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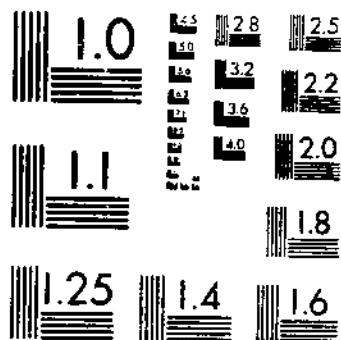
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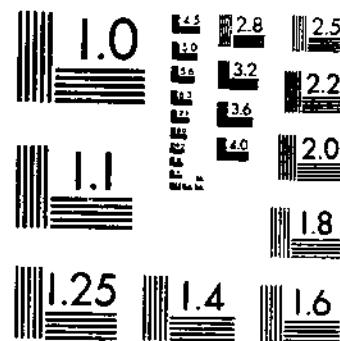
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DEVELOPMENT OF FIELD RESEARCH EQUIPMENT AND EVALUATION OF METHODS OF
HUNT, D. J., HULBURT, W. C., WAGNER, R. E. 1 OF 1

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Development of Field Research Equipment and Evaluation of Methods of Establishing Forage Crops

Development

1971

Forage Crops Research Laboratory

Technical Bulletin No. 1279

Agricultural Research Service
UNITED STATES
DEPARTMENT OF AGRICULTURE

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DEVELOPMENT OF FIELD RESEARCH EQUIPMENT AND EVALUATION OF METHODS OF ESTABLISHING FORAGE CROPS

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Introduction

Forage crops production practices, including methods of establishment, have undergone considerable change since 1950. Production has been increased greatly through the use of improved species, improved management and utilization practices, and increased and more efficient use of fertilizers. However, the full effectiveness of these improved practices frequently has been limited by inefficient methods of establishment.

Seeding and establishment failures with forage crops are probably more commonplace than are successes. Such failures in the past have been accepted with very little concern. Had such failures been as prevalent in so-called cash crops, they would have caused major concern. The increased interest in grassland farming and animal production and the increasing importance of economic production of these crops have focused attention on the importance of good stand establishment.

The losses in seeding failures with forage crops include: (1) Cost of seed and fertilizer, (2) cost of land preparation, (3) loss of important feed, (4) necessity for producing emergency crops, and (5) disruption of production plans and rotations. Other losses may be sustained that cannot be measured in direct monetary value, such as soil erosion and loss of fertility and humus from the soil. All are of major importance because they reduce profits.

Forage species generally are extremely slow in development, which makes establishment much more difficult than with other crops. Most field crops can be seeded, grown to maturity, and harvested while some of the pasture grasses and legumes are still becoming

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established. For this reason any seeding practice that speeds up emergence and development of the seedling usually improves the chances of success of the seeding.

Several factors may be responsible for seeding failures in forage crops and pastures. Some of these, such as improper soil preparation, inadequate amount and incorrect placement of fertilizer, infestation by insects and diseases, poor seeding practices, and weed competition, can be controlled directly through improved practices. Drought, one of the major causes of seeding failures, cannot be controlled directly; however, through improved seeding practices, this important seeding hazard can be materially lessened.

Some of the principles for successful establishment of forage crops have been recognized for a long time. Thorough seedbed preparation, including the proper compaction of the soil both below and above the seed, is necessary for normal emergence of most crop seeds. Firmness of the soil in the immediate vicinity of the seed is important in obtaining good germination and in promoting early plant growth. The seedbed should be firm enough in the seed row to give good seed-to-soil contact, to supply a solid base for the pressure needed for emergence, and to minimize moisture losses; yet it should be loose enough for aeration, root penetration, and water infiltration. Good fertility and depth of placement of seed are also of paramount importance.

Although many of the principles for successful seeding were recognized, the seeding methods most commonly used did not achieve these principles effectively. The conventional and most widely used method of seeding pasture and hay crops for many years has been broadcasting seed on top of the prepared seedbed and rolling or packing, usually with some type of corrugated roller. Fertilizer, when used, was broadcast and harrowed in before seeding. The broadcast method of seeding has several disadvantages: (1) Usually not more than one-third of the seed is placed at the proper depth—part of it is placed too deep, part too shallow. (2) Although compaction may be adequate, the seedbed tends to dry out faster than individually compacted furrows. (3) Compaction of the entire seedbed is conducive to weed emergence. Broadcasting fertilizer also has disadvantages. (1) Much of the fertilizer may be inaccessible to the young seedlings, since their root systems are very limited. (2) Weed seedlings throughout the seedbed have as much access to the fertilizers as the forage seedlings and respond accordingly.

The experiments reported here were designed to study various methods of seeding and to develop a method or methods that would effectively utilize most of the principles conducive to successful establishment.

Review of Literature

Methods of establishing forages underwent relatively little change and improvement until the early 1950's. Prior to that, recommendations were usually for broadcasting seed and fertilizer on a prepared seedbed. Drill seeding of forage crops has been practiced to a limited extent but, in most instances, in combination with broadcast fertilizer. The advantages of good seedbed preparation, compaction, and fertility were recognized, but research prior to the 1950's did very little to improve existing seeding methods and to better utilize these recognized principles. Thatcher, Willard, and Lewis (18),³ in 1937, stated

³ Italic numbers in parentheses refer to Literature Cited, p. 53.

that "it seems clear that failures in obtaining stands are becoming more frequent with each decade." They attributed this to the fact that soils are becoming more depleted of fertility and organic matter. It is, therefore, becoming increasingly more important to provide suitable conditions for establishment.

Thatcher, Willard, and Lewis (18) discussed the many factors involved in successful seeding of forage species. They presented a very thorough discussion of the advantages and disadvantages of various practices. Their discussion, however, did not include band seeding.

Species competition is also of considerable importance in the establishment of forage crops. Blaser and coworkers (2, 3, 4) have conducted rather extensive studies dealing with the factors involved in seedling competition and the advantages and disadvantages of various species mixtures.

Band placement of fertilizer has been used in row-crop production for many years. Possibly because of the almost exclusive practice of establishing forage crops by broadcasting, the advantage of band placement of fertilizer was not recognized. Cook and Millar (6) in experiments on legume fertilization noted a definite response of alfalfa seedlings directly over fertilizer rows as compared with those seedlings between the fertilizer rows. This response was attributed to the promptness with which the roots came in contact with the fertilizer when the plants were directly over the fertilizer band.

Nelson (15) discussed the factors affecting fertilizer placement and listed the advantages most frequently ascribed to band placement as follows:

1. Less reversion of nutrients into relatively unavailable forms through restricting the contact of the fertilizer with the soil.
2. The bands can be placed so that the nutrients are positionally available to the plant roots.
3. Early plant growth frequently can be stimulated.
4. The fertilizer can be placed at depths where it will most likely be in moist soil.
5. Less of the fertilizer nutrients is taken up by weeds.
6. Applied nutrient losses from wind and water erosion are minimized.

The term "band seeding" as applied to forage crops was used by Haynes and Thatcher (11) in field trials, started in 1948, on methods of seeding legumes. The principles of band seeding had been employed previously in various modifications with other crops. Band seeding, as presently used, refers to the placing of the legume or grass seed directly above but not in contact with drilled bands of fertilizer. Haynes and Thatcher (9, 10, 11) and Davis and Haynes (7) found that band seeding of legumes gave better stands and more vigorous seedlings than broadcast methods. They found that when the seed was placed $1\frac{1}{2}$ inches directly above the bands of phosphorus and potash the legume seedlings made excellent growth, but when the seed was placed even $\frac{1}{2}$ inch to the side of a band it acted as unfertilized seed. Their work also indicates the importance of phosphate fertilizer in legume establishment.

Tesar, Lawton, and Kavin (17) conducted studies to determine the efficiency of four seeding methods for alfalfa and birdsfoot trefoil on three soil types. In nine field tests band seeding resulted in 22 percent more seedlings than broadcast seeding. Band seeding also resulted in more vigorous seedlings than broadcast seeding. In only one out of six experiments, the placement of seed 1 inch to the side of the fertilizer band resulted in more seedlings than placement of seed directly over the band of fertilizer.

Tesar, Lawton, and Kawin (17) also conducted greenhouse studies with radioactive phosphorus in an effort to explain the superiority of band seeding in field tests. This study showed that, within 1 month after seeding, alfalfa seedlings 0, 1, 2, 3, and 4 inches away from fertilizer placed $1\frac{1}{2}$ inches deep received 98, 66, 15, 3, and 0 percent, respectively, of their phosphorus from the fertilizer. Two months after seeding, percentages of phosphorus obtained from fertilizer for the five distances were 77, 62, 50, 24, and 7, respectively. Further studies by these workers showed that alfalfa seedlings 1 and 2 inches away laterally from the fertilizer placed $1\frac{1}{2}$ inches deep produced only 80 and 60 percent as much topgrowth, respectively, as seedlings directly over the band. The phosphorus percentage in alfalfa directly over the band was 80 percent higher than in alfalfa 4 inches away from the band of fertilizer. These studies clearly support the findings of all the field experiments. They demonstrate the importance of fertilizer and its proper placement in the development of the young seedling.

Many studies similar to those previously mentioned have resulted in similar conclusions (5, 12, 16). These studies, conducted in most of the Northeastern States and in some of the Southeastern States, and the work at Beltsville, Md., have generally indicated that the advantages of band seeding are: (1) Better stands of forage can be obtained with less seed; (2) seedlings are more vigorous and better able to withstand adverse environmental conditions; (3) weed populations are significantly lower; (4) more leeway in time of seeding; and (5) higher production and earlier use of pastures. This bulletin is a summarization of the forage-establishment studies conducted at Beltsville, Md.; part of the results has been previously published (1, 12, 13, 14, 20, 21, 22).

Design and Development of Special Equipment for Experiments

In the winter of 1950-51, the Chief of the Bureau of Plant Industry, Soils, and Agricultural Engineering¹ created a special committee to formulate a research program on the establishment of pasture and hay lands (12). Up to this time little or no special equipment for field experiments had been designed and constructed by research engineers on this major crop.

