PELLET SEEDING OF LOVEGRASSES ON SOUTHERN ARIZONA RANGELANDS

by

Jack H. Wheeler

A Thesis Submitted to the Faculty of the

DEPARTMENT OF WATERSHED MANAGEMENT

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1964

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Jack H. Wheeler

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Gilbert L. Jordan
GILBERT L. JORDAN
Ass't Range Management Specialist

May 4, 1964
Date

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. Gilbert L. Jordan for his assistance and guidance during this study and for his helpful suggestions in the preparation of this paper. Appreciation is expressed to Dr. Ervin M. Schmutz and to Dr. Robert F. Wagle for editing the manuscript.

TABLE OF CONTENTS

TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

Wheeler, Jack H. 1964. Pellet Seeding of Lovegrasses on Southern Arizona Rangelands. Master of Science Thesis. Department of Watershed Management, University of Arizona.

Experimental work was conducted in the summers of 1962 and 1963 to evaluate the use of pelleted Lehmann and Boer lovegrass seeds in the revegetation of a shrub-dominated, desert grassland area. The experimental procedures consisted of broadcasting and drilling of pelleted and non-pelleted lovegrass seeds on the following types of seedbeds: (1) cleared, (2) cleared and pitted, and (3) untreated.

The results of these studies indicated that: (1) stands obtained from broadcasting pelleted lovegrass seeds were no better than those obtained from broadcasting non-pelleted lovegrass seeds, regardless of the amount of seedbed preparation; (2) stands obtained from drilling non-pelleted lovegrass seeds were better than those obtained from broadcasting pelleted or non-pelleted lovegrass seeds; and (3) stands obtained from drilling non-pelleted Lehmann lovegrass seeds were better than those obtained from drilling pelleted Boer lovegrass seeds, pelleted Lehmann lovegrass seeds, or non-pelleted Boer lovegrass seeds.

These studies did not indicate any advantages for pelleted seeds

ABSTRACT--Continued

in revegetating depleted southern Arizona rangelands. In contrast, an acceptable stand of grass was obtained by: (1) the removal of competitive vegetation, and (2) the drilling of an adapted species of grass such as Lehmann lovegrass.

INTRODUCTION

The effects of overgrazing, aggravated by prolonged periods of drought, have resulted in the deterioration of thousands of acres of rangeland in Southern Arizona. Much of this rangeland was dominated by valuable perennial grasses which offered good forage for livestock and provided protection for the soil. Today most of these perennial grasses are gone, and in their place are found annual grasses, weeds, and shrubby plants which offer poor forage for livestock and inadequate cover for soil protection. Revegetation of this rangeland by seeding grasses which are adaptable, nutritious, and palatable is desirable for adequate forage production and for lessening soil erosion.

One solution to this problem of revegetation, advocated by L. S. Adams of Tucson, Arizona, is the use of pelleted grass seed. In these pellets, grass seeds are encased in soil for broadcast dispersion. Mr. Adams theorized that the earthen pellet coating would substitute for the imbedding of the seed in the soil. The method, if practical, would provide an economical means of seeding hundreds of acres per day. Thus, experimental reseeding studies were initiated in the summer of 1962 to determine the practicality of using pelleted grass seeds in range revegetation.

To evaluate this method of revegetation, pelleted and non-pelleted seeds of Lehmann and Boer lovegrass were aerially broadcasted and drilled on the following types of seedbeds: (1) cleared, (2) cleared and pitted, and (3) untreated.

LITERATURE REVIEW

Interest in revegetating 90 million acres of deteriorated rangeland in the Western United States was enthusiastic and popular following World War II (Winter, 1947). The reason for this interest was the alluring possibilities of : (1) increasing meat production, (2) conserving renewable resources, and (3) conserving non-renewable resources (Ross, 1948; Burback, 1949).

It was thought (Anonymous, 1940) that the aerial sowing of seed held extraordinary potentialities for rapidly and economically revegetating areas which were inaccessible to ground equipment. Much of this early enthusiasm stemmed from the successful aerial seeding of burned-over watersheds in California (Gleason, 1944) and the aerial seeding of rice in California (Haystead, 1945). Unfortunately, this optimism was short-lived, for success with aerial sowing of grass was generally limited to selected situations such as the following: (1) seeding prior to leaf drop in deciduous tree areas (Hull and Stewart, 1948; Stewart et al., 1951); (2) seeding where rainfall was ample and dependable (Mark and Roaf, 1941; Price, Parker and Hull, 1948); (3) seeding in ashes of burned-over rangeland (Pearse and Plummer, 1948); (4) seeding where competition was slight (Killough, 1950; Bleak and Hull, 1958); and (5) seeding on a rough seedbed (Schwendiman, 1955). The failure of aerial seeding to produce acceptable stands of grass under conditions other than those mentioned above was attributed to poor distribution of the seed (Stewart, 1949); failure of the seed to penetrate the soil (Haystead, 1945); and inadequate protection of the seeds from rodents, insects, diseases or weather (Barnhill, 1946; Winter, 1947).

Pelleted Seeds

Because of certain obvious disadvantages of seeding non-pelleted seeds by air, the attention shifted to pelleted seeds. The idea of pelleting seeds was not new, having been occasionally used since World War I. However, it was not until after World War II that the large-scale manufacturing of pellets began. At that time, they were prepared for the sugar beet industry to improve row spacing (Rudolf, 1949). Later, pelleted seeds were used quite successfully in the truck crop industry (MacGillivray, 1953), and farmers can now buy them for crops such as lettuce, carrots, radishes, and many other small-seeded crops. Pelleted flower seeds (Anonymous, 1949) have been made available to the home gardener ensuring better spacing of seeds and permitting earlier planting.

Beginning in 1946, experimental seedings with pellets were given national publicity in popular magazines, and the following advantages were claimed for them:

(1) Pellets provide uniform distribution because of their weight (Towne, 1946; Winter, 1947).

(2) Pellets would have sufficient weight to penetrate the soil (Haystead, 1945; Barnhill, 1946).

(3) Pellets would provide protection to the seed because of their coating (Haystead, 1945).

(4) Pellets would germinate sooner than non-pelleted seed and still maintain high germination (Mahoney, 1946; Henry, 1947).

(5) Fertilizers, growth hormones, and chemicals to protect seeds against diseases and animals could be added (Towne, 1946).

Three common types of pellets have been manufactured for range reseeding: extruded, coated, and compressed.

Extruded Pellets

Extruded pellets are short and cylindrical. They are manufactured from a viscous, paste-like mixture of seed and soil which is forced under great pressure through round openings. This type of pellet was used only in the greenhouse and laboratory (Hull et al., 1963).

