RECLAMATION OF CREOSOTEBUSH-INFESTED RANGELAND

by

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ABSTRACT

Two studies were conducted at the University of Texas Lands, near Bakersfield, Texas, and at Texas Tech University during 1990 and 1991 to determine the reseeding requirements for creosotebush-infested rangeland, specifically the effects of soil temperature and soil water content upon the emergence and establishment of native and introduced range grasses as influenced by herbicide application, different types of mulching, and irrigation, and to assess the upper threshold temperature for the species under investigation (experiment 1), and to evaluate under growth chamber conditions the upper threshold of temperature on germination of the species commonly used to reseed semi-arid to arid rangeland (experiment 2).

In the first study, out of 17 analized dates, 4 were judged the dates that would describe best the environmental conditions affecting the experimental units as well as the experimental material. The dates were: July 3, 1990; July 17, 1990; August 7, 1990; and February 22, 1991. It was found that seedling emergence started to take place on July 17, 1990, when soil temperatures dropped below 32 °C, and an increase in soil water content above 12 %. These environmental conditions attained on July 17, 1990, were product of the first summer rain.

The application of the herbicide (tebuthiuron) at the rate of 0.56 kg. a.i./ha to control the creosotebush population in two blocks of the experimental area was excellent (90% kill). However, no significant differences ($P>0.05$) were found in soil water content as well as soil temperature regardless the combination of herbicide and irrigation. This indicates that despite the provided irrigation and the control of creosotebush, no seedling emergence was attained when soil temperatures were above 32 °C and soil water content was below 12 %; therefore, it is suggested from a management standpoint that creosotebush can be controlled after a good stand of grass has been successfully established.

When mulching treatments were affected by herbicide application and irrigation, soil moisture was not different ($P>0.05$). Generally, there was more soil moisture ($P<0.05$) at 15.24 cm than at 1.27 cm depth. With respect to the different types of mulching, it was found that hydromulch treatments were warmest of the three ($P<0.05$).

With respect to seedling establishment, there was significant difference ($P<0.05$) among the three mulching treatments, with the hay mulch treatments, resulting in the best establishment (number of seedlings /m^2), followed by hydromulch and no mulch treatments, respectively. Lehmann lovegrass was the only species that could survive in the hydromulch treatments, the remaining four species (Plains bristlegrass, sideoats grama, green sprangletop, and Old World bluestem) perished once they had emerged. The hydromulch treatment produced a kind of greenhouse effect compared to the hay mulch and no mulch treatments. Despite this characteristic, hydromulch treatments had better ($P<0.05$) establishment than the no mulch treatments. Hay mulch treatments were the best with respect to soil water content.

Seedling emergence and survival were significantly greater ($P<0.05$) with the hay mulch treatments (hydromulch and hay mulch) than with the no mulch treatments. Taking into account these results, it is suggested that seedings should not be conducted without a type of mulch, because the risk of failure would be greater. All the species except Old World bluestem attained establishment. This species apparently requires a less harsh environment to become established. It has been successfully adapted in areas where annual precipitation averages 500 mm or above, but it does not represent a promising species to reclamate disturbed areas located in the Trans-Pecos region of Texas, and the southwestern United States.

Sideoats grama had better establishment among the natives followed by Plains bristlegrass and green sprangletop, respectively. Green sprangletop apparently is more sensitive to high soil temperatures and low soil water content than the other two. Lehmann lovegrass had the best establishment of the five, this is apparently because it tends to put its root system along the moisture front attained due its rapid root growth and development once it has germinated.

In the second trial, it was found that the germination (%) of each species was significantly (P<0.05) affected by the different temperature regimes. All of the species exhibited maximum germination (%) when the temperature of the incubator cycled between 18 and 35 °C. Germination of all the species was drastically reduced between 18/35 and 18/40 °C. The upper threshold of temperature for the species used in this study was between 35 and 40 °C. The threshold soil temperature under field conditionn could be under 35 °C. This was true if we take into account the field results with respect to soil temperature attained in the first experiment.

Reseeding as an alternative to reclamate semiarid to arid ecosystems should be carefully considered. The likelyhood of a seeding failure to occur will always be present, especially, if the many negative factors that get involved with this practice are taken into consideration such as high soil temperatures, low soil water content, high evaporation rates, the presence of rodents and lagomorphs, etc. This practice should be conducted if it is the only alternative to restore denuded rangelands, before the soil is washed out through runoff.

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CHAPTER I

INTRODUCTION

On a worldwide basis, rangeland is the largest land resource occupying about 50% of the land area (Anonymous 1985, Busby 1987). In addition to the United States, other countries or regions of the world with large areas of rangeland are Canada, Mexico, South America, the Middle East, Africa, Australia, Russia, and China (Vallentine 1990). Specifically, in the southwestern United States and semiarid regions of Mexico, vast areas formerly dominated by perennial grasses have deteriorated to brush and need to be rehabilitated through various integrated range improvement practices.

Overgrazing, the total supression of fire, and changes in weather patterns have been the major causes of grasslands to have lowered their condition and allowed them to be invaded by shrubs that in some cases have formed impenetrable thickets due to their density and stature (Bogush 1952, Johnston 1962, Inglis 1964, York and Dick-Peddie 1969, Scifres 1980, Wright 1982, Branson 1985). Dense stands of woody plants adversely affect semiarid environments because of accelerated wind or water erosion (Gould 1982).

Humphrey (1958) and Buffington and Herbel (1965) indicated that climate has not changed enough to account for the rapid increment of shrubby species, but weather patterns are important (Barbour et al. 1987). Others such as Holechek et al. (1989) suggested that a change in climate could be added to the other suppositions causing the proliferation of shrubs and other undesirable range plants. Certain woody plants were always present on some range sites, and amounts not exeeding composition in the climax state for the site do not lower range condition class (Dyksterhuis 1958). There is considerable evidence that originally both the Chihuahuan and Sonoran Deserts were open grasslands or grasslands with scattered shrub species (Buffington and Herbel 1965).

In accordance to Holechek et al. (1989), the Chihuahuan Desert which is found in southwestern Texas and southcentral New Mexico has fewer species than the Sonoran

Desert located in southwestern Arizona due to colder weather in the winter and less precipitation. Because of low forage productivity and grazing resistance, livestock grazing is not practical in much of the Mojave and Sonoran Deserts. Tourism, wildlife, water, and recreation have become far more important resources than forage for livestock., whereas livestock production under extensive systems in the Chihuahuan Desert will probably be an important rangeland use (Holechek et al. 1989).

Areas invaded by brush species such as creosotebush (*Larrea tridentata*), tarbush (*Flourensia cernua*), and mesquite (*Prosopis spp.*) will not recover and improve their range condition because of heavy and permanent grazing pressure and low precipitation; therefore, recovery is often very slow or nonexistent (Smith and Schmutz 1975). In creosotebush-dominated areas, forage production is negligible (Gardner 1951).

It has been estimated that brush has invaded 128 million hectares of grazing lands in the United States (Klingam 1964); approximately 64 million are in Texas (Scifres 1980). Creosotebush, a shapely evergreen shrub, is one of the most characteristic plants of the southwestern Deserts. Extensive bright green oases contrasting sharply with the usual grayish tone of the Desert are formed by pure stands of this shiny-leaved yellow-flowered shrub that grows from 0.90 cm to 3.5 m in height. The plant has a creosote-like odor, especially when burned or wet, which accounts for its common name. It is known as gobernadora, hediondilla, greasewood, and numerous other common names referring to the strong, pungent odor or to the resinous properties of the plant. The specific name *tridentata* describes the stamen stalk. This plant is worthless as forage during all seasons and to all classes of livestock (USDA, Forest Service 1937).

It has been estimated that mesquite, creosotebush, and tarbush occur on 37.7, 18.8, and 5.4 million hectares, respectively, in the U.S. (Platt 1959). Hull et al. (1972) estimated that creosotebush occupies 14 to 19 million hectares of southwestern United States rangeland, and nearly 45 million hectares in northern Mexico (Leopold 1950) where it continues to invade grasslands (Buffington and Herbel 1965).

The Chihuahuan Desert in Texas and southern New Mexico is one-eighth the size it is in Mexico. The Desert enters Texas primarily along two routes; the largest area includes the Rio Grande drainage system from Del Rio, Texas, and continues to approximately Albuquerque, New Mexico. The alternate route is from the mouth of the Pecos River to approximately Roswell, New Mexico. The plants that inhabit this large ecosystem occur primarily on soils of calcareous origin. Despite the aridity of this zone, abundance of grassland is still noticeable in some areas after the invasion of the key indicator plants of the desert, namely creosotebush, tarbush, and mesquite (Warnock 1974).

According to Johnston (1974), the Chihuahuan Desert region is generally a very arid region lying in north-central Mexico and extending northward through the Trans-Pecos of Texas to southern New Mexico. It is a bluntly and irregularly cuneiform territory pointed south-southeastward to approximately San Luis Potosí, S. L. P, Mexico. At 31° N latitude, the broadest region, the east-west dimension is approximately 620 kilometers (372 miles). The greatest linear measurement from a point in New Mexico on the Rio Grande at 34 °30 ' N latitude south-southeastward to the farthest point near San Luis Potosí is approximately 1550 kilometers (930 miles).

Rzedowsky and Medellin (1958) and Miranda (1959) agreed that the Chihuahuan Desert reaches out as far south as the arid region of the "Mezquital Valley" of Hidalgo, Mexico. The total area is approximately 505,000 square kilometers (km^2) or 202,000 square miles (mi^2), the equivalent to four-fifths the size of Texas. In the Trans-Pecos region of Texas, creosotebush infests roughly 4 million hectares (SCS mimeographed material).

A substantial amount of research has demostrated that creosotebush can be controlled. However, very little emphasis is placed on improving creosotebush infested ranges because it has been characterized as unproductive rangeland or rangeland with very low potential. These lands have been subjected to different ecological changes (temperature extremes, changes in weather patterns, total fire supression), as well as man created problems (continuous overgrazing) through the years, such that the only way to recover their vanished productivity in many instances is through reclamation. If desirable grasses or shrubs could successfully reseed these areas, production could be dramatically increased.

Artificial seeding is frequently recommended to improve these rangelands. To subdue the risk of seeding failure in arid environments, it is necessary to better understand the factors involved in the process of seed germination and seedling establishment. Also, because species vary in their requirements for germination and growth, it is imperative to scrutinize the responses of different species to the alteration of the seedbed environment.

By reason of insufficient and inconsistent precipitation and also high evaporation rates as well as high temperatures present during the most favorable growing season in arid and semiarid regions, the soil moisture and soil temperature are often inadequate for seed germination and seedling establishment., hence these stages are the most critical for successfully revegetate these vast territories. Therefore, the objectives of this research were to determine:

a. the reseeding requirements for creosotebush-infested rangeland, specifically, the effects of soil temperature and soil water content upon the emergence and establishment of native and introduced range grasses as influenced by herbicide application, different types of mulching, and irrigation, and to evaluate the upper threshold temperature for the species under investigation (experiment 1);

b. the upper threshold of temperature on germination of the species commonly used to reseed semi-arid to arid rangeland (experiment 2).

CHAPTER II

LITERATURE REVIEW

Drought is a common phenomenon on rangelands confused sometimes with aridity. Aridity is a lasting condition of a general lack of water. Drought on the other hand is a period of low precipitation in relation to a longer-term average. It is a period when precipitation is less than 75% of the average amount (Society for Range Management 1974). With the manifestation of a drought, some key range grasses are replaced by others considered less important and the total herbage production is drastically lessened (Chamrad and Box 1965, Herbel et al. 1972a, Pieper and Donart 1973).

Rangeland revegetation emerged as an applied science in the U.S. approximately 100 years ago, following a noticeable downward trend in range condition associated with the settlement and intensive use of arid and semiarid lands. From the early 1890's to the mid 1930's, revegetation efforts were aimed at trying to halt land degradation resulting from overstocking with domestic animals and abandoning cultivation of what once was rangeland. Early revegetation efforts relied heavily upon conventional agricultural principles and practices, and were largely failures because seed was only available for cultivated forage plants adapted to the more mesic environment. Site preparation methods also were often inadequate (Stoddart et al. 1975).

During the 1960's and 1970's, with the passage of state and federal legislation, revegetation technology for drastically disturbed land, such as those associated with energy and mineral exploration developed markedly (DePuit 1986). Revegetation of disturbed lands is now perceived as a major environmental responsibility by land owners, managers, and users. Considerable progress has been made in better understanding the theoretical and practical aspects of revegetation, but much remains to understand this extensive practice that is subject to failure (Call and Roundy 1990).

Dahl et al. (1987) reported that failure to obtain a successful seeded stand is most commonly due to one or more of the following items: (1) lack of rain at the proper time; (2) inadequate seedbed preparation; (3) improper seeding depth; (4) weed competition; (5) seeding at the wrong time of the year; (6) insect and rodent damage; (7) non- adapted species; (8) poor quality seed; (9) improper equipment; or (10) lack of grazing protection until stand establishment. Thus, successful seedings depend on the attention devoted to the above items.

The nature of disturbance and widely divergent climatic and site conditions tremendously affect the revegetation practice of arid and semiarid rangelands (DePuit 1986). The size, intensity, and frequency of occurrence of disturbances vary considerably, and play a major role in community development and organization (Bazzaz 1983).

Revegetation practices represent disturbances that can influence community development. Climatic factors, primarily low and erratic precipitation and extremes in temperature, exert an overriding effect on the success or failure of a revegetation practice, regardless of the intensity of manipulation treatments used to prepare seedbeds and control undesirable plants (Bleak et al. 1965, Robocker et al. 1965, and Tadmor et al. 1968).

Soil water content and soil temperature are the primary environmental factors associated with seed germination and seedling establishment of native and introduced plant species (Hyder and Bement 1964, Herbel and Sosebee 1969, Sosebee and Herbel 1969, Hyder et al. 1971, Wester and Dahl 1980, Wight and Hanson 1987). Silcock (1986) estimated that favorable establishment conditions exist one year out of four in semiarid regimes of Australia.

Soil Moisture

Bleak et al. (1965) suggested that limited precipitation on arid salt desert shrublands in the Great Basin may only allow natural seeding recruitment or seedling establishment from artificial seeding once or twice every 15 years. Low water availability in arid or semiarid zones severely limits seed germination, seedling establishment, and maintenance of perennial grasses (McAlister 1944, Hassanyar and Wilson 1979). As rangeland environmental conditions become increasingly arid, seeds on the soil surface are exposed to prolonged periods of dessication and shorter periods of atmospheric saturation impairing the potential of seeds to germinate (Young et al. 1969).

