Establishing Perennial Grasses on Abandoned Farmland in Southeastern Arizona

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Abstract. Several hundred thousand hectares of semidesert grassland were plowed, sown to agricultural crops, and abandoned in southeastern Arizona. Abandonment occurred because of falling water tables and the transfer of water rights from agricultural uses to urban uses. Natural vegetation slowly invade these sites and strong winds and rain generated as summer thunderstorms pass over abandoned farmland and cause wind and water erosion. The purpose of this study was to determine the effects of planting season (spring, summer, or fall), the amount of supplemental irrigation water, and competition on the establishment and forage production of seven perennial grasses. Lehmann lovegrass (*Eragrostis lehmanniana*) A-68, L-28, and L-38 and Boer lovegrass (*Eragrostis curvula* var. *conferta*) A-84 seedlings did not emerge from the Pima silty clay loam soil. Catalina Boer lovegrass, and A-130 and SDT blue panicgrass (*Panicum antidotale*) seedlings emerged following spring, summer, and fall plantings, but seedlings emerging in the spring and fall died in less then 4 months. Catalina seedlings, irrespective of irrigation amount, died within 52 months, whereas blue panicgrass survived to 52 months only after receiving 15 and 20 cm (6 and 8 in.) of supplemental irrigation water. The downward trends in blue panicgrass densities and forage production may indicate that the selected plant materials and methods used in this study are unsatisfactory for reclaiming abandoned farmland in southeastern Arizona.

Introduction

In 1854 J.R. Bartlett described the valleys within the Santa Cruz Basin in southeastern Arizona [10].

> We were off this morning (from Tucson) . . . and soon entered a thickly wooded valley of mesquite. A ride of nine miles brought us to San Xavier de Bac . . . a mile further we stopped in a fine grove of large mesquite trees near the river, where there was plenty of grass. The bottom-land resembled meadows being covered with luxuriant grass and but few trees. The bottoms (between San Xavier and Tubac) in places were several miles wide . . . and covered with tall, golden colored grass (big sacaton) . . . divided by a meandering stream a dozen yards wide and as many inches deep, this shaded by cottonwoods, willows, and mesquites.

The soils associated with big sacaton (*Sporobolus wrightii*) grasslands within the Santa Cruz basin were extremely fertile [9, 14, 22], and farming activities began to accelerate around 1900 [6]. From 1900 to 1960 irrigated acreages increased from 9,000 to 550,000 ha (22,230 to 1,358,500 A) and by 1980 declined to 111,000 ha. Abandonment occurred because of falling water tables [1, 16] and the transfer of water rights from agricultural uses to urban uses [6]. As the urban demand increases in the future, more water will be diverted from agriculture, thus, resulting in more abandoned farmland.

Farmland is dominated by tumbleweed (*Salsola kali*) immediately after abandonment, and if undisturbed for 2 to 3 years, tumbleweed is replaced by mustards (*Descurainia* and *Susymbrium* spp.) and other introduced or nonnative annuals [13]. Annuals may be replaced in 3 to 10 years by half-shrubs such as *Baccharis sarothroides* and burroweed (*Haplopappus tenuisectus*). After 10 years abandoned fields are usually dominated by widely spaced half-shrubs and shrubs such as creosotebush (*Larrea tridentata*), mesquite (*Prosopis juliflora*), and saltbush (*Atriplex* spp.).

Raindrop impact on bare soil reduces infiltration and enhances runoff [16], but wind erosion at the present is the most serious safety problem [13]. In late June moisture surges from the Gulf of Mexico generate long squall lines in southern Arizona [11]. In front of the advancing squall lines wind gusts approach 30 m/sec (67.2 mil/hr), and visibility may decrease to zero. Dust storms, generated as squall lines, pass over abandoned farmland, and have been responsible for more than 440 automobile accidents in the past 20 years [13].

Lehmann lovegrass (*Eragrostis lehmanniana*)

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A-68, Boer lovegrass (*Eragrostic curvula* var. *conferta* Nees) A-84, and blue panicgrass (*Panicum antidotate*) A-130 have been successfully established on upland range in southeastern Arizona [12]. Plant breeders have developed genetically improved accession for each species [23–25]. However, the improved and original accessions have never been directly compared for the ability to establish and persist on abandoned agricultural land.

