Using mechanical equipment to modify the seedling environment[1]

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In arid and semiarid zones, the soil surface is infrequently moistened and the evaporation rate is high. Establishing seedlings is often difficult because of an adverse microenvironment (rapid drying, unfavorable temperatures, and crusting of the soil surface). Accordingly, the primary objective of seeding procedures is to place the seed in a favorable environment for germination and establishment of the seedling. This often requires varying the procedure to fit the site.

Good seedbed preparation for range seeding in some areas involves retaining a firm seedbed that favors infiltration and storage of moisture and leaving a trash-covered surface (Pearse 1952). Shallow disking, or other treatment that reduces weed competition, generally accomplishes these objectives. More intensive tillage is usually avoided not only because of increased cost but also because of the problem of excessive disturbance of the soil surface, bringing up heavier subsoils, or burying the friable topsoil and litter. Wind erosion is often a problem on loose, unprotected seedbeds. Loose seedbeds should be allowed to settle or be otherwise compacted before seeding.

In this paper, press wheel is used to describe soil firming prior to seeding, and packer wheel is used to describe soil firming after seeding. A scalper blade is a sweep that removes debris and plant competition from a seeded row. Ripping is used to describe a method of fracturing a hardpan, plowpan, or other impenetrable layer that impedes infiltration of moisture. Pits are shallow indentations or basins made in the surface of the soil to retain water from rainfall or snowmelt on a site.

Ripping, pitting, and furrowing

Water conservation in site preparation is essential in arid and semiarid areas. Staggered pits or interrupted contour furrows increase soil moisture (Anderson and Swanson 1948). They may be constructed with eccentric or cutaway disks.

The author has conducted pitting and furrowing trials on the Jornada Experimental Range near Las Cruces, New Mexico. A loam site was treated with a pitter disk seeder. The maximum summer soil temperatures at the 1.3-cm. depth were 10° C. lower (41° vs. 51° C.) in the pits than on adjacent flat areas. There was 10.5 cm. rainfall during the 66 days in summer following treatment. The soil moisture potential at the 1.3-cm. depth

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was between 0 and -15 bars for 36 days in the pits but none was recorded on the flat area. Figures 1 and 2 show the daily rainfall and soil moisture potential at the 1:3- and 10.2-cm. depth for the 66-day summer period. A fair stand of grasses emerged on the pitted area in September (Herbel 1972). Subsequent seedings with the pitter disk have been failures, probably because of poor seed placement. The seed is placed on the surface of the soil and covered with a drag chain.

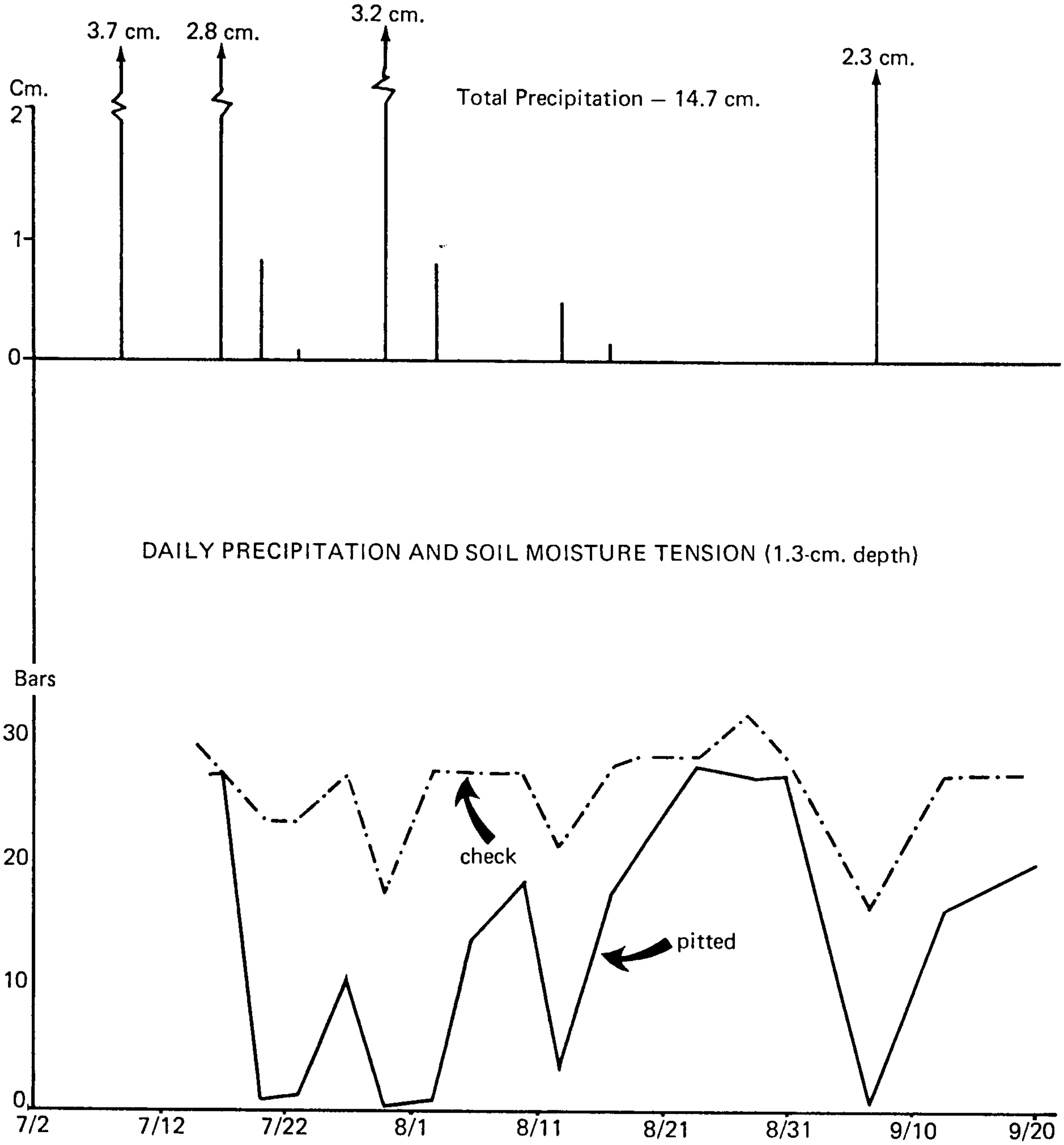

Figure 1.--Daily precipitation (cm.) and soil moisture potential (bars) at the 1.3-cm. depth in the bottom of pits and an adjacent flat area on the Jornada Experimental Range (Herbel 1972). The pits were formed with a pitter disk on July 11, 1962. Soil moisture was recorded twice weekly during the period July 16-September 20.