Brar et al. (1990) noted that in semiarid and arid territories surface soils often dry out quickly after being wetted. As a result of this, plants grown in these hostile conditions require the ability to develop a root system rapidly once rainfall has occurred in order to ensure a continuing water supply to meet transpirational demands. Evans et al. (1969) attributed seedling establishment to the ability of microsites to meet the specific seed germination and seedling growth requirements of invading species, and remarked that because of limited water and other environmental constraints the ecesis process comprises a high degree of uncertainty to succession on disturbed arid and semiarid rangelands in the west. The ability of a plant to become established is dependent upon its ability to withstand the conditions imposed by the habitat. Establishment implies that the species completes all of its life processes from germination to reproduction (Redente and DePuit 1988). Werner (1977) attributed unsuccessful establishment to failure at one of the phenological stages: seed germination, juvenile survival, flowering, or seed set.

One of the most critical phases is in the germination to early seedling stage when the plant's survival is dependent upon the moisture intake of the seminal root (Mueller and Weaver 1942, Tapia and Schmutz 1971). Frasier and Simanton (1987) found that root elongation must be sufficiently rapid to maintain contact with the receding soil moisture front if a seedling is to survive. Rapid seedling root elongation, as tested in the laboratory, may not always directly correspond with observed seedling establishment in the field. However, where periods of available water are limited it is reasonable to expect greater establishment from seedlings with root growth that is rapid enough to stay ahead of the soil drying front (Simanton and Jordan 1986).

Smucker and Erickson (1976) reported that when grown in an "ideal" environment, plant root systems grow in a form and shape dictated by their genetic makeup and may be approached in a mist chamber, but almost never are fully expressed when plants are grown in a field soil with its ever-changing environment. The ability of roots to rapidly elongate allows root growth to advance beyond the soil drying front so that the seedling can avoid desiccation (Harris and Wilson 1970). Seedling survival is dependent on eventually receiving precipitation before evapotranspiration dries the soil surface (Jensen 1982).

Moisture stress not only diminishes the extent, but also reduces the rate of germination (Laude 1956, Crocker and Barton 1957, McGinnies 1960, Mayer and Poljakoff-Maber 1963, Ellern and Tadmor 1966, Springfield 1966, Knipe 1967, Herbel and Sosebee 1969, Tapia and Schmutz 1971). Soil resistance to root penetration may prevail through the lower range of plant available soil moisture levels, but soil hydraulic resistance becomes more important as soil moisture becomes depleted (Belmans et al. 1979).

Hendrickson and Veihmeyer (1931) and Trouse (1972) demonstrated that roots will normally grow into moist soil zones. There is evidence that some warm season grass species will grow into soil zones where the moisture level is below the wilting point (Salin et al. 1965). Soil moisture is seldom uniformly distributed throughout the soil profile and root growth may be restricted in an area of low soil moisture, which may be compensated by greater growth in an area with favorable soil moisture. Without adequate root growth, the chances for plant success are greatly reduced (Russell 1973).

Olmsted (1941) and Hyder et al. (1971) observed that approximately three consecutive wet days were required for the successful establishment of adventitious roots of sideoats grama. Small plastic greenhouse containers were filled with dry mesh sand and seeded with ten seeds of sideoats grama or "Cochise" Atherstone lovegrass (*Eragrostis lehmanniana* Ness X *Eragrostis tricophera* Coss and Dur.). Various length combinations of wet day-dry day-wet day sequences were used in 14-day study periods. Results showed that 50-80% of the sideoats grama seedlings did not survive a 6 day-dry period following 3 wet days. Over 70% of "Cochise" Atherstone seedlings survived the same wet-dry regimen (Frasier et al. 1983).

Abbott and Roundy (1993) studied the fate of seeds of warm-season range grasses in relation to soil moisture availability and found that germinability of ungerminated seeds of native grasses decreased after long dry periods following early summer rains. In contrast, ungerminated seeds of Lehmann lovegrass remained viable and germinated throughout the same periods of low soil moisture availability. Frasier et al. (1984) showed that sideoats grama seedlings emerged in 18-24 hr but had over 80% seedling mortality during five dry days following the initial wetting. Other grasses such as Cochise lovegrass required a longer time for seedling emergence, but had less than 20% seedling mortality.

Native grass species, blue grama and western wheatgrass (*Elytrigia smithii*) showed that root elongation ceased at soil water potentials of -1.66 and -0.8 MPa, respectively (Majerus 1975). Noy-Meir (1973) found that soil water potential in the soil surface 10 cm of semiarid soils is not maintained above -1.5 MPa for extended periods in the summer. Portas and Taylor (1976) observed root elongation into dry soil (- 4.0 MPa) as long as the plant water potential remained sufficiently high and that water was available to other parts of the root system.

Wester and Dahl (1980) evaluated the effects of 16 treatments of simulated rainfall varying in pattern of application (days between rainfall events) and amount of water, at four soil temperatures on germination, emergence, and survival of alfalfa (*Medicago sativa*), sideoats grama, weeping lovegrass (*Eragrostis curvula*), and selection-75 kleingrass (*Panicum coloratum*). Each treatment provided 5 mm of water; soil temperatures of 38 °C, 30 °C, 24 °C, and 17 °C were maintained at a seeding depth of 0.6 cm. They found that viability of some species (e.g., sideoats grama) was practically eliminated at 30 °C. For some species (e.g., alfalfa) the pattern of simulated rainfall events was more important than amount of water received, while for other species (e.g., weeping lovegrass), total amount of water received was more important.

Soil Temperature

Soil temperatures vary with soil depth, with time during the growing season, from one year to the next, and with soil management, and the variations in soil temperatures can be remarkably important in controlling root depth and finally plant survival (Rendig and Taylor 1989). Root system morphology varies considerably among species, among individuals, within a species, and even within individual root systems (Rusell 1977). Each species of plants has a minimal soil temperature below which no growth of roots will occur. Above that minimal temperature, root growth is almost linear with tempreature to a maximum peak at the optimal temperature (Brouwer and Hoogland 1964).

Young and Evans (1982) found that as the daytime temperature increased to the 30 and 40 °C, the environment of the seedbed surface became more severe. They also reported that numerous grass species acquired maximum germination when the daily maximum temperature was about 20 and minimum was about 15 °C. The thinnest possible seed coverage with soil greatly enhances the germination of many seeds (Collins and Hector 1966). Osmond et al. (1980) detected that seedling establishment is generally more sensitive to environmental stress than germination of seeds.

Germination and seedling establishment in relation to precipitation and soil type suggests that factors affecting seedling survival may be a greater determinant of establishment than those affecting germination (Osmond et al. 1980). Selection of adapted and useful plant materials to environmental stresses such as drought, extreme temperatures, and poor soil aeration as well as salt tolerance is probably the greatest challenge, but also the most potentially successful decision-making that can be done in revegetating arid lands (Roundy 1987).

Toole et al. (1956) found that soil temperature is one of the most important of the specific conditions that must be met during the period of seed germination. Fourwing saltbush germination was adversely affected by 53 °C compared to 39 °C temperature regimes (Sosebee and Herbel 1969). This important shrub species germinated best in petri dishes at low temperatures 13 to 24°C (Potter et al. 1986). Reducing soil temperatures can improve seedling establishment in a hot, arid environment (Herbel 1972b). Laude et al. (1952) found that tolerance of perennial grass seedlings to high soil temperatures decreased from germination to emergence in a temperature range from 42 to 53 °C.

Knipe and Herbel (1960) reported that maximum germination of Lehmann lovegrass (*Eragrostis lehmanniana*) in a growth chamber was attained at 27 °C, and that it did not germinate at a constant temperature of 44 °C. Blue grama (*Bouteloua gracilis*) exhibited a 94% germination at constant temperatures ranging from 16 to 38 °C, whereas constant temperatures of 10 and 44 °C drastically reduced the germination of this specie. Galleta (*Hilaria jamesii*) had a germination of 85% at 16-32 °C; a constant temperature of 10 and 44 °C reduced germination of galleta to only 14%.

Sosebee and Herbel (1969) found that many seeds failed to germinate and many of the ones that germinated soon died because of inadequate moisture conditions and extremely high soil temperatures. They concluded that germination of fourwing saltbush (*Atriplex canescens*), Caucasian bluestem (*Andropogon caucasicus*), sideoats grama (*Bouteloua curtipendula*), Vaghun-sideoats grama (NM-28), black grama (*Bouteloua eriopoda*), rhodesgrass (*Chloris gayana*), boer lovegrass (*Eragrostis chloromelas*), tobosa (*Hilaria mutica*), vine mesquite (*Panicum obtusum*), alkali sacaton (*Sporobolus airoides*), bush muhly (*Muhlenbergia porteri*), Lehmann lovegrass and sacaton (*Sporobolus wrightii*) were judged to be "optimum" in petri dishes with alternating temperatures ranging from 20-35 °C.

Herbel and Sosebee (1969) studied the establishment of boer lovegrass and black grama in a controlled light-temperature chamber under two temperature regimes: 53-67 °C was considered the high temperature regime, and 38-51 °C considered the low regime. They found that it took about 70 mm of water for either species to survive in a 21-day trial in the low temperature regime and 231 mm of water in the high temperature regime.

Germination of sand bluestem (*Andropogon hallii*) caryopses was influenced by temperature; it was higher at 35° than at either 30° or 25 °C, but low temperatures favored seedling survival (Stubbendieck and McCully 1976). In southern Arizona, Jordan and Maynard (1970) found that seeding time was a critical element to establish Lehmann lovegrass seedlings. They found that in March and June the seedbed contained insufficient moisture for germination. Moisture was not sufficient for germination until the rains came in. Mayeux and Scifres (1978) found that optimum temperatures for germination of Drummond's goldenweed (*Isocoma drummondii*) seeds were 20° and 25 °C in small growth chambers.

Two woody legumes, retama (*Parkinstonia aculeata*) and twisted acacia (*Acacia schaffnery*), were studied in relation to germination temperature regimes. It was found that retama's germination was optimum at constant temperatures of 15° to 35 °C; twisted acacia had maximum germination at temperatures of 15° to 30 °C (Everitt 1983b). Seed germination tests were conducted to study the response of blackbrush (*Acacia rigidula*), guajillo (*Acacia berlandieri*), and guayacan (*Porlieria angustifolia*) to different temperature regimes; it was found that the three species germinated best at 25 °C (Everitt 1983a).

Scifres and Brock (1969) determined that honey mesquite (*Prosopis juliflora* var. *glandulosa*) germinated and produced more vigorous seedlings at 29 °C than at 38 °C. Scifres (1974) also detected that huisache (*Acacia farnesiana*) seeds germinated more successfully at 30 °C than at 16°, 21°, or 38 °C. Bitterweed (*Hymenoxys odorata*) seed germination peaked at temperatures between 20° and 25 °C (Whisenant and Ueckert 1982a).

Young et al. (1970) reported that optimum germination for Mt. Baker subterranean clover (*Trifolium subterraneum*) grown in California occurred at 20 °C rather than at 15 °C.

After seeds germinate, early root growth, whether seminal root or adventitious roots, usually is seriously penalized by temperature (Kittok and Patterson 1959, Tadmor and Cohen 1968, Cohen and Tadmor 1969). Wester et al. (1986) found that Ermelo weeping lovegrass and kleingrass selection-75 required 2 days of water to emerge at 30 °C and 24 °C, but there was no emergence at a soil surface temperature of 38 °C in a dry sand in a growth room.

Although early root growth varies greatly among plant species, the soil temperature always affects root growth and development (Kaspar et al. 1978, Taylor et al. 1978, Stone and Taylor 1983, Vincent and Gregory 1986). Root diameters often decrease with increasing soil temperatures.

The diameter of corn (*Zea mays*) averaged 0.6 mm at 17, 0.5 mm at 23 °C, and 0.44 mm at 30 °C. As a result of this tendency the root mass of corn was greater at 23 °C than at 17 °C or 30 °C, but root length was greatest at 30 °C (Anderson and Kemper 1964).

According to Stone et al. (1983), a 1 °C decrease in soil temperature would have decreased the taproot depth of soybean (*Glycine max*) to 1.86 m; and a 1 °C increase would have increased the depth to 2.22 m.

Optimum germination of sweetvetch (*Hedysarum boreale*), a potential revegetation species for disturbed lands, occurred at constant temperatures of 15 °C and 20 °C. Under alternating temperatures maximum germination was attained at 15-20 and 20-15 °C for 8 hr, respectively, (Redente 1982). Germination and radicle growth of kidneywood (*Eysendhardtia texana*) and little-leaf leadtree (*Leucaena retusa*) were greatest at 30 °C, but occurred under a wide range of temperatures and controlled environments (Whisenant and Ueckert 1982b).

Haferkamp and Jordan (1977) indicated that moistening, drying, and heating increased the rate of germination of Lehmann lovegrass seeds. Donart and Zambuck (1976) evaluated the seed germination, depth of planting, and amount of irrigation on the germination of black grama, bush muhly, and sacaton (*Sporobolus usinatus*). They concluded that germination was delayed and percentages were lower at cooler temperatures of 15-25 °C; bush muhly germinated best (68%) at 20-30 °C temperature; black grama and bush muhly germinated best and exhibited relatively high and rapid germination under the temperature alternations of 20-30 °C and 20-35 °C, respectively. In general 38 mm of water was required for emergence of black grama and bush muhly. They required more water for emergence than sacaton.

Briske and Wilson (1976) studied seeds from six blue grama accessions obtained from Nebraska, Kansas, and Texas. They were grown in pots with sandy loam soil in a growth chamber. They found that the greatest number of adventitious roots was obtained at a temperature of 20 °C, and produced the greatest extention and total root length at 30 °C. They concluded that the seedlings did not become established until one or more adventitious roots had extended into moist soil.

Wilson (1979) suggested that temperatures of 15 to 30 °C and from 2 to 4 days with a continously moist soil surface are required for successful extension of adventitious roots and seedling establishment of blue grama. Alfombrilla (*Drymaria arenarioides*), a toxic range plant collected on several dates in Chihuahua, Mexico, and grown in a growth chamber, germinated best at constant temperatures ranging from 14 to 25 °C. No germination was obserbed at temperatures below 11 °C or above 37 °C. Alternating temperatures ranging from 15 to 30 °C produced maximum germination 71 % in alfombrilla (Sanchez et al. 1978).

Fulbright and Redente (1981) investigated the effects of temperature, light, and physiological treatments on germination of green needlegrass (*Stipa viridula*) seeds and determined optimum conditions for germination and possible causes of dormancy. Germination was highest at a constant temperature of 20 °C and at alternating temperatures of 15-20 °C with 8 hr photoperiod.

