinus edulis* Engelm.) and southwest white pine (*Pinus strobiformis* Engelm.) were monitored in Christmas tree plantations located in Arizona's White Mountains. Plantings were made on three sites at respective elevations of 1525, 1920 and 2012 meters. Containerized planting, artificial shading and mulch coverings were tested for enhancement effects upon survival rates.

Plantings made with Arizona cypress container-grown seedlings and brutia pine (1-0) transplanted seedlings were the most successful, with 90 and 99 percent survival rates, respectively. Height growth averaged 50 cm for the Arizona cypress and 30 cm for the brutia pine. The remaining species had survival rates of 70 to 90 percent, but total heights after one growing season were a meager 6 to 15 cm. Shade and mulch treatments had little effect.

INTRODUCTION

Arizona has no large scale Christmas tree farms. Several attempts to establish tree plantations have been made in recent years, but all have failed (McVay 1973), probably due to Arizona's harsh climate and a lack of knowledge about regeneration techniques for adverse sites.

Both economic and biologic factors enter into determining a proper Christmas tree species for a given site (Bell and White 1966); however, the primary focus of this study will be the survival of given species in various locations. Once a species is proven adaptable to an Arizona woodland site, then equally important factors such as economics, genetic races and growth rates can be evaluated in greater detail.

The species selected should be compatible with the site; that is, adapted to the climate, soil and biotic environment (Smith 1962). The most logical way to meet this biological criterion would be to restrict the planting of a species to within its natural bounds, but this is not always possible for the Christmas tree producer with both limited land resources and a desire for a variety of marketable trees. In this study the plots were on the fringes of native Ponderosa pine (*Pinus ponderosa* Laws.) lands, and, therefore, were somewhat dry. Hopefully, this problem will be overcome by testing native and exotic trees in a variety of Arizona environments and using supplemental irrigation during the first year of establishment.

Arizona's timber types offer a broad selection of trees in four distinct habitats. In ascending elevation and precipitation ranges, they are (1) the upper Sonoran evergreen woodland, (2) transition, (3) Canadian or mixed conifer, and (4) Hudsonian or spruce life zones (Lowe 1972). From the evergreen woodland group, Arizona cypress (*Cupressus arizonica* Greene) and pinyon pine (*Pinus edulis* Engelm.) were selected. Chihuahua pine (*Pinus leiophylla* Schiede and Deppe) and the junipers (*Juniperus* spp.) are also reasonable Christmas tree possibilities of the evergreen woodland zone, but will not be studied at this time. Ponderosa pine, the only conifer of the transition zone, was omitted because of the pine's coarse appearance. From the mixed conifer zone, Douglas fir (*Pseudotsuga menziesii* var. *glauca* ((Beissn.)) Franco) and southwest white pine (*Pinus strobiformis* Engelm.) were chosen from a group that also includes white fir (*Abies concolor* ((Gordl and Glend.)) Lindl.). The remaining Hudsonian zone's blue and Engelman spruces (*Picea pungens* Engelm. and P. *engelmannii* Parry) were not considered because of their high precipitation requirements.

Also selected was the European brutia pine (_Pinus_ brutia Tenn.) which, in recent years, has been supplied by the Arizona State Land Department nursery and Tupper Trees of Sedona, Arizona, for planting on low elevation dry sites. This tree looks promising from the biological point of view because of its fast growth and dry site origins.

The objective of this thesis was to determine, using various silvicultural treatments, Christmas tree survival rates at three locations as follows:

1. Brutia and pinyon pines planted on an evergreen woodland site.

2. Arizona cypress and pinyon pine planted on a site at the transition between the juniper-pinyon and ponderosa timber types.

3. Douglas fir and southwest white pine planted on a ponderosa pine site.

The silvicultural treatments included the use of different types of seedling containers, and shading and mulching planted seedlings.

LITERATURE REVIEW

Arizona grows less than two percent of the Christmas trees sold within the state, and this small percentage comes entirely from wild cuttings (McVay 1973); hence, there is a lack of information on Christmas tree culture in Arizona. Therefore, the literature on forest regeneration practices for the Southwest and other dry adverse sites was reviewed. Specifically evaluated were: (1) the Christmas tree potential of each species, (2) the roles of containerized seedlings for planting, (3) various mulches, and (4) shade tolerance, all in relation to tree survival.

Christmas Tree Potential

In this study the emphasis for determining potential was a consideration of the tree's ecological tolerances and its possible acceptance on the Christmas tree market.

