

Introduction

Mesquite: Research and Technology in Perspective

W. G. McCully*

Why has mesquite (*Prosopis* spp.) spread onto some 56 million of the 107 million acres of Texas rangeland? Why does it continue to spread? What has been done to lessen its influence on the productivity of rangeland? Why is mesquite so difficult to control; are any side-effects associated with control measures? Finally, what is the impact of this plant on the economy of the ranching industry and of Texas?

Mesquite was considered a problem more than 75 years ago and has become symbolic of a vast array of woody plants infesting grazing lands. Research on which to base control methods was initiated at Texas A&M University almost 40 years ago. The technology available today contains significant inputs from ranchmen, researchers of The Texas Agricultural Experiment Station and the U.S. Department of Agriculture, specialists of The Texas Agricultural Extension Service, equipment and chemical manufacturers and many others. Effective control methods continue to evolve as technology advances, ranch production costs increase and ranchmen demand more efficient management tools. Ranchmen in Texas have levied a voluntary tax within their industry to supplement appropriated funds for research on brush control and range improvement.

Eradication of mesquite as a rangeland pest was optimistically predicted in early efforts. However, eradicating a native plant can be accomplished only with tedious and patient treatment and at considerable expense. In practice, controlling mesquite has been a more realistic approach. Controlling mesquite lessens its demands on water and space for growth so that these can be used for production of forage. Management must balance cost and length of control against such benefits as increased forage and livestock yields and savings in labor.

Brush control today is a complex problem. Highly successful control measures for mesquite are prescribed in more than 50 research publications of The Texas Agricultural Experiment Station and as many circulars

and fact sheets of The Texas Agricultural Extension Service. However, the researchers, extension specialists and teachers no longer are concerned only with control measures. They must also recognize the economic factors related to new methodology, the ecological niche of mesquite, its degree of competition with desirable forage plants, the cost of its control, the costs of labor needed to manage mesquite-infested rangeland and the life of a recommended control practice.

Successful ranchmen maximize net income considering such economic factors as internal rate of return, marginal profits and discounted investment. In addition, costs of production must be carefully evaluated. Using the "brushpopper" cowboy is no longer an economic practice because every pound of beef lost in handling cattle is added loss of income. Furthermore, every pound of forage not produced because mesquite or some other weed uses needed moisture, space or nutrients also represents a monetary loss.

The mesquite problem on grazing lands increases in severity as ranch management becomes more intensive. Today, the complexity of the problem requires inputs from a wide variety of specialties spanning plant ecology and physiology, chemistry, engineering, management and economics. Recommended control measures must be implemented as long term programs without damaging the rangeland environment or desirable plants and animals. This concern is an integral part of the research effort and a vital consideration present and future technology.

The following chapters provide an overview of many research accomplishments in mesquite control over the past 40 years by scientists at The Texas Agricultural Experiment Station and their coworkers. This technology, involving proper use of chemical and mechanical tools in management programs, was implemented by Extension specialists working with progressive ranchmen. This success story is a tribute to the continued and coordinated efforts of units of Texas A&M University and the sustained support of the ranching industry.

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mesquite

Growth and Development
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Uses

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The Mesquite Problem

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Mesquite's occurrence on extensive areas of grazing lands is a common problem of ranchmen of the Southwest. The present mesquite problem arose largely from increases in the density of brushy, many-stemmed plants which have gradually thickened to form moderate to heavy stands on the more productive range sites. These infestations seriously interfere with livestock management and often reduce the production of desirable range forage plants. Surveys conducted by the Soil Conservation Service published in 1964 indicated that mesquite occurred on 56 million acres of rangeland in Texas (Figure 1-1). Approximately 16 million acres of Texas rangeland are heavily infested with mesquite, 18 million acres have a moderate infestation and 22 million acres have a light infestation. Mesquite rapidly invades abandoned croplands, pastures seeded to perennial grasses, rights-of-way, fence rows and areas around stock ponds, dams and spillways.

Mesquite (*Prosopis* spp.) is a perennial belonging to the Mimosoideae subfamily of Leguminosae. The genus *Prosopis* is divided into two species—mesquite (*P. juliflora*) and screwbean (*P. pubescens*). Benson and Darrow (1) further divided mesquite into four varieties as follows: (a) mesquite [*Prosopis juliflora* (Swartz) DC. var. *juliflora*], (b) velvet mesquite (*Prosopis juliflora* (Swartz) DC. var. *velutina* (Woot.) Sarg.], (c) western honey mesquite [*Prosopis juliflora* (Swartz) DC. var. *torreyana* L. Benson] and (d) honey mesquite [*Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell].

Honey mesquite occurs primarily east and north-east of the Rio Grande River in New Mexico, throughout south and west Texas and extends to northern Oklahoma and to Louisiana on the east. Velvet mesquite predominates in Arizona, extreme western New Mexico, lower California and Mexico. Western

mesquite occurs in California, southern Nevada, Utah, western Arizona, southern New Mexico and parts of Texas. Honey mesquite is the primary problem species on rangeland in Texas. Because honey mesquite is commonly called "mesquite," that name will be used in this publication.

Varieties of mesquite that grow upright vary in growth form from single-stemmed trees, 10 feet or taller, to small, few- to many-stemmed shrubs (Figure 1-2). The many-stemmed growth form is often the result of sprouting following injury or top removal of the tree-type form (Figure 1-3).

Mesquite occurs at elevations up to 4,500 feet where the average annual minimum temperature exceeds -5° F with 200 or more frost-free days. Along the northern extremes of mesquite's distribution, newly developed leaves and twigs are occasionally killed by late spring freezes. Prolonged temperatures of -16° F in February 1932 killed the aerial growth of mesquite over extensive areas in northwest Texas. Mesquite occurs along drainageways in areas of low rainfall (6 inches or less), is adapted to moist soils in 15- to 20-inch rainfall belts and may occur on calcareous soils where rainfall exceeds 30 inches.

Highly prized grazing lands of mesquite savannahs in the Canadian breaks of Texas were described in 1820 by the Stephen Long Expedition (8). The R. B. March Expedition (1849 to 1854) reported mesquite varying from small, brushy plants in the Pecos area to open groves of medium to large trees with a carpet of buffalograss¹ and grama grasses underneath (10). Johnston indicated that prairies near San Antonio during the middle of the 19th century were largely covered with perennial grasses and supported only scattered bushes and small mesquite trees (7). Grasslands to the southwest graded into mesquite prairies. Johnston further postulated that the rapid takeover by mesquite may be attributed to increases in stature and density of plants rather than to invasion of previously brushless areas.

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¹Scientific names of plants mentioned in text are given in Appendix A.

MESQUITE DISTRIBUTION — TEXAS

LEGEND

LEGEND





Figure 1-2. The two primary growth forms of mesquite on rangelands are the large tree-type (top) and the many-stemmed, "brushy" type (bottom) usually resulting from disturbance of the large tree-type.

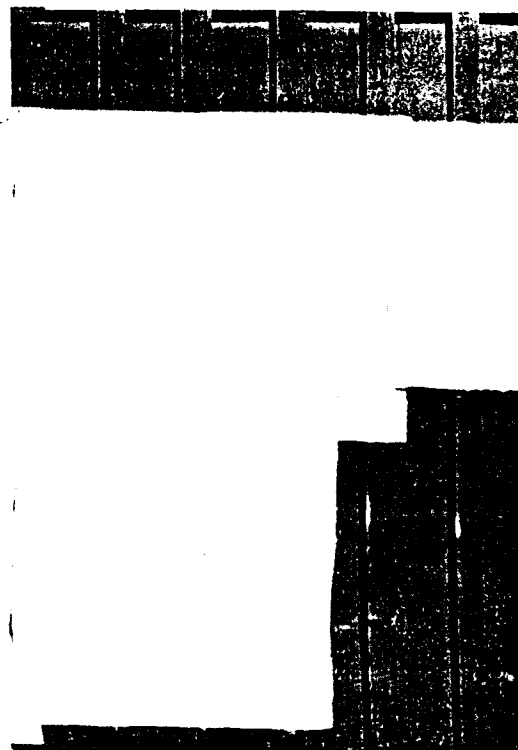
Increases in density and spread of honey mesquite occur only from seed, whereas increases in stature presumably are the result of overuse of associated vegetation. Malin (11) and Peacock and McMillan (12) also indicated that the major distribution of mesquite has been much the same for the past 150 years. Most workers agree that drastic increases in density of stands began in the early part of the 20th century. Around the turn of the century, workers observed a rapid increase in the population of many-stemmed mesquite plants in northwest Texas (6, 13). The shift from open to thick stands of honey mesquite appears to parallel closely the early increases of cattle numbers on rangeland. Germination of a high percentage of the seed in the droppings of grazing animals coupled with heavy use of fire plants and soil disturbance by trampling undoubtedly accelerated the increase in mesquite density.

Development of watering facilities, fencing and supplemental feeding resulted in concentration of grazing animals yearlong on rangeland and further aggravated the problem (5).