Perennial grass seeds need continuous soil moisture for 3 to 5 days to ensure germination, as well as additional soil moisture within 7 days of germination to ensure establishment [7, 8]. The summer and winter precipitation patterns and relatively mild winters of southern Arizona and northern Sonora suggest that perennial grass seedlings may establish following either winter or summer precipitation [4]. Seeding of grass seed has historically been conducted prior to summer precipitation but the total amount and seasonal distribution of summer rainfall needed to germinate and successfully establish perennial grasses, occurs in only 1 of 10 years [3].

Failure to establish perennial grasses successfully in semiarid regions has often been attributed to competition for soil moisture by annual and nonseeded perennial plants [5]. Competition of the species must be reduced during seed germination and seedling growth [15]. This study was conducted to determine the effects of the planting season, the addition of supplemental irrigation, and the effect of weed competition on the establishment and production of perennial grasses sown on abandoned farmland.

In order to determine differences among seasons of planting and the value of either providing supplemental water or reducing weed competition, studies are needed to verify plant persistance and potential animal-carrying capacity. We used plant density estimates as a measure of persistence and forage production as an indication of animal-carrying or grazing capacity.

Study Site

The study was conducted at the San Xavier Indian Reservation, 5 km (3.1 mi) south of Tucson in southeastern Arizona. The site was plowed and sown to either cotton (*Gossypium hirsutum*) or alfalfa (*Medicago sativa*) between 1933 and 1971, and abandoned in 1972. Elevation is 770 m (2526 ft) and soil is a Pima silty clay loam (thermic Typic Torrifluvent) [17]. Soils are recent alluvium, weathered from mixed rocks, moderately alkaline, slightly calcarious, and greater than 2 m (6.6 ft) in depth. Prior to cultivation, arroyo formation, and the lowering of the water table, these soils would have been classified as Haplustolls [16].

Precipitation distribution at the site is 60% in summer and 40% in winter [18], and freezing temperatures are not common (Fig. 1). The site is located in the Santa Cruz floodplain, where in winter nighttime temperatures may be 3 to 5°C (5 to 9°F) less than those at Tucson International Airport 2 km (1.2 mi) east (personal communications, National Weather Service, Tucson Airport).

After abandonment, the predominate species following summer precipitation are *Amaranthus palmeri, Portulaca oleracea, Salsola kali, Impomoea thurberi,* and *Xanthium spinosum;* and following winter precipitation, the predominate species are *Lactuca serriola, Schismus barbatis,* and *Teraxacum officinale*. There were no perennial grasses on site when the study was initiated.

Methods

Field Studies

A seedbed was prepared by disking to 30 cm (12 in.) in March (spring) and October (fall) 1980 to 1982, July (summer 1980 to 1981 and 1983). The disked area was divided into three 1.5 × 90 m (4.9 × 295.2 ft) blocks. Lehmann lovegrass 1) A-68, 2) L-28, and 3) L-38, Boer lovegrass 4) A-84 and 5) Catalina or blue panicgrass 6) A-130 and 7) SDT seed were each sown with a rangeland drill in five rows 30 cm apart. Lovegrass seeds were sown at a pure live seed (PLS) rate of 1.0 kg/ha and blue panicgrass seeds at PLS rate of 3.0 kg/ha. Plot size for each accession was 1.5 × 90 m, and seeds were sown at 0 to 2 cm depths.

A border disk pulled perpendicular to seeded rows divided a block into five 1.5 × 18 m (4.9 × 59.0 ft) subplots (Fig. 2). Subplots recieved either 0, 1, 2, 3, or 4 flood irrigations of 5 cm at either 0, 7, 14, or 21 days after planting. One-half of each subplot was hand weeded 15, 30, 45, and 60 days after the final irrigation. Total precipitation was recorded weekly, on site, and accumulated by month.

Within ten randomly placed 30 × 90 cm sampling areas in weeded and unweeded subplots the number of seedlings and established plants in the three center rows were either counted or harvested. Density (plants/m^2) was recorded at 4, 8, 12, and 24 months after seeding. Forage production (g/m^2) was harvested at 2.5 cm (1 in.) above the soil surface 4, 16, 28, 40, and 52 months after planting, with the exception of the summer 1983 planting, which was harvested 4, 16, and 28, months after planting. No sampling area was harvested more than once during the course of the experiment. Harvested samples were dried in a forced draft oven at 40°C (105°F) for 92 hours. Average density and forage production from the ten sampling areas of a grass accession within either a weeded or