Coated Pellets

Coated-pellets are generally ellipsoidal. They are made by building up a coating of numerous layers around the seeds while they are tumbled in a slowly revolving drum. When the desired size is obtained, they are dried and screened to uniformity. The coating material usually consists of a very fine mineral substance such as feldspar, fly ash, clay, or montmorillonite. Fertilizers, growth hormones, insecticides, fungicides, and rodent repellents are added to the coating material if desired. This type of pellet is manufactured at a central plant and shipped to the reseeding sites (Tisdale and Platt, 1951).

Studies were conducted by Hull (1959) in the sagebrush-grass vegetation type in Idaho with coated pelleted and non-pelleted seeds. These studies included both small-scale and large-scale seedings. Small-scale seedings were made on plowed, burned, and untreated seedbeds. Drilling of non-pelleted seeds was used on all ground treatments in the small-scale study. The large-scale seedings included three seedbed preparations: burned, plowed, and untreated. Methods used in the large-scale seedings were aerial broadcasting of pelleted seeds, aerial broadcasting of non-pelleted seeds, and drilling of non-pelleted seeds. In both studies seedings were made with wheatgrass (Agropyron desertorum (Fisch.)Schult.)[1] and/or intermediate wheatgrass (Agropyron intermedium (Host) Beauv.). Results of these studies indicated the following: (1) stands from the drilling of non-pelleted seeds were superior to stands from broadcasting pelleted or non-pelleted seeds, (2) stands from the broadcasting on plowed ground were better than those from broadcasting on either burned or untreated areas, and (3) stands from broadcasting were poor.

In studies by Moomaw (1951) and Moomaw et al. (1954) with coated pelleted and non-pelleted seeds of crested wheatgrass in the Crane Creek area of Idaho, non-pelleted seeds showed a significant advantage over coated pelleted seeds.

---

1. Scientific nomenclature cited from Kearney and Peebles (1951), Gould (1951), and Hitchcock (1951).

Between 1949 and 1951 Gatherum (1951) seeded 49 different kinds of plastic-coated pelleted seeds near Logan, Utah. These seeds were drilled and broadcast seeded on untreated, burned, and plowed areas. He found that: (1) 130 times more seedlings survived from drilled pelleted or non-pelleted seeds than from broadcast plantings, (2) 394 seedlings survived on plowed ground while no seedlings survived on untreated areas, (3) seeding foothill ranges in the Intermountain Region with plastic-coated pellets is not warranted. Gatherum (1961) further stated that bare seed showed much higher germination than any of the 40 plastic-coated pelleted seeds tested. However, Hull (1950) found in greenhouse studies that soil coatings had no effect on seed germination.

Compressed Pellets

The pellet most commonly used is the compressed earthen pellet developed by L. S. Adams of the Universal Pellet Co., Tucson, Arizona (formerly the International Seed Pellet Co., of Phoenix, Arizona). The idea for this pellet came from Mr. Adam's observations that seeds ingested by rabbits and then left in their droppings sprouted sooner than other seeds on the surface of the ground (Anonymous, 1948).

Compressed pellets (Figure 1) are spherical. They are made by a machine consisting of four gear-like wheels with a series of quarter spherical depressions around the rim (Figure 2). The four wheels meet at a common point and mesh so that the seed and soil mixture is pressed from four sides to form a pellet. Growth hormones, insecticides,

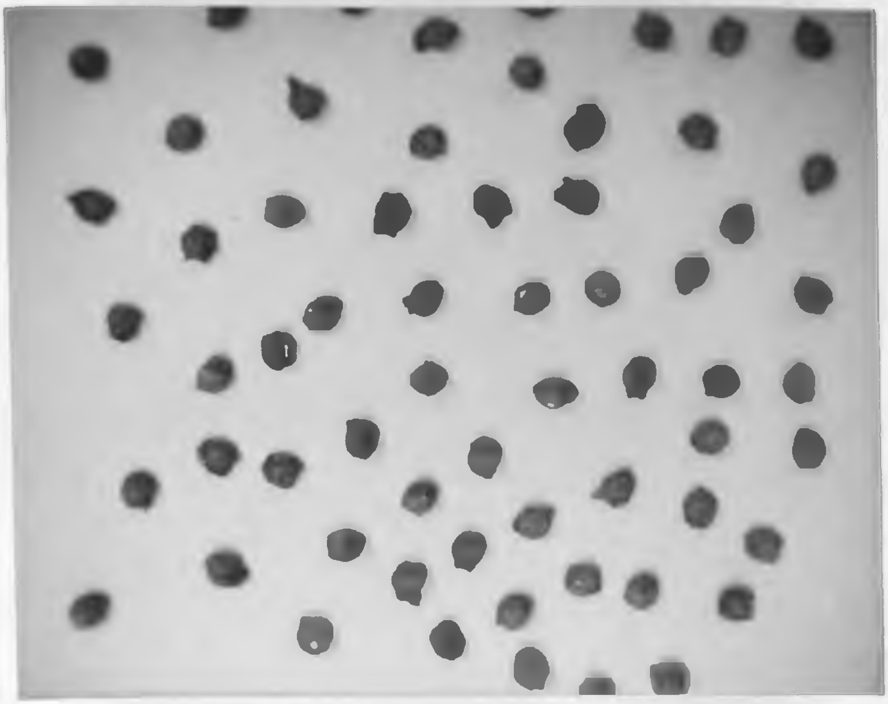

Figure 1. View of compressed earthen pellets. Pellets shown are approximately 3/8 inch in size.

Figure 2. View of compression-type pelleting machine.

fungicides, fertilizers, or rodent repellents are added if desired. The equipment was mobile and powered by a large diesel engine which permitted the pellets to be made on, or near, the seeding site. They were made from any soil with a reasonably high clay content to be found near the site to be seeded (Hull et al., 1963).

Between 1946 and 1948, 90 thousand acres were aerial seeded with compressed pellets on four Indian reservations: Papago, San Carlos, Hopi, and Navajo. In addition, 28 acres were quadruple disked and drilled with pellets on the San Carlos. Another 810 acres were aerial seeded with non-pelleted seeds on the Navajo reservation. Lehmann lovegrass (Eragrostis lehmanniana Nees.) and sand dropseed (Sporobolus cryptandrus (Torr.) Gray) were seeded on the San Carlos and the Papago. Weeping lovegrass (Eragrostis curvula (Schrad.) Nees.) was also seeded on the San Carlos. The Hopi and Navajo reservations were seeded to crested wheatgrass, western wheatgrass (A. smithii Rydb.), and sand dropseed.

Wagner (1949) and Wagner and Kinkor (1950) reported that none of the seedings were satisfactory. On the Papago they reported an average of only 75 plants per acre and no seedlings were found on the San Carlos. Observations on the Hopi grass stands indicate that they cannot be considered even partially satisfactory. The Navajo seedings were too recent (in 1950) to evaluate but the preliminary opinions of Navajo technicians were that: (1) results were directly proportional to ground treatment and (2) seeding with non-pelleted seeds gave about the same results as seeding with pelleted seeds. Rudolf (1949 and 1950), while working with pelleted tree seeds, also found that non-pelleted seeds gave the same results as pelleted seeds. Furthermore Wagner (1949) stated that the penetration of pellets into the soil was nil even where the soil was wet and soft.