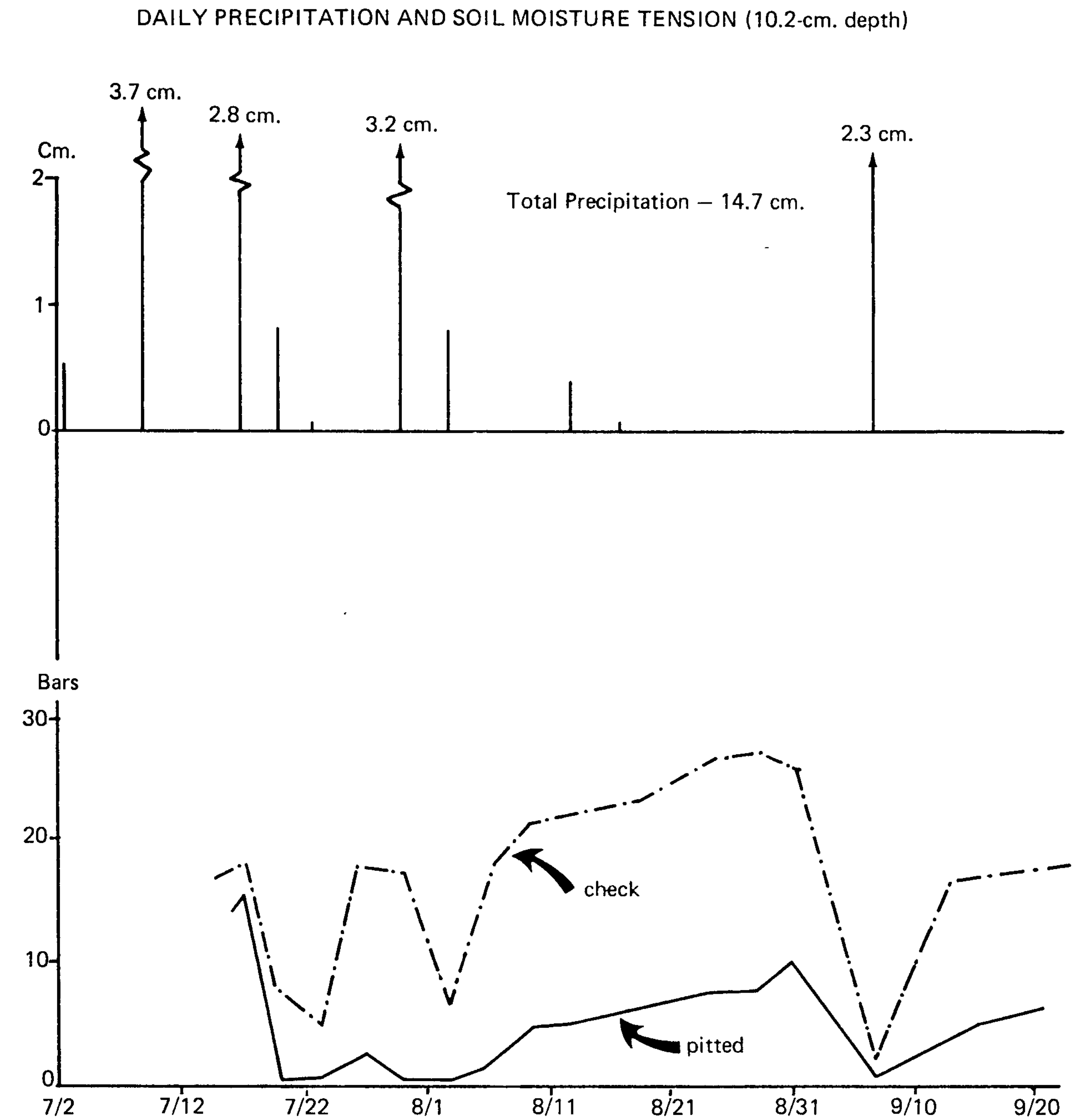

Figure 2.--Daily precipitation (cm.) and soil moisture potential (bars) at the 10.2-cm. depth for the same treatment as figure 1.

North-south and east-west furrows, 30 cm. deep, were established by the author on a loamy fine sand site in early summer. Grasses were seeded on the middle of each slope and in the bottom of each furrow. Excellent emergence was obtained on all the slopes within a few days after seeding. The average maximum air temperature 10 cm. above the surface of the ground during the summer was 34° C. The average maximum temperatures at the 1.3-cm. depth were 43°, 44°, 48°, and 43° C. for the north-, east-, south-, and west-facing slopes, respectively. During a 66-day period during summer, 11.7 cm. rainfall was recorded. Moisture potential at the 1.3-cm. depth was between 0 and -1 bar for 4 days on the slopes of the furrows and 13 days in the bottoms of the furrows (fig. 3). Deposition of sand in the furrows was a problem (Herbel 1972).

Pitting followed by cultipacker-seeding was the most consistent method of successfully seeding ranges in Arizona (Anderson and others 1957). Ripping and contour furrowing were also good methods of seedbed preparation on fine-textured bottomland soils.