Douglas Fir

This species naturally occurs at elevations of 2,400 to 2,900 meters in Arizona, and its annual precipitation ranges from 58 to 76 cm (Schubert and Pitcher 1973). It is often classed in the mixed conifer type because it is found in a mixture with ponderosa pine at its lower elevation ranges and with Engelmann spruce at its higher elevation limits.

Douglas fir was second in Tucson Christmas tree sales for the 1971 season (McVay 1973) and is considered a leading tree on the western market (Bell and White 1966, Douglass 1965).

Southwest White Pine

This species is found in approximately the same precipitation and elevation ranges as those of the Douglas fir (Schubert and Pitcher 1973).

Heit (1973) and Wright (1965) have suggested that southwestern white pine be used as a Christmas tree, but no reports indicating its acceptance were found. However, it is closely related to the eastern white pine (<u>Pinus strobus</u> L.), a Christmas tree already marketed in the East (Bell and White 1966). Heit (1973) cited the southwestern white pine's soft needle texture, rather silvery blue-green color and close density of the needles as good reasons for putting it on the market. Southwestern white pine growth studies were conducted in Nebraska and Michigan with Arizona and New Mexico races. After nine years, well formed trees were produced with heights ranging from 113 to 153 cm (Wright et al. 1971).

Pinyon Pine

This species is found in evergreen woodland habitats at elevations of approximately 1220 to 2130 m (Little 1950). It is a dry site tree receiving 30 to 50 cm of precipitation annually (Schubert and Pitcher 1973).

The pinyon is considered slow growing and, thus, a poor choice for a Christmas tree (Bell and White 1966, Heit 1968). However, the pinyon has a drought-resistant nature which is higly appealing. Also, a promising geographical race has been found that may grow faster than has been indicated by previous investigators.

Arizona Cypress

This species is found in the same general elevations and precipitation ranges as those of the pinyon pine (Schubert and Pitcher 1973). Arizona cypress stands are usually scattered, often forming groves in the evergreen woodland habitat (Little 1950). According to Sudworth (1915), Arizona cypress can grow on either moist or dry sites, but it does best on north-slope gulches and in canyons.

Arizona cypress has been widely planted as an ornamental within Arizona, but it has never been grown in plantations for Christmas trees in the state. However, successful Arizona cypress Christmas tree plantations are found in the Southeast (Brewer and Shih-Chang Hu 1974, Garin 1963, Hall 1965, Lennarty 1964, Shain 1959). Lennarty (1964) and Hall (1965) have reported its growth rate to be from one to two meters in three years' time. Also, Garin (1963) found that stump culture—the process of producing successive tree crops by sprouts below the cut stump—is successful for Arizona cypress in Alabama. The main difficulties with this species in the Southeast have been poor initial survival (Shain 1959) and disease attacking the fragile seedlings. A fungus (*Cercospora sequoiae* Ell. and Ev.) commonly causes a needle blight in Arizona cypress Christmas tree plantings throughout the South (Hodges 1975).

Brutia Pine

The elevation ranges of this exotic pine are from 90 to 1500 m (Mirov 1967). In trying to correlate precipitation data (World Weather Records 1951-1960, 1966) with natural distribution bounds (Critchfield and Little 1966), the precipitation rates within the natural range of the species were found to average about 50 cm to possibly as much as 75 cm annually. Also, summer droughts and mild winters are characteristic of the brutia pine's environments. It occurs naturally in Turkey, in areas bordering the Mediterranean and on the islands of Crete and Cyprus. It has been widely introduced for a number of years, and there are even conflicts over whether or not its common occurrence in Iran and Afghanistan is actually natural (Critchfield and Little 1966). Czezott (1954) indicates that brutia pine is drought hardy, since it can be used to reforest dunes and eroded hills. The species is covered widely in foreign literature, but little of this information is translated (Alemdag 1962, Melejeff 1929, Selik 1959).

No reports of brutia pine being used as a Christmas tree were found, but it is similar in appearance to Scotch pine (*Pinus sylvestris* L.)—the leading Christmas tree on the Tucson market in 1971 (McVay 1973). Also, Tupper Trees of Sedona, Arizona, refers to the brutia pine (Mondell pine) as the "world's fastest growing evergreen," a characteristic worth exploring for Arizona.

Containerized Planting

In general, the first and most important growth response of a seedling must be to establish root contact with the soil (Tinus 1974). The time lag in this process can be eliminated with the use of containerized planting stock. This idea is not new. In fact, the Aztecs used a fish carcass for a seedling container (Kinghorn 1974). In more recent history, ponderosa pine 2-1 stock, potted in gallon cans, was planted as a shelter-belt in North Dakota and has only suffered a few suppression losses since its 100 percent survival in 1938 (George 1974).