Under most conditions, mesquite is resistant to overgrazing and considered to be undesirable on grazing lands. Conversely, it has provided fuel, building materials and fence posts. During the dry summer season, mesquite often produces heavy crops of beans that are relished by grazing animals, rodents and other wildlife. Mesquite also provides shade and some protection for grazing animals and wildlife during severe winter seasons. However, horses and cattle may suffer serious digestive disturbances and even death from heavy consumption of mesquite beans (4). Moreover, mesquite thickets may hinder or prevent installation of many desirable range, livestock and wildlife production practices.



Figure 1-3. Removal of above-ground growth stimulates crown sprouting which results in a twofold to tenfold increase in the number of basal stems of mesquite.



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Figure 1-5. Root system of mesquite on eroded rangeland. The taproot of mesquite has been observed to penetrate to 30 to 40 feet deep or more. The lateral roots usually extend 30 to 40 feet away from the base of the plant.

Mesquite typically has a taproot with an extensive lateral root system and thrives best on moderate to deep, fine-textured soils. Seedlings rapidly establish root systems (Figure 1-4), and roots of well-established plants may penetrate vertically to depths of 15 to 40 feet. The roots often extend laterally as much as 50 feet from the base of the plant (Figure 1-5). When soil moisture is adequate, mesquite is an inefficient user of water (9). However, under extreme moisture stress, it is able to survive due to reduction of leaf area, increase in thickness of the leaf cuticle and almost complete cessation of growth (15). Thus, mesquite

withstands severe drouths, competition from perennial grasses and adverse conditions due to prolonged overgrazing of rangeland (14).

Effective management of infested grazing lands requires knowledge of processes influencing germination, establishment, growth and development of mesquite. This knowledge is the basis for better understanding the reaction of mesquite to various control procedures and the economic and management decisions underlying the selection of proper control technique(s).

LITERATURE CITED

1. Benson, L., and R. A. Darrow. 1944. Manual of southwestern desert trees and shrubs. Biol. Sci. Bull. No. 6. Univ. of Arizona. 80 p.
2. Bray, W. L. 1904. Forest resources of Texas. U.S. Dep. Agr. Bull. 47. 71 p.
3. Cook, O. F. 1908. Change of vegetation on the South Texas Prairies. U.S. Dep. Agr., Bur. Plant Ind. Circ. 17:7 p.
4. Dollahite, J. W., and W. V. Anthony. 1957. Malnutrition in cattle on an unbalanced diet of mesquite beans. Tex. Agr. Exp. Sta. PR-1056. 4 p.
5. Fisher, C. E. 1948. The mesquite problem in the southwest. J. Range Manage. 3:60-70.
6. Griffiths, D. 1904. Range investigations in Arizona. U.S. Dep. Agr. Bur. Plant Ind. Bull. 67. 62 p.
7. Johnston, M. C. 1962. Past and present grasslands of southern Texas and northern Mexico. Ecology 44:456-466.
8. Long, S. H. 1820. An account of an expedition from Pittsburgh to the Rocky Mountains performed in the years 1819 and 1820. From notes of Major Long, Mr. Say and others of exploring party, Edwin James Corp. In R. A. Thwaites, (Ed) *Early Western Travels, 1784 to 1846*. Vol. 14-17. 51. p.
9. McGinnies, W. G., and J. F. Arnold. 1939. Relative water requirements of Arizona range plants. Ariz. Agr. Exp. Sta. Bull. No. 96. 80 p.
10. Marcy, R. B. 1849. Report of exploration and surveys of route from Fort Smith, Arkansas, to Santa Fe, New Mexico, made in 1849. House Ex. Doc. 45, 31st Congress, 1st Session. Public Doc. 577. Washington, D. C.
11. Malin, J. C. 1953. Soil, animal and plant relations of the grasslands historically reconsidered. The Sci. Month., 76 (4):207-220.
12. Peacock, J. T., and C. McMillan. 1965. Ecotypic differentiation in *Prosopis* (mesquite). Ecology 46:35-51.
13. Smith, J. G. 1896. Fodder and forage plants exclusive of grasses. U.S. Dep. Agr., Div. of Agron., Bull. 2:10 p.
14. U.S. Department of Agriculture. 1937. Range plant handbook. For. Ser. Bull. 243 p. Washington, D. C.
15. Wendt, C. F., R. H. Haas, and J. R. Runkles. 1968. Influence of selected variables on the transpiration rate of mesquite. Agron. J. 60:382-384.

2

Growth and Development of Mesquite

R. H. Haas, R. E. Meyer, C. J. Scifres and J. H. Brock*

Mesquite is adapted to a broad range of environmental conditions over the southwestern United States. Fisher, Fults and Hopp (5) and Fisher *et al.* (6) described six growth forms which Meyer *et al.* (12) grouped into three basic forms. These include "the large single-stemmed tree, the erect many-stemmed bush or small tree, and the more or less decumbent, or running, bush." The two most common forms are the large single-stemmed tree and the many-stemmed bush or small tree (Figure 1-2).

Intensification of mesquite infestations, the result of seed dispersion and seedling establishment, has been attributed to drouth, heavy grazing and cessation of naturally occurring fires (15). Bogusch (3) cited hoof damage to ground cover, deposition of seeds in livestock manure and disturbance by man (land clearing and cultivation) as factors which promote mesquite invasion. Mesquite's distribution has been correlated with temperature (6) and rainfall (3).

Reinfestation of mesquite is a continual problem following initial efforts to control this persistent pest (14, 20). The large reservoir of viable, long-lived seeds in the soil assures reinfestation of rangeland (23).

LIFE CYCLE STUDIES

The life cycle of mesquite is characterized by three distinct stages: seed germination and seedling development, juvenile plant and mature plant. Each growth stage has different tolerances to environmental factors affecting its adaptation to rangeland conditions. Germination and seedling development is the most critical stage in the establishment of the plant. The second growth stage, the juvenile plant, follows seedling establishment and lasts throughout the first growing season or until the plant has developed a

mature, woody stem. After maturation, the mesquite plant undergoes a series of recurring events associated with the annual, seasonal growth cycle. Seasonal changes in mesquite's structure and function are regulated to a large degree by the plant's environment. Exploitation of the seasonal growth changes is most important to controlling the response of the plant to methods of control. Since mesquite is a long-lived woody perennial, it is tolerant to a wide range of environmental conditions (3).

GERMINATION

Description of Seed

Meyer *et al.* (12) described mesquite seeds as being "brown, oval, 5 mm wide, 7 mm long and 2 mm thick in the center"¹ (Figure 2-1). The seeds are borne in a legume-type fruit which is relished by wildlife and domestic livestock. The bony, protective covering surrounding each seed must be broken before germination occurs. This protective covering is responsible for the long life of mesquite seeds in soil (23). If not consumed by animals, the seed lies dormant until the seed coat is broken by weathering. Scarification (breaking of the seed coat) occurs most rapidly under natural conditions when the seeds are passed through the digestive tracts of domestic livestock and wildlife (Figure 2-2). Fisher *et al.* (6) found that 97, 99 and 16 percent of mesquite seed fed in the pods passed through the digestive tracts of horses, yearling steers and ewes, respectively. Germination of the seed which passed through the animals was 82 percent for horses, 69 percent for yearling steers and 25 percent for ewes. Mesquite's spread is attributed to transport of seed in the digestive tracts of animals (9).

Concentrated sulfuric acid treatment (10) or mechanical treatment (1) is used to scarify seed coats for laboratory studies. Flynt and Morton (7) developed a portable thresher for rapid processing of the seeds for experimental purposes.

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¹The metric system of measurement is used only in direct quotes in this publication. Readers are referred to Appendix B for conversion of the metric to English system.

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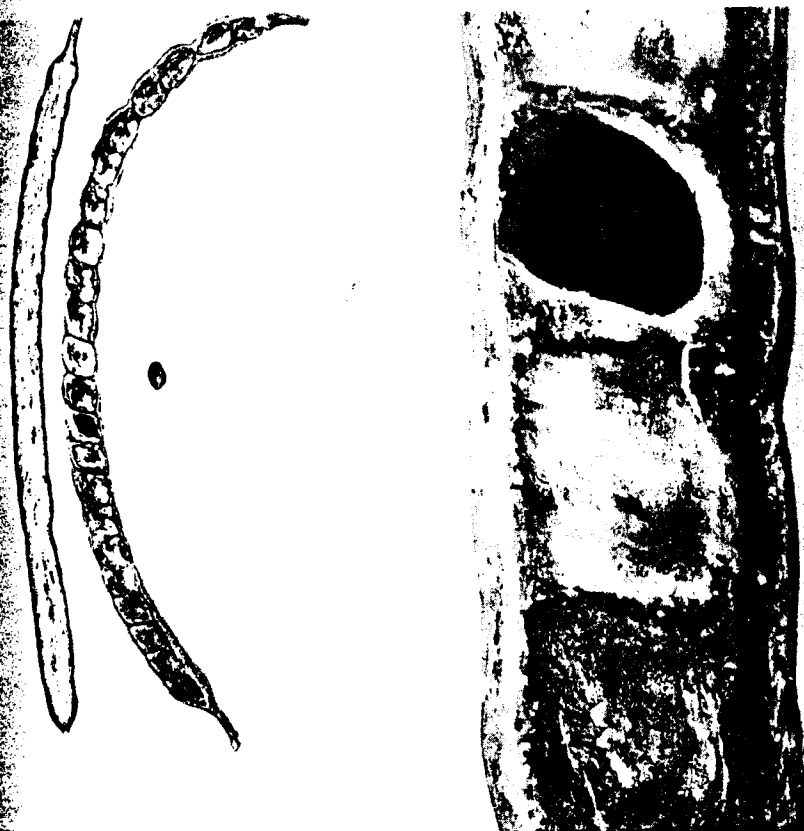


Figure 2-1. Mesquite "pod" (legume) and seeds: intact and cutaway mature legume or pod (left); enlarged cutaway showing bony endocarp which protects the seed (right).