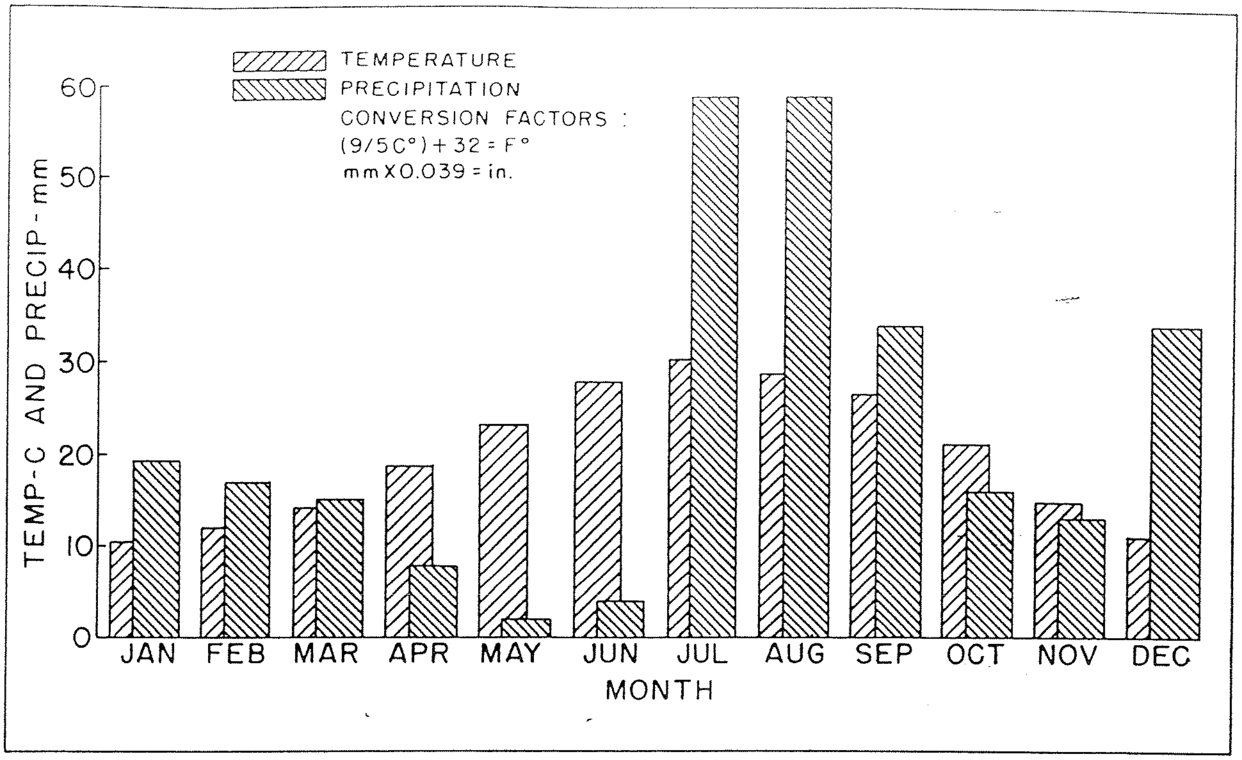

Fig. 1. Monthly temperature and rainfall means between 1970 and 1984 at the Tucson Airport (data provided by the National Weather Service).

unweeded subplot of the same water rate were used as individual data points in statistical analyses.

The experiment was conducted using a split (season)—strip (irrigation)—split (accession)—split (weeds) block design. Seeds were sown in three seasons within 3 years and there were three replications of five irrigation rates, seven grass accessions, and two levels of weed control. Planting dates, accessions, and weed control were randomized, but space and previous ditch construction limited complete randomization of water rates. Therefore, a single water rate was randomized in a strip across the seven accessions (Fig. 2). Irrigation or water rate is the accumulation of 5 cm (2 in.) of water applied at 7-day intervals.

Only three grasses were successfully established and those grasses were established only following summer plantings. Therefore, analyses of accession density and forage production means for the summer plantings were compared across irrigation rates and levels of weed control for each observation date by analysis of variance. When F values indicated significant main effects or interactions, Duncan's New Multiple Range Test [20] was used to separate means.

Results and Discussion

Seedling Emergence

The Lehmann lovegrass (A-68, L-28, and L-38) and Boer lovegrass (A-84) seedlings did not emerge following spring, summer, and fall plantings. Cox and Martin [4] collected soil at the study site and planted seeds of the seven grasses at five depths. Lovegrass (A-68, L-18, L-38, and A-84) seeds sown on the soil surface germinated, but seedling radicals grew horizontally along the surface and most died within 48 hours. Lehmann lovegrass seedlings failed to emerge when seeds were sown at 0.5-, 1.0-, 1.5-, and 2.0 cm soil depths; whereas Boer lovegrass (A-84) seedlings emerged from only 0.5-cm depths.