A large container size seems to increase survival chances. Southeastern loblolly (Pinus taeda L.) and slash (P. elliottii Engelm.) pines grown in tubes 20 cm long gave superior results over those grown in smaller tubes (Barnett 1974). Lincoln National Forest, New Mexico, ponderosa pine survival was 30 percent in both Canadian Styroblocks (33 cu cm) and book planters (490 cu cm), while survival was only 10 percent for seedlings in the smaller Conwed tube (74 cu cm) (Buchanan 1974). An August planting in northwest Montana made with ponderosa pine seedlings grown in 295 cu cm Conwed tubes resulted in a 90 percent first-year survival success compared to 43 and 72 percent survival with seedlings grown in smaller tubes (74 and 212 cu cm) (Hite 1974). In a trial on the east slopes of the Sierra Nevadas, Miller and Buddy (1974) used Jeffrey pine (Pinus jeffreyi Grev. and Balf.) seedlings grown in 295 cu cm Conwed tubes, and obtained 10 to 20 percent survival. By increasing the tube size to 452 cu cm, the survival percentages improved to 60 and 70 percent. However, additional increases in tube size to 590 cu cm actually reduced survival rates.

Although the concept of container planting in forestry is an innovation which gives highly variable results, it offers a tremendous potential when considering the present survival rates for bare root coniferous seedlings planted on dry sites. For example, 30 percent is the accepted pine seedling survival rate on the Lincoln National Forest, New Mexico (Buchanan 1974). The entire Rocky Mountain region reports 25 to 30 percent as the average range for seedling survival rates (Colby and Lewis 1973).

Mulching

Soil moisture is critical in seedling establishment. Quantitative data relating soil water potential* (matric potential) to plant growth is lacking for most species of conifers and is highly variable in studies that have been made. Sands and Rutter (1959) found a significant reduction in the growth of Scotch pine due to water stress. They found that one-year old stock stressed at -.3 bars grew less than those stressed at -.1 bar soil water potential. With three-year old seedlings growth reduction occurred at lower water potentials of -.5 to -1.5 bars. Glerum and Pierpoint (1968) stressed white spruce (*Picea glauca* ((Moench)) Voss), red pine (*Pinus resinosa* Ait.), and larch (*Larix laricina* ((Du Roi)) K. Koch) seedlings to -1, -6 and -15 bars soil water potential. The water stress had no effect on the white spruce, and it was not until -15 bars that terminal and diameter growth rates on the red pine and larch were reduced.

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*Soil water potential is a measure of the free energy status of the water in the soil. Theoretically, it is the sum of the osmotic, pressure and matric potentials. However, in soils low in salt the soil water potential is essentially equal to the matric potential (Kramer 1969).

Some of the variability may be explained by the studies of Knipling and Miller (1965) with loblolly pine seedlings, and Mace (1962) with mature ponderosa pine. They show that soil water potential is an inadequate measurement of moisture stress in a tree, and that direct measurement of the foliage water potential (osmotic potential) is the only true evaluation.

Even though one cannot always account for the effects of a specific soil water potential on a tree, numerous studies have indicated that mulching—which modifies the soil's water content (Lippert, Takatori and Whiting 1964)—does have an effect on tree growth. In northern Idaho, Loewenstein and Pitkin (1970) determined that a mulch covering of 4 mm black polyethylene (black plastic) placed around ponderosa pine seedlings increased their height growth and survival above that of similar seedlings planted with either white polyethylene mulch or herbicide treatment, or with surface vegetation removed. The increase in survival was attributed to the black polyethylene's ability to reduce weed competition and evaporation. In Pennsylvania, 4 mm black polyethylene mulching sheets favored poplar (Populus spp.) growth when rainfall was normal, but retarded growth during drought and light rainfall periods (Bowersox and Ward 1970). Ponderosa pine seedlings grown in Arizona responded to black polyethylene mulch with slight increases in survival, while such mulches as clear polyethylene sheets, wood chips and dead grass had no effect on the pines (Rietveld and Heidmann 1974). De Byle (1969) reported that a black plastic mulch increased Jeffrey pine survival in the Sierra Nevadas by reducing water evaporation from the soil.