Review of the few early experiments reported on grassland-establishment studies reveals that the planting and fertilizing treatments were conducted by production-line field machines. In some of these early studies, some minor alterations were made in the implements to meet possibly one or two treatments, but usually the limitations of the field machine determined the treatments to be used in the experiment. To approach the problem of grassland establishment in a more scientific manner, the factors apparently controlling the establishment of the plant or crop are first evaluated and from this analysis the various avenues of investigation are set up. The treatments are selected on a biological basis rather than decided by mechanical or field-equipment capabilities or limitations. Upon further study after this planning stage, some of the new methods or treatments outlined may be found impracticable or almost impossible to accomplish by mechanical means.

¹ Now a part of the Agricultural Research Service.

In such cases it may be necessary to resort to some arbitration that may possibly reduce the desired data from that expected in the original treatment. However, the adjusted treatment may still yield useful data on the subject.

With this in mind by the original framers of the program, precision equipment and methods of handling the field plots were of high priority. When the first study in the Bureau had been tentatively agreed upon by the scientists and engineers, it was the responsibility of the research engineers to provide equipment and field conditions to control the mechanical variables within the experimental-error limits of the field study. The construction of suitable and reliable equipment for studies of this nature requires considerable time and effort. Even after the first item or special machine has been provided and used in the field, many refinements or possibly complete revision of the equipment may be required as the seasons progress. This study was no exception. To meet the first three experiments scheduled in 1951, one of the Engineering Division's special machines used to study planting and fertilizing methods on vegetables and other row crops was adapted to grassland planting (figs. 1 and 2).

The F-32 special drill metered fertilizer fairly accurately and placed the material in a broadcast pattern by directing streams of fertilizer on half cones on a spreading board or in narrow bands by means of a series of double-disk openers. These openers were mounted on a gang so that fertilizer could be placed in contact with the seed or in a continuous band 1, 2, or 3 inches below the seed row, 1, 2, 3, or 4 inches to the side of seed row, or a combination of side and below placements. For the first grassland plots seven openers 8 inches apart were used.

After the first season (1951) the need for a complete new machine for the program was foreseen. Figure 3 shows one of the first special machines (F-54) provided primarily for research in the establishment of grassland.

The F-54 drill was designed and constructed at the Agricultural Engineering Laboratory at Beltsville, Md., in the fall and winter of 1951-52. One new technique developed along with the equipment was the straddling of the plot area with both equipment and power units. Plots approximately 5 feet wide and 20 or more feet long were found quite satisfactory for experiments on grassland crops. Tractors with front and rear wheels set 6 feet apart (wheels on F-54 were also 6 feet on centers) were used; with these the plots could be treated for their respective replications by merely straddling the intervening plots without altering the ground conditions. Companion tillage equipment was also provided for the rear three-point hitch of the tractor so that intertillage operations, such as mixing broadcast fertilizer in the soil, could be done without disturbing neighboring plots. Spike-tooth, spring-tooth, and disk harrows, weeders, corrugated rollers, and land levelers were obtained or altered to handle the 5-foot beds without affecting adjacent plots.

The special grassland drill was made to dispense fertilizer and seed much more accurately and uniformly than the farm field machines. These refinements were made not as a means of showing that field machines can be improved but more to place the level of accuracy high enough in the various operations in grassland establishment so that the small plot may be safely considered representative of the rates and placements given in the treatments in the outline of the

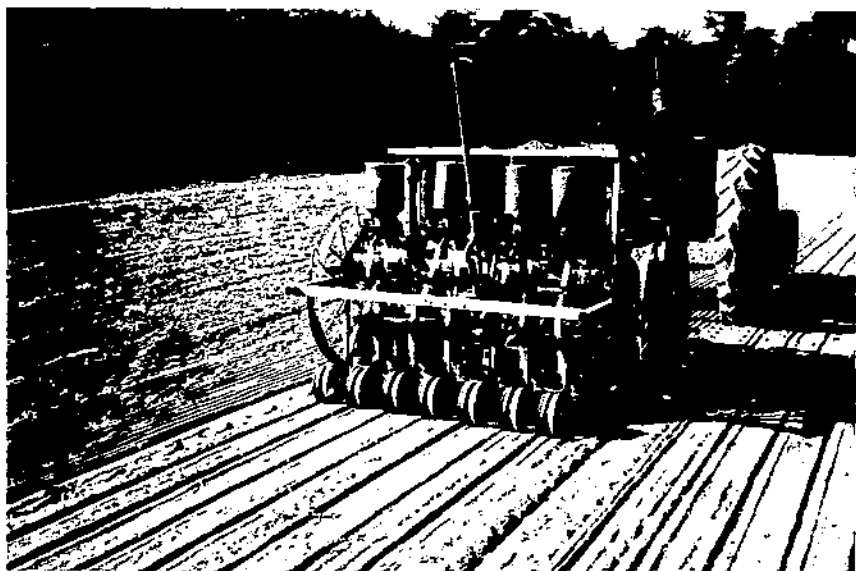
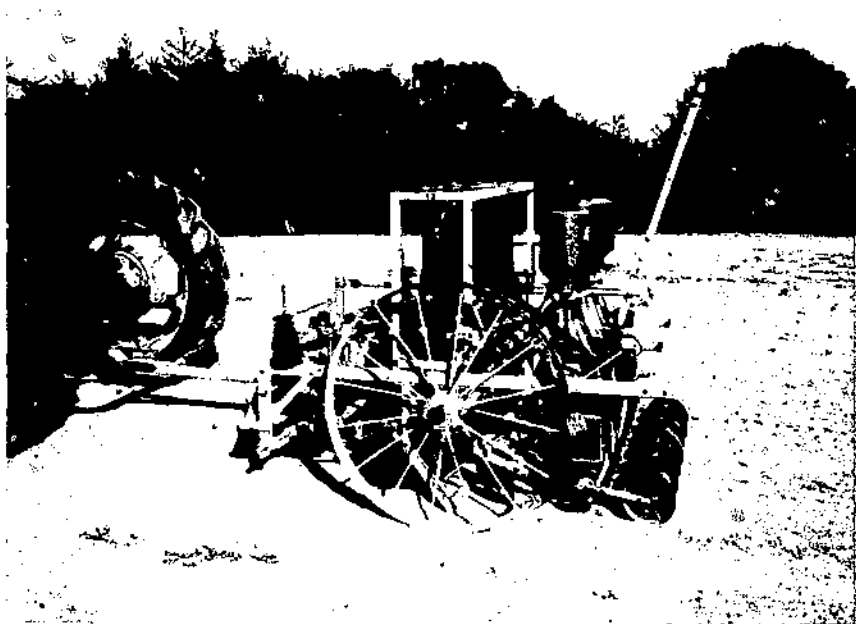


FIGURE 1.—Side and back views of U.S. Department of Agriculture special placement drill No. F-32 adapted to grassland establishment equipment, 1951. The four upright hoppers at the front metered fertilizer to double-disk openers for drilling (continuous bands) or directed the fertilizer on spreading cones for broadcast application. The four seedboxes directly in back of these, with two spouts each, metered legume seed. The seedboxes on the ground seeding units metered the grass seed.

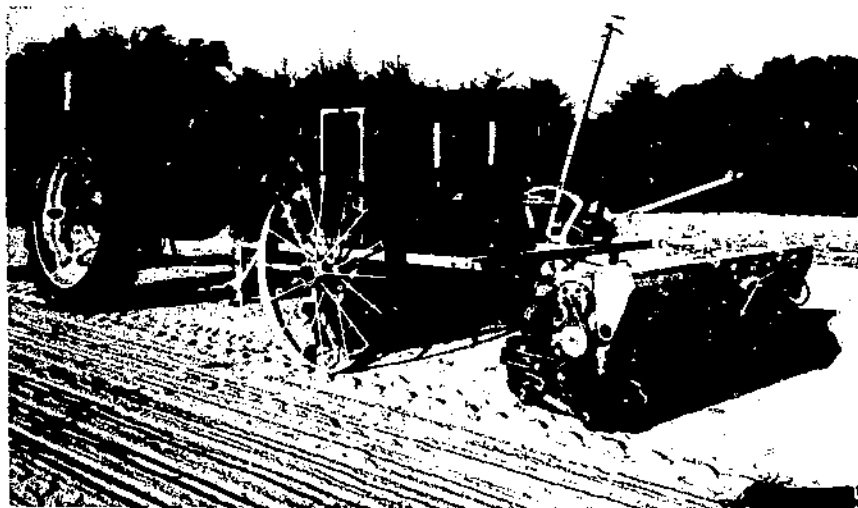


FIGURE 2.—U.S. Department of Agriculture special placement drill No. F-32 with a corrugated roller attached by a special hitch. This was used for banding fertilizer and broadcasting seed in grassland-establishment experiments at South Carolina and Alabama experiment stations, in 1951.