Haferkamp et al. (1981) conducted research to evaluate the outcome of temperature and presowing seed treatment on germination of rough and smooth velvet bundleflower

(*Desmanthus velutinus*) seeds. Seed were allowed to imbibe water under controlled environmental conditions for 14 days with night and day temperatures of 5/15 °C, 10/20 °C, 15/25 °C, and 20/30 °C, respectively, during 12 hr photoperiods. Seed treatments prior to imbibition included: mechanical scarification, immersion in hot water (80 °C), immersion in concentrated sulfuric acid, and control. Both species subjected to presowing treatments had higher germination than the untreated seeds in all but the 5/15 °C regime.

Kissock and Haferkamp (1981) also tested the effects of temperature and presowing seed treatment on germination of Engelmann daisy (*Engelmannia pinnatifida*) and western indigo (*Indigotera miniata* var. *leptosepala*) seeds. They found that percent germination was affected by both temperature and presowing seed treatments. Untreated Engelmann daisy untreated seeds attained the highest germination (43%), at 20/30 °C; western indigo seeds scarified or treated with acid had over (90%) germination in the 15/25 °C and 20/30 °C temperature regimes.

Mayeux and Leotta (1981) concluded that maximum germination of 70 % or more in non-dormant threadleaf snakeweed (*Gutierrezia spp.*) seed occurred at continuous temperatures of 15 to 25 °C, whereas broom snakeweed (*Gutierrezia sarothrae*) seed germinated best at 25 and 30 °C. An alternating temperature regime of 10 °C (16 hr photoperiod) and 20 °C (8 hr photoperiod) favored snakeweed germination during the afterripening period, but germination of non-dormant seed was greatest under alternating temperatures of 20 °C (16 hr photoperiod) and 30 °C (8 hr photoperiod).

Potter et al. (1983) evaluated the germination requirements of four species of pricklypear (*Opuntia spp.*) from western Texas under five constant and four alternating temperature regimes. Maximum germination of Engelmann pricklypear (*O. phaeacantha discata*) occurred at 20 °C following 30-minute-acid scarification. Texas pricklypear (*O. lindheimeri*) germinated best at 30 °C following 30-minute-acid scarification, Plains pricklypear (*O. macrorhiza*) germination was highest at 35 °C following 30-minute-acid scarification. Germination of brownspine pricklypear (O. *phaecantha major*) was maximum at 35 °C following the same procedure of the other three.

Germination and emergence characteristics of Maximilian sunflower (*Helianthus maximiliani*) and awnless bush sunflower (*Simsia calva*) were studied in a controlled environment. Both germination rate and total germination were greatest for both species under the 15/25 °C temperature regime and lowest under the 10/20 °C temperature regime (Owens and Call 1983). Fulbright and Flenniken (1985) explained that seeds of showy mendora (*Mendora longiflora*), a native half shrub that provides good forage for livestock and wildlife, were germinated under temperature regimes of 5°/15°, 10°/20°, 15°/25°, 20°/30°, 25°/30°, and 30°/40 °C with 12 hr photoperiods during the warmer temperature. Germination was highest at 20°/30 °C and did not differ between light and dark conditions.

Seeds of postrate bundleflower (*Desmanthus virgatus* var. *depressus*), a common native legume in south Texas, were germinated under temperature regimes of 5°/15°, 10°/20°, 15°/25°, 20°/30°, 25°/35°, and 30°/40 °C (light/dark). Germination of scarified seeds exedeed 90% at 15°/25° to 30°/40 °C with no difference between light and dark temperatures (Flenniken and Fulbright 1985).

Mulching

Mulching can improve seedbed water availability by reducing evapotranspiration of soil surface (Fanning and Carter 1963, Malcom 1972). The effects of mulching and supplemental irrigation on establishment and standing crop production of belvedere summercypress (*Kochia scoparia*), fourwing saltbush, King Ranch bluestem (*Bothriochloa ischaemum*), Selection-75 kleingrass, and Lehmann lovegrass were evaluated for two consecutive growing seasons on recently abandoned oil well slush pits in the western Edwards Plateau. Above average rainfall during May of the first growing season nullified the effects of 5 cm of supplemental irrigation water on establishment and production of most species. Mulching tended to increase establishment and productivity of most species on dryland plots (McFarland and Ueckert 1983). In some areas, an associated treatment is needed to reduce high soil temperatures and provide more soil water by practices such as mulching, establishing basins, or pits (Slayback and Renney 1972).

Providing a layer of shrubs will reduce soil temperatures, and the concentration of water with various land-forming procedures does not always ensure seedling establishment (Herbel 1972c).

Seedbed Preparation

Cultural seedbed modifications may not be effective enough to ensure successful establishment from direct seeding on some harsh sites (Brown 1962). Practices to promote plant establishment assume critical importance in successional augmentation. Such practices relate to both proper site or seedbed preparation and to strategies and methods of plant establishment (Evans et al. 1969). DePuit (1986) noted that initial modifications of soils and topography can serve in modifying ecological succession. Deep plowing may be beneficial to growth by increasing root penetration, infiltration rates, and leaching (Smith and Stoneman 1970, Sandoval and Reichman 1971). Plowing of some soils may decrease emergence, but increase seedling establishment by reducing weeds emphasizes the importance of competition control to succesful revegetation of arid areas (Wood et al. 1982).

Intermediate pits 0.15 m deep, 2 m long, and 1.5 m wide were superior for plant establishment to smaller conventional pits, larger bulldozer pits, and unpited check in southern Arizona (Slayback and Renney 1972).

A test to compare disk-chain, smooth chaining and disking alone was installed on rangeland infested with mesquite (*Prosopis juliflora*) in Vernon and Guthrie, Texas, where seedbeds were sown to kleingrass at two different seeding rates (1.1 and 2.2 kg. pls/ha). Disk-chain, and smooth chaining were significantly superior to disking alone regarding seedling establishment; 7.2 and 6.9 plants/m^2 respectively, compared to 4.7 obtained by disking alone (Wiedemann and Cross 1985).

Seeding into furrows increase soil water availability for germination and growth (McGuinnies 1959, Evans et al. 1970). Deep-furrow seeding may increase seedling establishment on semiarid sites compared to standard furrows, except on highly unstable vesicular-crusted soils (Wood et al. 1982). The aridland seeder combines a rootplow, a conveyor, a hydraulically operated dozer blade, and a press-wheel seeder to control brush such as creosotebush and tarbush, form basin pits to hold precipitation on seeded area, seed a variety of species, and leave the dead brush as a mulch on seeded surface (Abernathy and Herbel 1973).

Land imprinting which depresses furrows into the soil, may have potential for increasing establishment on unstable soils (Dixon 1980). This implement is an innovative mechanism that attempts to combine some of the principles of mechanical weed control and seeding, and the imprints provide a small water and litter catchment capable of storing sparse rainfall (Herbel 1987).

Herbicidal Brush Management

Tebuthiuron, (N-[5-(1,1dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea), a thiadiazole urea herbicide is used to control brush and weeds on rangelands and along rights-of-way (Scifres et al. 1979, Pettit 1979, McDaniel and Balliette 1986). Economic benefits of brush management in Texas were estimated by Whitson (1980). He found that if brush was reduced by 25 and 50% in Texas, beef production could be increased by 31 and 62 million of kilograms of beef annually, respectively.

According to Duncan (1981) and Scifres et al. (1981a), the best time for application of tebuthiuron is just prior to anticipated rainfall which activates quick vegetative growth. Consequently, late control only if rainfall is in the spring. Several weeks or months may lapse before sufficient rainfall occurs to leach tebuthiuron into the soil where it accumulates primarily in the upper 15 cm (Bovey et al. 1978). Vulnerable species treated with tebuthiuron commonly defoliate and refoliate before they are totally killed. This phenomenon induced by tebuthiuron is largely dictated by the rainfall pattern (Sosebee et al. 1978, Scifres et al. 1979). Forage production may be increased significantly through the second or even third growing season after tebuthiuron application (Scifres and Mutz 1978, Sosebee et al. 1978, Morton 1979, Gribble and Stritzke 1980, Stritzke 1980, Scifres et al. 1981b). In contrast, foliar applied herbicides generally defoliate woody plants within 30 days after application; grass yields during that growing season may increase considerably (Scifres et al. 1979).

Jacoby et al. (1982b), however, found that forage production increased slowly over two to three growing seasons depending primarily on rainfall. They also noted that the increased herbaceous yield may not always be desirable. Consequently, they suggested seeding following tebuthiuron application to establish a desirable and productive stand of species. Sites for seeding should be carefully chosen to ensure that adequate runoff will be harvested to allow forage species to become established.

In July 1976 and again in January 1977, three granular herbicides-dicamba (5% a.i.), picloram (10% a.i.), and prometone (5% a.i.) were applied at the rates of 0.28, 0.55, and 0.84 kg. a.i./ha to a creosotebush community in order to evaluate their effectiveness. Dicamba and picloram had the greatest kills on the summer application plots, while prometone had the greatest on the winter applications. Aerial cover of creosotebush was reduced 99% on plots receiving 0.84 kg/ha of picloram and prometone. Response of herbaceous vegetation to reduced aerial cover was greatest on plots receiving dicamba at 0.55 and 0.84 kg/ha which had increases of 69 to 81% in basal cover, respectively, compared to control plots (Beck 1980).

Hexazinone was applied in the form of a large pellet (1cc, 20% a.i.) in a grid pattern to creosotebush and mesquitecommunities in January 1981 in the Trans-Pecos region of Texas. Evaluations of the creosotebush plants have indicated a 52% or more reduction in canopy cover at all three treatment rates (0.28, 0.56, and 1.12 kg. a.i./ha), while in the mesquite communities reduction in canopy cover was 63% at all three treatment rates. On the creosotebush sites, herbaceous species composition was greater at 0.28 and 0.56 kg. a.i./ha rates compared to 1.12 kg. a.i./ha (Hoefler and Beck 1983).

Morton et al. (1978) concluded that tebuthiuron applied at 0.6, 1.1, and 2.2 kg/ha eliminated 77, 97, and 99% of the creosotebush, respectively, in Arizona. They concluded that relatively low rates of tebuthiuron will increase the carrying capacity for livestock on arid rangelands infested with tarbush and/or creosotebush. Tebuthiuron applied at 0.5 and 0.7 kg. a.i./ha in February or March reduced live creosotebush as much as 86% in the Trans-Pecos region of Texas (Ueckert et al. 1982b, Jacoby et al. 1982b). The same herbicide at 1 kg. a.i./ha essentially eliminated the stands of creosotebush; grass production on treated areas 32 months later was 100 kg/ha or less than that of untreated areas (Jacoby et al. 1982a). Ueckert et al. (1982a) stated that aerial application of tebuthiuron pellets in late winter killed 68% of the tarbush plants in an experiment in the Trans-Pecos region of Texas.

Various rates of tebuthiuron pellets were aerially applied on rangelands of the Jornada Experimental Range in south-central New Mexico to determine effects on noxious range plants. Creosotebush and tarbush shrubs were controlled with tebuthiuron pellets applied at rates of 0.4 and 0.3 kg. a.i./ha, respectively. About 1.1 kg.a.i./ha of tebuthiuron controlled honey mesquite growing on loamy sands or sandy loams. About 0.6 and 0.5 kg. a.i./ha of tebuthiuron pellets controlled white thorn acacia (*Acacia constricta*) and desert zinnia (*Zinnia pumila*), respectively. Higher rates of tebuthiuron are needed to control those shrubs on deep, fine textured soils compared to those growing on shallow, coarse textured soils (Herbel et al. 1985).

Other plants such as live oak (*Quercus virginiana*), whitebrush (*Aloysia lycioides*), and sand shinnery oak (*Quercus havardii*) were partially killed (80, 70, and 86%, respectively, using tebuthiuron rates of 1.1 kg. a.i./ha. Mortality of Macartney rose

(*Rosa bracteata*) and blackbrush acacia (*Acacia rigidula*) was 45 and 60 %, respectively, when treated with tebuthiuron at 2.2 kg. a.i./ha (Meyer and Bovey 1979, 1980a, 1980b, Jacoby and Meadors 1982c).

CHAPTER III

USE OF MULCH AND IRRIGATION TO INCREASE SEEDING SUCCESS IN DESERT ECOSYSTEMS

Introduction

Invasion of woody plants (Humphrey 1958), as well as the lack of a sound grazing management plan, and periodic droughts have been some of the causes that have been blamed for the drastic decrease in density of perennial grasses on many rangelands (Cox et al. 1982). Natural establishment of perennial herbaceous vegetation is very slow and sometimes nonexistent in many areas (Hyder et al. 1971); therefore, revegetation practices are eventually recommended. An adequate seedbed preparation is one of the most important factors to consider when reseeding in order to increment the likelihood of success (Anderson and Swanson 1949).

In arid and semiarid regions of the southwestern United States and the north-central plateau of Mexico, seedbed preparation should be aimed to provide certain environmental conditions, especially soil water and soil temperature adequate for seeds to germinate and for seedlings to develop a vigorous root system. It is necessary for seedlings to be able to take up water and nutrients as quickly as possible to avoid desiccation and allow the seedling to become established. Therefore, this phase of the research was initiated in 1990 to evaluate the effect of mulch and irrigation on reseeding a creosotebush-infested Chihuahuan Desert rangeland. Specifically, this study was designed to evaluate the influence of mulch and irrigation on soil temperature and soil water content and their effect on emergence and establishment of native and introduced range grasses. Also, a study was conducted to evaluate the upper threshold temperature for the species under investigation.

Study Area

This study was conducted on the University of Texas Lands located near Bakersfield, Texas (Pecos County) located in the Trans-Pecos region of Texas (Figure 3.1). Climate of the area is arid. Rainfall here is erratic and relatively unavailable during most of the year, with 80 % occurring in July through September. Precipitation events are very localized and the annual average is only about 254 mm. The annual evaporation rate is 2794 mm. Precipitation for 1990 and 1991 was 426.75 and 160 mm, respectively, (Figure 3.2).