Some of the effects that different mulch coverings have on the microclimate and soil have been monitored. Waggoner, Miller and De Roo (1960) and Clarkson (1960) found that black plastic mulch dampened diurnal temperature fluctuations and increased temperatures above and below the plastic by 5.5 degrees centigrade. Also, a polyethylene mulch reduced nitrate leaching during rainy seasons. Waggoner and Reifsnyder (1961) measured reflected or outgoing radiation of the same magnitude, whether the soil was bare or covered with such mulch materials as black plastic, hay mulch or dusty translucent plastic; hence, the transpiration rate should not show any increase due to heat increases from these coverings.

Shade Tolerance

Shade tolerance is a species' specific requirement, which sometimes changes as a tree advances in age (Spurr and Barnes 1973). Excess sunlight on a conifer seedling is known to react in a complex manner with the seedling's transpiration, photosynthesis and many metabolic activities (Kramer 1969, Slatyer 1967). A complete review of these interactions is beyond the scope of this study and, thus, the review is limited to a simple discussion as to whether or not the survival of seedlings of each species in the study would be influenced by shade in a plantation situation.

Pinyon pine is an intolerant conifer and will survive in areas having high evapotranspiration stresses, but it prefers shade in the seedling stage (Meagher 1943, Phillips 1909). In northern Arizona, over 50 percent of the pinyons under 30 cm were found growing under larger trees (Jameson 1965).

Intermountain races of Douglas fir require shade, especially during the first growing season (Fowells 1965, Krauch 1956). Ryker and Potter (1970) attributed Douglas fir seedlings' shade needs to a metabolic imbalance incurred as the result of prolonged foliage moisture stresses. However, once established, Douglas fir does well in full sunlight (Jones 1971).

Southwest white pine seedlings endure full sunlight. Jones (1971, 1974) reported no harmful effects from full exposure to the sun, either in spot seedings or in those wild seedlings he observed.

Arizona cypress does best on north slopes and in canyons (Sudworth 1915), indicating that some light modification may be advantageous. However, seedlings planted as ornamentals in Tucson can endure full sunlight as long as the soil moisture is adequate.

Brutia pine appears adaptable to grow in varied environments, considering its widespread successful introduction into many parts of Europe and Asia (Critchfield and Little 1966, Mirov 1967).

DESCRIPTION OF THE STUDY AREA

The study area is divided into three sites—East Fork of the White River, Post Office Canyon, and Wagon Wheel Ranch—all of which are located in the White Mountains of Arizona. All are on privately owned land that was forested at one time. The temperature and precipitation for the three sites varies in magnitude with elevation, but the seasonal precipitation patterns are similar throughout the White Mountains. The three summer months (July, August, and September) and three winter months (November, December, and January) receive 80 percent of the precipitation. Summer storms are from tropical air masses that originate in the Gulf of Mexico and bring almost daily showers. Winter precipitation comes from the Pacific Ocean and falls as snow about 30 percent of the time at 1525 m elevations to as much as 70 percent at 2025 m elevations. The spring months through June are characterized by drought and clear sunny days (Sellers and Hill 1974).

East Fork of White River

The site is an old field located near the east fork of the White River at an elevation of 1525 m. Riparian vegetation dominated the site prior to cultivation

(Fig. 1). The riparian tree species growing in or near the area are Arizona alder (Alnus oblongifolia Torr.), boxelder (Acer negundo L.), cottonwoods (Populas fremontii Wats. and P. acuminta Rydb.), Arizona walnut (Juglans major Torr.) and sumac (Rhus glabra L.). Bordering the river's flood plan there is an evergreen woodland which includes gray oak (Quercus grisea Liebm.), one-seed juniper (Juniperus monosperma Engelm.) and some pinyon pine. The soil is of alluvial origin and has a silty clay loam texture. Slope is level and irrigation water is available from an open ditch system. Daily summer temperatures range from a low of 13 to a high of 32 degrees centigrade. In the winter, -6 to 10 degrees centigrade is an average daily fluctuation. About 44 cm of precipitation falls annually (Sellers and Hill 1974).

Post Office Canyon

The site is located just south of Post Office Canyon on the fringes of the ponderosa pine timber type at an elevation of 1920 m (Fig. 2). The dominant trees in the area are ponderosa pine, junipers (Juniperus deppeana Steud. and J. scopulorum Sarg.), oaks (Quercus grisea Liebm., Q. undulata Torr., Q. gambelii Nutt. and Q. emoryi Torr.). The soil is a well drained sandy loam. The daily average low and high temperatures in degrees centigrade for the summer are from 15 to 30 and in the

Fig. 1. A General View of the East Fork of White River Study Area

Fig. 2. A General View of the Post Office Canyon Study Area

winter -8 to 7. The site receives about 50 cm of annual precipitation (Sellers and Hill 1974).