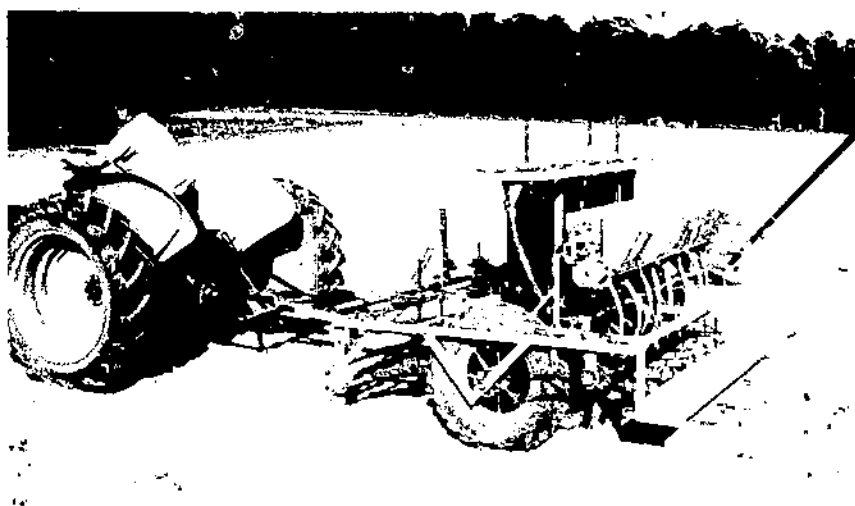


FIGURE 3.—U.S. Department of Agriculture grassland drill No. F-54 used for the first planting in the field experiments; on bahiagrass, Tifton, Ga., March 1952. The seedboxes included one for small seed (fluted external) and one for large seed (sliding sleeve adjustment of seed openings with reel agitator). The seeds were directed to a single-disk opener or broadcast spreader through clear-plastic tubes.

experiment. In addition, means of calibrating the hoppers and changing rates were made to save time, which was accomplished by permitting the calibration to be done quickly and with a minimum of trial-and-error operations. For example, the revolving cylinder top-delivery hoppers were used to effect a positive calibration of

fertilizer rates. This type of fertilizer hopper is driven by a ground wheel sprocket-chain drive. The rates of application are varied by slowing down or speeding up the turning of the hopper in relation to the ground wheel. This is done by changing the size of sprockets in the drive, which, in turn, changes the relative rate of volume discharge of the hopper. The proper sprocket combination is quickly calculated by use of one formula and a calibration chart. If the weight-volume relationship of the particular fertilizer to be used in the study and the row width each hopper serves are known, the rate setting, in pounds-per-acre can be quickly determined by using the formula and chart. This is made possible (which is almost unknown on farm equipment) by formulating a calibration chart based on the particular train drive of the hoppers on the special machine. An example of one of the calibration charts developed and formulated for the special grassland drill by the research engineers is shown in figure 4.

The F-54, in comparison with the F-32 adapted drill, had much more flexibility in broadcast placement of fertilizer and seed. The F-54 was designed to broadcast fertilizer and seed individually or simultaneously or place the two in the seed boot for contact placement. To broadcast the material, a small rigid tube was mounted 6 to 10 inches above the ground for each discharge tube; at the bottom of the small tube was a small half dome or cylinder that dispersed the material in an 8-inch band. Eight spreaders were mounted beside the fertilizer openers in the front, and, likewise, eight spreaders were mounted back of the seed openers. By shifting the discharge tubes from the disk openers to the spreader tubes, it was possible to compare banding treatments with broadcasting treatments definitely at the same rate of application. Often the mechanical spreading for the broadcast treatments of fertilizer and seed was much more uniform on the surface of the plot than hand spreading—a method that has been used for many years on plot work.

Possibly the most notable weaknesses of the F-54 were the lack of control of soil compaction around the seed and the inability to control the uniformity of seed depth. Uniformity of metering fluffy seeds was poor. One of the first refinements was the addition of a press wheel in back of the seed openers (fig. 5). This seed-firming wheel had a twofold objective as it was used as a gage wheel for controlling depth of the seed as well as to firm the seed in the soil.

The press wheels' distance back of the seed openers was adjustable from a few inches to 1½ feet. However, their use as gage wheels, at times, seemed to result in unequal planting depth. This was particularly noticeable in shallow planting, such as from ¼- to ½-inch depth. A small land leveler (as described later) helped some, but its use was not desirable on some types of soils. Consequently, the next step was to make the vertical position of the press wheel independent of the seed opener. To do this, the press wheel drag bar was pin-connected, rather than rigidly connected, to the seed opener. Lift rods and pressure springs were connected to the upper part of the frame holding the press wheel. To improve uniformity of depth of seed, gage wheels (6-inch diameter, 1½-inch flat surface) were mounted beside the disk openers. With this new arrangement seed could be planted with fairly uniform depth and firmness in the soil. Figure 6 shows this new arrangement and the various types of press wheels that were made to fit this machine.

Grassland Drill for Prepared Seedbed - Machine No. Pol-64

$$\text{REV} = \frac{\text{Rate} \times \text{width} \times 18.37}{(\text{Gage weight}) \times (\text{Drive wheel revolutions in 100 feet})}$$
$$\text{Number of teeth on ring gear} = \frac{\text{Rate X width X length}}{(\text{Gage weight}) \times 15.6}$$
[illegible]

FIGURE 4.—An example of a chart devised to give quick and positive calibration of the fertilizer metering device. (Only partial data shown.)

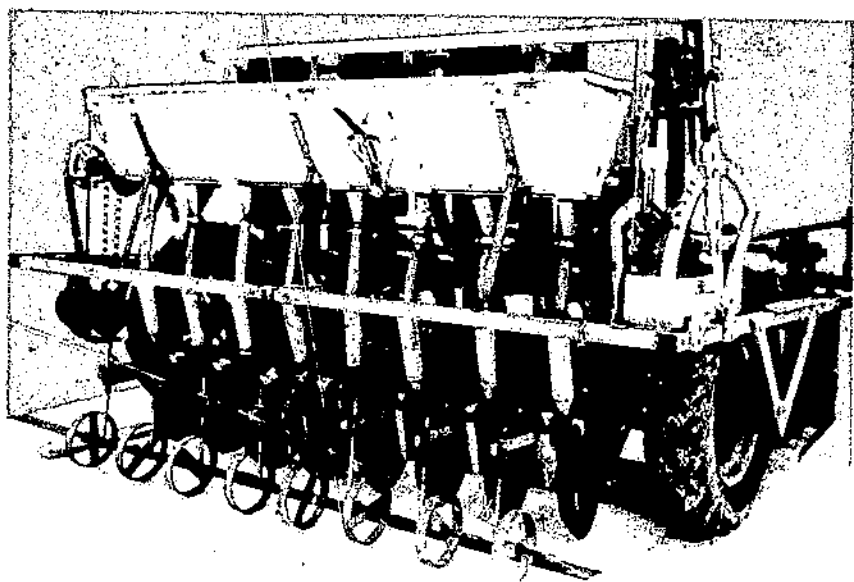


FIGURE 5.—U.S. Department of Agriculture grassland drill No. F-54 with addition of press wheels, which also acted as depth-gage wheels for the seed openers.

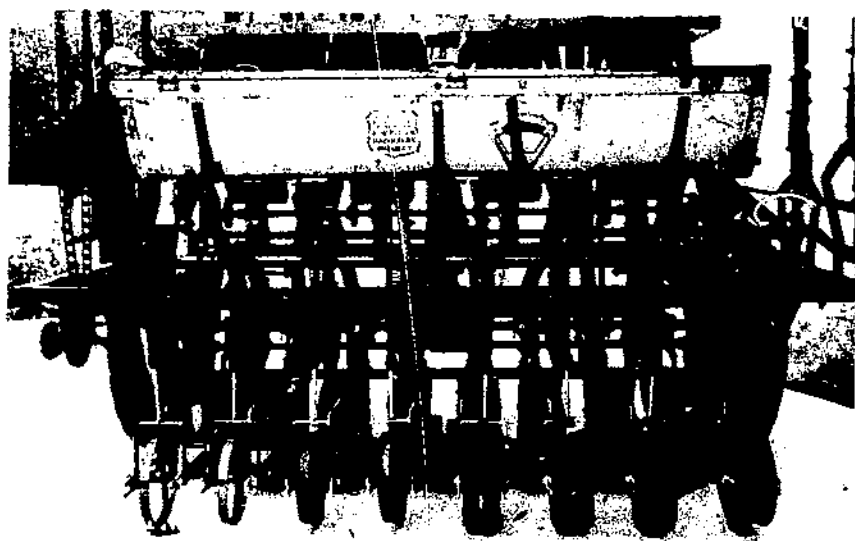


FIGURE 6.—U.S. Department of Agriculture grassland drill No. F-54 with flexible press-wheel arrangement from the seed opener. (Left to right) Narrow-flat, narrow-bevel, open-double, closed-double press wheels. Note the small 6-inch gage wheels to the side of the seed openers.

The narrow-flat press wheel firmed the soil quite well around the seed. However, when the soil had good moisture, the leveling bar in back of the fertilizer openers did not fill adequately the V-shaped opening left by the disks and the final position of the seed row often

was a narrow recessed trench. A dashing rain shortly after emergence of the seedlings was a hazard to the stand. Consequently, a set of double press wheels was mounted back of the double-disk fertilizer openers. These wheels brought soil into the opening and packed the soil after placement of the fertilizer. This action gave a uniform firm seedbed for the following operation of seed placement. Figure 7 shows the side view of the F-54 drill (left wheel removed) with the double press wheels for fertilizer openers at *e* and the press wheel for seed-furrow openers at *h*. Figure 8 gives a general view of the field operations at outlying cooperative experiments.

Figure 9 shows a closeup view of the soil conditions left after band seeding with one of the special grassland drills.