General Aspects of Germination

Gross changes during germination and early seedling development of mesquite were described by several workers (12, 16, 18, 19). Water uptake during germination is rapid with noticeable swelling of the seed coat within 2 to 3 hours after wetting. Within a day, the primary root emerges from the seed coat and elongates rapidly for 2 to 3 days, while the cotyledons expand slightly and turn from yellow to light green. The hypocotyl (seedling stem) elongates, pulling the cotyledons out of the soil. By the fifth day, the cotyledons are fully expanded, and the junction of the hypocotyl and root is easily located by the presence of a swelling referred to as the "collar" (12) or "cortical collar" (17) (Figure 2-3). Most workers agree that the cortical collar functions as anchorage of the seedling during emergence. On the fifth or sixth day, hypocotyl elongation ceases, and the epicotyl (central growing point) appears. The primary leaf is usually fully expanded within a week after germination.

Temperature and Germination

Once the seed coat is broken, mesquite seeds germinate within 6 hours at about 93° F (11). During this period, moisture content increases from about 7 to 49 percent of the dry seed weight. In other studies (18), water uptake at 85° F progressively increased the seed weight at the rate of 10 percent per hour. Scifres

and Brock (16) found that germination percentage, emergence at 72 hours and mesquite seedling vigor were greater at 85° F than at 70° or 100° F. Although percentage emergence was reduced, mesquite seedlings emerging at 100° F survived until moisture conditions became unfavorable. Germination was no higher under alternating 68° to 86° F temperatures than at constant temperature of 85° F.

Temperature regulates the rate and extent of water uptake by germinating mesquite seeds (18). Less



Figure 2-2. Mesquite seedlings germinated in horse manure. Passage of seed through digestive tracts of livestock breaks the hard seed coat, and animal manure provides perfect conditions for seedling growth.

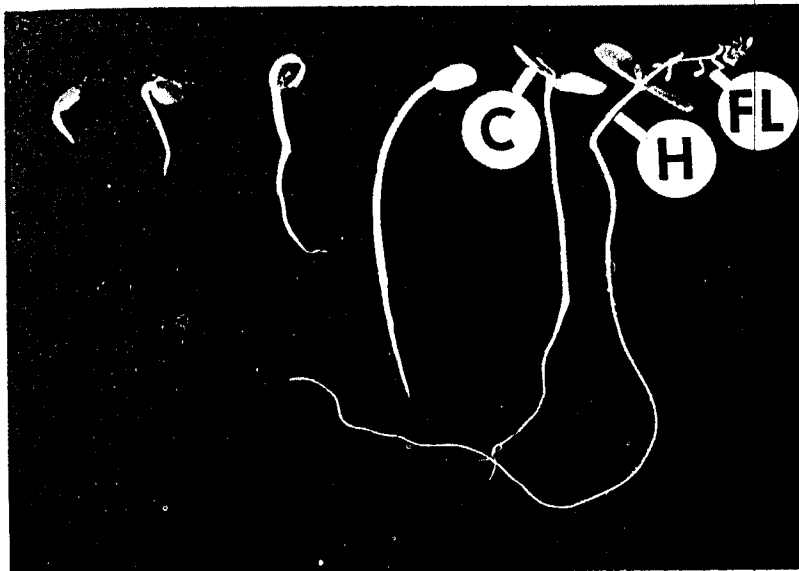


Figure 2-3. Mesquite seedlings during germination: (left to right) 1, 2, 3, 4, 5 and 7 days old. Important structures are FL = first true leaf, C = cotyledon and H = hypocotyl (left). Drawing of 7-day-old mesquite seedling illustrating important structures; lf = first true leaf, st = stem, br = bract, cot = cotyledon, hy = hypocotyl, cc = cortical collar and ra = radicle (right).

water is required for germination at the optimum temperature (85° F) than at lower (70° F) or higher (100° F) temperatures. The rate of water uptake at 70° F was about half that at the optimum temperature of 85° F.

There appears to be little genetic influence on the germination response of mesquite seeds to temperature. Germination of seeds from 26 populations from Mexico, Texas, New Mexico, Oklahoma and Arizona responded similarly to temperature (13). Seeds from populations of mesquite throughout Texas responded in exactly the same manner to germination temperature.

Moisture Availability and Germination

As a general rule, permanent wilting percentage is considered to occur at 15 atmospheres (atm) moisture tension. After 96 hours of exposure to the optimum temperature, percentage germination of mesquite seeds was not suppressed by moisture tensions up to 8 atm, and seedling vigor was not reduced by 4 atm (16). At high temperatures (100° F or higher), moisture stress was critical early in the germination process. At low temperatures (70° F or lower), growth was evidently regulated by temperature, and lack of moisture was not a limiting factor until later in the germination process.

Temperature regulates efficient use of water by germinating mesquite seeds. Reduced moisture availability is most influential on germination after temperatures reach optimum levels (18). Apparently, optimum physiological activity of mesquite seed tissues occurs at 85° F.

Cover of Seeds During Germination

Light does not regulate germination of mesquite seeds (19). Germination percentages under controlled conditions of full light, continuous dark or dark with intermittent light were no different when the same temperature was maintained. The hard seed coat and limiting temperatures were apparently critical factors in germination.

Maximum seedling establishment occurred when mesquite seeds were planted 0.2 inch deep in soil at 80° to 85° F (19). Seeds placed on the soil surface germinated, but no seedlings survived. The necessity of cover for anchorage and maximum contact of the seedling root with moisture was verified in field experiments (17). Mesquite seeds scattered on the surface of buffalograss or tobosa pastures did not produce seedlings. Seeds placed on the soil surface germinated and the radicles extruded about 0.1 inch before the seedling died. However, seedlings did become established where the seeds were covered by a thin layer of soil, organic debris or with freshly clipped topgrowth of herbaceous vegetation.

In greenhouse studies, seedling establishment was reduced when mesquite seeds were planted progressively deeper in a sandy clay loam (19). When seeds were planted 2 inches deep, no seedlings emerged. With seeding depths below 0.25 to 0.5 inch, emergence occurred at the expense of root development. Although seedlings did not emerge when seeds were planted 2 inches deep at 80° F, most produced a root of about 2.5 to 3 inches in length.

Placement depth of mesquite seed has ecological significance since it determines survival. Soil cover

is not required for germination but is necessary for seedling establishment.

ESTABLISHMENT OF SEEDLINGS

Under natural conditions, interactions among many factors regulate seedling survival. Results from controlled-environment studies as confirmed by field observations have defined the role of several important environmental factors.

Soil Temperature and Establishment

Emergence of mesquite seedlings in northwest Texas, under optimum moisture conditions, was dependent upon temperature reaching 77° F in the germination zone (19). Thus, temperature for seedling emergence in the field correlated well with results from laboratory and greenhouse studies. In field studies, mesquite seedling emergence was directly related to spring planting date when seeds were covered and moisture was adequate for germination. Poor emergence from March plantings was probably due to low soil temperatures in the planting zone (Figure 2-4). Peak seedling emergence (April 24) was preceded by 4 days of maximum soil temperatures around 77° F.

Seedling growth was most rapid when soil temperatures reached 80° to 90° F. However, establishment was reduced with occurrence of soil temperatures above 95° F in the germination zone in tests near Spur, Texas (19) (Figure 2-4).

Fall germination of mesquite was observed on rangeland of northwest Texas in 1968 and 1969 (Figure 2-5). However, the seedlings did not survive low temperatures the month (October) following their emergence. In South Texas, the longer growing season may permit seedling establishment.

Soil Moisture and Establishment

Bogusch (3) indicated that moisture in surface soil should probably persist for at least 3 to 5 days after germination to assure establishment of mesquite



Figure 2-5. Six mesquite seedlings shortly after emergence September 21, 1969, in rangeland in northwest Texas. These seedlings survived less than 3 weeks because of cool temperatures.

seedlings. A study was conducted near College Station to investigate the interrelationships of soil moisture and temperature on the emergence of seedlings. Moisture was adequate in the surface soil from March 3 to May 15 for seedling establishment, but 65 to 75 percent of the seedlings did not survive due to the cool temperatures (Table 2-1). Apparently, as the soil warmed more seeds germinated, and percentage seedling survival increased. Almost half of the seedlings survived from plantings on April 15 when soil moisture was high. Greatest survival occurred from May 15 and June 1 plantings when temperature conditions were ideal although soil moisture was relatively low. Rains replenished moisture in the surface soil after June 17, but few seedlings survived as soil temperatures usually exceeded 90° F and occasionally exceeded 110° F.