Wagon Wheel Ranch

The site is located near the Wagon Wheel community at an elevation of 2012 m and is adjacent to a stand of ponderosa pine, pinyon pine, Gambel oak (*Quercus gambelii* Nutt.) and alligator juniper (*Juniperus deppeana* Steud.) (Fig. 3). The plot was cultivated pasture prior to the study. The soil is highly eroded with little A-horizon remaining on the lower eastern portion of the plot. The 15 to 30 cm surface layer is a clay loam and the nearly exposed B-horizon is a heavy plastic clay. Slope is gentle and irrigation is available from a nearby pond. Average daily temperatures range from 10 to 25 degrees centigrade in the summer and -11 to 5 degrees centigrade in the winter. The area receives about 48 cm of annual precipitation (Sellers and Hill 1974).

Fig. 3. A General View of the Wagon Wheel Ranch Study Area

EXPERIMENTAL PROCEDURE

The study consisted of two phases: (1) growing the planting stock, and (2) out-planting these seedlings using various silvicultural treatments. The second phase was the main focus of the study and was highly dependent upon success in the first phase. Unfortunately, the seedling survival in step one did not follow the initial expectations. This resulted in modifications that made the experimental design more complicated than had been planned. With no further justification, the planting stock procedures, plot designs and treatments, and cultural practices are discussed separately, describing in each case the exact methodology used.

Planting Stock Procedure

Both bare root and container-grown seedlings were used in the study, and a separate discussion on each will follow.

Bare Root Seedlings

Southwest white pine 1-0 stock and Douglas fir 2-0 stock were purchased from C. E. Heit's nursery in New York. The white pine seedlings were about 5 cm in height and the Douglas fir seedlings were about 9 cm tall. The white pine seed originated from the Coconino National Forest, Arizona, and the Douglas fir seed came from the Lincoln National Forest, New Mexico.

Containerized Seedlings

All container stock—except brutia pine transplants—was grown from seed during the 1974 winter and 1975 spring months in Tucson. The transplanted brutia pines were bare root seedlings which were purchased from Tupper Trees of Sedona, Arizona, and transplanted as 1-0 stock into metal cans four months prior to out-planting. The Douglas fir, southwest white pine, pinyon pine and Arizona cypress seedlings were started in metal cans, and a remaining lot of brutia pine seedlings were started in plastic tubes. All seedlings were kept in a greenhouse from November to March. In April the stock was moved to a lathhouse at the Tucson City Nursery.

The containers for the metal can stock and brutia pine transplants were half-gallon juice cans, 10 cm in diameter by 15 cm in length (1178 cu cm). The tubes were a plastic mesh Conwed tube,* 5 cm in diameter by 15 cm in length (295 cu cm).

All seedlings were planted in a potting medium consisting of a mixture of four parts desert top soil, two

*A container manufactured by Conwed Corporation, 770 - 29th Ave., S. E., Minneapolis, Minn. 55414.

parts mortar sand and three parts peat. This was fertilized with 6 kg of 7-40-6 fertilizer per cubic m of soil (225, 560 and 160 lbs NPK per ac) and 4.5 kg of 90 percent sulfur per cub m of soil (2,900 lbs S per ac). Only unstratified seed was sown.

Mycorrhizal fungi were inoculated into all containers three months after germination. The mycorrhizal source consisted of small amounts of soil and slightly decomposed litter, collected from the forest floor of the mixed conifer timber type in Arizona's Coronado National Forest.

Damping-off was significant only with Douglas fir, killing about half of the 120 seedlings one month after germination. Thus, the containerized Douglas fir treatment was not replicated on the Wagon Wheel Ranch plot.

After approximately four months in a greenhouse and two months in a lathhouse, the planting stock varied in size according to species. Arizona cypress averaged about 15 cm in height and the rest were from 3 to 5 cm tall.

Root systems in the two container types did present some difficulties. The pinyon pine's single tap root was a problem in the mesh Conwed tubes because roots sometimes grew across into adjoining tubes. Tap roots of all species in the closed bottom cans showed some spiraling. The entire root system for the Arizona cypress seedlings seemed to out-grow their metal can containers, as was evidenced by spiraling of the laterals.

Seed sources and collection dates of the containerized stock were as follows: Arizona cypress—Seneca, Arizona (1960's); southwest white pine—Carson National Forest, New Mexico (1963); Douglas fir—Lincoln National Forest, New Mexico (1968); pinyon pine—Prescott National Forest, Arizona (1974); and brutia pine—Afghanistan (1973).