Catalina lovegrass and both blue panicgrasses emerged after all nine plantings. Seedlings emerging in spring died as soil dried in May and June, and those emerging in fall died in either dry or wet soil during winter. Only seedlings that emerged in summer had the potential to persist for more than 3 months.

Grass Densities, Summer Rainfall, and Supplemental Irrigation

The densities of Catalina lovegrass and both blue panicgrasses differed ($P \leq 0.05$) among water rates and years at 4, 8, and 12 months after planting. Differences among grass densities and water rates were measured at 24 months after planting, but densities on the same water rate were similar after 2 years because seedlings established during the

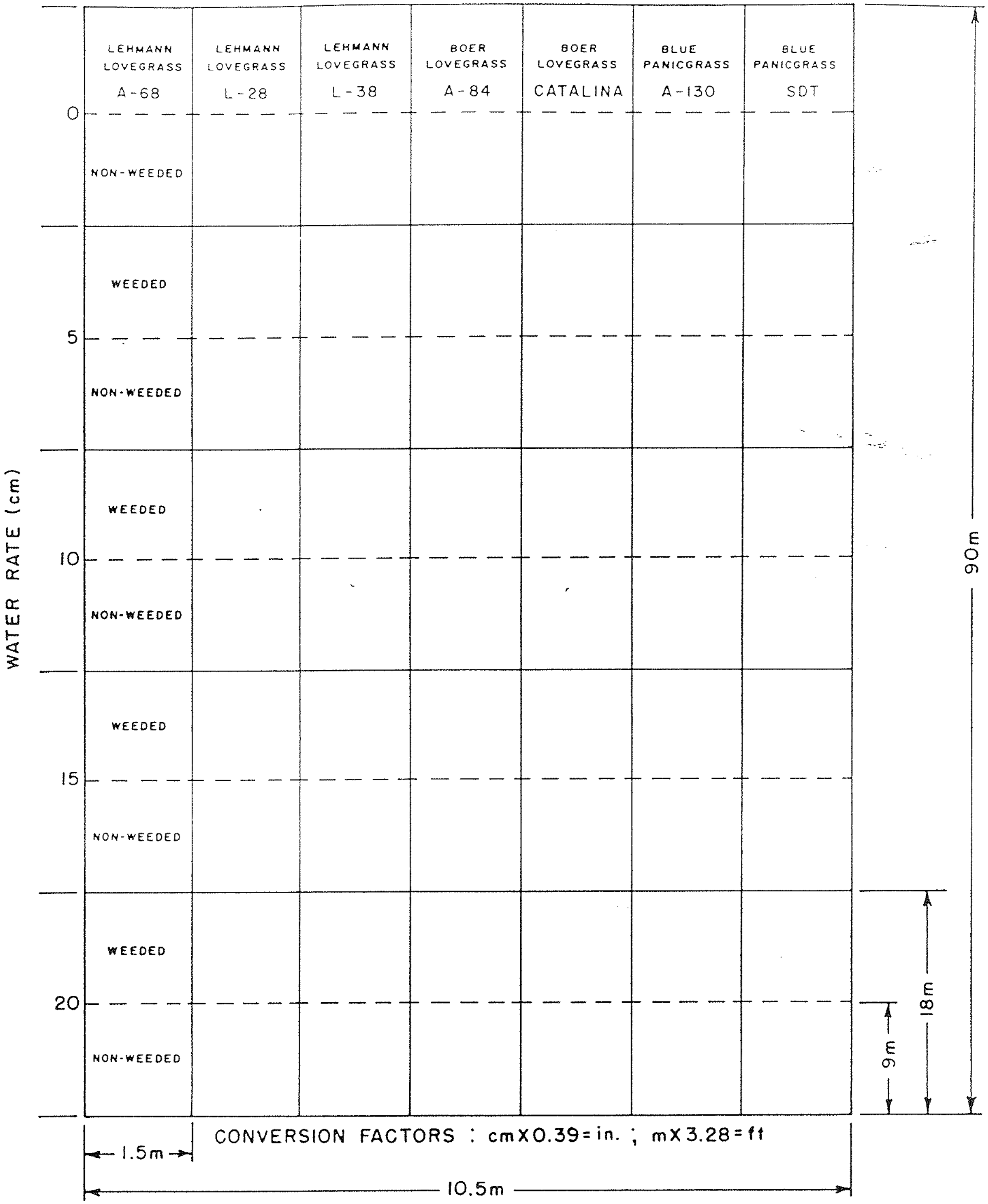

Fig. 2. Relationships among seeded grasses, water applications, and weed removal within a replication. One-half of the area within a water application sown to each grass was randomly selected and annual weeds were removed 15, 30, 45, and 60 days after the final water application.

above-average summer rainfall periods of 1981 and 1983 (Fig. 3) died (Fig. 4) when less favorable growing conditions returned in either 1982, 1984, or 1985.