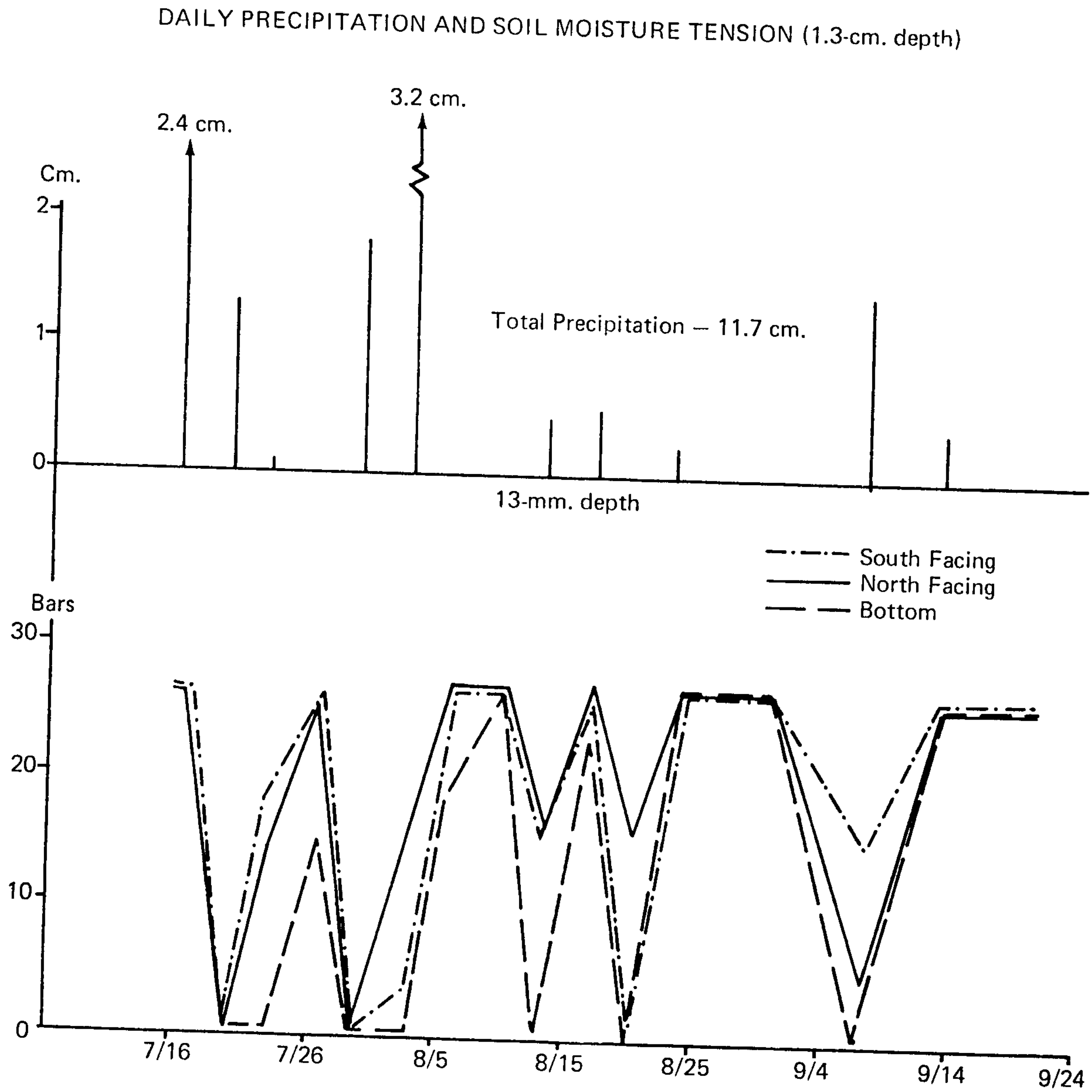

Figure 3.--Daily precipitation (cm.) and soil moisture potential (bars) at the 1.3-cm. depth in the bottom of a furrow and the middle of the north- and south-facing slopes of a furrow on the Jornada Experimental Range (Herbel 1972). The furrows were formed on July 11, 1962. Soil moisture was recorded twice weekly during the period July 16-September 20.

Ripping decreased runoff and erosion in New Mexico, but seeding attempts were mostly unsuccessful (Dortignac and Hickey 1963).

Range seeding with several grass species was studied near Barnhart, Texas, during 1950-55 (Thomas and Young 1956). During this period of below-average precipitation, most seedings were unsuccessful except those made in conjunction with pitting in 1954. Ten percent of the pits on open upland soils had established seedlings with broadcast seeding following pitting. Only 4.7 percent of the pits had seedlings when the seed was broadcast in front of the pitter.

In a 1958 trial at Bushland, Texas, seeding in the bottom of pits and broadcast seeding following furrowing to a 15-cm. depth were both failures (Dudley and Hudspeth 1964).

Three seeding methods in conjunction with disk pitting were studied in Oklahoma (Whitney and others 1967). Precision drilling of seeds across the length of the pits was generally superior to broadcasting seed into grooves followed by drag chains or broadcasting seed followed by a packer wheel. The drilling was accomplished by using opener blades which made slits for the seed 0.6 cm. wide and 1.9 cm. deep. A packer wheel followed to close each slit and to pack soil over the seed.

Pitting accompanied by seeding has been an unsuccessful practice for seedling establishment in the northern Great Plains (Barnes and others 1958). There was too much competition from native plants remaining after pitting during dry periods in the summer.

Successful regeneration of rangelands in the Northeast Pastoral Zone of South Australia depends on (1) trapping windborne seed, (2) concentrating moisture from light rains, and (3) protecting young seedlings from the effect of blasting by windborne sand (Young 1969). Contour furrows and pits successfully accomplished this, but it is difficult to keep furrows exactly on the contour. A tined pitter was developed, and it has resulted in a natural revegetation of desirable plants such as bluebushes (*Kochia* sp.) and saltbushes (*Atriplex* sp.). The tined pitter is mounted on two wheels with offcenter axles. As the pitter wheels turn, the sweeps are raised and lowered, thus forming interrupted pits. Two of the three sweeps are fastened to the front of the framework, and the other is fastened on the rear part of the framework. All the sweeps are in the ground together, but staggered pits are achieved because one sweep is mounted behind the other two. The pits are 60-90 cm. long, 15-25 cm. wide, and 10-15 cm. deep. The pit has sloping sides and ends, and the displaced earth is deposited on either side of the pit.