Top Removal and Establishment

Top removal by insects and browsing animals was cited as a deterrent to establishment of mesquite

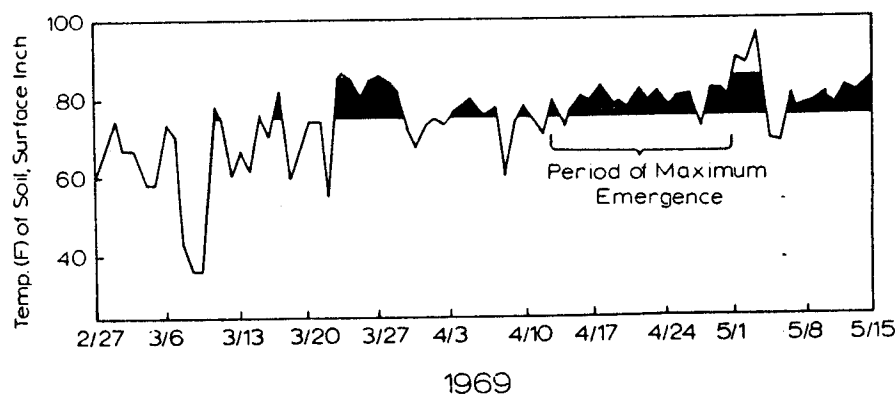


Figure 2-4. Average daily temperatures in the surface inch of soil and time of maximum emergence in a nursery in northwest Texas after planting mesquite at weekly intervals from February 27 to May 15.

TABLE 2-1. SOIL TEMPERATURE AND SOIL MOISTURE IN THE SURFACE INCH THE DAY OF PLANTING AND 5 DAYS AFTER PLANTING MESQUITE, AND SEEDLING SURVIVAL ON AUGUST 20, 1971, NEAR COLLEGE STATION

Planting date	Soil temperature ¹	Soil moisture (%)		Seedling survival (%)
		At planting	5 days after planting	
March 3	Below optimum	9.0	8.9	24
March 15		4.9	2.5	33
April 1	Optimum	0.8	1.9	38
April 15		8.4	7.8	47
May 1		1.3	0.9	38
May 15		1.0	1.1	47
June 1	Above optimum	1.3	1.3	53
June 17		1.6	2.1	8
June 30		3.5	0.5	5

¹Optimum temperature established from previous research (21, 23, 24) as 75° to 85° F in surface inch of soil.

seedlings on rangeland (17). Newly emerged seedlings (Figure 2-3), like most legume seedlings, are succulent and tender. However, the mature plant is not susceptible to extensive damage from browsing.

On mature plants, when the topwood is destroyed, sprouts arise from the trunk base below ground line but above root tissue (5). According to Meyer *et al.* (12), mature mesquite plants have no true terminal bud. When the terminal bud dies on seedlings or juvenile plants, the stem dies back, and a lower bud assumes the apical role. Sprouting is then regulated by the new bud. Moisture stress is thought to be primarily responsible for abortion of the terminal bud under field conditions.

Mesquite seedlings do not survive if tops are clipped beneath the cotyledons (5, 21). Seedlings are capable of branching from buds in the cotyledonary axils when tops are removed within 7 days after emergence (21). Removal of the upper portions of stems stimulates branching at the cotyledonary node (Figure 2-6). The older the seedling, the greater is the probability it will survive top removal. All new branches, regardless of seedling age at top removal, are formed from cotyledonary axils. Excavation and examination of mesquite showed that the tops may be removed several years in succession and the plants survive (20).

Light and Establishment

Although light is not necessary for germination, it is a requisite for mesquite seedling development. Strong shading is indeed "inimical to survival" (3). However, the seedlings may survive where radiant energy is less than half-full sunlight (22). Mesquite's adaptation to full sunlight is evidenced by its growing primarily in pure stands or as overstory brush in mixed-species stands (12).

Associated Vegetation and Establishment

The presence or absence of climax perennial grasses and associated species is extremely influential in mesquite seedling establishment. In 1970, Scifres, Brock and Hahn (20) reported the status of a non-grazed area protected following the establishment of seedlings in 1941 near Spur, Texas. Only 15 percent of the original seedling population remained in 1968, and the stand of plants 2 to 3 feet tall had apparently stabilized at about 400 plants per acre. The researchers felt that the rate and duration of mesquite invasion might be associated with the close grazing of the climax vegetation and the severe deterioration of the vegetative cover by extended drought. Foliar cover of grasses was essentially the same on both areas, but buffalograss was more abundant in the exclosure than in the grazed area. Also, vine mesquite, a native perennial grass and a part of the climax vegetation for the site, was not recorded in the grazed pasture but had increased in this protected area.

SEEDLING DEVELOPMENT

By the time the first true leaves develop, the plant has developed buds on the stem in the axil of the cotyledonary leaves. The young stem grows rapidly, both elongating and increasing in diameter. In the

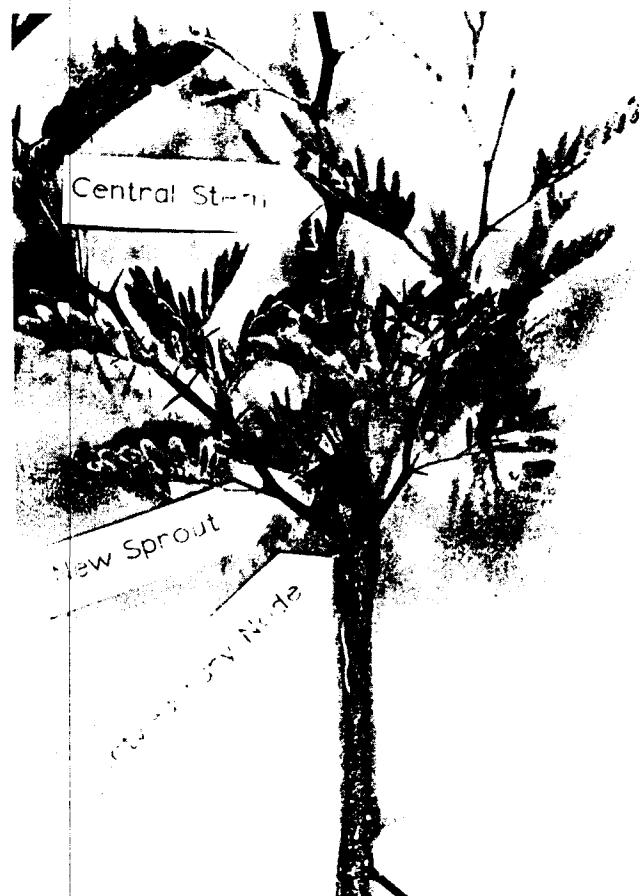


Figure 2-6. Branch formation after upper half of a 7-day-old mesquite seedling was removed. Branches were formed from buds in the cotyledonary axils.

center of the stem is a prominent pith. Outside of the pith is a ring of xylem bundles which transport water and nutrients from the soil to the aerial plant parts. The cambium (regions of active cell division) produces new phloem cells which transport carbohydrates and other food materials from the leaves to the roots and lower parts of the plant. After only 8 to 10 days following germination, the plant has all tissues necessary for normal function as a perennial.

The mesquite seedlings develop rapidly. Seedlings most often emerge in a harsh environment at the soil surface; hence only a small percentage of them usually survive. Mesquite seedlings have been observed to survive only in the more favorable conditions of late fall and early spring when moisture and soil temperatures favor growth. Even then, shading and competition from a good cover of range grasses will suppress development of seedlings and decrease the likelihood of their establishment. The seedlings are usually established by about 10 days after germination when the first true leaf is fully developed.

JUVENILE PLANT

The juvenile period extends from full development of the first true leaf to production of mature, woody xylem. This period may last for 2 or 3 years, depending on growth conditions. Root and shoot development continues at a rapid rate following seedling establishment. The rate of juvenile plant growth depends on soil moisture availability and is strongly regulated by soil temperature (24). The optimum soil temperature range for mesquite growth, as for germination, is from 85° to 90° F (Figure 2-7). Little is known about the rate of root development under field conditions. However, the roots of juvenile plants under controlled conditions have extended as much as 30 inches in 5 to 6 weeks following germination.

Although the juvenile plants develop rapidly during the first growing season, they are susceptible to many environmental pressures. Juvenile plants are relatively susceptible to hot, dry conditions unless their roots have extended into the moist, lower soil.



Figure 2-7. Juvenile mesquite plants developed with various soil temperatures.

The single stem continues to elongate naturally throughout the first growing season, unless arrested by some factor such as drouth. A single leaf arises at each stem node, and two buds develop initially in the axil of each leaf. Apparently, apical dominance plays an important role in suppressing activity of the axillary buds. If the apex of the plant is removed, the buds will develop one or more new stems. Juvenile plants may grow from only a few inches to about 3 feet tall during the first growing season. The height attained in the first growing season is dependent upon the duration of good growing conditions.