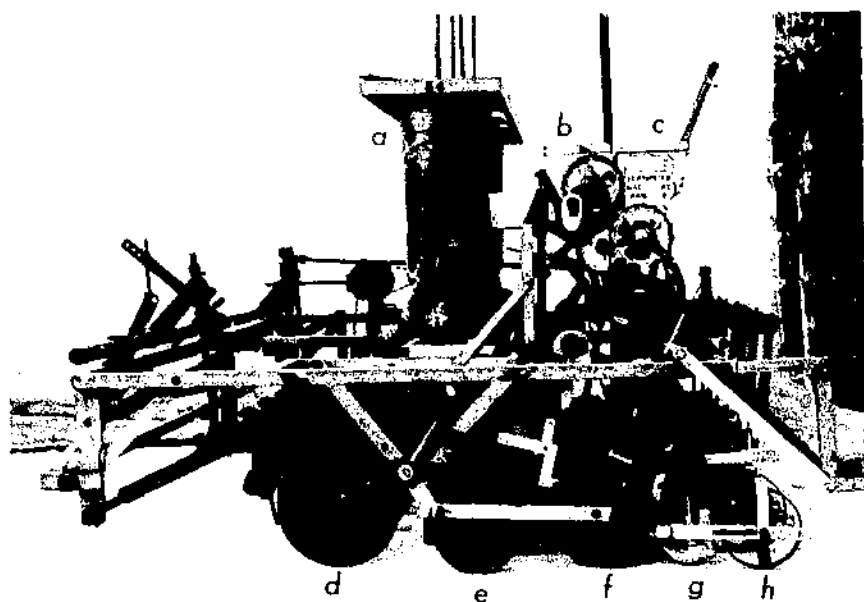


FIGURE 7.—U.S. Department of Agriculture grassland drill No. F-54 with left wheel removed to show parts of this special drill: *a*, Top delivery fertilizer hoppers; *b*, seedbox (small seed); *c*, seedbox (large, fluffy seed); *d*, double-disk fertilizer opener (mounted on parallelogram drawbar); *e*, double press wheels (on single bar); *f*, flat single disk for seed (mounted individually and with gage wheel on convex side); *g*, small runner for shallow seeding (for legumes); *h*, open-narrow press wheel which, under good soil conditions, deposited loose soil over seed firmed in the soil (to reduce soil crustation).

The success of the seed press wheel to operate as a gage wheel depended greatly on the flatness of the seedbeds. Also, the fertilizer openers in the front on F-54 were mounted rigidly on a single bar; hence, the flatness across the 5-foot beds was important for uniform placement of fertilizer. Consequently, a small land leveler was devised for the 5-foot plots. This equipment was used on the 3-point hitch of a tractor; thus, it was flexible for plot work and small enough for transporting to outlying field experiments. Figures 10 and 11 show this special tillage tool in use and means of transporting special equipment to cooperative field experiments.

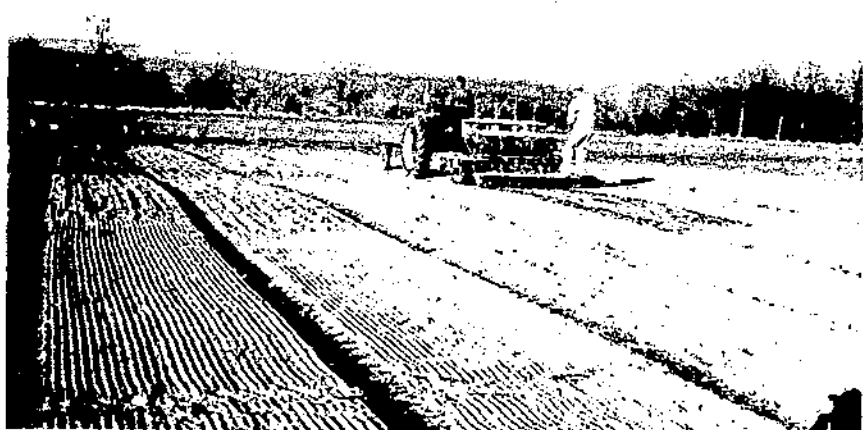
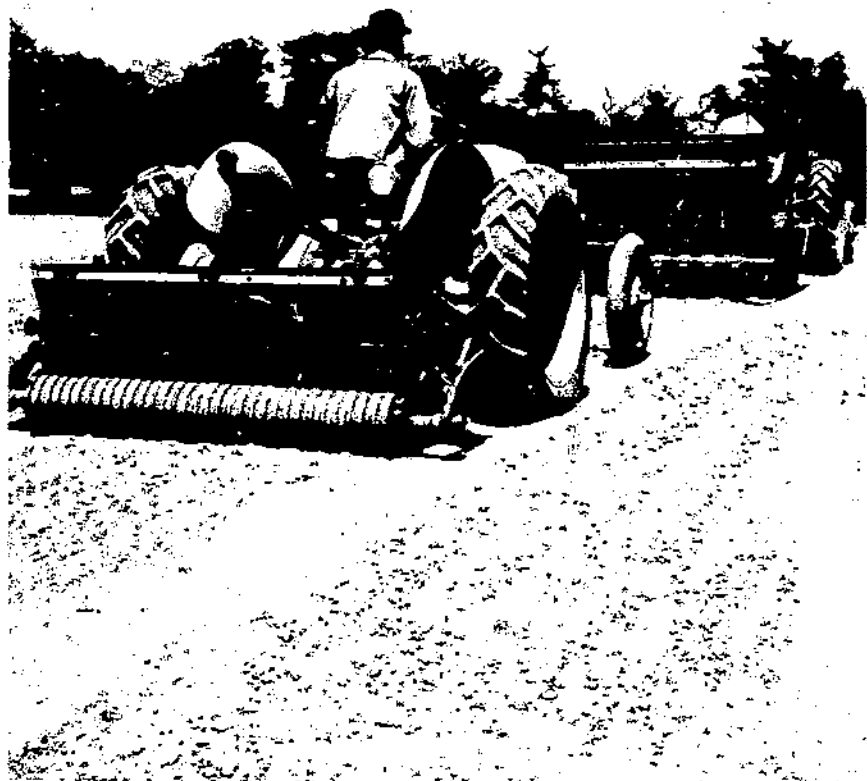


FIGURE 8.—The U.S. Department of Agriculture grassland drill No. F-54 in use in Ithaca, N.Y. (upper), and Storrs, Conn. (lower), on cooperative field experiments in 1954. On the Ithaca plot, the fertilizer was banded with the special drill and the seed drilled by a "common method" with the rear tractor.

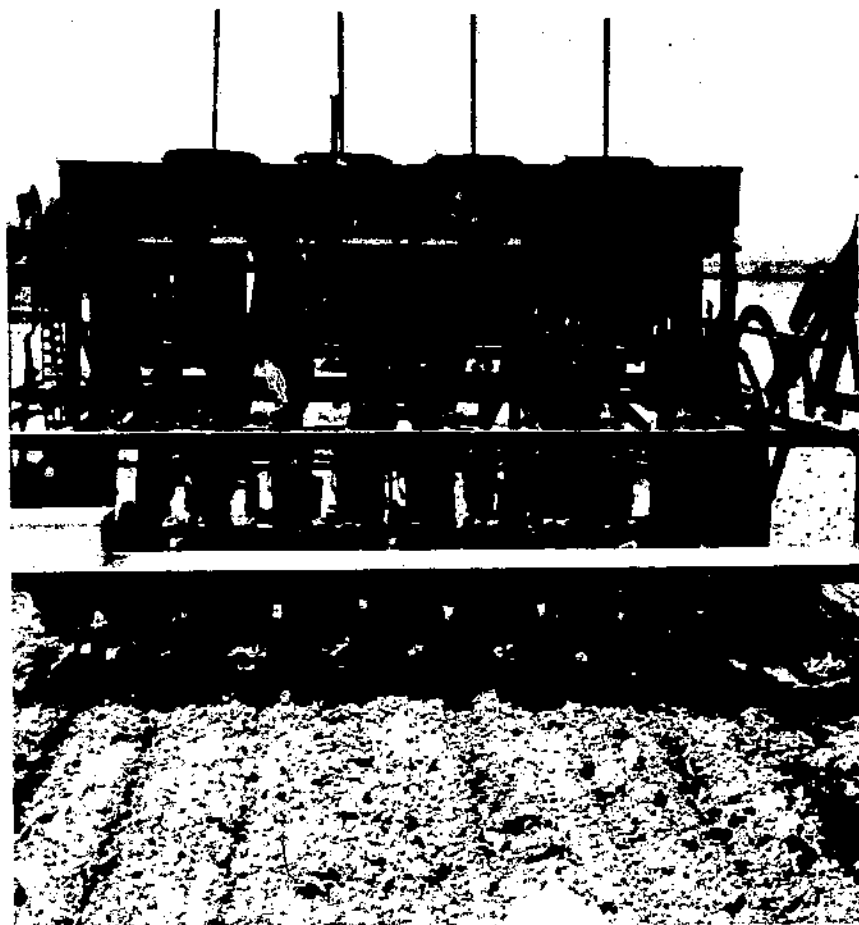


FIGURE 9.—Back view of U.S. Department of Agriculture special grassland drill in use. Soil is loose and friable after careful placement of fertilizer and firming of the seed with this drill. Loose soil and low fertility in the middles discourage weed competition.

The leveler worked well on many soils, but on the lighter soils the flat tail plate pulverized the soil considerably. (A finely granulated, but not a finely pulverized, soil is desirable for a forage-crop seedbed.) In reviewing this action with the cooperating soil scientists, it was felt that some grassland drills made for research should have independent vertical action of fertilizer openers and press-gage wheels as well as the seed openers and press wheels; thereby, the leveler would not be needed.

Consequently, a second grassland drill (F-55) for research was designed in 1954 and completed in 1955. The F-55 drill (fig. 12) had the following features that differed from the F-54. Each double-disk opener for the fertilizer depositors had individual lift rods and pressure springs. On each opener was a double press wheel that was adjustable vertically with a threaded crank and thereby also

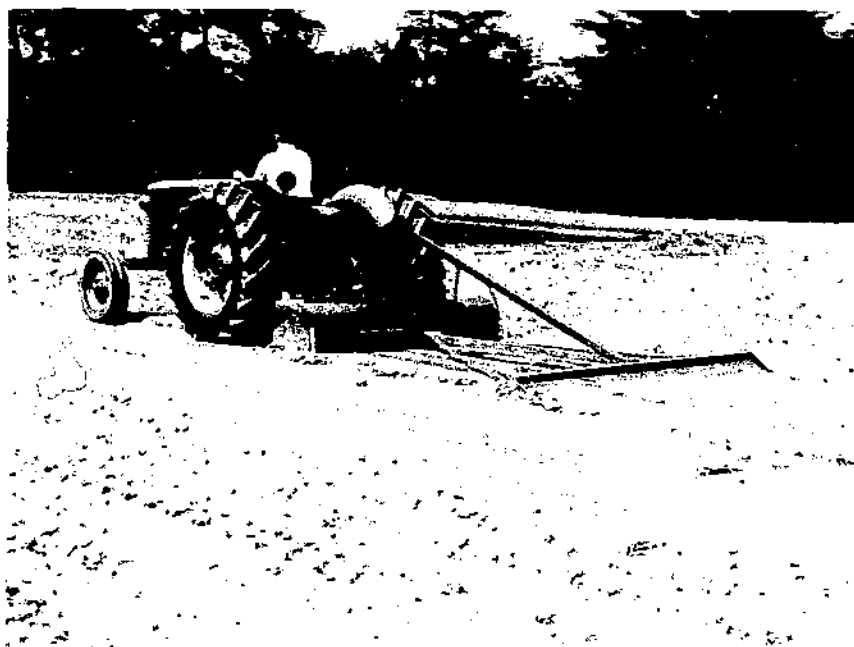


FIGURE 10.—Land leveler in use shaping plots for grassland-establishment experiments.