Frost and Hamilton (1965) have developed a basin-forming machine designed to produce fan-shaped basins on rough desert land. The fan-shaped basin has a steep sidewall (15-25 cm. deep) on the downslope side and gentle slopes to the bottom on the other three sides. A basin of this shape, sloping in three directions to one point, enables seed placement at various elevations to take advantage of various types of rainstorms. Grass stands have been established on both heavy- and light-textured soils near Tucson, Arizona, under various rainfall conditions.

The broad, shallow pits made with the basin-forming machine developed by Frost and Hamilton (1965) last longer than conventional pits in southern Arizona (Slayback and Cable 1970). Over a 4-year period, average production of seeded buffelgrass (*Cenchrus ciliaris*) was 773 kg./ha. on broad pits and 283 kg./ha. on conventional pits. The latter were made with a pitting disk. Initial establishment of buffelgrass was generally better in the conventional pits. However, production on the latter generally declined after the second year because of decreasing capacity of the pits to hold water. The broad pits were still effective, though partially filled, 5 years after construction.

The use of check dams or bulldozer pits has proven to be a successful method of establishing grasses, forbs, and shrubs on the Black Gap Wildlife Management Area in western Texas (Moore 1960). A series of pits are located on short or restricted watersheds or in overflow sites where soil is eroded. A dam 2.4 m. wide and 0.8 m. high is rapidly constructed. Seeds are hand-sown several weeks prior to the expected summer rains and covered immediately with a hand rake. The average annual precipitation at Black Gap is 18 cm.

Branson and others (1966) evaluated the effects of the following mechanical soil treatments on water storage: interrupted furrows made with a Model B Contour Furrower, broadbase furrows made with a motor grader, trenches made with a motor grader, pits made with spike-tooth or rotary pitters, pits made with an eccentric disk pitter, ripping with an auger ripper, and ripping with an auger ripper equipped with a furrow opener. The most effective treatments were contour-furrowing at intervals of 0.9-1.5 m. and depths of 20-25 cm. and broadbase furrows which had low dikes (0.5 m. high). The most consistent beneficial responses occurred on medium- to fine-textured soils.

Furrows 8, 15, and 30 cm. deep were spaced 1:8, 4.6, and 9.1 m. apart on a gently sloping sandplain in central Australia (Winkworth 1963). Surface flow water accumulated in the furrows during five rainy periods in 2 years. Spacing effects were inconclusive and greater accumulation in the deeper furrows was probably due to their larger and steeper banks. The moisture in the surface 2.5 cm. dried to -15 bar potential in about 1 day in the bottom of the furrows, as well as between the furrows. The 2.5- to 7.5-cm. layer remained moist 2 to 5 days following rain.

Hull (1970) studied the effects of eight furrow conditions on grass establishment in southeastern Idaho. Seedings in 2.5-, 5-, and 10-cm. furrows; north exposures; and on the level were superior to those on south exposures and on the ridges of furrows.

The inner coastal foothills in California have been successfully seeded by use of contour furrows (Cornelius and Burma 1970). Desert saltbush *(Atriplex polycarpa)* and several grasses are well adapted for seeding in that area.

Contour-furrowing and seeding with crested wheatgrass *(Agropyron desertorum)* were studied on saltsage rangeland in Wyoming (Nichols 1964). The major species on that area is Nuttall saltbush *(Atriplex nuttallii)*. The range was contour-furrowed and seeded in 1957. A combination furrowing and seeding machine made furrows approximately 1.5 m. apart and 25-30 cm. deep. A device created dams in the furrows every 3 m. After 4 years, the cover of Nuttall saltbush was similar on treated and untreated areas; the production of saltbush was 79 percent greater on the treated area (533 vs. 298 kg./ha.); and in addition, there were 539 kg./ha. of crested wheatgrass.

Closely spaced, interrupted, contour furrows are an effective reclamation treatment on eroded areas of the Cobar Peneplain and similar areas in western New South Wales in Australia (Cunningham 1967). The most suitable spacing between furrow lines was 1.2-1.5 m. That spacing was sufficient to moisten the furrows adequately and yet prevent runoff. The average annual precipitation is 30-38 cm. Ripping was ineffective because the rip lines sealed over within a year. Herbaceous plants and saltbushes (*Atriplex* sp.) from natural sources became established in the furrows.

An opposed disk plow with a centrally mounted ripper point was developed for furrow-seeding the Ord River Regeneration Project in northwestern Australia (Fitzgerald 1969). It is equipped with a seedbox and mounted on a three-point hookup on a wheel-type tractor. Early experience indicated that a bank formed from loose soil heaped onto compacted ground collapsed when wetted. The bank of loose soil proved more stable when a ripper point was placed between the disks. Buffelgrass, birdwoodgrass (*Cenchrus setigerus*), and kapokbush (*Aerva javanica*) have been successfully seeded with this technique.

Deep furrow drilling generally resulted in better revegetation than other methods on dry sites in the Intermountain region of the Western United States (Plummer and others 1955). McGinnies (1959) found that furrows only 10 cm. deep significantly increased available soil moisture and improved seedling establishment over an unfurrowed check. In unstable soils, the furrows were often filled by soil from local erosion in a relatively short time.

Waterponding

Waterponding assisted in reclaiming bare scalds in arid (less than 25 cm. annual precipitation) portions of New South Wales in Australia (Newman 1966). The treated areas were relatively flat and generally with less than 1-percent slope. The soils were deep clay to clay loam. Banks were constructed to pond water to depths of 15-25 cm. Good stands were obtained from seeding oldman saltbush (*Atriplex nummularia*), perennial saltbush (*A. vesicaria*), and several grasses.

Natural colonization of native plants has occurred on waterponded scalds near Nyngan, New South Wales (Cunningham 1970). The waterponding technique is based primarily upon handling of local water rather than that from outside areas. The water in each pond is from the actual rainfall on the ponded area, plus runoff from the small unponded catchment above each bank.

In New Mexico, Valentine (1947) studied five types of structures that retained runoff water. None of the structures were effective in improving the vegetation. Various soil factors were responsible for the failure of the structures.