Seeds sown in plots receiving only rainfall germinated and we observed seedlings in mid-July on the 1980 and 1981 plantings. During both years seedlings died in August when rainfall declined (Fig. 3), and no seedlings were present 4 months after planting (Fig. 4). August through October rainfall in 1983 was 78% greater than the long-term average, and seedlings of the three grasses were

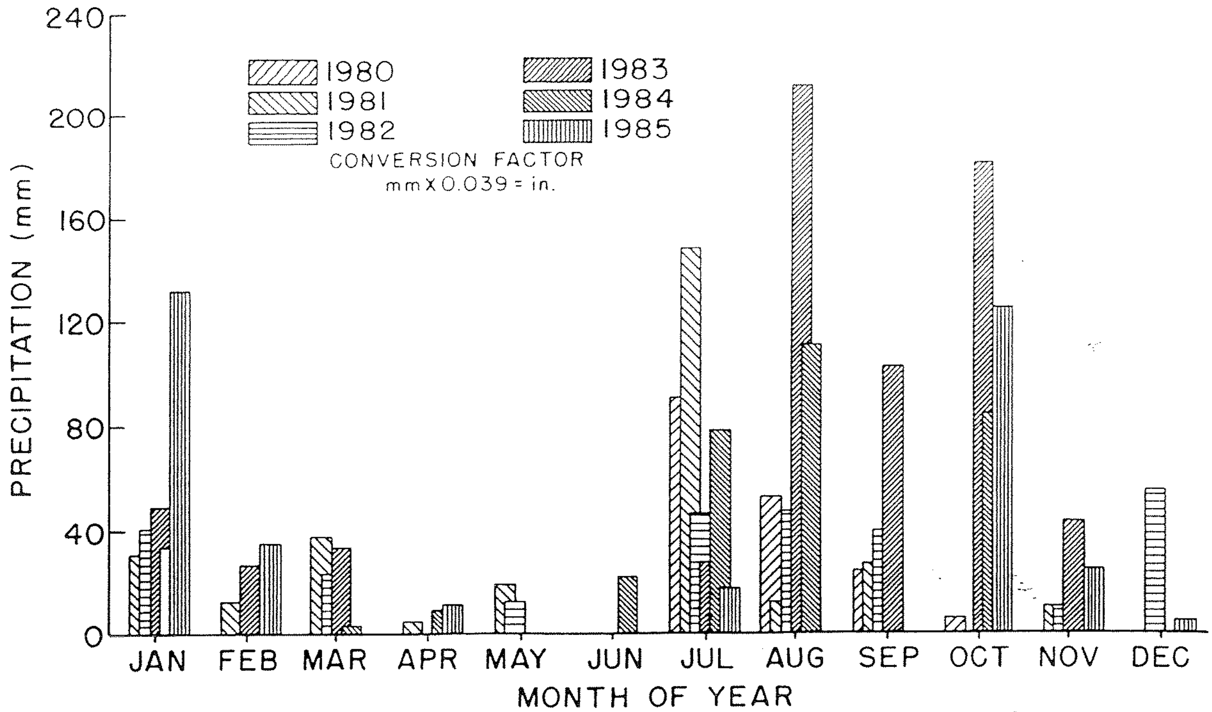

Fig. 3. Mean monthly precipitation between July 1980 and December 1985 at San Xavier Indian Reservation, Tucson, Arizona.