Bleak and Phillips (1950) worked with pellets in Utah on four range types: aspen, mountain brush, ponderosa pine, and pinyon-juniper. Two studies were set up in these areas: a large-scale extensive study, and a small, intensive study.

On the large-scale areas they seeded mixtures of species on all range types with the exception of one of the pinyon-juniper areas which was seeded to non-pelleted bulbous bluegrass (*Poa bulbosa* L.). Mixtures used in the aspen and ponderosa pine types included smooth brome (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), and timothy (*Phleum pratense* L.). Mountain brush was seeded to smooth brome, orchardgrass, crested wheatgrass, slender wheatgrass (*Agropyron trachycaulum* (Link.) Malte), and yellow sweetclover (*Melilotus officinalis* L.). The other pinyon-juniper area was seeded to smooth brome, crested wheatgrass, bulbous bluegrass, and yellow sweetclover. They used three aerial broadcasting treatments on the untreated seedbeds: one pellet per square foot, two pellets per square foot, and ten pounds of non-pelleted seed per acre. Each of these aerial seeding treatments were applied to all range types with the exception of the aspen type where the two-pellets-per-square-foot treatment was eliminated. The seedlings were counted in 1949, and it was found that in all four vegetation types, broadcasting non-pelleted seeds was superior to broadcasting pelleted seeds. There was little difference between number of seedlings counted in the one-and two-pellets-per-square-foot treatments although the seeding rate was double. Average stand ratings in all pellet-seeded plots were in the "very poor" class. Average stand ratings in non-pelleted plots ranged from "very good" in aspen to "medium" in mountain brush.

Bleak and Phillips carried out the small intensive studies in the mountain brush, ponderosa pine, and pinyon-juniper types. In the mountain brush type four seedbed treatments were applied prior to seeding: burned, plowed, harrowed, and untreated. Each of these treated areas was then sub-divided into four smaller ones. Each of these four smaller areas was then broadcast-seeded with one of the following treatments: one pellet per square foot, two pellets per square foot, ten pounds of non-pelleted seed per acre, and ten pounds of non-pelleted seeds per acre followed by harrowing. The pinyon-juniper and ponderosa pine areas were aerially broadcast-seeded on untreated seedbeds in the following manner: one pellet per square foot, two pellets per square foot, one pellet per square foot followed by harrowing or dragging, and ten pounds of non-pelleted seeds per acre followed by harrowing or dragging. The seedlings were counted in 1949 and the results of this intensive study paralleled those of the larger scale study.

Bleak and Hull (1958) reported on the above studies again in 1955 after resampling the areas involved. Although fewer plants per square foot were found on all treatments, the results confirmed the previous findings.

A study by Tisdale and Platt (1951) was conducted in an area of the sagebrush-grass vegetation type of Idaho which was accidentally burned in 1947. Two areas within this burn, known as Thorn Creek and Rattlesnake Butte, were seeded with compressed pellets. The two areas comprised 21 thousand acres and were seeded with crested wheatgrass and yellow sweetclover in a 3:1 ratio at a rate of two pounds of seed per acre. On the Thorn Creek area only, one additional strip was flown twice and another three times in an effort to increase the seeding rate to four and six pounds per acre, respectively. Seeding started towards the end of 1947 and was completed in January, 1948. They sampled the Thorn Creek area in 1948 and 1950. The stand was considered sparse and failed to show any relationship between seeding rate and number of seedlings. The authors reported that a satisfactory stand was not obtained. Moomaw et al., (1954) after resampling the Thorn Creek area in 1951 and 1953, reported that no change in the number of plants was found. They concluded that the seedings were unsatisfactory.

Bleak and Phillips (1950) showed that the compressed method of pelleting damaged the large seeds and reduced the germination as much as eighty percent. However, Wagner (1949) indicated that pelleting by the compressed method had little or no effect on seed germination of small, hard seeds.

Hull et al. (1963) evaluated all pelleted reseeding trials in the western United States and did not find a single instance in which the aerial broadcasting of any type of pelleted seeds produced a satisfactory stand of grass, regardless of seedbed preparation.

Failure of pelleted seeds to materialize as a means of revegetating areas inaccessible to machinery has been attributed to:

(1) The reduction in seed viability of compressed-pelleted seeds due to the pelleting process. (Barnard, 1949; Bleak and Phillips, 1950; Wagner, 1949; Moomaw, 1951; Tisdale and Platt, 1951; Gatherum 1951; Moomaw et al., 1954; Bleak and Hull, 1958; Gatherum, 1961).

(2) The failure of the pelleted seeds to penetrate the soil (Wagner, 1949; Wagner and Kinkor, 1950; Anonymous, 1950).

(3) The failure of the pelleted seeds to provide adequate protection for the seed (Wagner, 1949; Rudolf, 1949; Wagner and Kinkor, 1950; Anonymous, 1950).

(4) The competition to the seedlings from native vegetation (Wagner, 1949; Moomaw, et al., 1954; Bleak and Hull,

1958; Hull, 1959).

(5) The inability of seedlings from broadcasted pelleted seeds to anchor themselves properly which, in turn, prevented the seedlings from securing water and nutrients (Gatherum, 1951; Moomaw, et al., 1954).

(6) The slower germination rate of pelleted seeds as compared with that of non-pelleted seeds (Bleak and Phillips, 1950; MacGillivray, 1953; Hull, 1959).

Non-Pelleted Seeds

Standard on-the-ground methods of reseeding have been developed by Federal and State research agencies. These methods seem to offer the best chances for seeding success. In the semi-arid regions of the Southwest, Anderson et al. (1957) recommended preparatory soil treatments which reduce competition from both woody and herbaceous species. He also emphasized that drilling the seed at the proper rate and depth was a prerequisite for a successful stand. Similar findings were reported by Bridges (1941), Flory and Marshall (1942), Pingrey and Dortignac (1957), Reynolds (1959), and Lloyd and Cook (1960). Anderson further stated that reseeding is not recommended for areas that receive less than eleven inches of annual precipitation.

Wheeler and Hill (1957) stated that reseeding of Lehmann lovegrass on ranges receiving twelve to fourteen inches of annual precipitation in Southern Arizona, southern New Mexico, and extensive areas of

Texas, gave better results than any other species of grass. Fleming (1949) and Humphrey (1959) also found that Lehmann lovegrass is extremely drought hardy and well adapted to Arizona's semi-arid growing conditions.

Flory and Marshall (1942), Anderson etal. (1957), and Reynolds (1959), recommended drilling Lehmann lovegrass at rates of one-half to two pounds per acre prior to the summer rainy season in Arizona.