The soil consists mainly of a Reagan silty clay loam with slopes ranging from 0 to 3%. The surface layer is moderately alkaline and the depth varies from 0.18 to 0.70 cm. It is well drained, but permeability is moderate to moderately slow. The hazard of water erosion is severe and the hazard of soil blowing is moderate. The potential for re-establishing native range is low because of scarce and erraticly distributed precipitation (SCS-Soil Survey, 1980). The experimental area was dominated by creosotebush (*Larrea tridentata* (DC.) Cov.)*, tarbush (*Flourensia cernua* DC.), and mesquite (*Prosopis glandulosa* Torr.). Other range plants found in the experimental area included: bush muhly (*Muhlenbergia porteri* Scribn. ex. Beal), buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), Plains bristlegrass (*Setaria leucopila* (Scribn. & Merr.) K. Schum.), tobosa (*Hilaria mutica* (Buckl.) Benth.), mariola (*Parthenium incanum* H. B. K.), escobilla (*Buddleia scordioides* Kunt in H. B. K.), broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby). Other common plants spotted in the area included: burrograss (*Scleropogon brevifolius* Phil.), threeawns (*Aristida spp.* L.), fluffgrass (*Dasyochloa pulchella* Kunt in H. B. K.), whiplash (*Pappophorum vaginatum* Buckl.), alkali sacaton (*Sporobolus airoides* (Torr.) Torr.), desert holly (*Acourtia nana* (Gray) Reveal & R. King), allthorn (*Koeberlinia spinosa* Zucc.), tasajillo (*Opuntia leptocaulis* DC.),

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* Plant names follow nomenclature by Hatch et al. (1990).

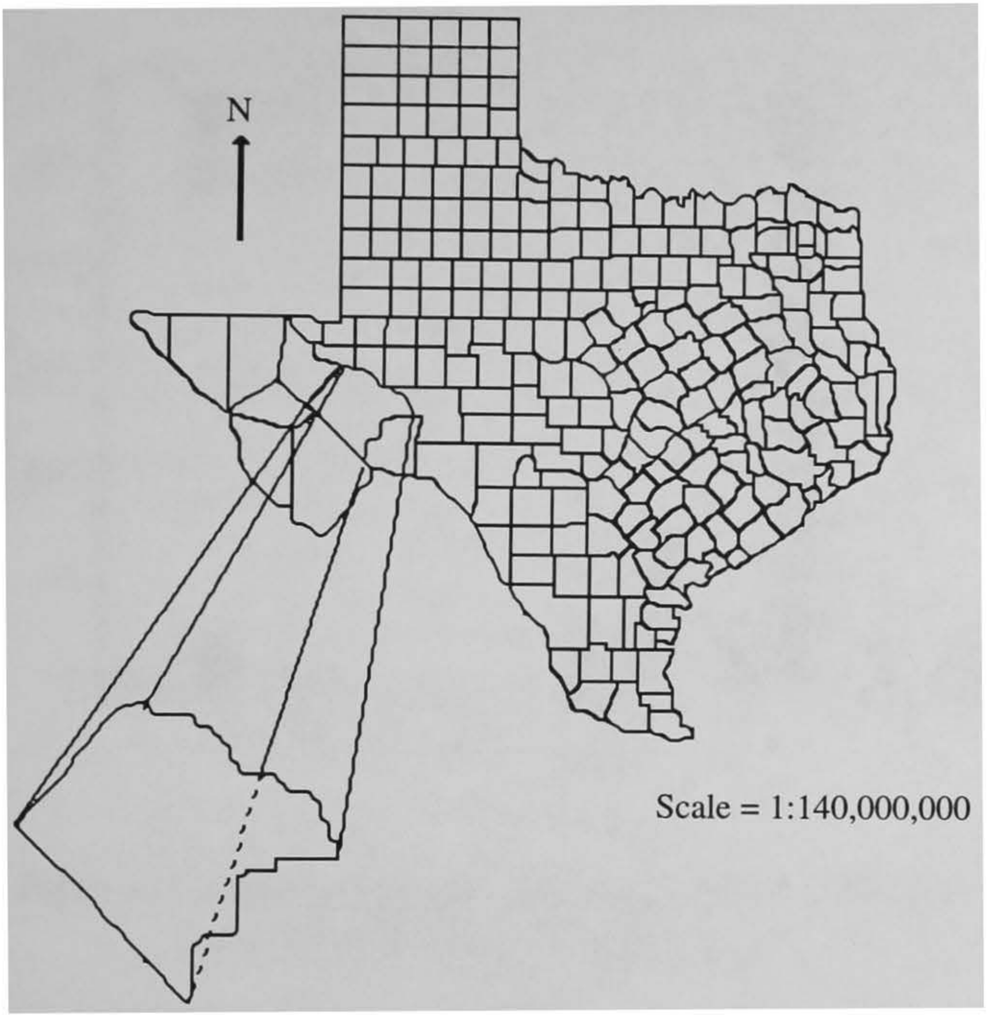

Figure 3.1: Map of Texas and the location of Pecos County.

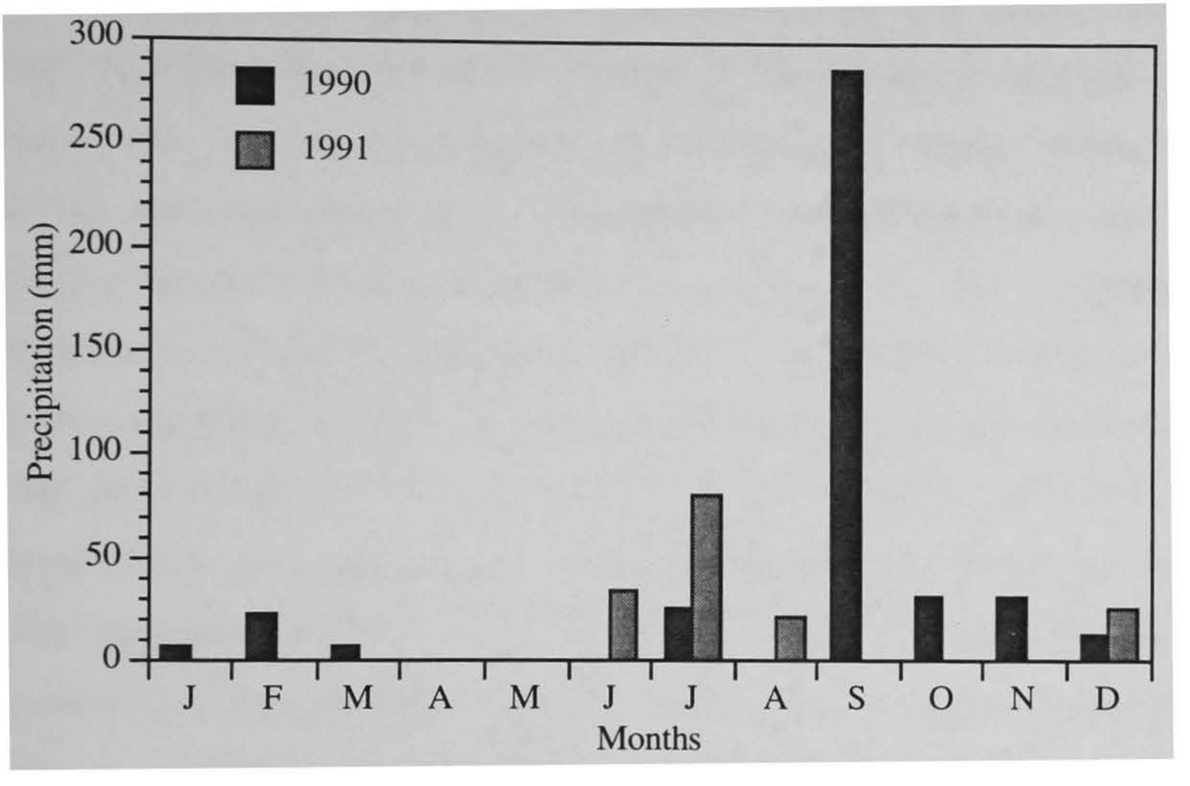

Figure 3.2: Annual precipitation (mm) recorded during 1990 and 1991 at the vineyard of the University of Texas Lands.

cholla (*Opuntia imbricata* (Haw.) DC.), soaptree (*Yucca elata* (Engelm.) Engelm.), algerita (*Mahonia trifoliolata* (Moric.) Fedde), fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.), and lotebush (*Zizyphus obtusifolia* (T. & G.) Gray.

Experimental Procedure

The experiment was established in a creosotebush-free and creosotebush-infested area. The experimental area consisted of 4 blocks, 2 with creosotebush and 2 without creosotebush. Creosotebush was controlled on 2 blocks prior to reseeding. During the fall of 1986, pelleted tebuthiuron (20 % a.i.) was applied with a solo-back-pack sprayer to two blocks at the rate of 0.56 kg a.i./ha before the first seeding in 1987. After controlling the creosotebush, reseeding was attempted in June, 1987, using a broadcast seeder; it was a failure due to drought and high soil temperature. Reseeding was again attempted in May, 1988, which was also a failure due to drought. In May, 1989, a third reseeding was again attempted and it was a failure even though the plots were irrigated every three days for three weeks and weekly thereafter through July 1989. In May, 1990, a study was initiated to test the effect of adding different mulches applied with and without irrigation on reseeding success in creosotebush-controlled and creosotebush-infested desert rangeland. Treatments included:

(1) creosotebush-control versus creosotebush-infested rangeland,

(2) 3 mulch treatments (hydromulch, hay mulch, and no mulch), and

(3) irrigation versus no irrigation.

A completely randomized design with split plot arrangement of treatments to test the effects of creosotebush-infestation, mulching, and irrigation on seeding success (Figure 3.3.). Two replications were employed. Each experimental unit was 61 x 6.4 m, subdivided (randomly) for irrigation versus no irrigation. Mulching treatments were randomly assigned within each experimental unit. Hydromulch treatments where applied through a hydromulcher that applied a layer of hydromulch of about 0.64 cm thick to appropriate

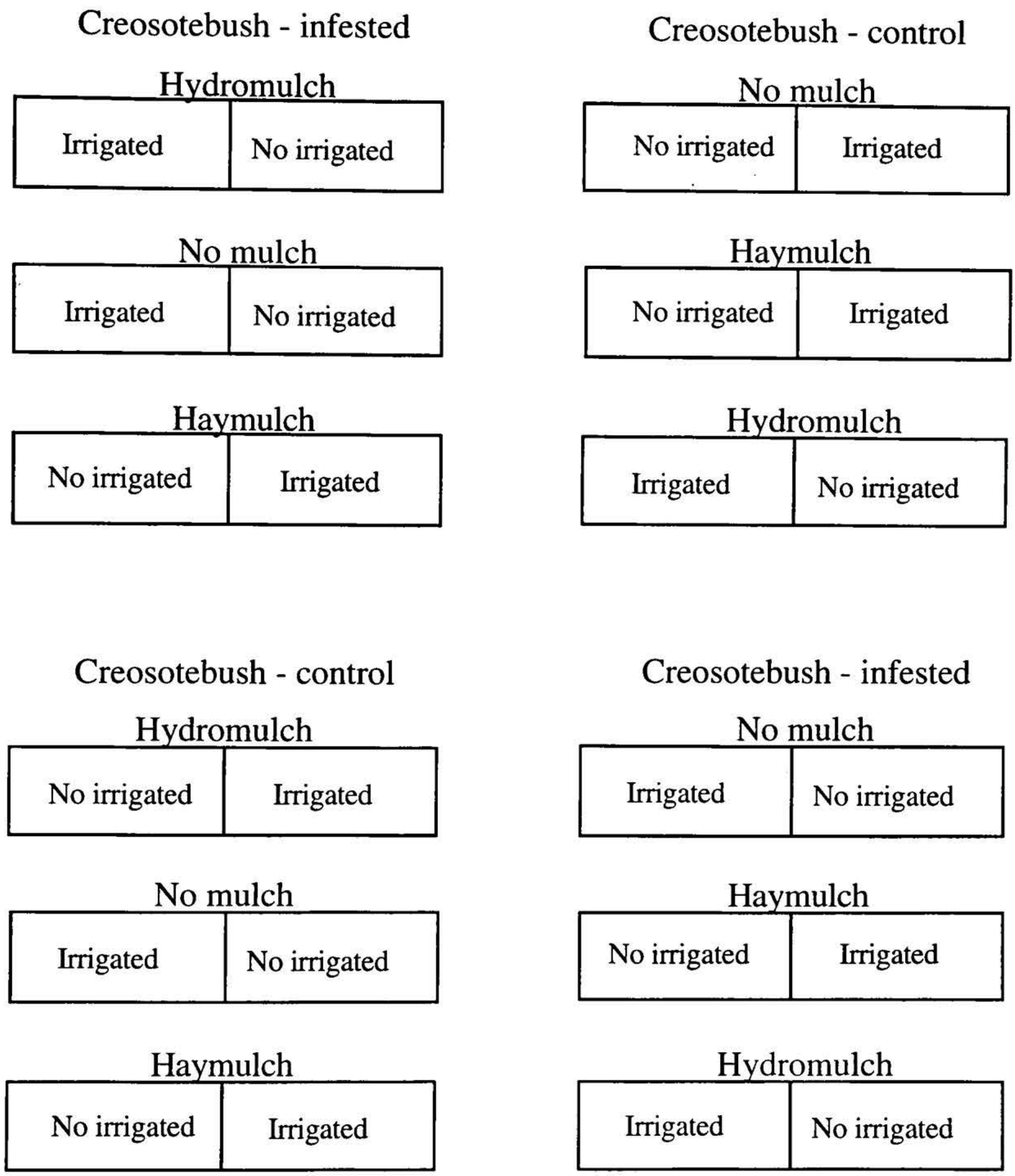

Figure 3.3: Experimental design of seeding trials involving crosotebush infested rangeland, mulching, and irrigation near Bakersfield, Texas. Plots were seeded in May, 1990.

treatments. Sudan sorghum hay was used on the hay mulch treatments. Five species were seeded in each experimental unit during May, 1990. Seeds were drilled 0.5 cm deep and covered slightly. Seed of each species were placed in separate boxes on the seeder in order to test emergence and establishment by specie. The space (width) between drill rows was about 21 cm, allowing 9 rows per swath width of 1.89 m. Three swaths were seeded in each experimental unit.

The species used in this research and recommended seeding rates (kg/ha) included Lehmann lovegrass, sideoats grama, Plains bristlegrass, green sprangletop, and Old World bluestem (Table 3.1). The purity and germination percentages of each species are summarized in Table 3.2.