Soil firming

Seedbed compaction can result in two opposite effects: (1) the water supply to seeds may be improved because of greater contact between seed and soil, and greater soil unsaturated conductivity, but (2) undesirable effects may result because of greater mechanical impedance to seedling emergence and root penetration as well as restricted aeration. One possible method to achieve optimal conditions is to compact the soil below the seeds and use loose soil above the seeds. A laboratory study, with no evaporation allowed, showed that compaction below the seeds improved emergence in some instances and reduced it in others. Compaction above the seeds reduced emergence in all trials (Tadmor and others 1968).

Trials in Israel indicated that *Atriplex halimus* could not emerge from a compacted surface (Koller and others 1958). Seeds were sown in moist, shallow furrows at a depth of 2-5 cm. In part of the furrows the covering soil was firmly packed while in others it was left loose. On drying, the packed soil formed a hard crust which most of the germinating seedlings were unable to penetrate. Full rows of seedlings appeared within 3-4 weeks after sowing in the loosely covered furrows.

Seeding of *Atriplex halimus* in heavy mud that had accumulated as a result of floods, behind dams and dikes, resulted in good establishment (Koller and others 1958). The seeds were broadcast 1-2 days after flooding.

The effects of cultipacking, prepacking, and postpacking on the establishment of crested wheatgrass seedlings were evaluated in northeastern Colorado by McGinnies (1962). Cultipacking prior to seeding increased the number of seedlings. Prepacking (wheel-track planting) improved seedling stands, but there was little difference in 32- or 136-kg. wheel pressures. Postpacking generally improved seedling stands but less than prepacking. If there was heavy pressure (136 kg.) on the packer wheel, it pushed the seed too deeply, and thus reduced seedling numbers.

Hyder and Bement (1969) designed a roller for firming and seeding light-textured soils. Interrupted furrows are formed to concentrate water on the seeded rows. Ridging of sandy loam soil by compacting with a heavy packer wheel prevented wind erosion from the modified seedbed (Marlatt and Hyder 1970). High intensity rain and hail did eliminate the ridges. A sandy loam soil should contain 9-12 percent moisture when packed to obtain a surface condition greatly resistant to wind erosion (Hyder and Bement 1970).

Plowing and seeding

A browse seeder has been developed that will plant an assortment of seeds on a variety of sites (Interagency Range Seeding Equipment Committee 1965). Various furrow openers, such as a moldboard and a scalper, may be used. Seed is planted immediately back of the furrow openers, and soil is firmed over the seed by a packer wheel. Furrow depth is controlled by depth regulators. The seeder has a fluted feed cylinder which has the desired grooves for seeds of different sizes and shapes. This method was used to successfully seed antelope bitterbrush (*Purshia tridentata*) in Idaho (Holmgren and Basile 1959). There, the purpose of the moldboard is to remove undesirable plants. The furrows are at least 0.8 m. wide and deep enough to prevent resprouting of perennial forbs. In Utah, drills equipped with scalpers (15-60 cm. wide) effectively eliminate weeds and provide a satisfactory method of seeding shrubs and perennial forbs in competitive annual types (Plummer, Christensen, and Monsen 1968).

Seeding native grasses at the time of rootplowing failed to provide satisfactory stands at several locations in the High Plains of Texas, where average annual precipitation ranges from 46 to 56 cm. (Jaynes and others 1968). Loss of plants after emergence was attributed to rapid depletion of soil moisture from the loose seedbed following rootplowing and to severe competition from weeds.

Fine sandy loam and gravelly sandy loam sites infested with brush were rootplowed on the Jornada Experimental Range where the average annual precipitation is 22 cm. This was followed by a till-and-pack seeder which pressed most of the brush into the soil. The maximum air temperature 10 cm. above the surface of the ground ranged from 29° to 34° C. during the latter half of July and the early part of September. During August it ranged from 38° to 40° C. The minimum relative humidity ranged from 27 to 57 percent during July and September, and 16 to 17 percent during August. Maximum soil temperatures at the 1.3-cm. depth averaged 51° C. with no ground cover and 38° C. under brush cover. A high temperature of 59° C. was recorded at the 1.3-cm. depth with no surface cover and 41° C. under brush cover. During an 82-day period, 12 cm. rainfall was recorded July 2-August 3 on the fine sandy loam site, followed by 2.3 cm. on September 7. Moisture potential at the 1.3-cm. depth was between 0 and -15 bars for 5 days on the area with no cover and 42 days on the area with brush cover (fig. 4). On the gravelly sandy loam site there were 8.6 cm. rainfall July 2-August 3 and 2.8 cm. on September 7. Moisture potential at the 1.3-cm. depth was between 0 and -15 bars for 23 days on the area without cover and 40 days on the area with brush cover (fig. 5). Poor seedling establishment was obtained with this seeding, primarily because of the severe environmental conditions in August (Herbel 1972).

The effects of dead shrubs on soil temperatures were studied on a fine sandy loam site on the Jornada Experimental Range. A single shrub plant was used for the light plant cover and a layer of three shrubs for the heavy cover. The average maximum air temperature 10 cm. above the ground surface for a summer period was 33° C. The average daily maximum soil temperature at the 1.3-cm. depth was 57° C. under no cover, 49° C. under light cover, and 36° C. under heavy brush cover (fig. 6) (Herbel 1972).