In the semi-arid regions of the Southwest, moisture is often a limiting factor in establishing and maintaining seedlings. Therefore, some form of soil moisture conservation is generally recommended. Anderson and Swanson (1949) found that pitting with an eccentric disc not only provided for moisture conservation, but also reduced annual and perennial weeds. Barnes (1952), Anderson et al. (1957), Barnes, Anderson, and Heerwagen (1958), and Reynolds (1959) also found that pitting is beneficial in range reseeding. Barnes, Anderson, and Heerwagen (1958) further stated that pitting is not recommended on rocky soils, soils heavily infested with brush, or on slopes greater than eight percent.

The results of the experimental work reviewed in this paper indicate that seeding pelleted seeds is generally an unsatisfactory method of revegetation. This study was conducted to try to determine some of the factors responsible for this failure and to make direct comparisons between pellet reseeding and various other seeding methods under different seedbed conditions and using different grass species.

METHODS AND MATERIALS

Description of Study Area

Pellet seeding studies were made on two adjacent areas, one in 1962 and the other in 1963. The sites were located approximately 22 miles south of Safford, Arizona in S26, R26E, T10S of the Gila and Salt River Meridian. The study area was within the desert grassland as described by Humphrey (1958) and was formerly dominated by three genera: Bouteloua, Hilaria, and Aristida. Woody plants, which were always present to some extent, were originally restricted to drainages and to the rocky or shallow-soil areas of the desert grassland. Since the turn of the century, much of the desert grassland including the study area became heavily infested with undesirable brush species (Figure 3). The dominant shrubs were mesquite (Prosopis juliflora var. velutina Woot.), catclaw (Acacia greggii Gray.), and yucca (Yucca elata Engelm.). The primary sub-dominants were black grama (Bouteloua eriopoda Torr.), bush muhly (Muhlenbergia porteri Scribn.), red threeawn (Aristida longiseta Steud.), purple threeawn (Aristida purpurea Nutt.), spidergrass (Aristida ternipes Cav.), burroweed (Aplopappus tenuisectus (Greene) Blake), and snakeweed (Gutierrezia lucida Greene). The primary species along drainage ways were sideoats grama (Bouteloua curtipendula (Michx.) Torr.), Arizona cottontop (Trichachne californica

Figure 3. A representative view of the study area before disturbance by seeding operations.

(Benth.) Chase), and cane beardgrass (Andropogon barbinodis Lag.). Plants of sixweek grama (Bouteloua barbata Log.), sixweek needle grama (Bouteloua aristidoides (. H. B. K.) Griseb.), rothrock grama (Bouteloua rothrockii Vasey), fluffgrass (Tridens pulchellus (H. B. K.) Hitch.), Tobosa (Hilaria mutica (Buckl.) Benth.), plains bristlegrass (Setaria macrostachya H. B. K.), and Opuntia sp. were also found scattered throughout the area.

The sites are located in the lower reaches of the watershed which drains from the east side of the Greasewood mountains into Sycamore wash and thence into San Simon Creek. The elevation is approximately 4100 feet. The mean annual precipitation is estimated at 12 inches (Greening, 1941) equally divided between summer and winter.

A soil map of Section 26 indicates that only Mohave gravelly loam is present on the study area.[2] This soil is underlain by hardpan at depths of six to twelve inches. The topography is rolling and active gullies are prevalent in the vicinity.

Following the selection of each study area and prior to any seed-bed treatment or seeding operations, fences were erected to protect the area from livestock grazing.

---

2. Information supplied by the Soil Conservation Service, Safford District Office, Safford, Arizona.

The compressed pellets seeded in this study contained approximately 60 live seeds, the pelleting process appeared to have no harmful effect on germination.[3] Mr. Adams, (no date) the pellet manufacturer stated that the pellets contained a growth promoting agent and both a rodent and insect repellent.

Experimental Procedure

The 1962 Studies

The experimental design for the 1962 studies was a randomized split-split-split-plot having four replications. Each replication consisted of sixteen 3/4 acre plots which included three seedbed treatments, two grass species, and two methods of seeding as follows:

Seedbed treatments. The three seedbed treatments included: cleared, cleared and pitted, and untreated. They were prepared in the following manner:

(1) Cleared seedbeds were prepared by bulldozer-blading all brush species.

(2) Cleared and pitted seedbeds were prepared by bulldozer-blading all brush species and then pitting the soil with a cut-away pitting disc (Figure 4) which prepares pits approximately 22 inches wide, 9 inches deep, and 60 inches long.

---

3. Personal communication with O. D. Knipe, Dept. of Watershed Management, The University of Arizona.

Figure 4. View of cut-away pitting disc (center) and Nisbet grass-seeder (left) used in seedbed preparation and planting.

(3) Untreated seedbeds were not disturbed and constituted the control treatments.

Species used and Method of seeding. The two methods of seeding used were broadcasting and drilling. They were employed to seed Boer (*Eragrostis chloromelas*) and Lehmann lovegrass in both the pelleted and non-pelleted form in the following manner:

(1) Pellets of both species were broadcast from an airplane over a part of each of the treated and untreated seedbeds at the rate of one pellet per square foot.[4]

(2) Non-pelleted seeds of both species were broadcast by means of a hand-operated Cyclone Seeder over a part of each area of treated and untreated seedbeds at a rate of 60 live seed per square foot. Hand broadcasting rather than aerial broadcasting was used to insure uniform seed distribution.

(3) Pelleted and non-pelleted seeds of both species were drilled with a Nisbet grass seeder (Figure 4) on cleared and pitted seedbeds only. Pelleted seeds were drilled at the rate of one pellet per linear foot. Depth of planting was for both pelleted and non-pelleted seeds approximately 1/2 inch.

---

4. Rate of seeding obtained from unpublished data, Project 516, Watershed Management Dept., Agricultural Experiment Station, The University of Arizona.

The 1963 Studies

The experimental design for the 1963 area was basically the same as that for the 1962 area with the following variations:

(1) A randomized split-split-strip-plot design was used with four replications. Each replication contained twelve 1/2 acre plots.

(2) Four additional drilled plots were added to each replication. These consisted of drilling pelleted and non-pelleted seeds into cleared and untreated seedbeds.

(3) Lehmann lovegrass only was seeded in both the pelleted and non-pelleted form.

The General Procedures on both Studies

Following seedbed preparation and seeding operations, a sampling line containing ten sampling plots within each treatment area was established in the following manner:

(1) The north 25 feet and the south 25 feet of each treatment area were excluded from sampling to serve as a buffer between treatments. The same buffer was established on both the east and west sides of each plot.

(2) The first sampling plot on the sampling line (south end) was determined at random from 0 to 16.6 feet. The subsequent nine sampling plots were located at ten foot intervals. Each sampling plot was marked permanently with a stake.