FIGURE 11.—U.S. Department of Agriculture grassland drill No. F-54 with land leveler and corrugated roller-seeder on truck as returned to Beltsville, Md., from cooperative field experiment at Clemson, S.C., October 1953.

acted as a gage wheel for fertilizer depth. Each opener penetrated the soil the distance its press wheel permitted, regardless of position of other openers. Two seedboxes replaced the grass seedbox. Both handled trashy seed and small grains and corn. The seed-metering unit was an adjustable internal-run seed wheel with a special throat

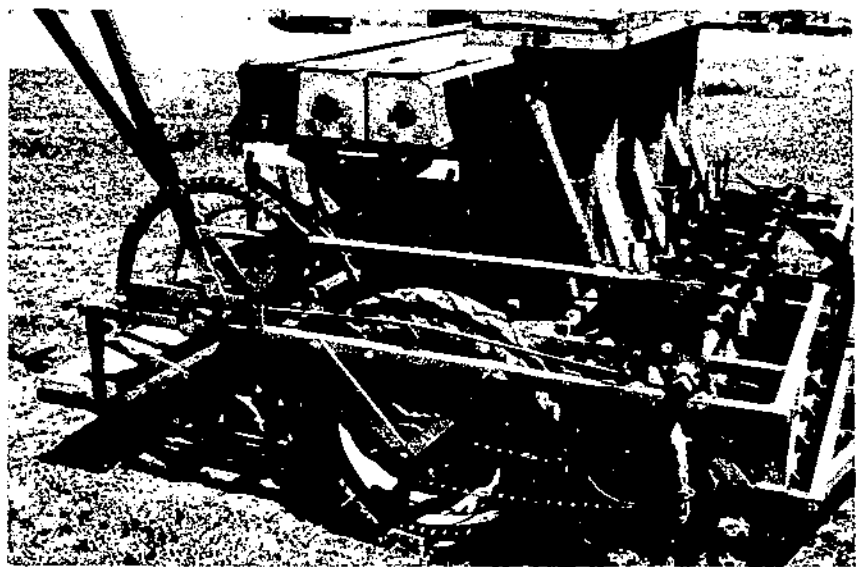


FIGURE 12.—U.S. Department of Agriculture grassland drill No. F-55. New features (from F-54) consisted of three boxes (one for companion crop or small grains) with two having an adjustable internal-run seed wheel, independently mounted double-disk opener for fertilizer, and a double press wheel on each opener that also served as a gage wheel for the fertilizer openers.

agitator with an oscillating vertical action. The rate of seeding was determined primarily by adjusting the exposure or the width of a metering wheel operating in the seed unit. A micrometer screw for each of the three seedboxes provided a means of making and recording the change of rates in calibration in an even and methodical manner.

Figure 13 shows a set of the micrometer screws made for the seedboxes on the special grassland drill and the companion seeders on the corrugated roller. Even with this refinement, trial-and-error runs were required on the initial calibration operation although interpolation between run settings were more easily effected and the final setting was attained much quicker by the decimal number system designed for the micrometer dials. This precise adjustment aided the calibration operation considerably when it was necessary to make several seed-rate settings in an experiment. To return to a previous setting quickly and with accuracy without requiring additional trial runs expedited the field work greatly.

The foregoing gives some of the highlights of the development of special equipment designed to meet specific experimental outlines of a crop-establishment study. Numerous smaller refinements were devised in the course of the use of the machine, but details of these are omitted. Special uses of the drills for certain research required alterations. For example, F-55 was altered (fig. 14) for the planting of a special variety of crimson clover in Maryland and also for companion-crop studies in New York. Through the Soil Bank activity in the midfifties additional research funds were received for grassland-establishment studies and four additional drills were made in 1956 and 1957. This expansion of research activity was also furthered by the interest of other experiment station units, and

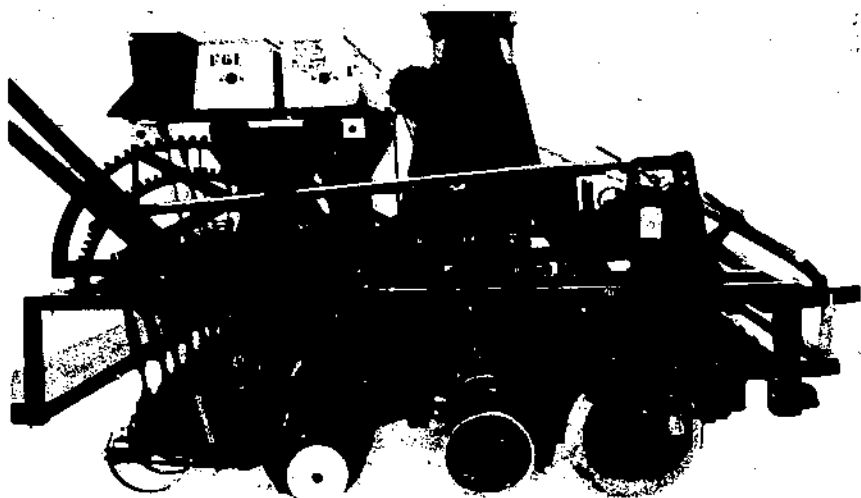


FIGURE 13.—Right view of the U.S. Department of Agriculture special grassland drill with right wheel removed. Micrometer screw adjustment for each seedbox is shown. Position of the gage wheel on the seed disk opener was different from that of earlier drills.

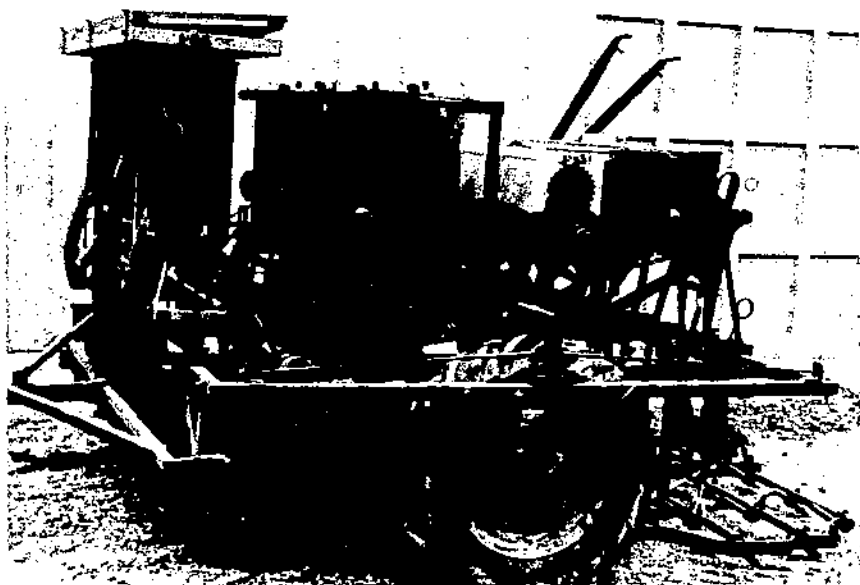


FIGURE 14.—U.S. Department of Agriculture grassland drill F-55 altered to include an extra set of hoppers for 16 streams of fertilizer. This has been used for interplanting grasses and legumes with small grains so that fertilizer could be placed near each seed row of the grains as well as the forages.

it is felt the availability of precision equipment to carry on basic field experiments had considerable bearing on the interest in this work.

To illustrate the activity of research in this field from 1951 to 1958, a tally of cooperative field experiments on establishment of grassland that were carried on with the Agricultural Engineering Research Division of the Agricultural Research Service in this period with the seven special drills is given (p. 18).

Experimental Methods and Conditions

The studies included in this bulletin were begun in 1952 at Beltsville, Md., as a part of a cooperative research program organized to study the factors affecting forage establishment with the object of improving establishment practices or developing new practices. The experiments were designed to determine the most effective rates and methods of application of fertilizer and seed for seedling establishment. The factors considered of greatest importance were: (1) Fertilizer rates, ratios, and placement; (2) seed rates and placement; (3) seedbed preparation; (4) compaction of the soil; and (5) the effect of climatic conditions.

The data summarized in this bulletin include experiments on tall fescue and ladino clover seeded in the fall of each year from 1952 through 1955, inclusive, and orchardgrass and *Sericea lespedeza* seeded in the early summer of each year from 1953 through 1955, inclusive. The fall and early-summer seedings are discussed separately, since different species were used and climatic conditions varied considerably.

The preparation of the land, design of the experiments, and methods used in comparable treatments were kept as uniform as possible from year to year. Each experiment, however, is treated individually since climatic conditions, soil type, and weed populations varied considerably from one year to the next. Treatments were added and others deleted from year to year as information developed.

The experiments were laid out in a completely randomized block design with four replications. Plots were 6 feet wide with a harvest length of 20 feet. The 6-foot plot width allowed for eight drill rows 8 inches apart or broadcast in a swath 64 inches wide. The seedbeds in all experiments were well prepared and in a reasonably firm condition at the time of seeding. Soil moisture and climatic conditions varied considerably at the time of and after seeding in the different experiments; therefore, these are discussed separately with each experiment.