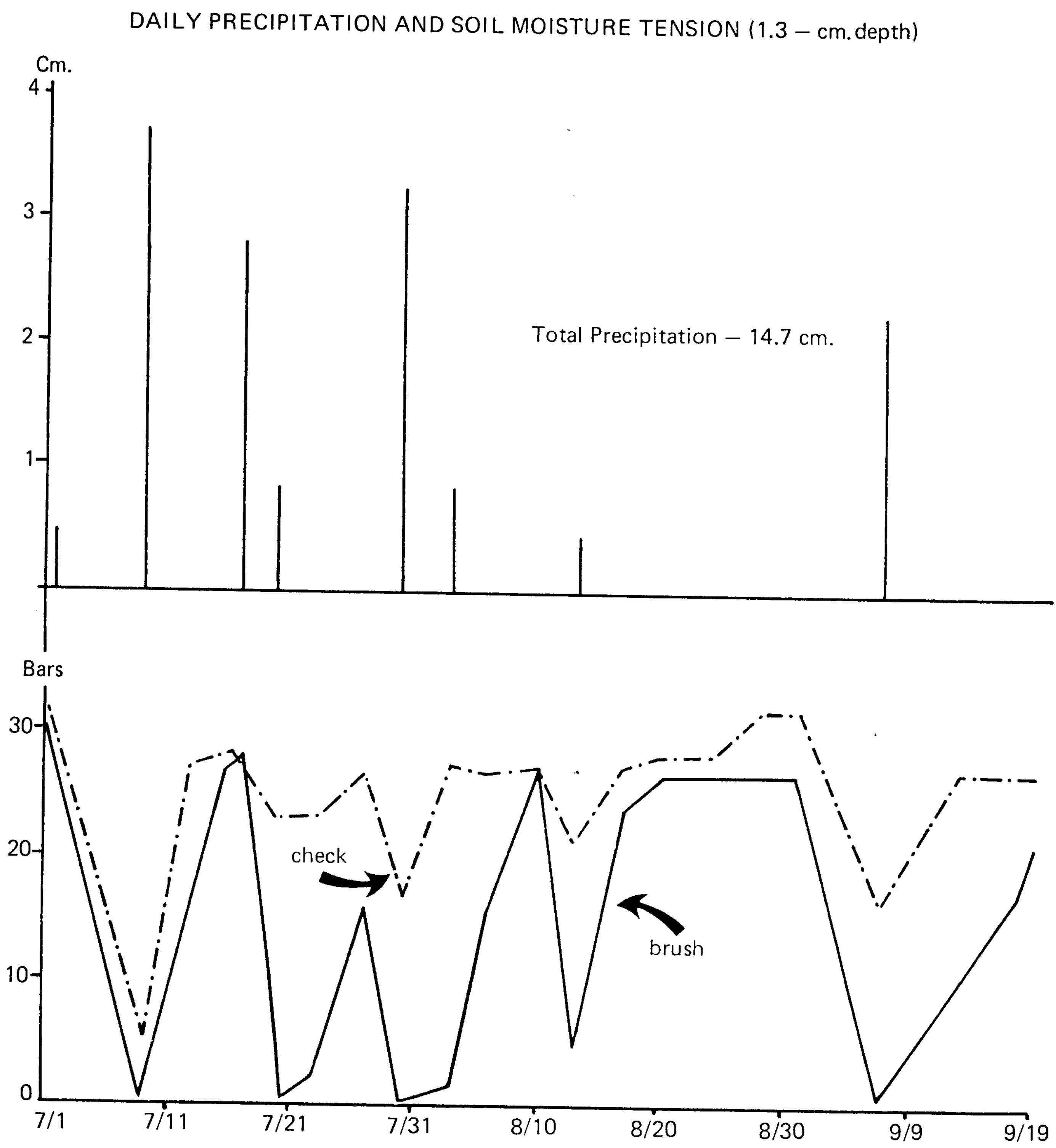

Figure 4.--Daily precipitation (cm.) and soil moisture potential (bars) at the 1.3-cm. depth without surface cover and under brush cover on a fine sandy loam site on the Jornada Experimental Range (Herbel 1972). The area was root-plowed and seeded with a till-and-pack seeder on June 25, 1962. Soil moisture was recorded twice weekly during the period July 2-September 20.