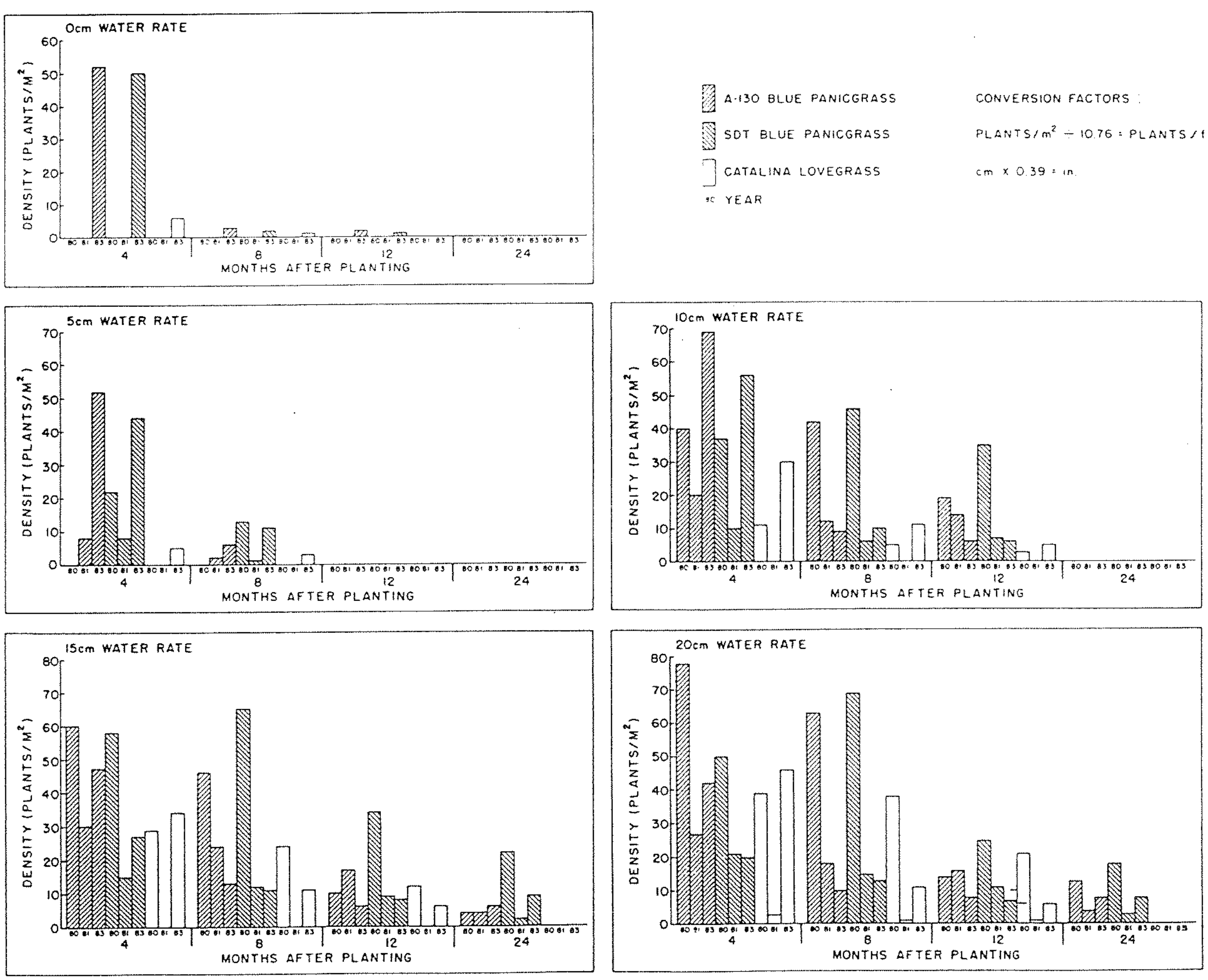

Fig. 4. Catalina Boer lovegrass and A-130 and SDT blue panicgrass densities 4, 8, 12, and 24 months after planting and providing flood irrigation applications of 0, 5, 10, 15, and 20 cm in summer 1980, 1981, and 1983.

present 4 months after planting. The majority of these seedlings died in winter 1983 to 1984, and all had died within 24 months.

All plants initially established on plots receiving 5- and 10-cm water applications died between 8 and 24 months (Fig. 4), and all Catalina lovegrass plants receiving 15- and 20-cm applications died within 24 months. Catalina lovegrass seed sown in sandy to sandy loam upland soils germinate and produce plants that persist for 15 years [3]. However, Catalina lovegrass did not persist at the study site and is not adapted for planting on Pima silty clay loam soils, even if supplemental water is available.

Densities of A-130 at 4 months were generally greater, but not significantly ($P \leq 0.05$), than SDT on 15 and 20 cm (6 and 8 in.) water applications (Fig. 4). The trend toward more surviving SDT and fewer A-130 seedlings began at 8 months and continued to 24 months. Wright and Dobrenz [24] observed the same trend and concluded that SDT seedlings were more drought tolerant than A-130 seedlings. Our observations and recently published information support an alternative hypothesis.