Plot Designs and Treatments

Each site in the three study areas was previously cleared and fenced. The Wagon Wheel and Post Office plots had a few Scotch pines scattered throughout, which limited a uniform experimental design for all three plots.

Treatments also varied with each site except for the shade applications. The standard procedure for the shade treatments was to use "1 x 12" boards 40 cm in length, propped with a brace at an angle of 70 degrees from the horizontal, and oriented at an azimuth of 125 degrees to provide shade from about Noon to 5 P. M. during the summer growing season.

Seedlings were hand-planted, the exact method varying with the type of stock used. A planting bar was used to plant the bare root seedlings. Those grown in the metal cans were removed and planted with the root-ball still intact. A can shears was used to slice the metal can on opposite sides to aid in removing the seedlings. The tube seedlings were planted without removal from the open-bottom mesh tube.

The remaining discussion on designs and treatments is separate for each plot as follows:

East Fork of White River

The one-tenth ha plot received six treatments replicated seven times in a randomized block design. Each treatment had six trees spaced at 1.5 m between trees and 2.4 m between rows. The treatments were: (1) brutia pine transplants, (2) brutia pine transplants with shade, (3) brutia pine tube stock with shade, (4) pinyon pine metal can stock, (5) pinyon pine metal can stock with shade, and (6) pinyon pine tube stock with shade. Planting was done in May 1975.

Post Office Canyon

The plot was one-tenth ha in size with 93 Scotch pine remaining from a previous study. Twenty east-west rows at 1.5 m intervals divided the plot into treatment units. The rows were blocked into two groups of eight and a remaining group of four. Eight treatments were applied, one per row, to the two large blocks, and the smaller block received two treatments per row in an alternating fashion. Approximately nine trees spaced 2.4 m apart were planted in each row. All seedlings were grown in the metal can containers. The treatments were: (1) pinyon pine with wood chip mulch and shade, (2) pinyon pine with black polyethylene mulch and shade, (3) pinyon pine with shade, (4) pinyon pine control, (5) Arizona cypress with wood chip mulch and shade, (6) Arizona cypress with black polyethylene mulch and shade, (7) Arizona cypress with shade, and (8) Arizona cypress control. The wood chip mulch was approximately 4 cm deep and the polyethylene was 4 mm thick. Both mulches covered a 30 cm radius around the tree. All trees were planted in large basins, having a water holding capacity for irrigation of about 15 liters. Planting was done in May 1975.

Wagon Wheel Ranch

The plot was one-fifth ha in size with 176 previously existing Scotch pine. For treatment units, the plot was divided into eight east-west rows 2.4 m apart, and blocked into two groups of four rows. However, due to planting stock failures only seven rows were used. Each row received about 40 trees spaced at 1.5 m intervals. The four treatments were: (1) Douglas fir metal can stock with shade, (2) Douglas fir 2-0 bare root stock with shade, (3) southwest white pine metal can stock, and (4) southwest white pine 1-0 bare root stock. All treatments were replicated twice except for the containerized Douglas fir. The bare root stock was planted in April 1975 and the containerized seedlings were planted in June 1975.

Cultural Practices

Irrigation was applied at ten-day intervals prior to the summer monsoon season that began on July 1. Thereafter, rainfall kept soil moisture at an adequate level.

All the plots were roto-tilled before planting and at two-week intervals during the growing season. Hand weeding with a shovel was done to remove weeds within the rows that were missed by roto-tilling operations.

RESULTS AND DISCUSSION

The main objective of this study, obtaining high seedling survival rates, was achieved (Table 1). However, the data only covers one growing season and should be viewed with that fact in mind.

Only survival data within treatments for a given species were tested with probability statements, since this study was not set up to make any other meaningful comparisons. The test used on the survival percentages is one developed by Goodman (1964). It is a multiple comparison test for binomially distributed data that allows separation of individual treatments within a group. Probability statements are made with 95 percent confidence which resulted in somewhat large testing intervals. The 95 percent level was chosen since the experimental design in this study was not the best and the experimental error in the final results could be substantial.

Each plot was treated differently and a separate discussion will follow for each.

East Fork of White River

The pinyon pine seedlings had acceptable survival rates, and height growth of less than 7 cm was in agreement with past reports of the pinyon pine's slow growth (Bell

Table 1. A listing by species of the percent survival and total numbers planted for each plot in the study.