Irrigation treatments were applied every 3 days for 3 weeks starting in early July and finishing on September 1, 1990. During this period, data were collected. From September 1, 1990, to June, 1991, data were collected once a month. A water hose was used to irrigate the plots subject to irrigation and 1 hour per plot was usually spent in every treatment to wet the surface. Prior to the irrigation, seedling emergence and soil samples were collected for water content measurement. Soil temperature was measured as well. A rectangular quadrat 0.33 x 0.95 cm (0.3135 m^2) was used to evaluate seedling emergence and survival. Seedling emergence and survival measurements were replicated 3 times across at randomly selected locations within each plot. The average number of seedlings/m^2 by species was based upon the average of the 3 replications/plot. The parameters evaluated on each sampling date included:

(1) soil moisture at 1.27 cm depth;

(2) soil moisture at 15.24 cm depth;

(3) soil temperature at 1.27 cm depth;

(4) soil temperature at 15.24 cm depth;

(5) seedlings emergence and survival.

Table 3.1: Species and recommended seeding rates (kg/ha) used in experiment 1 near Bakersfield, Texas, in May 1990.

Species	kg PLS[1]/ha
Lehmann lovegrass (*Eragrostis lehmanniana* Ness)	0.6
Premier-sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)	5.5
Plains bristlegrass (*Setaria leucopila* (Scribn. & Merr.) K. Schum.)	6.0
Green sprangletop (*Leptochloa dubia* (Kunth in H. B. K.) Ness)	5.0
WW Spar-Old World bluestem (*Bothriochloa ischaemum* (L.) Keng)	1.2

[1] Seeding rates recommended by the SCS for southwest Texas were based upon PLS (Pure Live Seed [kg/ha]).

Table 3.2: Purity and germination percentages of the 5 species used in experiment 1 near Bakersfield, Texas, in May 1990.

Species	% Germination	% Purity	% PLS[1]
Lehmann lovegrass	92	99.8	91.81
Sideoats grama	92	94.5	86.94
Plains bristlegrass	92	92.0	84.64
Green sprangletop	88	96.0	84.48
Old World bluestem	96	85.0	81.60

[1] % PLS = % Germination X % Purity / 100

A Reotemp thermometer (Reotemp. Inst. San Diego, California) was used to determine soil temperatures. It was inserted to the appropriate depths (1.27 and 15.25 cm). Soil temperatures were measured from midday to mid afternoon on all the sampling dates. Gravimetric analysis was used to compute soil water content. The measurements of soil temperature, soil water content, and seedling emergence and survival were measured at the same randomly selected spots within every experimental unit over the sampling dates and the data were analyzed using the General Linear Model (GLM) of Statistical Analysis System (SAS 1985) through a completely randomized design with split-plot arrangement (Steel and Torrie 1980). Differences among means were separated using Fisher's protected least significant difference (LSD) procedure (alpha level = 0.05) (Ott 1988).

Results and Discussion

In this experiment 4 dates out of 17 were statistically analyzed that were considered the ones that best described the environmental conditions present during the conduction of this trial. The dates analyzed for both environment and number of seedlings were: July 3, 1990; July 17, 1990; August 7, 1990; and February 22, 1991. The environmental data of (soil water content [%] and soil temperature [°C]) of the remaining 13 dates are presented on Appendix A. Appendix B presents the emergence and establishment of the different species (number of seedlings/m^2) for the 4 dates discussed previously. No seedling emergence occurred on July 3 and July 10, 1990; therefore, no tables for these species are presented. Number of seedlings recorded on August 22, 1990; September 8, 1990; October 13, 1990; November 10, 1990; December 8, 1990; and January 22, 1991, remained constant; therefore, their data are not presented in Appendix B. On February 22, 1991, there was a slight change with respect to number of seedlings; therefore, this date was statistically analyzed and explained in the text. Number of seedlings for March 28, 1991; April 28, 1991; May 30, 1991; and June 28, 1991, remained unchanged; therefore, their data are not shown in Appendix B.

Environmental Conditions

Soil Moisture-July 3, 1990

Three-way interactions were significant ($P<0.03$) involving treatments at levels of herbicide-irrigation; herbicide at levels of treatments-irrigation; irrigation at levels of herbicide-treatments; and depth as an individual factor. Comparing treatments at levels of herbicide-irrigation, it was found that regardless of the combination of herbicide and irrigation, there was no difference among mulch treatments with respect to soil moisture (Table 3.3). Comparing herbicide at levels of treatments-irrigation, soil moisture was greater in the treatments that were subject to herbicide application (0.56 kg a.i./ha) in the non-irrigated, hay mulch treatments, and in the irrigated, no mulch treatments; in all other combinations of mulch and irrigation, there were no differences ($P>0.05$) between herbicide treatments with respect to soil moisture (Table 3.4). Comparing irrigation at levels of herbicide-treatments, there was higher soil moisture in the irrigated plots when herbicide was not applied and hay mulch treatments applied than those in the non-irrigated plots. On all other combinations of herbicide and treatments, there was no difference in soil moisture between irrigated and non-irrigated treatments (Table 3.5). With respect to depth as an individual factor, it was found that regardless of herbicide, treatments, or irrigation, there was more soil moisture ($P<0.05$) at 15.24 cm than at 1.27 cm. Table 3.6 summarizes the results of depth as individual factor as well as results of Tables 3.3, 3.4, and 3.5.

Soil Temperature-July 3,1990

Three-way and two-way interactions were significant at different P levels. The depth at levels of treatments-irrigation interaction was significant ($P<0.02$); depth at levels of herbicide-irrigation interaction was significant ($P<0.03$); depth at levels of herbicide-treatments interaction was significant ($P<0.04$); treatments at levels of

Table 3.3: Comparison of soil water content (%) of mulching treatments at levels of herbicide-irrigation. Water content means within a level of herbicide and irrigation followed by the same lower case letter are not significantly different (P>0.05).

		Treatments		
Herbicide	Irrigation	Hydromulch	Hay mulch	No mulch
None	Yes	3.28 a	3.50 a	2.67 a
None	None	2.97 a	2.52 a	2.78 a
0.56 kg. a.i./ha	Yes	3.81 a	3.03 a	3.55 a
0.56 kg. a.i./ha	None	3.04 a	3.60 a	3.04 a

Table 3.4 : Comparison of soil water content (%) of herbicide treatments at levels of treatment-irrigation. Herbicide means within a combination of treatments and irrigation levels followed by the same lower case letter are not significantly different (P>0.05).

		Herbicide	
Treatment	Irrigation	None	0.56 kg.a.i./ha
Hydromulch	Yes	3.27 a	3.82 a
	None	2.97 a	3.04 a
Hay mulch	Yes	3.50 a	3.03 a
	None	2.52 b	3.60 a
No mulch	Yes	2.67 b	3.55 a
	None	2.78 a	3.04 a

Table 3.5 : Comparison of soil water content (%) of irrigation treatments at levels of herbicide-treatments. Irrigation means within a combination of herbicide and treatments followed by the same lower case letter are not significantly different (P>0.05).

		Irrigation	
Herbicide	Treatment	Yes	None
None	Hydromulch	3.27 a	2.96 a
None	Hay mulch	3.50 a	2.52 b
None	No mulch	2.67 a	2.78 a
0.56 kg.a.i./ha	Hydromulch	3.81 a	3.04 a
0.56 kg.a.i./ha	Hay mulch	3.03 a	3.60 a
0.56 kg.a.i./ha	No mulch	3.55 a	3.04 a

Table 3.6 : Summary of soil water content (%) of different interactions individually treated in Tables 3.3, 3.4, and 3.5, and the results of depth as a single factor affecting soil moisture.

			Treatments		
Herbicide	Depth (cm)	Irrigation	Hydromulch	Hay mulch	No mulch
None	1.27	Yes	1.82	2.07	1.48
None	1.27	None	1.88	1.53	1.82
None	15.24	Yes	4.74	4.95	3.86
None	15.24	None	4.05	3.51	3.75
0.56 kg. a.i./ha	1.27	Yes	1.98	2.13	1.94
0.56 kg. a.i./ha	1.27	None	2.12	1.85	1.85
0.56 kg. a.i./ha	15.24	Yes	5.65	3.95	5.17
0.56 kg. a.i./ha	15.24	None	3.97	5.36	4.24

		Treatments		
Herbicide	Irrigation	Hydromulch	Hay mulch	No mulch
None	Yes	3.28 a[1] A[2] z[3]	3.51 a A y	2.67 a A z
None	None	2.97 a A z	2.52 a A z	2.78 a A z
0.56 kg. a.i./ha	Yes	3.82 a A z	3.04 a A z	3.55 a B z
0.56 kg. a.i./ha	None	3.04 a A z	3.61 a B z	3.05 a A z

Depth	Mean
15.4	4.43 a [4]
1.27	1.87 b

[1] Treatment means within an herbicide and irrigation level followed by the same lower case letter (a) are not significantly different (P>0.05). [2] Herbicide means within a treatment and irrigation levels followed by the same upper case letter (A, B) are not significantly different (P>0.05). [3] Irrigation means within an herbicide and a treatment followed by the same lower case letter (y, z) are not significantly different (P>0.05). [4] Depth means followed by the same letter are not significantly different (P>0.05).

irrigation-depth the interaction was significant ($P<0.02$); herbicide at levels of irrigation-depth the interaction was ignificant ($P<0.03$); irrigation at levels of treatment-depth interaction was significant ($P<0.02$); herbicide at levels of treatment-depth interaction was significant ($P<0.04$); irrigation at levels of herbicide-depth interaction was significant ($P< 0.03$); treatments at levels of herbicide-depth interaction was significant ($P<0.04$). Taking into account depth at levels of treatments-irrigation, the soil temperature was greater at 1.27 cm than at 15.24 cm regardless of the combination of treatment and irrigation (Table 3.7). Depth at levels of herbicide-irrigation soil temperature was greater at 1.27 cm than at 15.24 cm regardless of the combination of herbicide and irrigation (Table 3.8). Soil temperature was greater at 1.27 cm than at 15.24 cm regardless of the combination of herbicide and treatment (Table 3.9). Despite the fact that every three-way interaction involving depth was significant, soil temperature was always greater at 1.27 cm than at 15.24 cm, regardless of the levels of herbicide, treatment or irrigation.

The results of soil temperature of the mulch treatments at levels of irrigation and depth indicate that at 15.24 cm in the non-irrigated treatments, there was no difference in soil temperatures among the 3 mulching treatments (Table 3.10). At 15.24 cm in the irrigated plots and at 1.27 cm in the non-irrigated ones, soil temperatures were greater in the hydromulch treatments than in the hay mulch or no mulch treatments (Table 3.10). At a depth of 1.27 cm in the irrigated plots, soil temperatures were greater in the hydromulch and hay mulch treatments than in no mulching treatments (Table 3.10).

Results of soil temperature of the herbicide at levels of irrigation and depth show that it was greater at a depth of 1.27 cm than at 15.24 cm in the treatments subject to no herbicide application when plots were irrigated (Table 3.11). There was no difference in soil temperature between the herbicide treatments at depth 15.24 cm in the irrigated plots, or in the non-irrigated ones (Table 3.11).

When the interaction of irrigation at levels of treatments and depth was present, soil temperatures in the no mulch treatment were greater at the 1.27 cm depth in the

Table 3.7 : Comparison of soil temperature (°C) of depth at levels of treatment-irrigation. Depth means within a combination of treatment and irrigation followed by the same letter are not significantly different (P>0.05).

		Depth (cm)	
Treatment	Irrigation	15.24	1.27
Hydromulch	Yes	29.86 a	38.74 b
Hydromulch	None	28.60 a	39.85 b
Hay mulch	Yes	27.49 a	38.00 b
Hay mulch	None	28.60 a	37.49 b
No mulch	Yes	27.36 a	34.44 b
No mulch	None	27.83 a	37.08 b

Table 3.8 : Comparison of soil temperature (°C) of depth at levels of herbicide-irrigation. Depth means within a combination of herbicide and irrigation followed by the same letter are not significantly different (P>0.05).

		Depth (cm)	
Herbicide	Irrigation	15.24	1.27
None	Yes	28.60 a	39.22 b
None	None	28.70 a	38.98 b
0.56 kg. a.i./ha	Yes	27.86 a	34.90 b
0.56 kg. a.i./ha	None	27.99 a	37.31 b

Table 3.9 : Comparison of soil temperature (°C) of depth at levels of herbicide-treatment. Depth means within a combination of herbicide and treatment followed by the same letter are not significantly different ($P>0.05$).

		Depth (cm)	
Herbicide	Treatment	15.24	1.27
None	Hydromulch	29.85 a	40.41 b
None	Hay mulch	27.91 a	37.31 b
None	No mulch	28.19 a	39.16 b
0.56 kg. a.i./ha	Hydromulch	28.60 a	38.19 b
0.56 kg. a.i./ha	Hay mulch	28.19 a	37.77 b
0.56 kg. a.i./ha	No mulch	26.98 a	32.35 b

Table 3.10 : Comparison of soil temperature (°C) of mulching treatments at levels of irrigation-depth. Treatment means within a combination of irrigation and depth followed by the same letter are not significantly different (P>0.05).

		Treatments		
Irrigation	Depth (cm)	Hydromulch	Hay mulch	No mulch
Yes	1.27	38.74 a	38.00 a	34.44 b
Yes	15.24	29.85 a	27.49 b	27.35 b
None	1.27	39.85 a	37.49 b	37.07 b
None	15.24	28.60 a	28.60 a	27.82 a

Table 3.11 : Comparison of soil temperature (°C) of herbicide treatments at levels of irrigation-depth. Herbicide means within a combination of irrigation and depth followed by the same letter are not significantly different ($P>0.05$).

		Herbicide	
Irrigation	Depth (cm)	None	0.56 kg. a.i./ha
Yes	1.27	39.22 a	34.90 b
Yes	15.24	29.71 a	27.86 a
None	1.27	38.97 a	37.31 a
None	15.24	28.70 a	27.99 a

non-irrigated treatment than in the irrigated one. At all other combinations of mulch and depth, irrigation treatment had no effect on soil temperature (Table 3.12).

When herbicide at levels of treatments and depth was significant, soil temperatures in the no mulch treatments were greater at depth of 1.27 cm in the treatments subject to no herbicide application than in the treatments where herbicide was applied. In all other combinations of treatment and depth, herbicide treatments had no effect on soil temperature (Table 3.13).

Soil temperature data with irrigation at levels of herbicide and depth indicated a higher temperature in the non-irrigated plots than in the ones with irrigation at a depth of 1.27 cm in the treatments subjected to herbicide application. There was no difference in soil temperature between irrigation treatments at other combinations of herbicide and depth (Table 3.14).

When treatments at levels of herbicide and depth interacted, the mulching treatments had no effect on soil temperature at the 15.24 cm depth regardless of herbicide treatments. In treatments where herbicide was not applied, soil temperatures at the 1.27 cm depth were greater in the hydromulch than in the hay mulch treatments. In treatments with herbicide, soil temperatures at the 1.27 cm depth were greater in the hydromulching and hay-mulching treatments than in no-mulching treatments (Table 3.15).