SDT seed planted in three summers continued to germinate for 2 years and new seedlings replaced dead or dying seedlings in planted rows, whereas replacement A-130 seedlings were never observed or measured after the initial summer growing season. Frasier et al. [7] have shown that the total A-130 seed population germinates when soils are saturated, seedlings develop quickly, and most seedlings survive 5 to 7 consecutive days when soil moisture is below the permanent wilting point. Whereas 50 to 80% of the SDT seed popualtion germinates quickly, remaining seed are viable and may germinate when soil moisture conditions improve, seedlings develop slowly, and seedlings die whenever soil moisture is below the permanent wilting point.

Rapid seed germination and seminal root elongation have been reported to be important characteristics for establishing plants in arid and semiarid areas [21, 26]. However, seeds and seedlings of the most successfully established perennial grasses in the southwestern United States and northern Mexico germinate slowly and seedlings grow slowly [19]. Apparently, plants in semiarid areas have a greater chance of surviving if a portion of the seed population is dormant but viable, and dormancy decreases in time. The remaining viable seeds can then germinate during subsequent wet periods.

Forage Production and Supplemental Irrigation

Forage production of the three grasses at 4 months after planting averaged 25 and 59 g/m^2 (223 and 527 lb/A) on the 0 and 5 cm water applications, respectively, and varied from 215 to 250 g/m^2 across the 10, 15, and 20 cm water applications (Fig. 5). Forage production of the two blue panicgrasses peaked at 28 months, and declined between 28 and 52 months on the 15 and 20 cm water applications. The decline in forage production is suspected to be related to 1) low summer rainfall in 1984 (189 mm or 7.4 in.) and 1985 (57 mm or 2.2 in.), 2) the lack of floodwater, and 3) competition among established blue panicgrasses. Big sacaton growing in Pima silty clay loam soil produced 135 g/m^2 (1205 lb/A) during dry summers when flooding did not occur, and 325 g/m^2 when flooding did occur [2]. After initially receiving either 15 or 20 cm of supplemental irrigation to aid in establishment, SDT blue panicgrass forage production varied from 215 to 230 g/m^2 in two dry summers.

SDT blue panicgrass forage production was consistently greater than A-130 between 4 and 28 months (Fig. 5), but significant differences ($P \leq 0.05$) between the two accessions were measured only at 28 months. The trend toward greater SDT forage production continued, but differences between the accessions were not significant at 40 and 52 months.

Grass Densities, Forage Production, and Weeding

We expected seeded grasses and weeds to compete and believed we would find less vigorous and fewer grasses growing where weed competition had not been reduced. Therefore, weeding effects with respect to grass establishment and forage production were expected in each of the five water applications. Differences ($P \leq 0.05$) in seedling densities and forage production did not occur between weeded and nonweeded areas within a water application, even though seedlings appeared to be more vigorous when growing in weeded areas. Both blue panicgrass accessions grew rapidly after emergence and seedling heights in weeded and nonweeded areas averaged 30 cm (12 in.) at 15 days, 60 cm at 30 days, and 90 cm at 45 days. More than 30% of the blue panicgrass canopy was above the weed canopy in 30 days and more than 50% in 45 days.

Conclusions and Implications

The intent of our study was to determine the effects of planting season, supplemental irrigation water, and weed competition on the establishment and production of seven perennial grasses. We found