Juvenile development may drastically influence the mature form of the mesquite plant. If the top of the juvenile plant is removed, persistent buds located below the cut surface will produce new stems. Under conditions of mowing or heavy grazing, mesquite with juvenile tops have been observed to have root systems and lower stems 7 or more years old. It is assumed that this phenomenon is primarily the result of repeated clipping of the young stem tissue. Under these conditions, the plants are likely to develop into many-stemmed shrubs.

If the plant survives the first growing season, it can be expected to develop into a hardy, persistent woody plant. The duration of the juvenile stage is indefinite since it is dependent upon development of the plant top. The plant does not flower or produce seeds during the juvenile stage. Under good growing conditions, juvenile mesquite plants may reach a height of 5 or 6 feet in 2 or 3 years.

MATURE PLANT

Mesquite is usually fully mature after 3 years. Typically, the mature plant is either a single-stemmed tree or a many-stemmed shrub (Figure 2-8). The single-stemmed tree results from unaltered and vigorous growth during the juvenile stage. The many-stemmed shrubs result from removal or interruption of top growth during the juvenile stage.

New branches arise from buds near the stem tip each spring or from buds as much as 2 to 5 nodes back from the tip of the previous year's growth (12). In general, the number of new branches in the plant canopy increases about 20 to 35 percent annually on mature trees. Consequently, the mature canopy has a somewhat umbrella-like appearance (Fig. 2-8).

The impressive mesquite thorn is a modified stem which arises on new growth. Thorns may grow 1 to more than 2 inches long and generally occur singly on young branches. Since thorns are produced only on new wood, they are subsequently buried in the stem by radial growth.

The color and texture of mesquite stems vary considerably. New stems are frequently red on the upper surface exposed to the sun and green on the shaded sides. Within the first year, a single layer



of protective cells begins to form the corky bark. Eventually, the surface of the older branches and the main trunk develop a deeply furrowed, brown or reddish-brown surface. Frequently, lichens grow on the exposed surface of the corky stem surface, giving it a gray or grayish-green appearance.

The mature mesquite plant has tremendous ability to regrow following injury because of an accumulation of dormant buds along the trunks and stems. Lateral buds are produced in the axil of leaves along new stem growth. Following the juvenile stage, one of the axillary buds usually produces an inflorescence. If a new flush of foliar growth is stimulated by a wet period later in the season, both leaves and inflorescences may emerge from axillary buds.

In the second growing season following their formation, buds near the stem tip produce leaves, stems and inflorescences from the same node. As many as seven leaves, three stems or six inflorescences have been found to arise from a single node (12). In succeeding years, the original leaf scar is buried by secondary tissue, and the buds eventually become inconspicuous.

The dormant buds are buried in living tissue immediately under the corky stem surface. If the corky bark is stripped from the tree, bud traces are apparent on the wood (Figure 2-9). The "dormant bud" (Figure 2-9) occurs at the end of the bud trace just under the stem surface. Dormant buds occur along the trunks, branches and twigs of mature trees. If a stem is injured or if it dies, the buds below the injury will produce new stems. An accumulation of dormant buds, the "bud zone," occurs at the base of the plant below the soil surface. Following ineffective



Figure 2-8. Two mature mesquite growth forms: the single-stemmed tree (left) and the many-stemmed shrub (right), showing the umbrella-like appearance of mature mesquite canopies.

application of chemicals or mechanical top removal, numerous new stems will arise from this area.

Mesquite typically produces both a tap root and an extensive lateral root system (4, 5). Fortunately, adventitious buds do not develop from the root tissues, and the plant dies if all stem tissues are killed. Thus, basal treatment with kerosene or oil-dissolved herbicides should be applied to contact the "bud zone" at or below the soil surface. This treatment must penetrate the stem surfaces and kill the bud and outermost living tissues (2, 5, 6).

ANNUAL GROWTH CYCLE

Annual patterns of growth of mature mesquite plants are established primarily by seasonal, climatic conditions and are well correlated with the physiological condition of the plant. Consequently, events in the annual growth cycle dictate the effective season for herbicide application (Figure 2-10). Following opening of the leaf buds in the spring, the plants undergo a period of rapid twig elongation and leaf growth. Twig elongation precedes active radial trunk growth, and trunk growth is repressed until stem elongation is completed in early May. A period of maximum trunk growth follows the period of stem elongation. Growth rate is reduced with the onset of summer drought (8).

Twig elongation begins in the early spring when soil temperatures reach 65° to 70° F and continues for approximately 6 weeks. Soil moisture, accumulated during the winter months, is used sparingly under the mild climatic conditions usually existing in April and early May. Root growth also occurs during this period although soil temperatures are normally below

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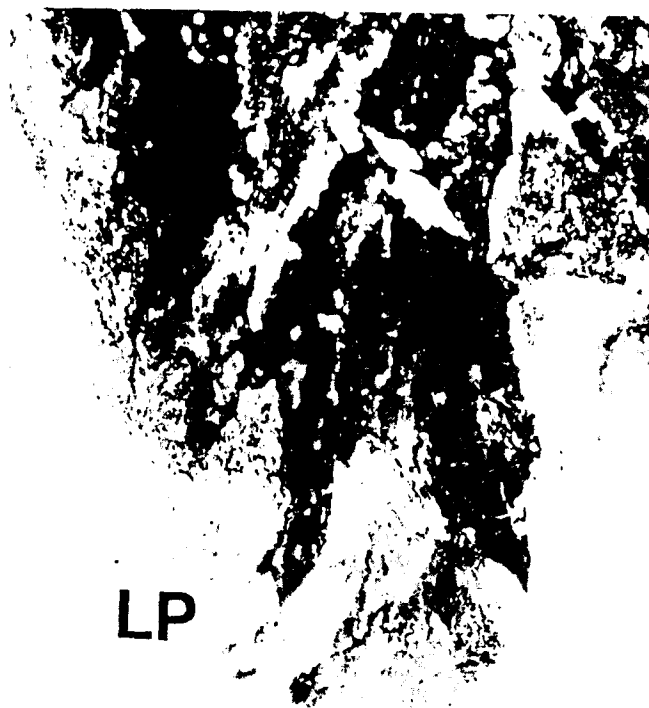


Figure 2-9. Mesquite tree with bark stripped away showing bud traces on the wood surface (left); microscopic view of bud area in the rays with the leaf primordia (LP) of the bud (right).

optimum for maximum root growth. In May, stem elongation ceases, the foliage is dark green and radial trunk and branch growth begins.

Maximum radial trunk growth continues until soil moisture becomes limiting. The period of maximum trunk growth coincides with flowering and early seed development.

The period of maximum trunk growth also coincides with the time recommended for application of broadcast, foliar-applied herbicides. The most effective period for controlling mesquite with foliar herbicides is from 40 to 90 days after the first growth appears in the spring (6). The occurrence of maximum trunk growth at this period suggests that susceptibility is dependent upon environmental conditions favorable to maximum plant activity, especially production and movement of carbohydrates and other photosynthetic products to the trunk and lower plant parts. Mesquite growth diminishes in relation to the severity of summer drought conditions. The driest conditions usually occur in late July or August for much of the mesquite-infested area in Texas.

Although the mature plant responds rather uniformly to seasonal changes in temperature, day length and soil-water conditions, individual plants do not respond in the same manner to short-term weather changes. Events which interrupt the seasonal patterns of development, such as late spring or early summer

rains, produce a variable population of plants. Not all trees respond in the same manner to the rainy periods. Consequently, when adverse weather conditions break the normal pattern of seasonal development, greater variability exists among the individual mesquite plants. This variability is probably important in explaining the erratic results from herbicide application obtained in some years. Mesquite plants are dormant by late fall. Most of the trees have been defoliated by early November by killing frost or leaf removal by insects.

CONCLUSIONS

The life cycle of mesquite has three distinct stages: seed germination and seedling development, juvenile plant and mature plant. Mesquite can germinate under fairly dry conditions and become established if temperature is optimum. However, seedling establishment evidently requires adequate moisture in the germination zone for several days after emergence to allow penetration of the soil by the seedling root. The ability of mesquite to germinate and survive under low moisture conditions at the optimum temperature makes it well adapted to dry range sites.

Coverage of seeds is not a requisite for germination but is necessary for seedling establishment. The thin cover required for establishment may be afforded under natural conditions by plant litter, blowing soil, trampling by livestock or deposition in manure.