Several variations of broadcasting or drilling of seed and fertilizer were used. In all broadcast-fertilizer treatments, the fertilizer was spread on the soil surface and harrowed in lightly. Seeding on these plots was then by one of three methods: (1) Broadcast with the special grassland drill with a baffle or spreader plate to spread the seed as it emerged from the seed tubes, and then the plots were rolled with a corrugated roller; (2) seeded with a commercial roller-seeder with a small packer wheel design; and (3) drill seeded with the special grassland drill in drills 8 inches apart. In the drill-seeded and drill-fertilizer plots, the seed was placed $\frac{1}{2}$ inch deep with fertilizer either in bands 1 inch below the seed, 1 inch below and 1 inch to the side, or in contact with the seed. The banding of fertilizer was effected by double-disk furrow openers with press wheels closing the furrow, repacking the soil, and acting as gage wheels for uniformity of depth. Soil over the seed row was firmed with an 8-inch open press wheel with a 1-inch flat metal surface. After the 1953 seedings, the press wheel

COOPERATIVE GRASSLAND ESTABLISHMENT EXPERIMENTS

*Planting and Fertilizing Equipment and Practices Investigations,
Agricultural Engineering Research Division, Agricultural Research Service*

[Tally of States by years, 1951-58]

	1951	1952	1953	1954	1955	1956	1957	1958
	S.C. Ala.	S.C. Ga. Md. (ARC ¹) (2)	S.C. Md. (ARC ¹) (3)	S.C. Va. Md. (ARC ¹) (2) Md. Pa. N.J. N.Y. (2) Conn. Vt.	Md. (ARC ¹)(2) Md. (2) Pa. (2) N.J. N.Y. (2) Conn. Vt.	Ga. La. Md. (ARC ¹) (2) Md. (6) Pa. N.J. N.Y. Conn. Vt. Mass.	Ga. La. Md. (ARC ¹) (2) Md. (6) N.J. N.Y. Conn. Vt. Mass. Tenn. Tex. (4) Wis. (2) Wash. Mich. (3)	Ga. (6) La. (2) Ala. Tenn. (7) Md. (4) Ind. Mich. (2) Wash. (2) Tex. (7) N. Mex.
Yearly total by States---	2	3	2	8	6	9	14	11
Experiments-----	2	4	4	11	11	16	27	35
Number of special drills--	1	1	1	2	4	6	6	7

¹ Agricultural Research Center.

was changed to a double-bevel wheel to prevent deep furrowing of the seed row.

Fertilizers were all compounded from the same source material throughout the studies. Ammonium sulfate, 21 percent N, was used as a source of nitrogen; superphosphate, 20 percent P_2O_5 , as a source of phosphorus; and muriate of potash, 60 percent K_2O , as a source of potassium. An inert filler was used to facilitate the proper dispensing at very low rates.

Determination of Treatment Response

Evaluation of the experiments was based on plant counts to determine differences in emergence and, in some experiments, later plant counts to determine survival. Plant counts were based on three random 1-square-foot-count quadrats per plot. Point-quadrat determinations were made in the 1952 and 1953 experiments with the tall fescue and ladino clover mixture in addition to the count quadrats. Determination of weed populations was made along with the plant counts.

A measure of the early response and development of the seedlings was determined by counting the number of tillers in fescue (in one experiment, the height of the plants was measured, also) and the number of trifoliate leaves in clover and by measuring the height of orchardgrass and *Sericea lespedeza*. These measurements have proved to be of great value in the measurement of establishment.

Yield determinations were made the first year after seeding by harvesting once at what would be considered the hay stage. However, in the 1954 seedings drought and weeds made yield determinations impractical. In addition to adverse climatic conditions, the sites chosen for the 1954 seedings of orchardgrass with *Sericea lespedeza* and of tall fescue with ladino clover were extremely weedy with extreme variation in the weed distribution over the experimental area.

For determining yields, a 3- by 20-foot strip through the center of each plot was cut with a 36-inch knife-bar power mower. The herbage from this strip was weighed green, and a 3- to 4-pound subsample was taken for determining dry matter and botanical composition. Subsamples were taken on all plots in all replications.

The subsamples were weighed immediately after harvest, placed in a forced-draft hay drier at a temperature of approximately 180° F., and weighed again in order to compute the dry-matter percentage. These dry-matter percentages were then applied to the herbage yield of the individual plot from which the subsample was taken to determine dry-matter yield.

Botanical composition was determined by separation analysis of each dried subsample. Independent estimates of botanical composition were made by two or three experienced individuals, and averages of the estimates were recorded as the actual composition. A regular number of samples were hand separated to check on accuracy and to maintain the estimator's perspective and in cases where the estimators disagreed considerably on estimates. Botanical composition estimates included the percentage of each seeded species and weeds. The final composition percentages were then applied to the dry-matter yield to calculate weed-free dry matter.

Data on plant counts, growth responses, and yields were subjected to an analysis of variance. Duncan's new multiple range test was used in interpreting the data (8).

Experiments on Fall Seeding of Tall Fescue and Ladino Clover

A mixture of tall fescue (*Festuca arundinacea* Schreb.) and ladino clover (*Trifolium repens* L. var. *ladino*) was used in a series of experiments.

In the first of this series, the area was seeded on September 17 and 18, 1952. The experiment consisted of 24 treatments, or various combinations of three seeding rates, five seeding methods, three fertilizer rates, and four fertilizer-placement methods (table 1).

The experimental area was on a fine sandy loam soil of the Luka Series that had not been cropped in recent years. The fertility level of the soil was low, as indicated by the poor stands where plots were planted in rows or in broadcast pattern but with no fertilizer (fig. 15).



FIGURE 15. Tall fescue and ladino clover planted without fertilizer: (Left) Seed drilled in 8-inch rows; (right) same amount of seed broadcast. Planted Sept. 17, 1952; photographed Mar. 31, 1953.

TABLE 1.—*Plant count and seedling development of tall fescue and ladino clover under different seeding and fertilizing treatments, Beltsville, Md., 1952*¹

[Seeded Sept. 17-18, 1952; plant counts and measurements made Oct. 8-10, 1952, by count-quadrat method]

Treatment		Plants per square foot			Seedling development	
Seeding rate and method ²	Fertilizer rate and placement ³	Fescue	Clover	Fescue and clover	Height of fescue	Trifoliolate leaves in clover
		Number	Number	Number	Inches	Percent
High:	High:					
Drilled	Be	35.4	18.3	53.7	2.6	12
Do	Band, 1-s, 1-b	30.2	17.4	47.6	2.8	7
Drilled, zone	Band, 1-b	30.4	16.3	46.7	2.4	13
Drilled	Band, 1-b	34.1	11.2	45.3	3.2	43
Drilled, alt	Band, 1-b	31.2	12.9	44.1	3.3	58
Drilled	Contact	36.1	4.8	40.9	3.0	20
Be	Band, 1-b	15.8	21.8	37.6	2.0	12
Be	Be	18.9	17.5	36.4	2.3	17
Be (com.)	Be	10.2	10.2	20.4	1.8	15
Low:						
Drilled	Band, 1-s, 1-b	16.2	7.8	24.0	2.5	9
Be	Be	11.4	9.8	21.2	2.0	7
Drilled	Band, 1-b	12.3	7.5	19.8	2.7	31
Do	Be	10.5	8.2	18.7	2.4	15
Be	Band, 1-b	7.8	9.7	17.5	1.9	8
	Low:					
Drilled	Band, 1-b	15.0	10.2	25.2	3.1	51
Do	Band, 1-s, 1-b	12.9	10.0	22.9	2.3	7
Be	Band, 1-b	10.8	11.3	22.1	1.9	4
Drilled	Contact	15.3	5.4	20.7	2.7	26
Be	Be	10.9	9.4	20.3	1.9	4
Drilled, alt	Band, 1-b	13.8	6.5	20.3	3.2	39
Drilled	Be	11.5	6.8	18.3	2.4	4
Drilled, alt, 4	Band, 1-b	9.4	4.4	13.8	2.8	37
High:						
Drilled	None	33.0	15.4	48.4	1.9	4
Be	do	20.1	12.2	32.3	1.5	0
Standard error of mean		1.84	1.42		.14	6.03

¹ Adapted from (12).

² High rate—8 pounds of tall fescue and 2 pounds ladino clover per acre; low rate—4 pounds of tall fescue and 1 pound of ladino clover per acre, except as indicated; drilled—in rows, 8 inches apart; drilled, zone—seed planted in depths from $\frac{1}{4}$ to 1 inch; drilled, alt.—alternate-row planting of grass and clover; Be—broadcast and seedbed rolled after

Be; Be (com.)—broadcast as corrugated roller rolled seedbed.

³ High rate—750 pounds of 3-12-6 fertilizer per acre; low rate—250 pounds of 3-12-6 fertilizer per acre; band—in rows, 8 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed; Be—broadcast and disked in before planting.

⁴ 2 pounds of tall fescue and $\frac{1}{2}$ pound of ladino clover per acre.

Soil moisture was good at the time of seeding and light rains followed soon after seeding, which resulted in good emergence. For 6 weeks after seeding, however, the area received only 1.5 inches of rain as compared with a longtime average of 5.5 inches.