Seedling Emergence and Seedling Establishment

<u>July 3, 1990</u>

For this date no seed germination was noticed on any of the plots including the ones subjected to irrigation. High temperatures (above 32 °C) and low soil water content (below 12 %) were the factors that affected the germination process. When irrigation was being applied to the irrigated plots it was observed that the moisture quickly vanished due to the soil dryness as well as excessive evaporation rates.

Table 3.12 : Comparison of soil temperature (°C) of irrigation at levels of treatments-depth. Irrigation means within a combination of treatments and depth followed by the same letter are not significantly different (P>0.05).

		Irrigation	
Treatments	Depth (cm)	Yes	None
Hydromulch	1.27	38.74 a	39.85 a
Hydromulch	15.24	29.85 a	28.60 a
Hay mulch	1.27	38.00 a	37.49 a
Hay mulch	15.24	27.49 a	28.60 a
No mulch	1.27	34.44 a	37.07 b
No mulch	15.24	27.35 a	27.81 a

Table 3.13 : Comparison of soil temperature (°C) of herbicide treatments at levels of treatment-depth. Herbicide means within a combination of treatment and depth followed by the same letter are not significantly different (P>0.05).

		Herbicide	
Treatments	Depth (cm)	None	0.56 kg. a.i./ha
Hydromulch	1.27	40.41 a	38.19 a
Hydromulch	15.24	29.85 a	28.60 a
Hay mulch	1.27	37.72 a	37.77 a
Hay mulch	15.24	27.91 a	28.19 a
No mulch	1.27	39.16 a	32.35 b
No mulch	15.24	28.19 a	26.98 a

Table 3.14 : Comparison of soil temperature (°C) of irrigation at levels of herbicide-depth. Irrigation means within a combination of herbicide and depth followed by the same letter are not significantly different (P>0.05).

		Irrigation	
Herbicide	Depth (cm)	Yes	None
None	1.27	39.22 a	38.97 a
None	15.24	28.60 a	28.70 a
0.56 kg. a.i./ha	1.27	34.90 a	37.30 b
0.56 kg. a.i./ha	15.24	27.86 a	27.98 a

Table 3.15 : Comparison of soil temperature (°C) of treatments at levels of herbicide-depth. Treatment means within a combination of herbicide and depth followed by the same letter are not significantly different (P>0.05).

		Treatments		
Herbicide	Depth (cm)	Hydromulch	Hay mulch	No mulch
None	1.27	40.41 a	37.72 b	39.16 a b
None	15.24	29.85 a	27.91 a	28.19 a
0.56 kg. a.i./ha	1.27	38.19 a	37.77 a	32.35 b
0.56 kg. a.i./ha	15.24	28.60 a	28.19 a	27.12 a

Environmental Conditions

Soil Moisture-July 17, 1990

On this date the four-way, three-way, and two-way interactions were not significant; only depth as a single factor was significant ($P<0.01$). Comparing treatments at level of depth there was greater soil moisture in the hay mulch and hydromulch treatments than the no mulch treatment at the 1.27 cm depth. A similar situation was present at the 15.24 cm depth, where soil water content was greater in the hydromulch and hay mulch treatments than in the no mulch treatments (Table 3.16).

Soil Temperature-July 17, 1990

Comparing soil temperature of mulching treatments at levels of herbicide-depth-irrigation it was higher ($P<0.05$) at a depth of 1.27 cm than at the 15.24 cm depth, regardless of other treatment factors. Herbicide and irrigation interacted ($P<0.03$) in their effect on soil temperature. However, there was no difference in soil temperature between irrigation levels in either herbicide treatment, and no difference in soil temperature between herbicide treatments in either level of irrigation (Table 3.17).

Seedling Emergence and Seedling Establishment

July 17, 1990

Seedling emergence was observed with increases in soil moisture and the concomitant decrease in soil temperature. Seedlings of sideoats grama and Plains bristlegrass were the only vegetative material that emerged on this date. Emergence of seedlings of the other species, namely Lehmann lovegrass, green sprangletop, and Old World bluestem was nil; therefore, statistical analyses were conducted only on the two species that emerged.

Table 3.16 : Comparison of soil moisture (%) of treatments at level of depth. Treatment means within a depth followed by the same letter are not significantly different (P>0.05).

	Treatment		
Depth (cm)	Hydromulch	Hay mulch	No mulch
1.27	12.74 a	13.38 a	10.88 b
15.24	14.77 a	14.67 a	12.31 b

Table 3.17 : Comparison of soil temperature (°C) of treatments at levels of herbicide-depth- irrigation.

Herbicide	Depth (cm)	Irrigation	Treatments		
			Hydromulch	Hay mulch	No mulch
None	1.27	Yes	23.88	23.88	24.72
None	1.27	None	24.16	24.99	26.10
None	15.24	Yes	30.27	30.55	31.38
None	15.24	None	23.88	31.94	31.38
0.56 kg. a.i./ha	1.27	Yes	24.16	24.44	24.16
0.56 kg. a.i./ha	1.27	None	23.88	23.88	23.88
0.56 kg. a.i./ha	15.24	Yes	31.38	28.33	29.72
0.56 kg. a.i./ha	15.24	None	29.34	29.44	28.87

Irrigation	Herbicide	
	None	0.56 kg. a.i./ha
Yes	27.45 a[1] A[2]	27.03 a A
None	27.07 a A	26.55 a A

Depth (cm)	Mean
15.24	24.34 a
1.27	29.70 b

[1]Irrigation means within a level of herbicide followed by the same lower case letter are not significantly different (P>0.05). [2]Herbicide means within a level of irrigation followed by the same upper case letter are not significantly different (P>0.05).

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Sideoats grama

Treatments within a level of irrigation and irrigation within a level of treatment were the factors that interacted. Seedling emergence of sideoats grama was greater in mulched plots where irrigation was applied. When no irrigation was supplied, there were no differences in seedling emergence with regard to sideoats grama among the three mulching treatments. When mulch was provided, seedling emergence was greater in irrigated plots than in non-irrigated plots (Table 3.18).

Plains bristlegrass

Irrigation was the only factor that had an effect on seedling emergence. There was a greater ($P<0.05$) number of emerged seedlings in the irrigated plots than in non-irrigated plots (Table 3.19).

Environmental Conditions

<u>Soil Moisture-August 7, 1990</u>

Results of soil moisture with mulching treatments at levels of herbicide-depth-irrigation interacted. The data indicated a greater ($P<0.05$) soil water content in the non-irrigated than in the irrigated treatments, and at the 15.24 cm as opposed to the 1.27 cm depth. In treatments where herbicide was not applied, soil moisture was greater ($P<0.05$) in the hay mulch treatment than in the no mulch treatment; however, in the treatments subject to herbicide application, soil moisture was greater ($P<0.05$) in the hydromulch treatment than in the no mulch treatment (Table 3.20).

Table 3.18 : Number of seedlings of sideoats grama//m^2 within a level of irrigation, and within a treatment, in a reseeded area near Bakersfield, Texas in July 1990. Treatment means within a level of irrigation followed by the same lower case letter are not significantly different (P>0.05). Irrigation means within a treatment followed by the same upper case letter are not significantly different (P>0.05).

	Treatments		
Irrigation	Hydromulch	Hay mulch	No mulch
Yes	2.50 a A	3.00 a A	0.00 b A
None	1.50 a B	1.25 a B	0.00 a A

Table 3.19 : Number of seedlings of Plains bristlegrass/m^2 at irrigation levels in a reseeded area near Bakersfield, Texas in July 1990. Irrigation means followed by the same letter are not significantly different (P>0.05).

Irrigation	Mean
Yes	1.16 a
None	0.38 b

Table 3.20 : Comparison of soil water content (%) of treatments at levels of herbicide-depth-irrigation.

Herbicide	Depth (cm)	Irrigation	Treatments: Hydromulch	Hay mulch	No mulch
None	1.27	Yes	15.74	16.23	14.01
None	1.27	None	15.54	18.47	15.97
None	15.24	Yes	16.47	18.19	15.76
None	15.24	None	17.10	19.50	16.52
			16.21 a b [1]	18.09 a	15.56 b
0.56 kg. a.i./ha	1.27	Yes	15.29	15.29	13.97
0.56 kg. a.i./ha	1.27	None	17.91	15.18	13.98
0.56 kg. a.i./ha	15.24	Yes	16.96	16.37	16.69
0.56 kg. a.i./ha	15.24	None	18.01	16.95	16.26
			17.04 a	15.95 a b	15.22 b

Irrigation	Mean
Yes	15.91 a [2]
None	16.78 b

Depth (cm)	Mean
1.27	15.63 a [3]
15.24	17.06 b

[1]Treatment means within a level a level of herbicide followed by the same letter are not significantly different (P>0.05). [2]Irrigation means followed by the same letter are not significantly different (P>0.05). [3]Depth means followed by the same letter are not significantly different (P>0.05).

Soil Temperature-August 7, 1990

For this specific date, soil temperature for mulching treatments at levels of herbicide-depth-irrigation interacted (P<0.04) and was greater (P<0.05) at the 1.27 cm depth as compared to the 15.24 cm depth. Also, soil temperature was greater (P<0.05) in the no mulching treatments than either the hydromulching or the hay mulching treatment regardless of the herbicide treatment (Table 3.21).

Seedling Emergence and Seedling Establishment

August 7, 1990

Lehmann lovegrass

The mulching treatment was the only factor significant (P<0.02). Among the treatments, the number of seedlings for the hydromulch and hay mulch treatments were greater (P<0.05) than the no mulch treatment. However, they were not significantly different from each other (P>0.05) (Table 3.22).

Sideoats grama

Mulching treatment interaction was the only significant (P<0.05) factor. Hydromulch and hay mulch treatments had more (P<0.05) seedlings than the no mulch treatment. However, they were not significantly different from each other (P>0.05) (Table 3.23).

Plains bristlegrass

Mulching treatments were significant (P<0.01). Hydromulch and hay mulch treatments had more seedlings than the no mulch treatment (P<0.05). However, a significant difference was not detected between the two (P>0.05) (Table 3.24).

Table 3.21 : Comparison of soil temperature (°C) of treatments levels of herbicide-depth irrigation.

			Treatments		
Herbicide	Depth (cm)	Irrigation	Hydromulch	Hay mulch	No mulch
None	1.27	Yes	27.21	26.38	27.70
None	1.27	None	26.10	25.83	28.33
None	15.24	Yes	21.10	21.66	21.66
None	15.24	None	21.36	21.66	22.49
			24.51 b [1]	24.30 b	26.04 a
0.56 kg. a.i./ha	1.27	Yes	27.49	25.83	27.21
0.56 kg. a.i./ha	1.27	None	27.21	27.77	26.38
0.56 kg. a.i./ha	15.24	Yes	21.38	21.66	21.38
0.56 kg. a.i./ha	15.24	None	21.94	21.94	22.49
			23.95 b	23.88 b	25.04 a

Depth (cm)	Mean
15.24	21.66 a [2]
1.27	26.94 b

[1]Treatment means within an herbicide followed by the same letter are not significantly different (P>0.05). [2]Depth means followed by the same letter are not significantly different (P>0.05).

Table 3.22 : Number of seedlings of Lehmann lovegrass/m^2 as a response to treatments at Bakersfield, Texas in August, 1990. Treatment means followed by the same letter are not significantly different (P>0.05).

Treatment	Means
Hydromulch	4.75 a
Hay mulch	3.63 a
No Mulch	0.00 b

Table 3.23 : Number of seedlings of sideoats grama/m^2 as a response to treatments at Bakersfield, Texas, August 7, 1990. Treatment means followed by the same letter are not significantly different (P>0.10).

Treatment	Means
Hydromulch	4.25 a
Hay Mulch	4.75 a
No Mulch	0.00 b

Table 3.24 : Number of seedlings of Plains bristlegrass/m^2 as a response to treatments at Bakersfield, Texas, August 7, 1990. Treatment means followed by the same letter are not significantly different (P>0.05).

Treatment	Means
Hydromulch	2.63 a
Hay mulch	3.75 a
No Mulch	0.00 b

Green sprangletop

No mulching treatment was significant for this species. Treatment means were not different among the 3 mulching treatments (P>0.05) (Table 3.25).

Old World bluestem

Mulch, irrigation, and herbicide treatments did not affect green sprangletop seedling emergence and seedling establishment. Treatment means were not different from each other (P>0.05) (Table 3.26).

Environmental Conditions

Soil Moisture-February 22, 1991

Depth was the only significant factor (P<0.01). Soil moisture was greater (P<0.05) at 15.24 cm than at 1.27 cm (Table 3.27).

Soil Temperature-February 22, 1991

Various interactions were significant for this specific date with respect to soil temperature. Mulching treatment at level of depth; treatments at levels of herbicide-irrigation; herbicide treatments at levels of treatment-irrigation; and irrigation treatments at levels of herbicide-treatments were the significant interactions on this date. Results of mulching treatments at level of depth indicate that soil temperature was higher (P<0.05) in the no mulch and hay mulch treatments than in the hydromulch treatments at both the 1.27 cm and at 15.24 cm depth. No significant differences (P>0.05) were found between the hay mulch and no mulch treatments at either depth (Table 3.28).

Results of mulching treatment at level of herbicide-irrigation show that soil temperature in the irrigated plots was lower in the hydromulch treatments than in the other treatments (hay mulch and no mulch), regardless of level of herbicide.

Table 3.25 : Number of seedlings of green sprangletop/m^2 as a response to treatments at Bakersfield, Texas, August 7, 1990. Treatment means followed by the same letter are not significantly different ($P>0.05$).

Treatment	Means
Hydromulch	1.25 a
Hay Mulch	1.25 a
No Mulch	0.00 a

Table 3.26 : Number of seedlings of Old World bluestem/m^2 as a response to treatments at Bakersfield, Texas, August 7, 1990. Treatment means not followed by the same letter are not significantly different (P>0.05).

Treatment	Means
Hydromulch	0.00 a
Hay Mulch	0.25 a
No Mulch	0.00 a

Table 3.27 : Soil water content (%) as affected by depth. Means followed by the same letter are not significantly different (P>0.05).

Depth (cm)	Mean
15.27	9.84 a
1.27	4.30 b

Table 3.28 : Soil temperature (°C) of treatments as affected by depth. Treatment means within a depth followed by the same letter not differ significantly (P>0.05).