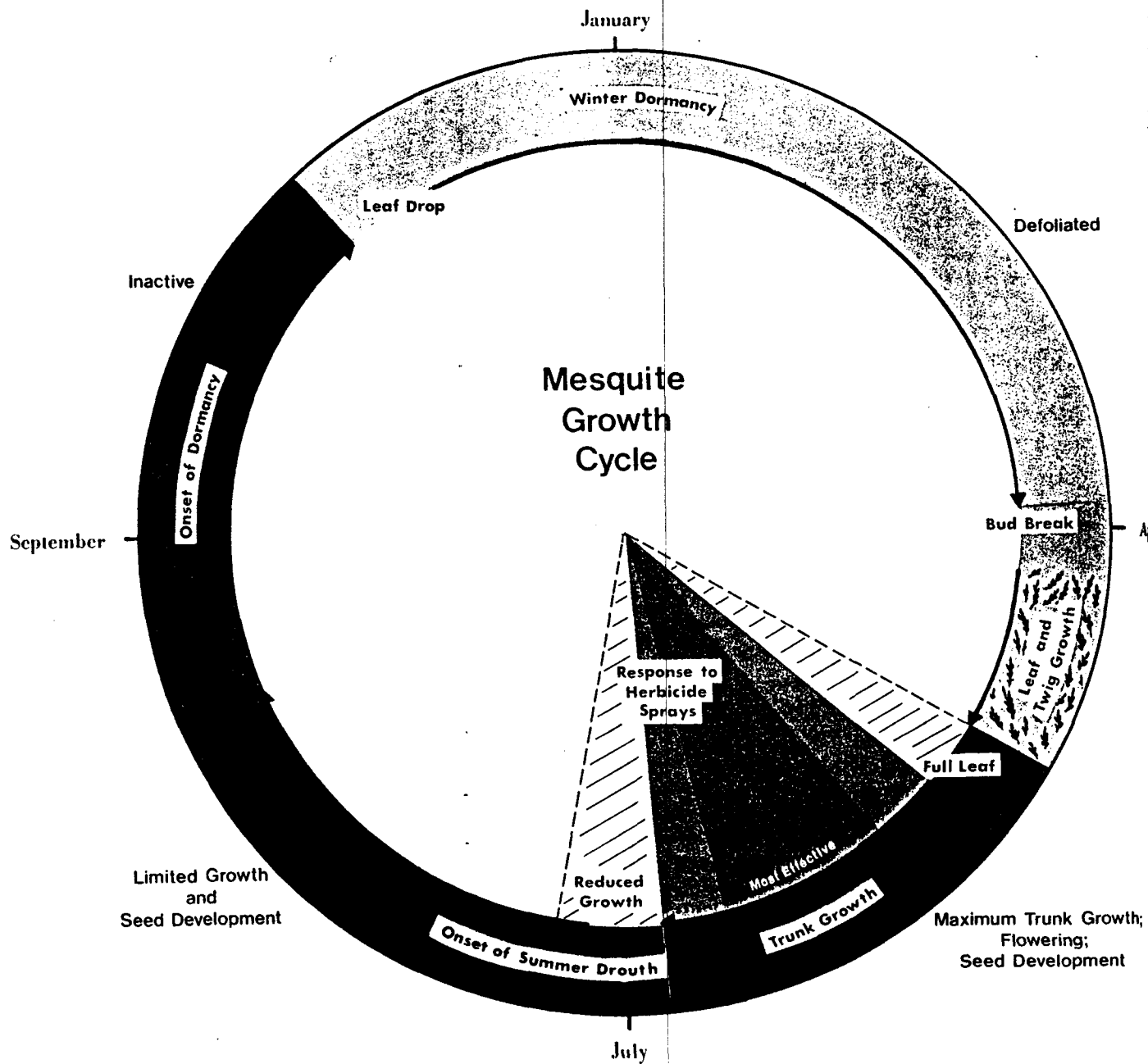


Figure 2-10. Annual mesquite growth cycle, correlated events and effective period for broadcast, aerial or ground, foliar-applied herbicide sprays.

Passage of intact seed through the digestive tracts of livestock provides the scarification necessary for breaking seed coat dormancy (Figure 2-2). The microclimate provided by manure of domestic livestock meets all of the requisites for mesquite establishment. A complex of factors interacts to form a suitable environment, but temperature is apparently most critical to mesquite seedling establishment. Mesquite's distribution northward, according to Bogusch, has been regulated by the frequency of average January temperatures lower than 32° F over half the years. The probability that freeze damage and low spring temperatures will restrict seed germination and/or seedling establishment governs mesquite's northernmost distribution. Deterioration of rangeland vegetation by close grazing, drouth and soil disturbance provides conditions for invasion and establishment of mesquite. Once seedlings become established, control procedures are usually necessary for grassland renovation.

The first 8 to 10 days following seed germination are most critical for the establishment and survival

of mesquite. Juvenile plants are readily capable of vegetative reproduction if damaged or injured by grazing or other forms of top removal. Repeated removal of the juvenile mesquite tops results in many-stemmed, shrub-like plants rather than single-stemmed trees.

The annual growth cycle of a mature mesquite plant is regulated by climatic conditions. Following bud opening, rapid leaf and twig growth produces the canopy. Active, radial stem and trunk growth occurs after completion of twig elongation and leaf growth. The canopy is composed of only mature leaves and appears dark green during most active radial stem growth. The amount and seasonal distribution of effective rainfall during the rapid growth period determine the duration of continued growth activity. The onset of summer drouth reduces the growth rate in the mature mesquite plant. Usually, the period of summer drouth is followed by the onset of dormancy in the fall. The mesquite plants remain inactive until the first frost, at which time final leaf drop occurs.

LITERATURE CITED

1. Bartin, L. V. 1947. Special studies on seed coat impermeability. Contrib. Boyce Thompson Inst. 14:355.
2. Blair, B. O., and G. E. Glendening. 1953. Intake and movement of herbicides injected into mesquite. Bot. Gaz. 115:173-179.
3. Bogusch, E. R. 1951. Climatic limits affecting distribution of mesquite (*Prosopis juliflora*) in Texas. Tex. J. Sci. 3:554-558.
4. Cannon, W. A. 1911. The root habits of desert plants. Carnegie Inst. Wash. Publ. 131. 96 p.
5. Fisher, C. E., J. L. Fuels and H. Hopp. 1946. Factors affecting action of oils and water soluble chemicals in mesquite eradication. Ecol. Mono. 16:109-126.
6. Fisher, C. E., C. H. Meadors, R. Behrens, E. D. Robinson, P. T. Marion and H. L. Morton. 1959. Control of mesquite on grazing lands. Texas. Agr. Exp. Sta. B. 935. 24 p.
7. Flynt, T. O., and H. L. Morton. 1969. A device for threshing mesquite seed. Weed Sci. 17:302-303.
8. Haas, R. H., and R. E. Steger. 1965. Evaluation of environmental factors influencing the growth of mesquite. 18th Ann. Mtg. S. Weed Conf., Proc. 633-640.
9. Johnston, M. C. 1962. The North American mesquites. *Prosopis* Sect. *Algarobia* (Leguminosae) Brittonia 14:72-90.
10. Khudairi, A. K. 1956. Breaking the dormancy of *Prosopis* seeds. Physiol. Plant. 9:452-461.
11. Lacher, J. R., J. Davies, K. Gardner and C. Jones. 1963. Germination studies on mesquite seeds. Assoc. Off. Seed Anal. No. Amer. Proc. 58:55.
12. Meyer, R. E., H. L. Morton, R. H. Haas and E. D. Robinson. 1971. Morphology and anatomy of honey mesquite. U.S. Dep. Agr., Agr. Res. Serv., Tech. Bull. 1423. 185 p.
13. Peacock, J. T., and C. McMillan. 1965. Ecotypic differentiation in *Prosopis* (mesquite). Ecology 46:35-51.
14. Rechensthein, C. A., H. M. Bell, R. J. Pederson and D. B. Polk. 1964. Grassland restoration II. Brush control. Un-numbered Bull. U.S. Dep. Agr., Soil Cons. Serv., Temple, Texas. 39 p.
15. Rechensthein, C. A., and H. N. Smith. 1967. Grassland restoration. V. Effect on water yield and supply. Un-numbered Bull. U.S. Dep. Agr., Soil Cons. Serv., Temple, Texas. 46 p.
16. Scifres, C. J., and J. H. Brock. 1969. Moisture-temperature interrelations in germination and early seedling development of mesquite. J. Range Manage. 22:334-337.
17. Scifres, C. J., and J. H. Brock. 1970. Growth and development of honey mesquite seedlings in the field and greenhouse relative to time of planting, planting depth, soil temperature and top removal. Texas Agr. Exp. Sta. PR-2817 in Brush Research in Texas, 1970:65-71.
18. Scifres, C. J., and J. H. Brock. 1971. Thermal regulation of water uptake by germinating honey mesquite seeds. J. Range Manage. 24:157-158.
19. Scifres, C. J., and J. H. Brock. 1972. Emergence of honey mesquite seedlings relative to planting depth and soil temperatures. J. Range Manage. 25:217-219.
20. Scifres, C. J., J. H. Brock and R. R. Hahn. 1971. Influence of secondary succession on honey mesquite invasion in North Texas. J. Range Manage. 24:206-210.
21. Scifres, C. J., and R. R. Hahn. 1971. Response of honey mesquite seedlings to top removal. J. Range Manage. 21:296-298.
22. Scifres, C. J., D. J. Elrod and C. R. Kienast. 1973. Honey mesquite seedling growth and susceptibility to 2,4,5-T as influenced by shading. J. Range Manage. 23:58-60.
23. Tschirley, F. H., and S. C. Martin. 1960. Germination and longevity of velvet mesquite seed in the soil. J. Range Manage. 13:94-97.
24. Wendt, C. W., R. H. Haas, and J. R. Runkle. 1968. Influence of selected environmental variables on the transpiration rate of mesquite. Agron. J. 60:382-384.