	Total Planted	Percent Survival
East Fork of the White River Plot		
Pinyon Pine	126	71%
Brutia Pine	126	94%
Post Office Canyon Plot		
Arizona Cypress	93	90%
Pinyon Pine	94	90%
Wagon Wheel Ranch Plot		
Douglas Fir	126	75%
Southwest White Pine	167	86%

and White 1966, Heit 1968) Table 2). Seedlings grown in both types of containers survived equally well and shade treatments had little effect on survival (Table 3).

Brutia pine had both good survival and adequate growth rates (Table 4). The containerized transplant method gave better results than did the Conwed tubes, and the shade treatments had no effect on survival rates (Table 5). Brutia pine looks very promising, from a growth and survival standpoint, as a future Christmas tree for Arizona's many arid sites similar to the White River area (Fig. 4).

Post Office Canyon

Arizona Cypress survived well and height growth was exceptional for first-year seedlings (Table 6). Shade and mulch treatments had no beneficial effect (Table 7). In fact, the shade boards were removed in August to avoid possible suppression losses. Arizona cypress was definitely a success and should be studied in considerable detail as a future Christmas tree for Arizona (Fig. 5).

The pinyon pine had acceptable survival rates (Table 8). The treatments had no effect except for the wood chip mulch which buried and killed some of the seedlings during the summer monsoon season (Table 9). Again, the slow growth character of the pinyons was exhibited,

Table 2. East Fork of White River—pinyon pine: a summary of planting, survival and height data for all treatments.

	Planting Stock Treatments		
	Metal Cans	Metal Cans with Shade	Conwed Tubes
Total Planted	42	42	42
Total Survived	26	34	30
Percent Survival	62%	81%	71%
Average Height (cm)	6.42	6.65	6.10
Standard Deviation of Heights (cm)	1.06	1.07	1.49

Table 3. East Fork of White River—pinyon pine: statistical comparisons of survival percentages for all treatment pair combinations.

Planting Stock Treatments	Metal Cans	Metal Cans with Shade	Conwed Tubes
Metal Cans	---	-1.973	-.878
Metal Cans with Shade	---	---	1.080

Where $P(-2.395 < \text{tabled value} < 2.395) = .95$; hence there are no treatment differences (Goodman 1964).

Table 4. East Fork of White River—brutia pine: a summary of planting, survival and height data for all treatments.

	Planting Stock Treatments		
	Transplants	Transplants with Shade	Conwed Tubes with Shade
Total Planted	42	42	42
Total Survived	41	42	36
Percent Survival	98%	100%	86%
Average Height (cm)	30.66	29.43	13.58
Standard Deviation of Heights (cm)	5.00	7.07	4.53

Table 5. East Fork of White River—brutia pine: statistical comparisons of survival percentages for all treatment pair combinations.

Planting Stock Treatments	Transplants	Transplants with Shade	Conwed Tubes with Shade
Transplants	---	-.926	2.078
Transplants with Shade	---	---	2.615*

Where P(-2.395 < tabled value < 2.395) = .95 (Goodman 1964).

*Transplants with shade are significantly different from the Conwed tubes with shade with 95% probability.

Fig. 4. A Brutia Pine Transplant on the East Fork of White River Plot that is 30 cm Tall After One Growing Season

Table 6. Post Office Canyon—Arizona cypress: a summary of planting, survival and height data for all treatments.

	Treatments			
	Wood Chip Mulch with Shade	Shade	Black Plastic Mulch with Shade	Control
Total Planted	27	21	25	20
Total Survived	25	19	21	19
Percent Survival	93%	90%	84%	95%
Average Height (cm)	42.36	48.37	57.14	52.58
Standard Deviation of Heights (cm)	11.06	11.16	10.36	8.77

Table 7. Post Office Canyon—Arizona cypress: statistical comparisons of survival percentages for all treatment pair combinations.

Treatments	Wood Chip Mulch with Shade	Shade	Black Plastic Mulch with Shade	Control
Wood Chip Mulch with Shade	---	.367	1.020	-.298
Shade	---	---	.610	-.613
Black Plastic Mulch with Shade	---	---	---	-1.249

Where $P(-2.635 < \text{tabled value} < 2.635) = .95$; hence there are no treatment differences (Goodman 1964).

Fig. 5. An Arizona Cypress on the Post Office Canyon Plot that is 60 cm Tall After One Growing Season

Table 8. Post Office Canyon—pinyon pine: a summary of planting, survival and height data for all treatments.