The data taken for the evaluation of treatments in the experiment can be divided into four categories: (1) Plant populations, or stand density, (2) yield, (3) botanical composition, and (4) seedling development. Plant population, or stand density, was determined by plant counts taken by the count-quadrat method approximately 3 weeks after seeding and by the point-quadrat method 6 months after seeding. These data are presented in tables 1 and 2, respectively. Yields

TABLE 2.—*Botanical composition of fescue-clover forage under different seeding and fertilizing treatments, Beltsville, Md., 1952-53*¹

[Seeded Sept. 17-18, 1952; plant counts made Mar. 31, 1953, by point-quadrat method]

Treatment		Botanical composition				
Seeding rate and method ²	Fertilizer rate and placement ³	Bare	Weeds	Fescue	Clover	Fescue and clover
High:	High:	Percent	Percent	Percent	Percent	Percent
Drilled	Band, 1-b	21	5	68	6	74
Do	Contact	26	1	73	0	73
Do	Band, 1-s, 1-b	31	6	55	8	63
Drilled, alt.	Band, 1-b	39	4	42	15	57
Drilled, zone	Band, 1-b	36	8	49	7	56
Drilled	Bc	26	21	47	6	53
Bc	Band, 1-b	43	11	31	15	46
Bc	Bc	39	21	30	10	40
Bc (com.)	Bc	44	27	17	12	29
Low:	Low:					
Drilled	Band, 1-b	25	4	65	6	71
Do	Band, 1-s, 1-b	44	7	42	7	49
Do	Bc	39	22	32	7	39
Bc	Band, 1-b	49	17	24	10	34
Bc	Bc	44	31	19	6	25
Drilled	Band, 1-b	35	6	46	13	59
Do	Contact	37	5	49	9	58
Drilled, alt.	Band, 1-b	48	9	31	12	43
Do	Band, 1-b	55	9	23	13	36
Drilled	Band, 1-s, 1-b	59	7	29	5	34
Bc	Band, 1-b	73	8	13	6	19
Drilled	Bc	58	30	12	0	12
Bc	Bc	63	25	11	1	12
High:	High:					
Drilled	None	72	14	14	0	14
Bc	do	90	10	0	0	0
Standard error of mean.		4.96	3.90	3.90	2.13	

¹ Adapted from (12).

² High rate—8 pounds of tall fescue and 2 pounds ladino clover per acre; low rate—4 pounds of tall fescue and 1 pound of ladino clover per acre, except as indicated; drilled—in rows, 8 inches apart; drilled, zone—seed planted in depths from $\frac{1}{4}$ to 1 inch; drilled, alt.—alternate-row planting of grass and clover; Bc—broadcast and seedbed rolled after Bc; Bc (com.)—broadcast as corrugated roller rolled seedbed.

³ High rate—750 pounds of 3-12-6 fertilizer per acre; low rate—250 pounds of 3-12-6 fertilizer per acre; band—in rows, 5 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed; Bc—broadcast and disked in before planting.

⁴ 2 pounds of tall fescue and $\frac{1}{2}$ pound of ladino clover per acre.

TABLE 3.—*Botanical composition and dry-matter yield of fescue-clover forage under different seeding and fertilizing treatments, Beltsville, Md., 1952-53*¹

[Seeded Sept. 17-18, 1952; harvested May 27, 1953]

Treatment		Botanical composition			Dry-matter yield (weed-free)
Seeding rate and method ²	Fertilizer rate and placement ³	Fescue	Clover	Weeds	
High:	High:	Percent	Percent	Percent	Pounds per acre
Drilled.....	Band, 1-b.....	99	1	0	3,331
Do.....	Contact.....	99	1	0	2,923
Drilled, alt.....	Band, 1-s, 1-b.....	99	1	0	2,590
Drilled.....	Band, 1-s, 1-b.....	98	1	1	2,443
Drilled, zone.....	Band, 1-b.....	97	2	1	2,014
Drilled.....	Be.....	94	3	3	1,960
Be.....	Be.....	81	8	11	1,439
Be.....	Band, 1-b.....	78	11	11	1,264
Be (com.).....	Be.....	51	14	35	838
Low:	Low:				
Drilled.....	Band, 1-b.....	97	2	1	2,865
Do.....	Band, 1-s, 1-b.....	95	2	3	1,756
Do.....	Be.....	89	3	8	1,485
Be.....	Be.....	52	9	39	817
Be.....	Band, 1-b.....	53	1	46	488
Drilled.....	Band, 1-b.....	88	10	2	1,855
Do.....	Contact.....	96	3	1	1,825
Drilled, alt.....	Band, 1-b.....	96	2	2	1,525
Do.....	Band, 1-b.....	90	4	6	1,330
Drilled.....	Band, 1-s, 1-b.....	74	5	21	1,030
Be.....	Band, 1-b.....	52	3	45	333
Drilled.....	Be.....	29	1	70	224
Be.....	Be.....	31	1	68	200
High:	High:				
Drilled.....	None.....	29	1	70	55
Be.....	do.....	0	0	100	0
Standard error of mean.....					148.2

¹ Adapted from (12).

² High rate—8 pounds of tall fescue and 2 pounds ladino clover per acre; low rate—4 pounds of tall fescue and 1 pound of ladino clover per acre, except as indicated; drilled, in rows, 8 inches apart; drilled, zone—seed planted in depths from $\frac{1}{4}$ to 1 inch; drilled, alt.—alternate-row planting of grass and clover; Be—broadcast and seeded rolled after Be; Be (com.)—broadcast as corrugated roller rolled seedbed.

³ High rate—750 pounds of 3-12-6 fertilizer per acre; low rate—250 pounds of 3-12-6 fertilizer per acre; band—in rows, 8 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed; Be—broadcast and disked in before planting.

⁴ 2 pounds of tall fescue and $\frac{1}{2}$ pound of ladino clover per acre.

were taken on May 27, 1953, at which time botanical estimates were made (table 3).

Seedling development was measured in this preliminary experiment by determining the average height of the fescue plants and the percentage of trifoliate leaves on ladino clover (table 1).

The results of this initial experiment indicated that band seeding, which consisted of drilling the seed $\frac{1}{4}$ inch deep in rows and placing a band of fertilizer 1 inch directly below the seed, gave much better stands and a higher yield than broadcasting either the fertilizer or the seed, or both (figs. 16-23 and table 3).

At the high rate of seed and fertilizer (8 pounds fescue and 2 pounds ladino clover and 750 pounds 3-12-6 fertilizer), band seeding (drilled



FIGURE 16.- Tall fescue and ladino clover broadcast and fertilizer broadcast, both at the low rates. Planted Sept. 17, 1952; photographed Mar. 31, 1953.



FIGURE 17.—Tall fescue and ladino clover broadcast and fertilizer broadcast, both at the high rates. Planted Sept. 17, 1952; photographed Mar. 31, 1953.

seed and banded fertilizer) produced 3,331 pounds of weed-free dry matter per acre as compared with 1,439 pounds where both seed and fertilizer were broadcast. This represents an increase of 131 percent in forage yield from band seeding (figs. 17 and 22).

At the low rate of seed and fertilizer (4 pounds fescue and 1 pound ladino clover and 250 pounds 3-12-6 fertilizer), 1,855 pounds of weed-free dry matter per acre were produced where both seed and fertilizer



FIGURE 18.—Tall fescue and ladino clover broadcast and fertilizer banded 1 inch below seed in 8-inch rows, both at the high rates. Planted Sept. 17, 1952; photographed Mar. 31, 1953. The only plants that survived the winter are those directly over the bands of fertilizer.

were drilled (fig. 20) as compared with 1,439 pounds where both seed and fertilizer were broadcast at the high rate. This represents an increase in forage yield of 29 percent from band seeding, and with only one-half the seed and one-third the fertilizer. Broadcasting both seed and fertilizer at the low rate produced only 200 pounds of dry matter.



FIGURE 19.—Plots seeded with tall fescue and ladino clover: (Left) Seed and fertilizer broadcast at the high rates; (right) seed banded in 8-inch rows at the low rate and fertilizer banded at the high rate 1 inch below the seed. Broadcast plot was seeded with a commercial double-corrugated roller with mounted seedbox. Planted Sept. 17, 1952; photographed Mar. 31, 1953.

The importance of rapid early development in stand establishment is clearly demonstrated by those plots at the high rate of seed and fertilizer in which seed was broadcast and fertilizer banded (table 1). The seedlings emerged uniformly over the plot, but it soon became evident that those seedlings directly over the fertilizer band were growing much more rapidly than the others. In measurements of



FIGURE 20.—Tall fescue and ladino clover drilled in 8-inch rows and fertilizer banded 1 inch below seed, both at the low rates. Planted Sept. 17, 1952; photographed Mar. 31, 1953.

seedling development made about a month after seeding, the height of fescue plants was 2 inches and percentage trifoliolate leaves in clover was 12 percent for this treatment. These measurements were 3.2 inches and 43 percent in the comparable band-seeded treatment. By the following spring the plots appeared to be drill seeded (fig. 18) as only those plants over the fertilizer band had survived the



FIGURE 21. - Tall fescue and ladino clover drilled in 8-inch rows and fertilizer broadcast, both at the high rates. Planted Sept. 17, 1952; photographed Mar. 31, 1953. There is less growth than where seed was drilled and fertilizer banded. Also, weeds are more abundant.

winter. This vividly illustrates the effect of fertilizer placement on the early development and subsequent survival of seedlings.

The precision placement of fertilizer with relation to the seed is important in the proper development and growth of the seedlings. This was illustrated by the plots in which fertilizer was banded 1 inch below and 1 inch to the side of the seed rather than directly below it. These plots produced 2,443 pounds per acre as compared with 3,331 pounds for those in which fertilizer was placed directly



FIGURE 22.—Tall fescue and ladino clover drilled in 8-inch rows and fertilizer banded 1 inch below seed, both at the high rates. Planted Sept. 17, 1952; photographed Mar. 31, 1953.

below the seed (table 3). Where seed and fertilizer were placed in contact, there was a depression in clover stand. The contact placement, however, had little or no effect on grass stand and forage yield of the plots.