8

Interrelation of Grazing Management and Mesquite Control

L. B. Merrill and G. O. Hoffman*

Planned management of grazing will increase benefits from brush control and is essential to the continued success of a brush control program. Mesquite control is valuable for releasing growth of native forage plants and for improving conditions of all animal life. Forage plants need rest from grazing, and a systematic deferred-rotation grazing program is the most satisfactory method of attaining systematic rest periods. It is not necessary to rest each pasture during every growing season of the year. However, it is necessary that all pastures rest during each growing season over a period of years (for example, March, April, May and June in 1973; July, August, September and October in 1974; and November, December, January and February in 1975 and 1976). Scheduling rest periods on a 4-year rotation has proved satisfactory at the Sonora Research Station.

A grazing rotation program can be initiated either entirely on native rangeland, in conjunction with tame pastures, or in conjunction with feedlots. A grazing management program combined with mesquite control should be outlined in step-by-step procedures for at least a 15-year period. Such planning will assure maximum benefit from mesquite control in the overall range program.

FACTORS AFFECTING LIVESTOCK DISTRIBUTION

Livestock distribution is important in any grazing system and is especially important where a brush control practice is in effect. Several factors are important in proper livestock distribution.

Water

Water is essential for the well-being of livestock. Additional watering locations offer not only the opportunity for better grazing distribution but increased grass or livestock production. Under Texas conditions, development of new watering facilities usually

means 1) drilling a well, putting in a pumping unit and constructing a tank and troughs, 2) constructing an earthen tank to impound runoff water or 3) piping water to a new location. Location and costs usually dictate the type of water development.

Reservoirs should be constructed to hold as much water as needed for usable rangeland reached by livestock but with minimal surface area to reduce evaporation. When feasible, earthen reservoirs should be fenced and water piped to troughs. This improves sanitation and allows supply shutoff if the surrounding area needs resting. Minimum daily requirements are 10 to 15 gallons per cow with calf and 1 to 1.5 gallons for a ewe and lamb or a doe and kid.

Salting

Proper salting, either alone or in a mixture with other supplements, is beneficial in obtaining desired distribution of grazing. Stock usually go from water to grazing and then to salt and back to grazing. Thus, it is not only unnecessary to place salt and water together, but it is actually beneficial to have them separated. Salt should be placed in areas not normally frequented by livestock to encourage utilization of otherwise ungrazed forage and increase the usable land in a given pasture. Where more than one unused or lightly used area is present in a pasture, salt can be moved occasionally to a new location. Such movement should be gradual, or the animals should be trained to use the new location by placing them on the salt ground and making certain that they are aware of its location. Otherwise, some animals in a pasture will suffer from lack of salt.

Salt troughs should be large enough so that all animals in a pasture can have ready access without long waiting periods. In general, adequate amounts are 3 to 4 pounds per head per year for sheep and goats, 20 to 25 pounds per head for mature cattle and 30 to 40 pounds for horses. However, salting areas should be carefully watched and kept replenished. Granulated salt in troughs protected from weather is most satisfactory.

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Pasture Size

Small pastures are more easily managed and can be grazed much more uniformly than large ones. So, numerous small pastures greatly facilitate the ease of establishing a deferred-rotation program. However, the smaller the pasture, the greater the cost per acre for fencing and water development. Therefore, the economic aspects of a program should be considered carefully in setting up a rotation program where new pastures must be established or where existing pastures should be subdivided. Where possible, existing watering facilities should be used. According to figures issued 1967 to 1969 by the Agricultural Stabilization and Conservation Service, average cost of water development and fencing was \$1.76 and \$0.84 per acre, respectively, to establish a four-pasture rotation system on a four-section pasture which would be cross-fenced into four separate pastures and the additional water provided.

GRAZING MANAGEMENT SYSTEMS AND MESQUITE CONTROL

Types of grazing management systems include year-long; two-, three- or four-pasture deferred rotation; intensive or high intensity-low frequency rotation; native-tame pasture; and off-and-on or decision rotation. One system may be suited for one area or condition; another system is best adapted to another. In designing a grazing management system, certain guidelines should be followed:

1. The proper number of animals should be grazed.
2. Over a period of years, each pasture should rest during all growing seasons, resting during one growing season the first year and another the following year.
3. The proper kind or combination of livestock should be grazed.
4. Each pasture should be grazed as uniformly as possible.
5. Stock watering places should be located to aid in distribution of grazing.
6. Salt, minerals and protein supplements should be located on normally undergrazed sites.
7. New fences should be located properly—they affect natural movements of grazing animals with respect to topography and prevailing wind direction.
8. Areas of dense brush for wildlife habitat and trail cover should be left for wildlife to move from one area to the other.
9. Stocking rates should be flexible for moderate use of forage plants.

Yearlong Grazing

An estimated 75 percent of the 107 million acres of Texas rangeland produces less than half its potential because of range deterioration resulting from

mismanagement. These deteriorated rangelands are characterized by a dominance of unpalatable and low-producing forage species. The high-producing and palatable species become limited in number. When ranges are in this condition, improvement is extremely slow, even at light grazing rates. Grazing animals select the most desirable species and graze them heavily, tending to hold vegetation condition constant or causing deterioration. Such a system of grazing can hinder or prevent range improvement following brush control and should be avoided.

Deferred Grazing

Removal of all livestock from a given area for a specified period of time can be significant following mesquite control. To be most effective, the rest period should permit most desirable forage species to produce seed before grazing is resumed. The practice should be continued each year until desirable forage has occupied most of the area previously covered by undesirable brush. The length of each rest should be determined by the response of the desirable vegetation. The system has no consistent patterns, and its success or failure is dependent upon the observation and action of the landowner. A well-planned system covering a period of years is more satisfactory and more likely to result in reestablishment of desirable grass stands than short-term systems.

Deferred-Rotation Grazing

Any of the following types of deferred-rotation grazing can produce satisfactory responses from desirable forage species following mesquite control. However, the system must be properly designed if the maximum in growth and reproduction from the primary forage species is to be realized.

Off-and-On or Decision Rotation

This system is designed for all animals to be concentrated for a relatively short time on one of a series of pastures. One pasture is grazed until the operator feels forage is properly used; he then switches the animals to an ungrazed pasture. The success of this practice, as with deferred grazing is dependent upon the knowledge and correct decisions of the operator. If decisionmaking is good, the system can be very productive. Poor or untimely decisions or carelessness can lead to overuse of vegetation and harmful effects on the livestock. Vegetation should be adequately used without being overused. It may be difficult for the operator to select the most desirable time for moving stock. Therefore, a well-planned system with established moving dates is most likely to produce favorable seed germination, plant establishment and growth.

Relative benefits of this practice are not known, other than that it is favorable over no deferment following brush control and should be used if other treatments do not appear feasible.

TABLE 8-1. DESIGN OF THE TWO-PASTURE 4-MONTHS-ON-4-MONTHS-OFF DEFERRED-ROTATION SYSTEM

	Pasture numbers	
	Graze	Rest
March, April, May, June	1	2
July, August, September, October	2	1
November, December, January, February	1	2
March, April, May, June	2	1

Nonintensive Systematic Deferred Rotation

This system involves the grazing of one or more pastures for a given period of time while one of the series rests. Livestock do not place extreme stress on the areas which they are grazing, and it is possible for them to remain in the pastures for relatively long periods without detrimental effects upon the vegetation or the livestock.

Two-Pasture: Graze Four Months, Defer Four Months System: This common practice usually produces favorable forage responses and is simple to install. The frequent rest periods are beneficial to brush control programs. The grazing sequence is illustrated in Table 8-1.

Mesquite control should be carried out on the pasture which will be rested next. If the rest period is March, April, May and June, mesquite control by mechanical methods should be completed before March 1. However, with aerial spraying, the time of rest would need to be changed so that the rest period would follow the most desirable spraying time, as May, June, July and August. This might not be the best time for a rest period to begin and end when both pastures are considered, but it would greatly help the treated area until good forage was well established. When mechanical control is used, care must be exercised with this system because the controlled pasture must be grazed with a double load of livestock during July, August, September and October. Also, if rainfall were light in early spring and summer and the forage species not well established during the rest period, they would be heavily damaged or destroyed by the summer-fall grazing. This situation would probably be critical only in the case of severe

TABLE 8-2. DESIGN OF SOUTH AFRICAN SWITCHBACK GRAZING SYSTEM WITH MAXIMUM REST FOR TREATED PASTURE

	Rest	Graze	Period sequence in months
January, February, March	1	2	3
April, May, June, July, August, September	2	1	6
October, November, December	1	2	3
January, February, March	2	1	3
April, May, June, July, August, September	1	2	6
October, November, December	2	1	3
January, February, March	1	2	3
April, May, June, July, August, September	2	1	6
October, November, December	1	2	3
January, February, March	2	1	3

disturbance such as root plowing and seeding or other methods that destroy the existing vegetation. It should be successful with treatments such as front-end grubbing and seeding or with any type of spray work.