Direction of sample from each stake (west or east) was determined by a coin toss. Sampling of these plots was accomplished by using a 1 by 5-foot quadrat constructed of 1/4-inch steel rod. The quadrat was placed down with the stake in one corner. A wire pin was then inserted in the ground in the end corner of the frame away from the sampling line. The plants that fell within this quadrat were counted. The quadrat was then flipped over (away from the sampling line) and marked with another wire pin inserted into the ground in the corner away from the sampling line. The plants were again counted and this count was added to that of the previous 1 by 5-foot area counted. The two 1 by 5-foot samples taken at each stake constituted the complete sample taken at each sampling plot. The wire pins were left as placed to facilitate relocation of the frames when making future samplings of the same areas.[5]

Seedling counts were made at the close of each growing season and at other times during the season depending on rainfall distribution and growth conditions.

Four gypsum, soil-moisture blocks were buried in each seedbed treatment at 1/8, 2, 6, and 12 inches. To follow the relative differences

---

5. Methods for establishment of sample line and sampling procedure were obtained from unpublished data, Project 516, Watershed Management Dept., Agricultural Experiment Station, Univ. of Ariz.

in soil moisture between seedbed preparations during the growing season, the electrical resistance through these blocks was measured twice daily (8:00 a.m. and 5:00 p.m.). These measurements were taken until soil moisture was exhausted from the 12-inch level. Moisture blocks were replicated twice in 1962 and four times in 1963.

A recording-type rain gauge and hygrothermograph were located within the study areas. These instruments were maintained on a weekly basis from June, 1962 to October 1, 1963. To supplement the recording rain gauge, wedge-type rain gauges were located at the corners of the study areas to determine any non-uniformity in precipitation.

Rodents, particularly jackrabbits, have been a prime factor in the failure of some artificial reseeding projects (Norris, 1950). A program was initiated to control them by baiting (in 1962) with poison grain. Shooting with .22 caliber firearms was used as a supplementary means of control. In 1963 control measures were continued although rodents were no longer a problem.

RESULTS

Past field observations have indicated that soil moisture should be within the available range for plant use from five to seven days if seed germination and subsequent emergence is to take place. Therefore, the experimental results are presented with emphasis on the relationship of available soil moisture to seed germination and plant emergence. Since precipitation directly affects soil moisture it was also considered as a factor in seed germination. The effective rainfall periods are based on resistance readings of soil moisture blocks for the 1/8-inch depth.

The 1962 Study

In the summer of 1962 the study area received the average summer rainfall of approximately six inches (Table 1). The first appreciable amount of rainfall (.75 inch) fell on July 4th, but it was not followed by sufficient rainfall to support seed germination. Observations of the area indicated that practically no plants resulted from this rain.

The first rains effective enough for general seed germination (.15-inch) commenced on July 22nd. This rain was followed by the well distributed precipitations on July 23rd, 28th, 29th, 30th, and 31st with .74, .70, .02, .10, and .05 of an inch, respectively (Table 1).

Table 1. Distribution of precipitation for the 1962 summer growing season.

Date	Daily Rainfall	Cumulative total
	------- Inches -------	
June	0.00	0.00
July		
2	.03	.03
3	.03	.06
4	.75	.81
9	.08	.89
16	.05	.94
22	.15	1.09
23	.74	1.83
28	.70	2.53
29	.02	2.55
30	.10	2.65
31	.05	2.70
August		
22	.03	2.73
23	.07	2.80
September		
4	.10	2.90
6	.06	2.96
8	.15	3.11
13	.25	3.36
24	.15	3.51
25	.08	3.59
26	1.54	5.13

Resistance readings of soil moisture blocks were begun on the morning of July 26th. These readings indicated that soil moisture was available in all seedbeds at the 1/8-inch level for a period long enough to support seed germination (Table 2).

Plant emergence began on July 29th. By August 6th the newly emerged plants in the cleared and non treated seedbeds exhibited considerable moisture stress. Soil moisture observations for the 1/8-inch level indicated that soil moisture in these seedbeds was below the range of availability for germination. Plants in the cleared-pitted seedbeds did not exhibit soil moisture stress at this time.

The first plant count was made on August 7th. The results of this count are presented in Table 3. These data showed that seedlings were mostly lacking on all treatments except the drilled non-pelleted Lehmann lovegrass plots; thus, an analysis of variance could not be run on this data.[6]

The August drought period (Table 1) following the first plant count resulted in severe plant losses on all seedbeds. Observations showed that almost all the plants emerging from the broadcasted pelleted and non-pelleted lovegrass seeds died, as well as half of the seedlings on the drilled pelleted and non-pelleted areas.

The final rainfall period effective enough for general seed germination began on September 24th with .15 inch. This was followed

---

6. Personal communications with Dr. H. Tucker, Statistician, University of Arizona.

Table 2. Duration of soil moisture at the 1/8-inch depth under three different seedbed conditions in 1962.

Periods of Available Soil Moisture*		
Cleared & Pitted Seedbeds	Cleared Seedbeds	Non-treated Seedbeds
July 26-Aug. 26**	July 26-Aug. 5	July 26-Aug. 3
Sept. 5-Sept. 18	Aug. 22-Aug. 26	Sept. 5-Sept. 6
	Sept. 5-Sept. 12	Sept. 9-Sept. 11

* Moisture was considered available when ohms resistance readings of soil moisture blocks were below 100,000 ohms (Bouyoucos, 1959).

** Dates are inclusive.

Table 3. Results of the 1962 plant counts from pelleted and non-pelleted Lehmann and Boer lovegrass seeds on the different seedbeds.

Seedbed Treatments and Species	Seeding Methods	Plant Counts Non-pelleted Aug. 7	Non-pelleted Oct. 20	Pelleted Aug. 7	Pelleted Oct. 20
		- - - - Plants Per Square Foot* - - -			
Lehmann lovegrass					
Cleared-pitted	Broadcast	.10	.02	.02	.05
Cleared	"	.00	.00	.04	.04
Untreated	"	.00	.00	.00	.00
Cleared-pitted	Drilled	.74	.61	.09	.15
Boer lovegrass					
Cleared-pitted	Broadcast	.00	.00	.00	.12
Cleared	"	.00	.00	.01	.02
Untreated	"	.00	.00	.00	.00
Cleared-pitted	Drilled	.08	.15	.03	.06

* Each numerical value represents the mean of forty 1 by 10 foot samples.

on September 25th and 26th with .08 and 1.54 inch, respectively (Table 1). Plant emergence began at the end of September, and the final plant count was made on October 20th. The results of this plant count are presented in Table 3 with the previous plant count.

These data showed that plants were generally few in number in all plots. Because of the few plants an analysis of variance was not run on all the data. However, there were sufficient data to run an analysis of variance, as a completely randomized block problem, on the drilled pelleted and non-pelleted Lehmann and Boer lovegrass plots (Table 4).[7] The mean separation was accomplished with the Duncan's multiple-range test (Steel and Torrie, 1960) and is presented in Table 5. These data indicate that on a cleared and pitted seedbed, emergence from drilled non-pelleted Lehmann lovegrass seeds is significantly better than from drilled pelleted Lehmann lovegrass seeds, drilled pelleted Boer lovegrass seeds, or drilled non-pelleted Boer lovegrass seeds. No significant differences were found between the latter three treatments.