	Treatments			
	Wood Chip Mulch with Shade	Shade	Black Plastic Mulch with Shade	Control
Total Planted	23	26	24	21
Total Survived	18	26	22	19
Percent Survival	78%	100%	92%	90%
Average Height (cm)	7.56	8.04	7.91	8.16
Standard Deviation of Heights (cm)	1.10	2.03	1.48	1.42

Table 9. Post Office Canyon—pinyon pine: statistical comparisons of survival percentages for all treatment pair combinations.

Treatments	Wood Chip Mulch with Shade	Shade	Black Plastic Mulch with Shade	Control
Wood Chip Mulch with Shade	---	-2.574*	-1.364	-1.107
Shade	---	---	1.445	1.529
Black Plastic Mulch with Shade	---	---	---	.233

Where P(-2.634 < tabled value < 2.635) = .95 (Goodman 1964).

*Treatments in question are very close to significance with 95% probability.

suggesting limited use as a plantation Christmass tree (Fig. 6).

Wagon Wheel Ranch

Douglas fir seedlings had an acceptable survival percentage. Height values for the bare-root stock were better than those for the containerized seedlings, but initial differences in planting stock sizes prevented any meaningful comparison (Table 10). The container seedlings were 3 to 4 cm smaller than were the bare-root seedlings at the time of planting. Since the planting dates for the two planting methods also differed by a month, the statistical test for container versus bare root survival had little meaning. As the literature suggested (Fowells 1965, Krauch 1956), all Douglas fir seedlings in the study were shaded, and whether or not the trees will survive in full sunlight after they outgrow the shading remains to be observed. Twenty bare-root Douglas fir seedlings were planted on the edge of the plot without shade and only five died, but overall growth and vigor was less than that for the shaded seedlings.

Southwest white pine survived well for both the bare-root and container planting methods (Table 11). The data indicates a survival advantage of the bare-root stock over that of the container stock, but this inference

Fig. 6. A Pinyon Pine on the Post Office Canyon Plot that is 8 cm Tall After One Growing Season

Table 10. Wagon Wheel Ranch—Douglas fir: a summary of planting, survival and height data for the treatments; and a statistical comparison of survival percentages.

	Treatments		
	Metal Can Stock with Shade	2-0 Bare Root Stock with Shade	Statistical Test
Total Planted	37	89	---
Total Survived	28	67	---
Percent Survival	76%	75%	.119*
Average Height (cm)	5.32	14.63	---
Standard Deviation of Heights (cm)	.94	2.93	---

*Where $P(-2.240 < .119 < 2.240) = .95$; hence there is no treatment difference with a probability of 95%.

Table 11. Wagon Wheel Ranch—Southwest white pine: a summary of planting, survival and height data for the treatments; and a statistical comparison of survival percentages.

	Treatments		
	Metal Can Stock	1-0 Bare Root Stock	Statistical Test
Total Planted	80	87	---
Total Survived	64	79	---
Percent Survival	80%	91%	-2.028*
Average Height (cm)	4.21	7.77	---
Standard Deviation of Heights (cm)	.70	1.48	---

*Where P(-2.240 < -2.028 < 2.240) = .95; hence the treatments are very close to being significantly different with a 95% probability.

is subject to the same biases as were described above for the Douglas fir seedlings.

On the basis of one year's data, neither species in the Wagon Wheel Ranch plot looks appealing as a short rotation Christmas tree (Figs. 7 and 8).

Fig. 7. A Douglas Fir (2-0 Seedling) on the Wagon Wheel Ranch Plot that is 15 cm Tall After One Growing Season

Fig. 8. A Southwest White Pine (1-0 Seedling) on the Wagon Wheel Ranch Plot that is 8 cm Tall After One Growing Season

SUMMARY

During the summer of 1975, the seedling survival and height growth rates of brutia pine (Pinus brutia Tenn.), Arizona cypress (Cupressus arizonica Greene), Douglas fir (Pseudotsuga menziesii var. glauca ((Beissn.)) Franco), pinyon pine (Pinus edulis Engelm.) and southwest white pine (Pinus strobiformis Engelm.) were monitored in Christmas tree plantations located in Arizona's White Mountains. Plantings were made on three sites at elevations of 1525, 1920 and 2012 meters, respectively. Containerized planting, artificial shading and mulch coverings were tested for enhancement effects upon survival rates.

Plantings made with Arizona cypress container-grown seedlings and brutia pine (1-0) transplanted seedlings were the most successful, with 90 and 99 percent survival rates, respectively. Height growth averaged 50 cm for the Arizona cypress and 30 cm for the brutia pine. The remaining species had survival rates of 70 to 90 percent, but total heights after one growing season were a meager 6 to 15 cm. Shade and mulch treatments had little effect.

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