Two-Pasture South African Switchback System: This system has been studied on the Texas Range Station at Barnhart and on the Experimental Ranch at Throckmorton, Texas (Table 8-2). Returns from the system were not significantly greater than from continuous grazing over a 10-year period at Barnhart, but were significantly greater at Throckmorton. The sequences of both rest and grazing periods are established in periods by months of 3-6-3-3-6-3. Such a sequence is shown for 3 years in Table 8-2.

If the primary goal is to permit germination and establishment of desirable seedlings following mesquite control, the control practice should be completed on Pasture 2 (Table 8-2) before April 1. The area then rests April, May, June, July, August and September. This provides a long period of complete rest and should provide adequate time for plant establishment even with brush control treatments such as root plowing and reseeding. It also provides for grazing during October, November and December after seed maturity when little harm will come to new plants from grazing. This is then followed by a January, February and March rest the following year which should provide a good start for new forage plants.

Three-Pasture Deferred Rotation: This system of grazing is similar to the two- and four-pasture systems except that there are only two herds. It requires 36 months to complete the grazing cycle by using a 6-month deferment and 12-month grazing sequence. This system can also be carried out on a 3-month rest and 6-month grazing schedule (Table 8-3). This system provides satisfactory rest periods for grass establishment following mesquite control. It appears that it would function satisfactorily even under a root plowing and seeding program. Brush control should be carried out on the pasture which is scheduled to begin a 6-month rest. In this system, like the two- and four-pasture systems, the rest periods can be shifted 1 or 2 months to coincide with the most desirable time for mesquite control. Observation has shown that response of desirable forage species has been favorable under this system, but little is known about comparative economic returns.

Four-Pasture Deferred Rotation: The four-pasture deferred rotation grazing system is rather simple in design. All four pastures should be about equal in

TABLE 8-3. RESTING SEQUENCE FOR THREE-PASTURE DEFERRED-ROTATION SYSTEM

March 1-Aug. 31	Sept. 1-Feb. 28	March 1-Aug. 31	Sept. 1-Feb. 28
1	2	3	1
2	3	1	2
3	1	2	3

TABLE 8-4. RESTING SEQUENCE FOR FOUR-PASTURE DEFERRED-ROTATION SYSTEM

March 1 to June 30	July 1 to Oct. 31	Nov. 1 to Feb. 28
Pasture 1 Pasture 4 Pasture 3 Pasture 2 etc.	Pasture 2 Pasture 1 Pasture 4 Pasture 3 etc.	Pasture 3 Pasture 2 Pasture 1 Pasture 4 etc.

carrying capacity; otherwise overgrazing will be detrimental to the weakest pasture, causing the system to be less productive. The total number of livestock on all four pastures is divided into three herds. Three pastures are grazed while one is deferred. The deferment sequence and duration for the Sonora Station is given in Table 8-4, but different rest periods can be established for specific areas or ranches. The deferment period should be based on climatic factors, rainfall and growing season.

The four-pasture, systematic, deferred-rotation grazing program has resulted in increased net income of 47 percent at Sonora and 33 percent at Barnhart as compared to yearlong grazing at the same stocking rate. At the Experimental Ranch near Throckmorton, there has been an increase of \$11.75 per cow over that of yearlong grazing.

This system originated in 1949 at the Ranch Experiment Station at Sonora. The system was then stocked at 32 animal units per section with cattle, sheep and goats. Vegetation improvement was rapid and continued through the drouth years of the 1950's. The stocking rate was increased to 43 animal units per section after the drouth years, and the pastures are still improving. In addition, 12 animal units per section of white-tailed deer grazed and occupied the systematic deferred rotation pastures, whereas adjacent yearlong grazed pastures at 32 animal units per section had fewer deer. Ranchmen using deferred rotation grazing systems have experienced even greater increases than reported at the Ranch Experiment Station.

The four-pasture system can be used with any kind of mesquite control program. Mesquite should be treated on the pasture which will rest immediately following completion of the control practice. It seemed doubtful that this practice would be entirely satisfactory with root plowing and seeding because of the 12-month grazing period following the 4-month rest. However, the system was applied at the Sonora Station on a pasture root-plowed and seeded in the spring of 1970. Weather conditions were not favorable the first summer and were poor in spring and early summer of the second year, but good in late summer. Vegetation response was excellent, and animal returns were higher than from four-pasture rotation without root plowing.

The four-pasture system was also applied with excellent response on areas which were front-end

grubbed and seeded and on areas aerielly sprayed. Therefore, it appears that satisfactory results can be obtained from any method of brush control when used with a four-pasture system.

Intensive Rotation Systems

These systems can be referred to in terms of grazing as simply intensive—meaning intensive grazing use on a single area—or as high-intensity, low-frequency grazing systems. Each system concentrates all animals on one pasture while deferring all others. Seven to nine or even more pastures in a single system are more desirable than systems with only three or four pastures. Much is to be learned about these systems (even though they have been known and used for many years) particularly with tame grass or grass-legume sods with high amounts of fertilizer. A six-pasture intensive system has been in operation on the Barnhart Station for more than 10 years and a seven-pasture system has been used on the Sonora Research Station for more than 2 years. Both are producing very good vegetation response but animal gains are not quite as good as on continuous use.

The six-pasture system at Barnhart, on which each pasture is grazed for 25 days and then rested for 125 days, produced returns slightly lower than those of continuously grazed pastures at the same stocking rate, while the four-pasture rotation system produced 33-percent greater returns than continuous use. However, it was determined that the six-pasture system was being undergrazed, and the stocking rate has now been increased by one-third. Vegetation has shown no harmful effects in a 2-year period, and returns per acre were slightly more in 1971 than from the four-pasture rotation system. At Sonora, vegetation response has been so outstanding on a seven-pasture rotation system that the stocking rate has already been increased from 40 to 50 animal units per section in a period of 2 years and despite a 6-month dry period with less than 3 inches of rainfall. Vegetation has never been utilized as much as 50 percent, and further increase is anticipated. Livestock returns, however, have not been as great as from the four-pasture system.

The high-intensity, low-frequency rotation system is by far the most desirable to use with any kind of brush control. It provides short grazing and long rest periods. Grazing pressure is not so critical that a pasture treated for brush control cannot be skipped in the grazing sequence if the vegetation does not appear ready for use when it is time for it to be grazed.

The seven-pasture system established at Sonora provides a 21-day grazing period for each pasture, followed by 126 days of rest. All livestock from the seven pastures are concentrated on one pasture for the 21-day period. The intensive system provides an ideal graze-rest sequence needed in such programs as root plowing and seeding and is very satisfactory when applied to any other mesquite control practices.

Since mesquite control is carried on in an effort to increase desirable forage for livestock, it is absolutely necessary to follow each brush treatment with a deferment or rotation-deferment practice designed to reap the maximum returns from the brush control measure. Once the grazing system has been designed, the most effective and economical method for initial control of mesquite can be selected.

Maintenance control methods can be designed to fit the grazing system. Initial control methods may include aerial application of herbicides, chaining, root plowing, tree grubbing or individual plant treatment with herbicides, depending upon density of the mesquite. From one-sixth to one-fourth of the ranch should be treated each year. Generally, an area will require maintenance control within 4 to 6 years following initial treatment.

The initial brush control method should be applied to the pasture that is to receive the longest period of deferment during the growing season following control. For example, a ranch operator using a four-pasture deferred-rotation grazing system would apply herbicides by aerial method to the pasture that would be deferred from July 1 through October 31. In low rainfall areas of the State, control treatments should be applied to the pasture that is to be deferred during the period when effective rainfall is most likely to occur.

Pastures that are root plowed and seeded should be deferred at the beginning of the growing season. Annual weeds should be controlled with herbicides if the infestations reduce establishment of forage plants. A fast-growing grass such as sorghum alnum seeded on disturbed areas is helpful in controlling

weeds and providing adequate ground cover and a rapid supply of forage for short-period grazing without causing harm to seeded perennial grasses.

A good grass cover offers competition to seedling mesquite plants. However, it appears that once the mesquite plant becomes taller than the grass, it will continue to grow and become larger regardless of the grass cover.

INTENSITY OF INFESTATION AND THE MANAGEMENT DECISIONS

Intensity of mesquite infestation dictates the control method to be used. It is important to know the kind of native forage species that will grow on an area before control measures are initiated. Many times it is necessary to defer a pasture one growing season before control to determine the amount of seed source available for reestablishment of desirable forage plants. A growing season deferment prior to root plowing is recommended. If desirable plants are not abundant, seeding with adapted species at the time of root plowing is recommended. If there were no desirable forage species, then it would be necessary to control the mesquite, plant grasses and follow with good grazing management. A range site in poor condition with a dense stand of mesquite that receives additional runoff water should be plowed, seeded, fenced and temporarily managed as a tame pasture.

Low-potential range sites should be left untreated and set aside for wildlife habitat. Each area of rangeland should be used for its highest productive capacity. Different objectives other than domestic livestock production must be determined, and the landowner should change to obtain outlined objectives.