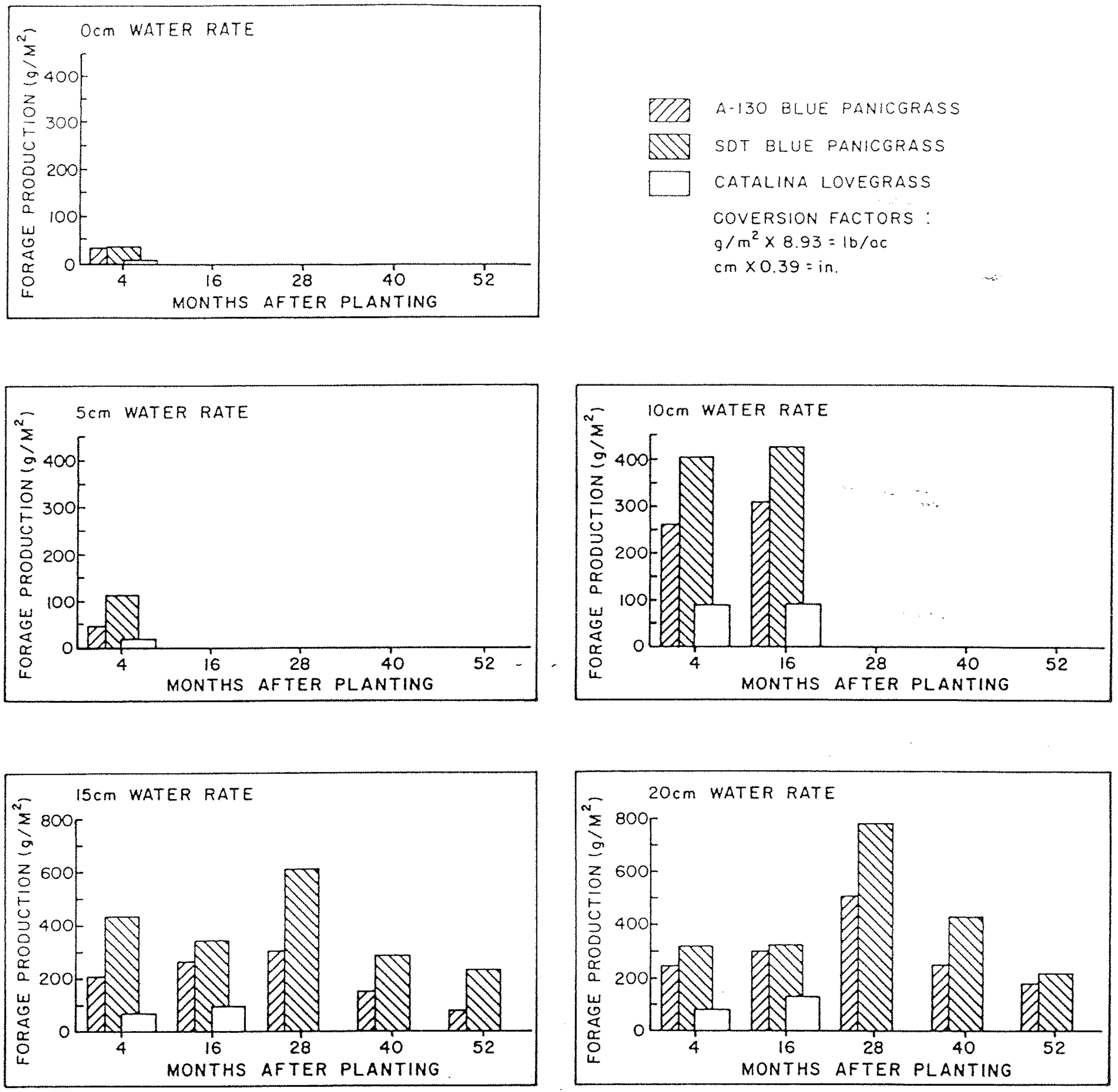

Fig. 5. Catalina Boer lovegrass and A-130 and SDT blue panicgrass forage production 4, 16, 28, 40, and 52 months after planting and providing flood irrigation applications of 0, 5, 10, 15, and 20 cm in summer 1980, 1981, and 1983.

that silty clay loam soil prevented the establishment of A-68, L-28, and L-38 Lehmann lovegrasses and A-84 Boer lovegrass irrespective of planting season, irrigation amount, or weed competition; and hence, these grasses were unacceptable for reclaiming abandoned farmland.

Catalina Boer lovegrass, and A-130 and SDT blue panicgrass seedlings from seed planted in summer often persisted for 4 months or more after planting, whereas seedlings from seed that germinated in fall or spring always died in less than 4 months. Our most important finding is that Catalina lovegrass and both blue panicgrass seeds will germinate and produce seedlings under natural rainfall, but long-term persistence was unreliable because plants eventually died. We might have missed this important point, and recommend seeding without supplemental water, if the study plan had not included long-term evaluations. Therefore, these grasses are not adapted for planting on abandoned farmland if their survival is dependent on natural rainfall.

Blue panicgrass A-130 and SDT plants established with 15 to 20 cm (6 to 8 in.) of supplemental irrigation water applied in summer will persist for 52 months after planting (Figs. 4 and 5), and weeding to remove annual plant competition is unnecessary. The steady decline in plant persistence and forage production with time, however, may suggest that neither blue panicgrass accession is adapted and both will disappear eventually. Thus there is the distinct possibility that the methods and plant materials used in this study are not adequate to reclaim abandoned farmland in southeastern Arizona.

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