Depth (cm)	Treatments		
	Hydromulch	Hay mulch	No mulch
1.27	12.14 a	13.12 b	13.26 b
15.24	11.11 a	11.52 b	11.46 b

In non-irrigated plots, soil temperatures were lowest in the hydromulch treatments, highest in the hay mulch treatments, and intermediate in the no mulch treatments in the plots with herbicide. However, where herbicide was not applied soil temperature in the no mulch plots was greater than soil temperature in hydromulch or hay mulch treatments (Table 3.29).

Results of herbicide at level of treatment-irrigation indicate that soil temperature was lower in the plots with no herbicide application if plots were irrigated in the hydromulch treatment, and also if plots were non-irrigated under the hay mulch treatment. In all other combinations of treatment and irrigation, there was no influence of herbicide on soil temperature (Table 3.30).

Results of soil temperature with respect to irrigation at levels of herbicide-treatment suggest that soil temperature in irrigated plots was warmer than non-irrigated plots on hay mulch treatments where herbicide was applied. In other combinations of herbicide and treatment, there was no effect of irrigation on soil temperature (Table 3.31).

Seedling Emergence and Seedling Establishment

February 22, 1991

Lehmann lovegrass

Mulching treatment was the only factor significant ($P<0.05$). Among the treatments, hydromulch and hay mulch treatments had more ($P<0.05$) seedling than the no mulch treatment. However, they were not significantly different from each other ($P>0.05$) (Table 3.32).

Table 3.29 : Soil temperature (°C) of treatments as affected by levels of herbicide-irrigation. Treatment means within a level of irrigation not followed by the same letter are not significantly different (P>0.05).

		Treatments		
Herbicide	Irrigation	Hydromulch	Hay mulch	No mulch
None	Yes	11.38 a	12.49 b	12.35 b
None	None	11.66 a	11.94 a	12.49 b
0.56 kg. a.i./ha	Yes	11.80 a	12.21 b	12.35 b
0.56 kg. a.i./ha	None	11.66 a	12.63 b	12.22 c

Table 3.30 : Soil temperature (°C) of herbicide at levels of treatments-irrigation. Herbicide means within a treatment and irrigation followed by the same letter are not significantly different (P>0.05).

		Herbicide	
Treatments	Irrigation	None	0.56 kg. a.i./ha
Hydromulch	Yes	11.38 a	11.80 b
Hydromulch	None	11.66 a	11.66 a
Hay mulch	Yes	12.48 a	12.21 a
Hay mulch	None	11.94 a	12.63 b
No mulch	Yes	12.35 a	12.35 a
No mulch	None	12.49 a	12.21 a

Table 3.31 : Soil temperature (°C) of irrigation at levels of herbicide-treatments. Irrigation means followed by the same letter are not significantly different (P>0.05).

		Irrigation	
Herbicide	Treatment	Yes	None
Yes	Hydromulch	11.38 a	11.66 a
Yes	Hay mulch	12.49 a	11.94 b
Yes	No mulch	12.35 a	12.49 a
0.56 kg. a.i./ha	Hydromulch	11.80 a	11.66 a
0.56 kg. a.i./ha	Hay mulch	12.21 a	12.63 a
0.56 kg. a.i./ha	No mulch	12.35 a	12.21 a

Table 3.32 : Number of seedlings of Lehmann lovegrass/m^2 as a response to treatments at Bakersfield, Texas, February 22, 1991. Treatment means followed by the same letter are not significantly different (P>0.05).

Treatment	Means
Hydromulch	6.62 a
Hay Mulch	5.87 a
No Mulch	0.00 b

Sideoats grama

Mulching treatment was the only significant (P<0.05) factor. Hydromulch and hay mulch treatments had more seedlings (P<0.05) than the no mulch treatments. However, they were not significantly different from each other (P>0.05) (Table 3.33).

Plains bristlegrass

Mulching treatment was significant (P<0.01). Hydromulch and hay mulch treatments had more seedlings than the no mulch treatment (P<0.05). However, a significant difference was not detected between the two (P>0.05) (Table 3.34).

Green sprangletop

None of the factors was significant (P>0.05) for this specie. Mulch, irrigation, and herbicide treatments did not affect green sprangletop seedling emergence and seedling establishment. Treatment means were not significant in any of the 3 mulching treatments (P>0.05) (Table 3.35).

Old World bluestem

Mulching treatments at levels of herbicide, and herbicide at levels of treatment were significant. Mulching treatment were not different from each other (P>0.05) (Table 3.36).

Table 3.33 : Number of seedlings of sideoats grama/m^2 as a response to treatments at Bakersfield, Texas, February 22, 1991. Treatment means followed by the same letter are not significantly different (P>0.05).

Treatment	Means
Hydromulch	4.35 a
Hay Mulch	5.00 a
No Mulch	0.00 b

Table 3.34 : Number of seedlings of Plains bristlegrass/ m^2 as a response of treatments at Bakersfield, Texas, February 22, 1991. Treatment means not followed by the same letter are not significantly different (P>0.05).

Treatment	Means
Hydromulch	2.75 a
Hay Mulch	3.75 a
No Mulch	0.00 b

Table 3.35 : Number of seedlings of green sprangletop/m^2 as a response to treatments at Bakersfield, Texas in February, 1991. Treatment means not followed by the same letter are not significantly different ($P>0.05$).

Treatment	Means
Hydromulch	1.25 a
Hay Mulch	1.25 a
No Mulch	0.00 a

Table 3.36 : Number of seedlings of Old World bluestem/m^2 as a response to treatments at herbicide level; and a response to herbicide at levels of treatments at Bakersfield, Texas in February, 1991. Treatment means within a level of herbicide followed by the same lower case letter are not significantly different (P>0.05). Herbicide means within a treatment followed by the same upper case letter are not significantly different (P>0.05).

	Treatments		
Herbicide	Hydromulch	Hay mulch	No mulch
None	0.00 b A	0.75 a A	0.00 b A
0.56 kg. a.i./ha	0.00 a A	0.00 a B	0.00 a A

CHAPTER IV

SEED GERMINATION OF HIGH TEMPERATURE THRESHOLD FOR SPECIES USED TO SEED CHIHUAHUAN DESERT RANGELAND

Introduction

Various definitions of seed germination have been proposed. To the seed physiologist, germination is defined as the emergence of the radicle through the seed coat. The seed analyst defines germination as the emergence and development from the seed embryo of those essential structures which, for the type of certain seed, are indicators of the ability to produce a normal plant under favorable conditions (AOSA 1983). Seeds of different species have many requirements that must be met before the germination process begins; such as seed maturity, seed coat permiability, composition of the seed, enzyme activation, environmental factors such as water, oxygen and carbon dioxide,temperature and light, etc. (Copeland and McDonald 1985). Some seeds of native trees and native grasses germinate best under alternating temperatures (Harrington 1923). Harrington also determined that where alternating temperatures are required, the range between the high and low temperature seems to be more important than the actual temperatures.

Evidence suggests that alternating temperatures cause a change in the macromolecular structure of components in the seed which, in the original form, prevents germination (Cohen 1958). Toole et al. (1956) reported that alternating temperatures may form a balance of the intermediate products of respiration at the high temperature cycle which, though unfavorable for germination at that temperature, may promote germination at the lower temperature.

Knipe and Herbel (1960) found that maximum germination of Lehmann lovegrass was attained at 27 °C, and it did not germinate at a constant temperature of 44 °C. Galleta had a germination of 85 % at 16-32 °C; a constant temperature of 10 and 44 °C drastically reduced germination of this species to 14%. Blue grama showed a 94 % germination at a constant temperature ranging from 16 -38 °C, whereas constant temperatures of 10-44 °C reduced its germination. This study was conducted in a growth chamber. Sosebee and Herbel (1969) studying germination of several species commonly used to seed semiarid to arid rangelands found that their optimum germination in petri dishes was attained with alternating temperatures ranging from 20-35 °C.

Fulbright and Redente (1981) reported the effects of light, temperature, and physiological treatments on germination of green needlegrass seeds and concluded that highest germination was attained at a constant temperature of 20 °C and at alternating temperatures of 15-20 °C with an 8 hr photoperiod. Much remains to be found in the area of germination; therefore, the objective of this study was to determine the upper threshold of temperature on germination of the species commonly used to reseed semiarid to arid rangeland.

Experimental Procedure

Germination tests were conducted from January to April 1991 in a dark growth chamber using seeds of grass species commonly seeded in the Chihuahuan Desert including: Lehmann lovegrass (LLG), Premier-sideoats grama (SOG), Plains bristlegrass (PBG), green sprangletop (GST), and WW Spar-Old World bluestem (OWB). Four treatments with four replications were used to test the effect of different temperatures on germination of these five species. The different temperatures (treatments) were alternated on a 10-hour cycle for 10 days according to the following schedule:

(1) 18/30 °C/10 hours alternating temperature/10 days;

(2) 18/35 °C/10 hours alternating temperature/10 days;

(3) 18/40 °C/10 hours alternating temperature/10 days; and

(4) 18/45 °C/10 hours alternating temperature/10 days.

Fifty seeds of every species were placed on Whatman filter paper in petri dishes and were left for 10 days in the incubator were no light was provided. The filter papers were moistened with 5 ml of distilled water which was added as it was required in order to maintain near 100 % relative humidity in the petri dishes.

The petri dishes were arranged in a completely randomized design (Steel and Torrie 1990) in a seed incubator. Seeds were considered germinated when the radicle protruded through the seed coat. The percent germination was determined at the end of each treatment. Data on seed germination were analyzed using the General Linear Model (GLM) of Statistical Analysis System (SAS 1985). Treatment means were separated using Fisher's protected least significant difference (LSD) procedure (alpha level = 0.05) (Ott 1988).

Results and Discussion

Germination of each species was significantly ($P<0.05$) affected by temperature (Table 4.1). All of the species exhibited maximum germination (%) when the temperature of the incubator cycled between in the 18 and 35 °C. Germination of all species was significantly ($P<0.05$) reduced when the maximum temperature exeeded 35 °C. Germination of all the species was drastically reduced between 18/35 and 18/40 °C. The upper threshold of temperature for the species used in this study was between 35 and 40 °C. These data correlate to the reseeding work done by Sosebee and Herbel (1969) on the Jornada Experimental Range. They also suggest that unless mulch reduces the surface (upper 1.20 cm) soil temperature to 95 °F (35 °C), it is of no benefit. Our field data support this since we got no emergence and survival at temperatures over 35 °C, even under hay mulch treatments.

Table 4.1: Germination (%) of 5 grass species subjected to alternating temperatures (°C) in a dark seed incubator at Texas Tech University, 1991.

Species	Temperature Regimes (°C)			
	18/30	18/35	18/40	18/45
Lehmann lovegrass	67.50a [1]	81.25b	38.00c	28.75d
Sideoats grama	77.50a	86.00b	31.50c	23.25d
Plains bristlegrass	75.50a	83.75b	28.75c	20.25d
Green sprangletop	78.25a	83.50b	21.00c	13.00d
Old World bluestem	82.75a	86.50a	14.50b	8.00c

[1]Means within a species not followed by the same letter are significantly different ($P<0.05$).

Royo and Melgoza (1986) found that temperatures ranging from 27 °C to 32 °C were the best for germination of Lehmann lovegrass. It should be considered that the origin of germoplasms can affect seed germination of different species since temperature and humidity where these accessions are grown can be very dissimilar (Turreson 1922, Eddelmann 1979).

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APPENDIX A

SOIL WATER CONTENT AND SOIL TEMPERATURE TABLES

Table A.1 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, July 10, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	2.44	2.24	2.27
		Yes	2.97	2.38	2.52
	15.24	None	4.67	4.34	4.23
		Yes	5.37	4.51	4.39
0.56 kg. a.i./ha	1.27	None	2.34	2.15	2.30
		Yes	2.67	3.16	2.74
	15.24	None	4.40	4.00	3.91
		Yes	4.51	6.20	4.80

Table A.2 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, July 10, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	41.94	42.49	42.22
		Yes	41.66	40.55	41.66
	15.24	None	30.83	31.10	29.44
		Yes	30.27	29.99	28.33
0.56 kg. a.i./ha	1.27	None	39.16	40.27	37.77
		Yes	38.05	39.99	34.44
	15.24	None	30.55	30.55	34.99
		Yes	29.16	29.71	29.99

Table A.3 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, July 24, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	11.32	9.71	10.13
		Yes	11.41	11.30	10.19
	15.24	None	12.51	9.32	10.80
		Yes	13.01	11.68	11.60
0.56 kg. a.i./ha	1.27	None	10.70	11.08	9.55
		Yes	10.88	11.53	10.93
	15.24	None	12.47	12.55	11.16
		Yes	12.59	12.93	11.22

Table A.4 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, July 24, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	25.83	24.71	24.44
		Yes	25.55	24.16	22.49
	15.24	None	22.49	22.22	21.66
		Yes	21.94	21.38	21.66
0.56 kg. a.i./ha	1.27	None	27.21	27.21	26.94
		Yes	25.83	26.66	25.83
	15.24	None	22.49	23.33	22.22
		Yes	22.49	22.49	21.94

Table A.5 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, August 2, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	13.80	14.67	12.69
		Yes	14.88	16.15	12.86
	15.24	None	16.41	14.99	15.39
		Yes	17.12	17.71	15.43
0.56 kg. a.i./ha	1.27	None	14.75	17.58	14.92
		Yes	17.01	17.85	16.88
	15.24	None	17.83	17.69	12.96
		Yes	18.27	18.71	15.84

Table A.6 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, August 2, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	22.88	24.80	25.27
		Yes	23.49	23.60	23.60
	15.24	None	21.66	22.30	21.38
		Yes	21.66	21.66	20.83
0.56 kg. a.i./ha	1.27	None	23.88	23.88	23.33
		Yes	23.60	23.33	23.33
	15.24	None	21.94	22.22	21.38
		Yes	21.66	21.94	21.10

Table A.7 : Soil water content (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, August 14, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	8.24	7.16	6.25
		Yes	8.69	8.19	7.30
	15.24	None	11.54	11.40	11.52
		Yes	13.20	11.44	11.59
0.56 kg. a.i./ha	1.27	None	6.55	7.50	6.98
		Yes	7.52	8.75	7.87
	15.24	None	10.88	11.88	10.45
		Yes	11.79	12.81	11.12

Table A.8 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, August 14, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	34.71	36.94	37.79
		Yes	33.33	31.94	37.21
	15.24	None	25.83	27.79	27.49
		Yes	25.27	24.99	26.94
0.56 kg. a.i./ha	1.27	None	37.21	33.05	36.94
		Yes	36.10	28.88	35.27
	15.24	None	25.83	26.10	26.94
		Yes	24.44	25.83	26.10