The plants were again counted on the entire (1962) area at the close of the 1963 growing season. The results of this count indicated a plant population reduction of approximately 40 percent below the final 1962 count. It appears that the major factor in the plant reduction was the coalescence of plants rather than actual plant loss. Initially, these

---

7. Ibid.

Table 4. Statistical analysis of plant numbers from the cleared, pitted, and drilled plots seeded to pelleted and non-pelleted Lehman and Boer lovegrass seeds; October 20, 1962 plants count.

Source	df	ss	ms	F
Among replications	3	74,37.69	2,479.23	8.84**
Within replications	12	33,66.25	280.52	
Total	15	10,803.94		

**Indicates significance at the 1 percent level.

Table 5. Mean separation of plant numbers from the cleared, pitted, and drilled plots, by the Duncan's Multiple-Range Test; October 20, 1962. Plant count.

Treatment	Treatment Means in Plants Per Square Foot
Pelleted Boer lovegrass	.0825
Pelleted Lehmann lovegrass	.1500
Non-pelleted Boer lovegrass	.1525
Non-pelleted Lehmann lovegrass	.6125**

The standard error is .083 and the appropriate values for the comparisons at the 1 percent level are:

2	3	4
36.15	38.08	39.17

**Indicates significance at the 1 percent level.

plants emerged in scattered groups throughout the study area. During the seedling counts of the first year, each plant could readily be seen and counted. However, by the close of the 1963 growing season these groups of plants had grown together frequently making separation of individual plants impossible. This resulted in the counting of one plant where previously more than one plant had been counted.

It is of interest to note (Table 3) that no plants were ever found which germinated from the broadcasted pelleted seeds on the untreated seedbed. However, on cleared and pitted plots where competition from brush species was reduced and the non-pelleted seeds drilled to the proper depth, satisfactory stands of grass were obtained. This is of primary interest because pelleted seeds are supposedly designed for broadcasting on untreated seedbeds (Adams, no date).

The results of the 1962 study indicated that: (1) the number of plants resulting from broadcast pelleted lovegrass seeds was no greater than from broadcast non-pelleted lovegrass seeds; (2) the number of plants resulting from drilled non-pelleted Lehmann lovegrass seeds was greater than from broadcast pelleted and non-pelleted seeds; and (3) the number of plants resulting from drilled non-pelleted Lehmann lovegrass seeds was significantly greater than from drilled pelleted Lehmann lovegrass seeds, drilled pelleted Boer lovegrass seeds, or drilled non-pelleted Boer lovegrass seeds. In no case did broadcasting produce a satisfactory stand of grass.

The 1963 Study

The 1963 summer growing season was unique in the respect that most areas in the state received approximately 50 percent more precipitation than normal while this study area received approximately one and one-half inches less than the normal six-inch average.

The first appreciable amount of rainfall (.80 inch, Table 6) that produced a period of available moisture long enough to support seed germination (Table 7) fell on August 5th. However, this rainfall produced only a very small number of seedlings in selected areas where organic matter was present. The organic matter was the result of the clearing and subsequent covering of brush species during the clearing and/or pitting process.

The first rains effective enough for general seed germination began on August 22nd with 1.05 inch (Table 6). This rain was followed at fairly regular intervals by additional precipitation. Resistance readings of soil moisture blocks indicated that soil moisture was within the available range for seed germination at the 1/8-inch depth in all seedbeds from August 22nd to August 30th. Plant emergence began at the end of August and the first plant count was made on September 5th (Table 8).

The final rains effective enough for general seed germination did not occur until October 18th and 21st. Wedge-type rain gauges indicated that an additional inch of precipitation fell on the study area.

Table 6. Distribution of precipitation for the 1963 summer growing season.

Date	Daily Rainfall	Cumulative total
	- - - - - - - Inches - - - - - - - -	
June	0.00	0.00
July		
8	.20	.20
9	.08	.28
10	.05	.33
18	.05	.38
21	.18	.43
26	.03	.61
28	.04	.64
29	.08	.68
31		.76
August		
5	.80	1.56
10	.17	1.73
12	.12	1.85
15	.05	1.90
16	.47	2.37
17	.03	2.40
22	1.05	3.45
23	.32	3.77
26	.10	3.87
September		
3	.37	4.24
4	.11	4.35
15	.09	4.44

Table 7. Duration of soil moisture at the 1/8-inch depth under three different seedbed conditions in 1963.

Periods of Available Soil Moisture*		
Cleared & Pitted Seedbeds	Cleared Seedbeds	Non-treated Seedbeds
July 8-July 12**	July 8-July 12	July 8-July 12
July 27-Aug. 13	July 27-July 30	July 27-July 29
Aug. 22-Sept. 10	Aug. 1-Aug. 13	Aug. 1-Aug. 8
	Aug. 22-Sept. 7	Aug. 12-Aug. 13
		Aug. 22-Sept. 7

* Moisture was considered available when ohms resistance readings of soil moisture blocks were below 100,000 ohms (Bouyoucos, 1959).

** Dates are inclusive.

Table 8. The results of the 1963 plant counts from broadcasted and drilled pelleted and non-pelleted Lehmann lovegrass seeds on three different seedbeds.

Seedbed Treatment	Seeding Methods	Plant Counts			
		Non-pelleted		Pelleted	
		Sept. 5	Oct. 25	Sept. 5	Oct. 25
		- - - - Plants Per Square Foot* - - -			
Cleared-pitted	Drilled	1.35	.97	.20	.17
Cleared	"	.87	.75	.11	.13
Untreated	"	.26	.34	.05	.04
Cleared-pitted	Broadcast	.08	.16	.22	.15
Cleared	"	.06	.08	.11	.23
Untreated	"	.00	.16	.05	.06

* Each numerical value represents the mean of forty 1 by 10 foot samples.

Temperatures remained favorable for seed germination during the month of October and numerous plants emerged following these October rains. The final plant count was made on October 25th (Table 8).

The results of an analysis of variance[8] of the data from the final plant count are presented in Table 9. The only significant differences were found: (1) between seeding methods (broadcasting versus drilling) and (2) between the interaction of seeding methods and seed treatments (pelleted seeds versus non-pelleted seeds). Mean separation within the above mentioned areas of significance was accomplished with the least significant difference method (LSD) (Steel and Torrie, 1960). The results of this mean separation are presented in Table 10 and indicate that: (1) stands resulting from drilling were significantly better than those from broadcasting, (2) stands resulting from drilling non-pelleted seeds were significantly better than those from broadcasting non-pelleted seeds, (3) stands resulting from drilling non-pelleted seeds were significantly better than those from drilling pelleted seeds, (4) stands resulting from drilling pelleted seeds were not significantly better than those from broadcasting pelleted seeds, and (5) stands resulting from broadcasting pelleted seeds were not significantly better than those from non-pelleted seeds.