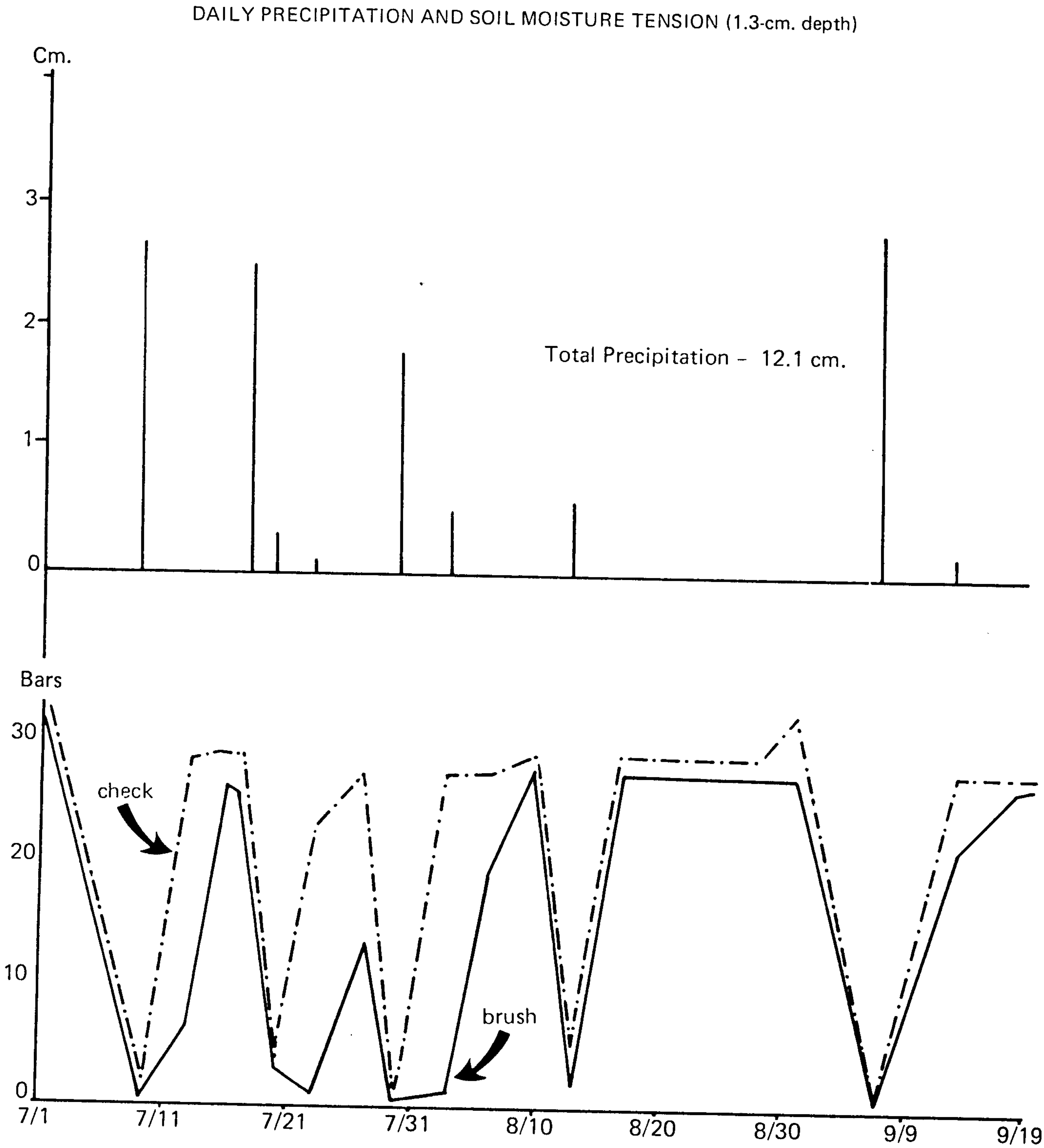

Figure 5.--Daily precipitation (cm.) and soil moisture potential (bars) at the 1.3-cm. depth without surface cover and under brush cover on a gravelly sandy loam site on the Jornada Experimental Range (Herbel 1972). The area was root-plowed and seeded with a till-and-pack seeder on June 25, 1962. Soil moisture was recorded twice weekly during the period July 2-September 20.

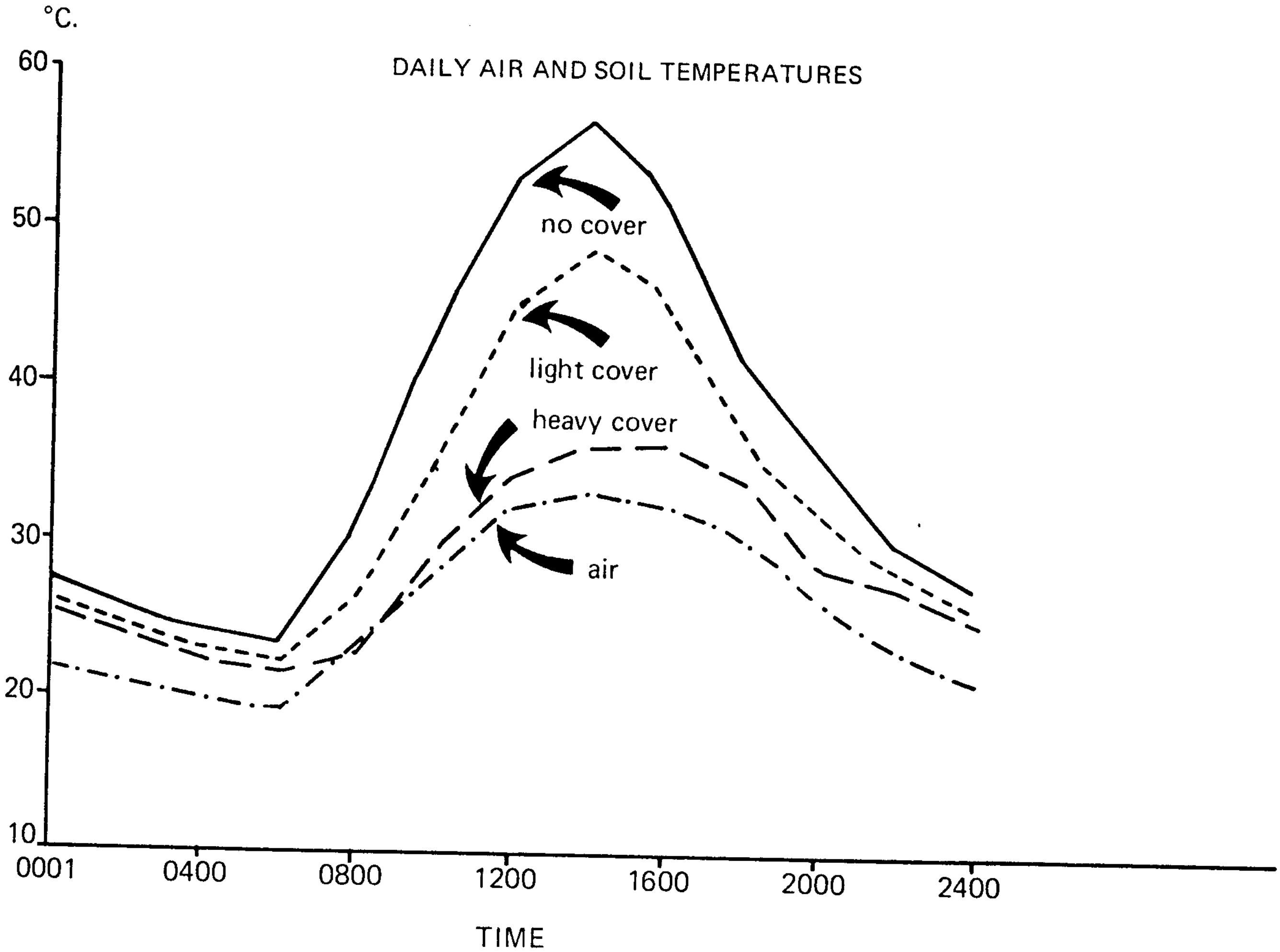

*Figure 6.--Average daily soil temperatures (°C.) at the 1.3-cm. depth with light and heavy brush cover, without surface cover, and air temperature 10 cm. above the surface of the soil for the period July 28-August 15, 1964, on the Jornada Experimental Range (Herbel 1972). Light brush cover = one dead tarbush (*Flourensia cernua*) plant; heavy brush cover = three dead tarbush plants.*

A light chamber study elucidated the effects of soil temperatures, observed under field conditions, on emergence and initial growth of 12 grass species and fourwing saltbush (*Atriplex canescens*) in a soil medium (Sosebee and Herbel 1969). The two maximum daily temperatures were 39° and 53° C., and the soil moisture was maintained at field capacity. The emergence of fourwing saltbush was 0.5 percent in the high temperature regime and 170 percent of viable seed, as determined by a standard germination test, in the low temperature regime. The latter indicated a more favorable environment than conditions considered "optimum" in a standard laboratory germination test. There was no survival of emerging seedlings of fourwing saltbush after 21 days in the high temperature regime and 98 percent survival in the low temperature regime. The plant height and root length after 21 days in the low temperature regime was 5 and 11 cm., respectively. In a similar study, but with various moisture levels, it took 7 cm. of water for survival of two grass species in the low temperature regime and 23 cm. for survival in the high regime in a 21-day trial (Herbel and Sosebee 1969).