Table A.9 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, August 22, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	5.33	5.72	5.62
		Yes	5.53	6.71	5.80
	15.24	None	9.87	9.97	9.80
		Yes	10.88	10.34	10.58
0.56 kg. a.i./ha	1.27	None	4.55	6.47	4.67
		Yes	4.93	6.61	5.65
	15.24	None	8.37	8.67	8.04
		Yes	10.05	9.46	8.98

Table A.10 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, August 22, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	27.77	27.49	35.27
		Yes	27.77	26.30	34.16
	15.24	None	36.66	35.55	28.05
		Yes	35.55	33.60	27.49
0.56 kg. a.i./ha	1.27	None	36.94	35.82	34.94
		Yes	35.52	33.88	35.96
	15.24	None	26.94	28.05	26.94
		Yes	26.38	26.94	26.10

Table A.11 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, September 8, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	3.32	3.35	3.39
		Yes	3.58	3.77	4.13
	15.24	None	8.06	7.79	7.19
		Yes	8.14	8.38	7.96
0.56 kg. a.i./ha	1.27	None	3.40	3.20	3.10
		Yes	4.05	4.85	3.69
	15.24	None	6.61	5.84	6.31
		Yes	7.48	7.59	6.49

Table A.12 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, September 8, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	43.88	40.55	39.16
		Yes	43.60	40.55	38.88
	15.24	None	35.33	33.60	30.83
		Yes	34.99	33.05	30.83
0.56 kg. a.i./ha	1.27	None	41.94	40.55	40.82
		Yes	41.66	39.44	39.16
	15.24	None	31.33	34.99	34.16
		Yes	31.10	32.21	30.83

Table A.13 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, October 13, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	6.32	7.01	5.95
		Yes	7.83	7.02	6.38
	15.24	None	12.32	12.68	12.00
		Yes	13.56	13.11	12.73
0.56 kg. a.i./ha	1.27	None	6.58	6.66	6.45
		Yes	7.11	6.71	6.85
	15.24	None	11.48	11.16	11.68
		Yes	12.42	12.48	12.32

Table A.14 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, October 13, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	31.10	29.16	30.83
		Yes	30.83	30.27	31.38
	15.24	None	17.49	17.77	17.77
		Yes	18.05	17.77	17.49
0.56 kg. a.i./ha	1.27	None	30.55	29.71	31.10
		Yes	30.27	31.38	31.38
	15.24	None	18.05	17.49	17.78
		Yes	16.94	17.77	18.05

Table A.15 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, November 10, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	13.73	12.31	14.03
		Yes	14.23	13.03	14.97
	15.24	None	16.04	15.34	12.98
		Yes	16.22	15.61	13.68
0.56 kg. a.i./ha	1.27	None	11.32	11.79	9.74
		Yes	12.21	13.57	10.59
	15.24	None	12.35	14.12	13.59
		Yes	13.81	16.04	13.63

Table A.16 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, November 10, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	19.72	18.60	17.77
		Yes	18.05	17.49	18.88
	15.24	None	10.55	17.77	12.12
		Yes	11.38	13.60	11.38
0.56 kg. a.i./ha	1.27	None	17.77	15.55	16.38
		Yes	17.49	15.83	17.49
	15.24	None	12.22	11.11	11.38
		Yes	9.99	11.94	10.83

Table A.17 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, December 18, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	9.03	9.58	9.15
		Yes	10.10	10.04	9.77
	15.24	None	13.52	14.02	12.87
		Yes	13.91	14.26	13.61
0.56 kg. a.i./ha	1.27	None	9.14	9.14	9.33
		Yes	10.13	13.19	10.08
	15.24	None	11.07	11.48	11.64
		Yes	13.67	12.63	12.69

Table A.18 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, December 18, 1990.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	14.44	12.77	13.33
		Yes	14.72	12.77	13.33
	15.24	None	11.94	9.99	9.72
		Yes	11.94	9.99	9.72
0.56 kg. a.i./ha	1.27	None	14.72	13.05	12.49
		Yes	14.72	13.05	12.49
	15.24	None	11.11	10.27	9.99
		Yes	11.11	10.27	9.99

Table A.19 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, January 22, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	28.65	25.47	26.25
		Yes	31.80	29.05	28.32
	15.24	None	20.52	20.55	20.01
		Yes	22.70	20.90	26.29
0.56 kg. a.i./ha	1.27	None	26.73	27.09	24.76
		Yes	27.24	27.42	27.40
	15.24	None	21.52	19.61	21.20
		Yes	22.18	22.20	22.40

Table A.20 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, January 22, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	0.83	0.55	0.27
		Yes	0.83	0.27	0.55
	15.24	None	0.27	0.00	-0.27
		Yes	0.00	-0.55	-0.27
0.56 kg. a.i./ha	1.27	None	0.83	0.00	-0.27
		Yes	1.11	-0.55	0.00
	15.24	None	0.00	-0.55	-0.27
		Yes	0.55	-0.55	0.00

Table A.21 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, March 28, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	3.31	3.34	2.71
		Yes	4.46	4.18	4.20
	15.24	None	12.86	13.08	10.52
		Yes	13.88	13.21	10.87
0.56 kg. a.i./ha	1.27	None	2.33	3.10	3.26
		Yes	2.88	4.41	4.17
	15.24	None	9.99	11.00	11.94
		Yes	10.77	12.50	12.98

Table A.22 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, March 28, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	31.10	28.88	29.16
		Yes	30.55	28.60	28.88
	15.24	None	24.16	22.49	22.22
		Yes	24.16	21.94	22.22
0.56 kg. a.i./ha	1.27	None	31.38	28.88	28.88
		Yes	31.10	28.60	28.60
	15.24	None	23.33	21.94	21.94
		Yes	23.05	21.94	21.66

Table A.23 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, April 28, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	2.51	1.98	1.72
		Yes	2.64	2.06	2.03
	15.24	None	7.71	5.90	5.96
		Yes	7.97	6.36	6.37
0.56 kg. a.i./ha	1.27	None	2.34	1.40	1.54
		Yes	2.93	1.72	2.17
	15.24	None	5.62	6.10	5.11
		Yes	5.77	6.48	5.72

Table A.24 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, April 28, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	33.33	31.90	31.94
		Yes	33.33	31.38	31.38
	15.24	None	28.33	27.77	27.84
		Yes	28.33	27.77	27.77
0.56 kg. a.i./ha	1.27	None	33.60	31.66	31.66
		Yes	33.60	31.66	31.38
	15.24	None	28.05	28.05	27.49
		Yes	28.05	28.05	27.21

Table A.25 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, May 30, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	1.47	1.55	0.98
		Yes	1.54	1.83	2.62
	15.24	None	6.95	5.30	7.63
		Yes	7.16	6.14	8.06
0.56 kg. a.i./ha	1.27	None	1.45	1.50	1.19
		Yes	1.94	2.34	1.75
	15.24	None	5.32	4.04	5.13
		Yes	5.37	4.77	5.70

Table A.26 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, May 30, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	37.21	35.27	37.10
		Yes	36.94	34.99	36.10
	15.24	None	31.66	28.16	28.88
		Yes	31.66	28.88	28.33
0.56 kg. a.i./ha	1.27	None	37.21	34.99	35.55
		Yes	36.84	34.94	35.55
	15.24	None	31.47	28.88	28.61
		Yes	30.73	28.33	27.77

Table A.27 : Soil water content (%) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, June 28, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	1.87	2.03	1.90
		Yes	2.08	2.25	2.43
	15.24	None	6.05	8.33	7.08
		Yes	6.88	8.53	7.49
0.56 kg. a.i./ha	1.27	None	2.09	2.06	1.96
		Yes	3.01	2.56	2.49
	15.24	None	4.87	5.74	6.40
		Yes	6.85	7.22	6.52

Table A.28 : Soil temperature (°C) by treatment as affected by herbicide-depth-irrigation near Bakersfield, Texas, June 28, 1991.

			Mulch		
Herbicide	Depth (cm)	Irrigation	Hydro	Hay	None
None	1.27	None	41.38	38.32	39.88
		Yes	40.82	31.10	39.44
	15.24	None	31.66	38.60	31.66
		Yes	31.38	27.77	31.10
0.56 kg. a.i./ha	1.27	None	41.10	38.72	39.71
		Yes	40.82	38.85	39.71
	15.24	None	32.22	28.33	31.38
		Yes	31.66	27.49	30.83

APPENDIX B

NUMBER OF SEEDLINGS OF DIFFERENT SPECIES TABLES

Table B.1: Number of seedlings/m^2 of Lehmann lovegrass by treatment near Bakersfield, Texas, July 24, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.5	0.5	0.0
	Yes	2.0	1.0	0.0
0.56 kg. a.i./ha	None	1.0	0.5	0.0
	Yes	1.5	1.0	0.0

Table B.2 : Number of seedlings/m^2 of sideoats grama by treatment near Bakersfield, Texas, July 24, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	2.5	2.0	0.0
	Yes	4.5	4.5	0.0
0.56 kg. a.i./ha	None	2.5	3.0	0.0
	Yes	4.0	5.0	0.0

Table B.3 : Number of seedlings/m^2 of Plains bristlegrass by treatment near Bakersfield, Texas, July 24, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	1.0	0.5	0.0
	Yes	2.0	2.5	0.0
0.56 kg. a.i./ha	None	0.5	2.0	0.0
	Yes	1.5	3.5	0.0

Table B.4 : Number of seedlings/m^2 of green sprangletop by treatment near Bakersfield, Texas, July 24, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.0	0.0	0.0
	Yes	2.0	0.5	0.0
0.56 kg. a.i./ha	None	0.0	0.5	0.0
	Yes	0.5	1.0	0.0

Table B.5 : Number of seedlings/m^2 of Old World bluestem by treatment near Bakersfield, Texas, July 24, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.0	0.0	0.0
	Yes	0.5	0.0	0.0
0.56 kg. a.i./ha	None	0.0	0.0	0.0
	Yes	0.0	0.0	0.0

Table B.6: Number of seedlings/m^2 of Lehmann lovegrass by treatment near Bakersfield, Texas, August 2, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	3.0	4.0	0.0
	Yes	3.5	4.5	0.0
0.56 kg. a.i./ha	None	4.0	5.0	0.0
	Yes	4.0	5.5	0.0

Table B.7 : Number of seedlings/m^2 of sideoats grama by treatment near Bakersfield, Texas, August 2, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	3.5	3.5	0.0
	Yes	5.0	5.0	0.0
0.56 kg. a.i./ha	None	4.0	4.0	0.0
	Yes	4.5	6.5	0.0

Table B.8 : Number of seedlings/m^2 of Plains bristlegrass by treatment near Bakersfield, Texas, August 2, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	2.0	3.0	0.0
	Yes	3.0	3.5	0.0
0.56 kg. a.i./ha	None	2.0	3.5	0.0
	Yes	3.5	5.0	0.0

Table B.9 : Number of seedlings/m² of green sprangletop by treatment near Bakersfield, Texas, August 2, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.5	0.5	0.0
	Yes	2.5	1.0	0.0
0.56 kg. a.i./ha	None	1.0	2.0	0.0
	Yes	1.0	1.5	0.0

Table B.10 : Number of seedlings/m² of Old World bluestem by treatment near Bakersfield, Texas, August 2, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.0	0.0	0.0
	Yes	0.0	0.0	0.0
0.56 kg. a.i./ha	None	0.0	0.0	0.0
	Yes	0.0	1.0	0.0

Table B.11: Number of seedlings/m^2 of Lehmann lovegrass by treatment near Bakersfield, Texas, August 14, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	4.5	6.0	0.0
	Yes	4.5	6.5	0.0
0.56 kg. a.i./ha	None	7.0	6.5	0.0
	Yes	7.5	7.5	0.0

Table B.12: Number of seedlings/m^2 of sideoats grama by treatment near Bakersfield, Texas, August 14, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	4.0	3.5	0.0
	Yes	5.0	5.0	0.0
0.56 kg. a.i./ha	None	4.0	4.5	0.0
	Yes	4.5	6.5	0.0

Table B.13: Number of seedlings/m^2 of Plains bristlegrass by treatment near Bakersfield, Texas, August 14, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	2.0	3.0	0.0
	Yes	3.0	3.5	0.0
0.56 kg. a.i./ha	None	3.0	3.5	0.0
	Yes	3.5	5.0	0.0

Table B.14: Number of seedlings/m^2 of green sprangletop by treatment near Bakersfield, Texas, August 14, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.5	0.5	0.0
	Yes	2.5	1.0	0.0
0.56 kg. a.i./ha	None	1.0	2.0	0.0
	Yes	1.5	1.5	0.0

Table B.15: Number of seedlings/m^2 of Old World bluestem by treatment near Bakersfield, Texas, August 14, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.0	0.0	0.0
	Yes	0.0	0.0	0.0
0.56 kg. a.i./ha	None	0.0	0.5	0.0
	Yes	0.0	1.0	0.0

Table B.16: Number of seedlings/m^2 of Lehmann lovegrass by treatment near Bakersfield, Texas, August 22, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	4.5	6.0	0.0
	Yes	4.5	6.5	0.0
0.56 kg. a.i./ha	None	7.0	6.5	0.0
	Yes	7.5	7.5	0.0

Table B.17: Number of seedlings/m^2 of sideoats grama by treatment near Bakersfield, Texas, August 22, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	4.0	3.5	0.0
	Yes	5.0	5.0	0.0
0.56 kg. a.i./ha	None	4.0	4.5	0.0
	Yes	4.5	6.5	0.0

Table B.18: Number of seedlings/m^2 of Plains bristlegrass by treatment near Bakersfield, Texas, August 22, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	2.0	3.0	0.0
	Yes	3.0	3.5	0.0
0.56 kg. a.i./ha	None	3.0	3.5	0.0
	Yes	3.5	5.0	0.0

Table B.19: Number of seedlings/m^2 of green sprangletop by treatment near Bakersfield, Texas, August 22, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.5	0.5	0.0
	Yes	2.5	1.0	0.0
0.56 kg. a.i./ha	None	1.0	2.0	0.0
	Yes	1.5	1.5	0.0

Table B.20 : Number of seedlings/m^2 of Old World bluestem by treatment near Bakersfield, Texas, August 22, 1990.

		Mulch		
Herbicide	Irrigation	Hydro	Hay	None
None	None	0.0	0.0	0.0
	Yes	0.0	0.0	0.0
0.56 kg. a.i./ha	None	0.0	0.5	0.0
	Yes	0.0	1.0	0.0