---

8. The analysis of variance of this problem was set up and processed by the Numerical Analysis Laboratory, University of Arizona.

Table 9. Statistical analysis of plant numbers from the broadcasted and drilled pelleted and non-pelleted Lehman lovegrass seeds on three different seedbeds; October 25, 1963.

Source	df	ss	ms	F
Replications	3	.7480	.2493	
Seed treatments	3	.8060	.8060	7.86
Error (a)	3	.3074	.1025	
Seeding methods	1	.9352	.9352	6.04*
Seeding methods Seed treatments	1	1.1781	1.1781	6.04*
Error (b)	6	.9296	.1549	
Seedbed preparations	2	.5050	.2525	2.55
Error (c)	6	.5951	.0992	
Seedbed preparations Seed treatments	2	.1459	.0730	0.63
Seedbed preparations Seeding methods	2	.1513	.0756	0.66
Seedbed preparations Seeding methods Seeding treatments	2	.1298	.0649	0.56
Error (d)	18	2.043	.115	
TOTAL	47	8.4767		

* Indicates significance at the five percent level.

Table 10. Mean separation of plant numbers by the LSD method (1) between seeding methods and (2) between seeding methods and seed treatments; October 25, 1963 plant count.

Seeding Method	Seed Treatment Means Pelleted	Non-pelleted	Seeding Method Means
Drilling	0.112	0.684	0.398
Broadcasting	0.146	0.092	0.119

Standard error and LSD values appropriate for the comparison:

1. Between seeding method means

   Standard error, 0.114

   LSD value 5%, 0.229; 1%, 0.423

2. Between two levels of seeding methods at one level of seed treatment

   Standard error, 0.161

   LSD value 5%, 0.394; 1%, 0.597

3. Between two levels of seed treatments at one level of seeding method

   Standard error, 0.131

   LSD value 5%, 0.235 and 1%, 0.649

DISCUSSION

The data obtained in this two-year study did not show that pelleted lovegrass seeds have any advantages in the revegetation of Southern Arizona rangelands. During both years the stand produced from broadcasting pelleted seeds was unsatisfactory, even on extensively prepared seedbeds. In fact, the earthen coating surrounding the seeds did not appear to be a substitute for placing the seed in the soil. In both years of this study, broadcasted pelleted seeds have failed to produce a significantly greater number of plants than broadcasted non-pelleted seeds. In any case, the number of plants resulting from broadcasting pelleted or non-pelleted seeds was too low and did not significantly increase with additional seedbed preparation. These data obtained in this study with broadcasting pelleted seeds parallels, essentially, the findings of Hull et al. (1963).

The number of plants resulting from drilled pelleted seeds was no greater than those obtained from broadcasted pelleted seeds. In both years of this study, drilled non-pelleted seeds produced more plants per square foot than the combined number of plants from broadcasted pelleted seeds, broadcasted non-pelleted seeds, and drilled pelleted seeds.

Previous studies indicated that the inability of pelleted seeds to produce a satisfactory stand of grass in this semi-arid region can probably be attributed to two factors: (1) the pelleted seeds require two to three days longer to germinate than non-pelleted seeds (Hull, 1959) and (2) the pelleted seeds do not provide adequate seed coverage (Gatherum, 1951). Either of these factors operating alone or both together could result in a shortage of moisture near the seed and unfavorable conditions for seed germination. A shortage of soil moisture during the summer growing season results primarily from: (1) unreliable precipitation, (2) low humidity, (3) high temperatures, and (4) prevailing winds. Under these climatic conditions, range soils tend to dry rapidly, especially on the surface. Therefore, seeds that are inadequately covered or seeds that require an additional two or three days to germinate would not be in contact with moist soil for a sufficient length of time for the germination process to occur. Therefore, satisfactory stands are difficult to obtain under these conditions.

In both years of this study, drilled non-pelleted Lehmann lovegrass produced the greatest number of plants on prepared seedbeds. Therefore, these results indicate that requirements for satisfactory stands of grass include: (1) the removal of competitive vegetation and (2) the drilling of an adaptable species of grass such as Lehmann lovegrass.

SUMMARY

Experimental work was conducted in the summers of 1962 and 1963 to evaluate the use of pelleted Lehmann and Boer lovegrass seeds in the revegetation of a shrub-dominated, desert grassland area. The experimental procedures consisted of broadcasting and drilling of pelleted and non-pelleted lovegrass seeds on the following types of seedbeds: (1) cleared, (2) cleared and pitted, and (3) untreated.

The results of these studies indicated that: (1) stands obtained from broadcasting pelleted lovegrass seeds were no better than those obtained from broadcasting non-pelleted lovegrass seeds, regardless of the amount of seedbed preparation; (2) stands obtained from drilling non-pelleted lovegrass seeds were better than those obtained from broadcasting pelleted or non-pelleted lovegrass seeds; and (3) stands obtained from drilling non-pelleted Lehmann lovegrass seeds were better than those obtained from drilling pelleted Boer lovegrass seeds, pelleted Lehmann lovegrass seeds, or non-pelleted Boer lovegrass seeds.

These studies did not indicate any advantages for pelleted seeds in revegetating depleted southern Arizona rangelands. In contrast, an acceptable stand of grass was obtained by: (1) the removal of competitive vegetation, and (2) the drilling of an adapted species of grass such as Lehmann lovegrass.

LITERATURE CITED

Adams, L. S. (No date). Pellet seeding. Universal Pellet Co., Tucson, Arizona. 18 p.

Anderson, D., and A. R. Swanson. 1949. Machinery for seedbed preparation and seeding on Southwestern ranges. Jour. Range Mgmt. 2:64-66.

_____________., L. P. Hamilton, H. G. Reynolds, and R. F. Humphrey. 1957. Reseeding desert grassland ranges in Southern Arizona. Univ. of Ariz. Agric. Exp. Sta. Bul. 249. 32 p.

Anonymous, 1940. Farming takes to the air. Popular Mechanics. 74:371-373, 120A.

_____________., 1948. New grass for the West. Life 25(16):85-86, 89.

_____________., 1949. Pelletized seed. Nature Magazine 43:144.

_____________., 1950. What's new in range research - pellet range seeding trials fail to live up to advanced publicity. Crops and Soils 2:25.

Barnard, D. M. 1949. An evaluation of pellet seeding as it applies to range land. Unpub. M.S. Thesis, Univ. of Wyoming, Laramie. 56 p.

Barnes, O. K. 1952. Pitting and other treatments on native range. Wyo. Agric. Exp. Sta. Bul. 318. 23 p.

_____________., D. Anderson, and A. Heerwagen. 1958. Pitting for range improvement in the great plains and the southwest desert regions. U.S.D.A., A.R.S., S.C.S., in cooperation with Wyo. Agric. Exp. Sta. Production Res. Report 23. 17 p.