We found that brush cover could be utilized to reduce soil temperatures substantially, and increase the period of available soil moisture. Subsequently, in cooperation with Dr. George Abernathy, Agricultural Engineering Department at New Mexico

Figure 7.--Root plow, brush conveyor, pitter, and seeder for converting areas infested with noxious brush to areas producing useful vegetation. The brush conveyor is operated by a hydraulic motor and the height of the pickup unit is hydraulically controlled. The basin pits are made with a hydraulically-controlled bulldozer blade. The press-wheel seeder firms the soil prior to seeding. The brush conveyor and pitter were designed and developed by Dr. George Abernathy, Agricultural Engineering Department, New Mexico State University.

State University, we developed and tested equipment for seeding rangeland infested with brush (fig. 7). The brush and other competing vegetation are controlled with a root plow with a blade 2.4 m. wide. The rootplowed seedbed is very loose and fluffy. Then we designed a seeder, patterned after the Oregon Press Seeder (Hyder and others 1961), which firms the soil. The seed is placed in a V-shaped groove pressed into the soil. Drag chains cover the seed with loose soil to a depth of about 1.3 cm. A brush conveyor was then developed that picks up the brush behind the root plow and deposits it behind the seeder. The seeder is only 1 m. wide, so the brush from a 2.4-m. area is concentrated on a strip 1 m. wide. In addition, there is a hydraulically-operated bulldozer blade in front of the seeder that forms basin pits. Thus, we were able to concentrate water and provide shade for part of the seeded area. This method was used to seed 12 plots across southern New Mexico in 1967-68. A variety of grass species and fourwing saltbush was seeded on each plot. Good to excellent establishment was obtained on nine of the 12 plots. Even on the other three plots with droughty conditions, good stands were obtained under some of the brush cover, which coincided with slight depressions where water was concentrated (Herbel 1971). Virtually all the establishment of fourwing saltbush occurred under brush cover, even on the sites that had above-average precipitation.

Conclusions

The major objectives of preparing seedbeds for range seeding are: (1) to prepare a favorable microenvironment for seedling establishment, (2) remove or substantially reduce competing vegetation, and (3) if possible, leave litter on the surface of the soil to reduce erosion hazards and to improve the microclimate. Broadcasting is the poorest method of seeding, particularly on unprepared seedbeds. Some form of plowing or otherwise mixing the surface soil with the soil from deeper depths may create a more favorable environment. The deeper soils often have a higher level of nutrients, a more favorable microbiota and, in the case of sandy soils, a higher capacity for holding moisture.

Only limited seeding success was obtained following pitting with a pitting disk and ripping. Ripping lines often seal over in a relatively short time. Narrow pits can fill with soil rather rapidly on some sites. Part of the problem with pits made with a pitter disk is that the cut made by the disk is smooth and slightly compacted and, therefore, a poor environment to obtain seedling establishment. In pitter disk seeding, the seeds are generally broadcast in the pitted area and covered somewhat by use of drag chains. Whitney and others (1967) used opener blades and a packer wheel to improve pitter disk seeding. In a grass sod, the pitter disk often does not reduce competition sufficiently to permit establishment of seeded species. In areas where there is a natural supply of seed of desirable species, pitting or furrowing provides a good seedbed for an increase of plants growing in the vicinity.

The broad, shallow pits made with the basin-forming machine developed by Frost and Hamilton (1965) made a good seedbed. A similar procedure is to make pits with a bulldozer blade (Moore 1960). Pitting is generally most successful on medium- to heavy-textured soils on flat or gently sloping sites.

Contour furrows form good seedbeds on medium- to heavy-textured soils. It is desirable to use interrupted furrows (1) to prevent a large water loss if a furrow wall breaks and (2) to preclude the necessity of furrowing exactly on the contour. On slopes, it would be desirable to leave spoil from the furrow on the downslope side. Considerable research is needed (1) to determine optimum furrow shape for different soil types and slopes, (2) to study the possibility of seeding on the slope of the furrow, and (3) to determine the proper orientation for furrows at various locations. In Wyoming, furrow seeding increased the yield of the native Nuttall saltbush as well as yielding a substantial amount of the seeded grass (Nichols 1964).

Waterponding of relatively large basins was effective in reclaiming bare scald areas both from seeded species (Newman 1966) and from natural colonization of native plants (Cunningham 1970). This practice, and basin pits, may have considerable application for substantially increasing herbage yields on relatively flat (0-1 percent slopes) areas.

Soil firming beneath the seed was more successful than firming the soil surface after seeding in most trials. Firming the soil after seeding has these disadvantages: (1) It may push the seed deeper then desired, (2) it may restrict aeration in the seed zone, and (3) it enhances crusting on some soils. A successful method of seeding on some sandy soils is to firm the soil into interrupted furrows (Hyder and Bement 1969).

A method of seeding arid areas infested with brush has been discussed by Herbel (1971). The brush and competing vegetation are controlled by a rootplow. Basin pits are formed and about 40 percent of the area is seeded with a press-wheel seeder. An attempt is made to concentrate the brush and water on the seeded area. Brush control, pitting, seeding, and brush placement are accomplished with one pass over the land.

Concentrating water, as with various land-forming procedures, does not always insure seedling establishment. The surface soil still dries rapidly, particularly in hot arid and semiarid areas. This rapid drying may lead to the formation of a heavy crust on medium- to heavy-textured soils. In those instances, if the surface could be protected to reduce evaporation, seedling emergence and establishment would be greatly enhanced.