Barnhill, O. H. 1946. Revolution in range reseeding. Amer. Hereford Jour. 36 (18):24.

Bleak, A. T., and T. A. Phillips. 1950. Seeding stands from airplane broadcasting of pelleted and unpelleted seed in southeastern Utah. Intermountain Forest and Range Exp. Sta. Res. Paper 22. 14 p.

Bleak, A. T., and A. C. Hull, Jr. 1958. Seeding pelleted and unpelleted seed on four range types. Jour. Range Mgmt. 11:28-33.

Bouyoucos, G. J. 1959. Taking the guesswork out of irrigation. Crops and Soils 11(10): 22-23, 39.

Bridges, J. O. 1941. Reseeding trials on arid range land. New Mex. Agric. Exp. Sta. Bul. 278, 48 p.

Burback, H. J. 1949. Range reseeding - no panacea for all conservation ills. National Wool Growers 39(1) :14-18.

Fleming, R. 1949. A new method for reseeding desert range. Crops and Soils 1(6): 6-9.

Flory, E. L. and C. G. Marshall. 1942. Regrassing for soil protection in the southwest. U.S.D.A. Farmers Bul. 1913. 60 p.

Gatherum, G. E. 1951. Pellet seeding on sagebrush range. Unpub. M. S. Thesis. Utah State Agric. College, Logan. 39 p.

____________., 1961. Pellet seeding on sagebrush range. Jour. Range Mgmt. 14:160.

Gleason, C. H. 1944. Directions for sowing mustard for erosion control in burned areas of southern California. U.S.D.A. Forest Service and Calif. For. and Range Exp. Sta. For. Res. Note 37. 32 p.

Gould, F. W. 1951. Grasses of Southwestern United States. Univ. of Ariz. Biol. Sci. Bul. 7, 343 p.

Greening, G. K. 1941. Climate of Arizona <u>In</u>: Climate and man, the 1941 yearbook of agriculture. p. 761-772.

Haystead, Ladd. 1945. The farm column - 20,000 acres per hour. Fortune 31(6): 166-168.

Henry, H. H. 1947. Seeds away. Amer. Forests 53(3): 120-121, 139-140.

Hitchcock, A. S. 1951. Manual of the grasses of the United States. U.S.D.A. Misc. Pub. 200. 1051 p.

Hull, A. C. Jr., and G. Stewart. 1948. Seeding southern Idaho rangeland by airplane. Intermountain Forest and Range Exp. Sta. Res. Paper 16. 14 p.

Hull, A. C. Jr. 1959. Pellet seeding of wheatgrasses on southern Idaho rangelands. Jour. Range Mgmt. 12:155-163.

___________., R. C. Holmgren, W. H. Berry, and J. A. Wagner. 1963. Pellet seeding on western rangelands. U.S.D.A. and U.S.D.I. Misc. Publ. 922. 34 p.

Humphrey, R. R. 1958. The desert grassland. Univ. Ariz. Agric. Exp. Sta. Bul. 299. 62 p.

___________., 1959. Lehmann's lovegrass, pros and cons. Univ. Ariz. Agric. Exp. Sta. and Extension Service Spec. Report No. 2. 28 p.

Kearney, T. H., and R. H. Peebles. 1951. Arizona flora. Univ. Calif. Press, Berkeley and Los Angeles. 1085 p.

Killough, J. R. 1950. Restoring the range by airplane. Jour. Range Mgmt. 3:33-41.

Lloyd, R. D. and C. W. Cook. 1960. Seeding Utah ranges. Utah Agric. Exp. Sta. Bul. 423. 19 p.

MacGillivray, J. H. 1953. Vegetable production. The Blakiston Co., New York. 397 p.

Mahoney, M. 1946. Sky planting in the desert. Travel 87 (5) : 5-8, 30.

Mark, F. A. and J. R. Roaf. 1941. Range reseeding by airplane. Soil Conservation 6:270-272.

Moomaw, J. C. 1951. Some effects of pelleting on seeds of range forage species. Unpub. M. S. Thesis, Univ. Idaho, Moscow. 63 p.

___________., E. W. Tisdale, L. A. Sharp, and K. P. Platt. 1954. Studies of pelletized seed for range reseeding. Univ. of Idaho Forest, Wildlife, and Range Exp. Sta. Res. Note 11. 10 p.

Norris, J. J. 1950. Effects of rodents, rabbits, and cattle on two vegetation types in semi-desert rangeland. New Mex. Agric. Exp. Sta. Bul. 353. 23 p.

Pearse, K. C. and A. P. Plummer. 1948. Restoring the range by reseeding. In: Grass - the 1948 yearbook of agriculture. p. 227-233.

Pingrey, H. B. and E. J. Dortignac. 1957. Cost of seeding northern New Mexico rangelands. New Mex. Agric. Exp. Sta. Bul. 412. 43 p.

Price, R., K. W. Parker, and A. C. Hull, Jr. 1948. Improvement through reseeding. In: Grass, the 1948 yearbook of agriculture. p. 564-568.

Reynolds, H. G. 1959. Range reseeding practices in Arizona. Univ. of Ariz. Agric. Exp. Sta. and Extension Service Spec. Report No. 2. p. 26-27.

Ross, R. 1948. Seeds are sown by airplane. Science News Letter 53:298-299.

Rudolf, P. O. 1949. Pelleted seed for reforestation. Lake States Forest Exp. Sta. Misc. Report 5. 13 p.

__________., 1950. A test of pelleted jack pine seed. Jour. of Forestry 48:703-704.

Schwendiman, J. L. 1955. Succeed with range seeding. Crops and Soils 7(6):9-11.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481 p.

Stewart, G. 1949. Range reseeding by airplane compared with standard ground methods. Agron. Jour. 41:283-288.

__________., L. A. Stoddart, H. J. Burback, J. A. Libby, R. L. Wrigley, D. M. Gaufin, and R. A. Roundy. 1951. Recommendation for range reseeding in Utah. Utah State Agric. Ext. Bul. 212. 12 p.

Tisdale, E. W. and K. B. Platt. 1951. Pellet reseeding trials on southern Idaho range lands. Univ. of Idaho Forest, Wildlife, and Range Exp. Sta. and U.S.D.I. Spec. Res. Report - Project 16. 23 p.

Towne, C. W. 1946. Foolproof seeds are on the way. Sat. Eve. Post 219 (14): 6.

Wagner, J. A. 1949. Results of airplane pellet seeding on Indian reservations. Jour. of Forestry 47:632-635.

Wagner, J. A. and C. P. Kinkor. 1950. Will pellet seeding work? American Forests 56:25, 44-45.

Wheeler, W. A. and D. D. Hill. 1957. Grassland seeds. D. Van Nostrand Co., Inc., New York. 734 p.

Winter, W. 1947. Bombing the desert with pellets. Popular Mechanics 88:165-168.