A very striking difference in weed population between broadcast plots and band-seeded plots was observed (figs. 19 and 24). Where

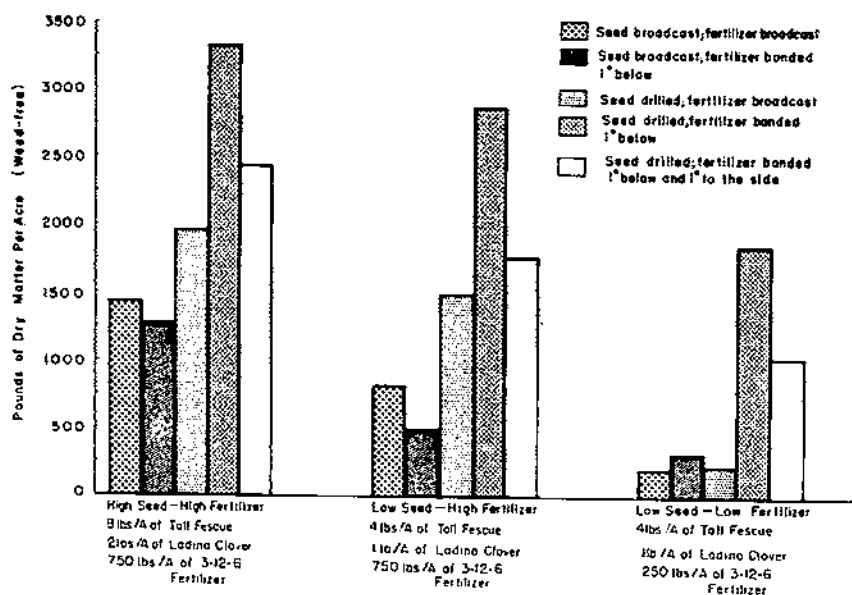


FIGURE 23.—Yield of weed-free dry matter of tall fescue and ladino clover under different seeding and fertilizer treatments, planted in fall of 1952, Beltsville, Md.

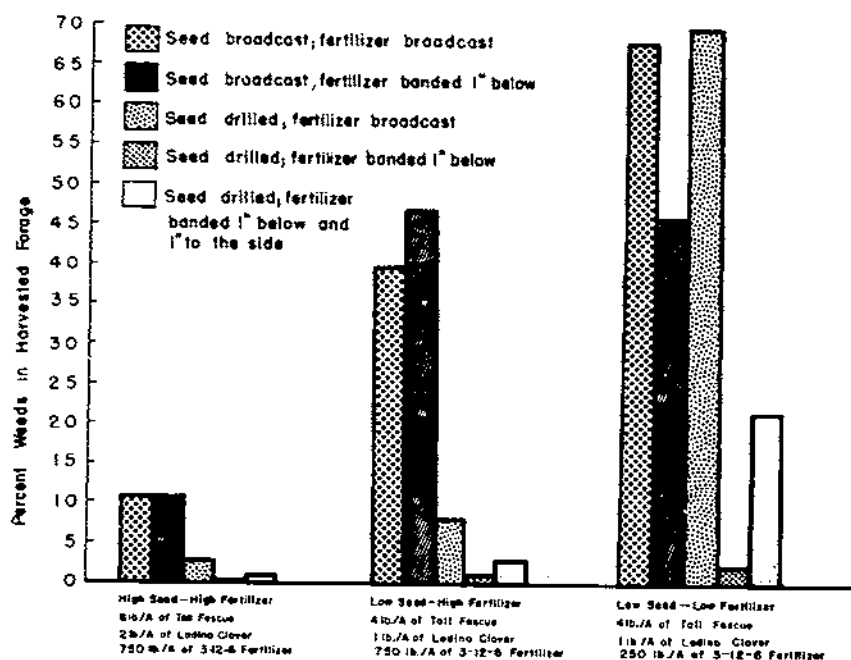


FIGURE 24.—Percentage of weeds in harvested fescue-clover forage under different seeding and fertilizer treatments, Beltsville, Md.

seed and fertilizer were both banded, very few weeds developed regardless of seed or fertilizer rates; but where the broadcast method was used for the seed or the fertilizer or for both, the weed population was very large. (See figs. 21 and 22.) The average percentage ground cover attributed to weeds (table 2) in band-seeded treatments was 6 percent as compared with an average of 26 percent in comparable broadcast treatments. The weed content of the harvested forage, based on actual separation analysis (table 3), showed the same general comparison.

The plots in the second of this series of experiments were seeded Sept. 15, 1953. The plots were located on Christiana fine sandy loam soil of very low fertility. Soil moisture remained low for about 50 days after seeding. A total of 0.52 inch of rain was measured

TABLE 4.—*Plant count, seedling development, and dry-matter yield of tall fescue and ladino clover under different seeding and fertilizing treatments, Beltsville, Md., 1953-54*

[Seeded Sept. 15, 1953; plant counts and measurements made Nov. 4, 1953; harvested May 1954]

TREATMENTS COMPARING DIFFERENT RATES AND METHODS OF SEEDING AND DIFFERENT RATES AND PLACEMENT OF FERTILIZER

Treatment		Plants per square foot		Seedling development of fescue		Dry-matter yield (weed-free)
Seeding rate and method ¹	Fertilizer rate and placement ²	Fescue	Clover	Tillers per plant	Height of plants	
High:	High:	Number	Number	Number	Inches	Pounds per acre
Drilled.....	Band, 1-b.....	11.6	1.9	2.3	2.5	2,063
Do.....	Contact.....	9.7	.3	1.9	1.8	1,223
Drilled, alt.....	Band, 1-b.....	15.3	3.2	3.0	3.3	1,465
Drilled.....	Band, 1-b, 1-s.....	14.0	5.9	1.1	1.8	1,255
Do.....	Be.....	14.6	4.6	1.7	2.1	889
Bc.....	Be.....	13.0	2.3	2.1	2.4	1,995
Bc (com.).....	Band, 1-b.....	6.9	2.9	1.2	2.0	679
Do.....	Be.....	8.0	5.1	1.9	2.2	1,238
Low:						
Drilled.....	Band, 1-b.....	9.0	1.5	2.7	2.8	1,368
Do.....	Band, 1-b, 1-s.....	9.5	1.6	1.4	2.0	488
Do.....	Be.....	12.6	1.1	2.4	2.5	1,140
Bc (com.).....	Be.....	5.7	.4	1.8	1.9	1,079
Do.....	Band, 1-b.....	3.3	1.4	2.4	1.8	610
Drilled ³	Band, 1-b.....	5.3	1.0	2.4	2.1	1,507
	Low:					
Do.....	Band, 1-b.....	10.0	1.8	2.1	2.3	1,220
Do.....	Contact.....	10.0	.5	1.9	2.1	615
Drilled, alt.....	Band, 1-b.....	8.1	4.0	2.1	2.3	1,315
Drilled.....	Band, 1-b, 1-s.....	9.8	2.0	1.4	1.6	1,200
Bc (com.).....	Band, 1-b.....	5.7	1.3	.9	1.6	822
Drilled.....	Be.....	11.4	2.1	1.3	1.7	273
Bc (com.).....	Be.....	5.0	.5	1.6	1.5	53
Drilled ³	Band, 1-b.....	6.7	1.1	1.9	2.1	1,165
Drilled, alt. ³	Band, 1-b.....	6.0	1.5	2.2	2.4	1,534
High:						
Drilled.....	None.....	17.4	7.3	1.0	1.2	233

See footnotes at end of table.

TABLE 4.—*Plant count, seedling development, and dry-matter yield of tall fescue and ladino clover under different seeding and fertilizing treatments, Beltsville Md., 1953-54—Continued*

TREATMENTS COMPARING DIFFERENT FERTILIZER ELEMENTS ALONE AND IN VARIOUS COMBINATIONS UNDER TWO METHODS OF APPLICATION

Treatment		Plants per square foot		Seedling development of fescue		Dry-matter yield (weed-free)
Seeding rate and method ¹	Fertilizer placement, ² kind used, and rate	Fescue	Clover	Tillers per plant	Height of plants	
High:	Band, 1-b:	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Inches</i>	<i>Pounds per acre</i>
Drilled	22.5 lb. N	12.0	3.8	1.1	1.4	544
Do	15 lb. N	17.5	5.2	1.3	1.7	763
Do	90 lb. P ₂ O ₅	13.3	3.6	2.0	2.1	1,771
Do	60 lb. P ₂ O ₅	15.5	5.8	2.3	2.2	1,613
Do	45 lb. K ₂ O	14.0	4.9	1.3	1.8	744
Do	30 lb. K ₂ O	13.5	6.9	1.2	1.5	940
Do	90 lb. P ₂ O ₅ , 45 lb. K ₂ O	17.5	3.6	2.1	2.5	1,063
Do	22.5 lb. N, 90 lb. P ₂ O ₅	15.8	5.8	2.1	2.1	1,902
Do	22.5 lb. N, 45 lb. K ₂ O	14.0	2.5	1.3	1.7	907
Do	Contact:					
Do	15 lb. N	10.3	.6	1.1	1.3	49
Do	60 lb. P ₂ O ₅	15.4	1.3	1.9	2.2	1,379
Do	30 lb. K ₂ O	14.0	1.9	1.4	1.5	42
Do	7.5 lb. N	15.0	2.0	1.0	1.0	41
Do	30 lb. P ₂ O ₅	13.0	3.3	1.8	2.0	735
Do	15 lb. K ₂ O	13.3	5.9	1.3	1.2	340
Standard error of mean.		1.61	.77	.21	.32	331.8

¹ High rate—8 pounds of tall fescue and 2 pounds ladino clover per acre; low rate—4 pounds of tall fescue and 1 pound of ladino clover per acre, except as indicated; drilled—in rows, 8 inches apart; drilled, alt.—alternate-row planting of fescue and clover; bc—broadcast and seedbed rolled after bc; bc (corn.)—broadcast as corrugated roller rolled seedbed.

² High rate—750 pounds of 3-12-6 fertilizer per acre; low rate—250 pounds of 3-12-6 fertilizer per acre; band—in rows, 8 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed; bc—broadcast and disked in before planting.

³ 2 pounds of tall fescue and ½ pound of ladino clover per acre.

⁴ 1-b—1 inch below seed.

during this period (September 15 through October 28), all of which occurred in showers of less than 0.10 inch. Rainfall for the months of October and November measured 2.71 and 1.30 inches, respectively, most of which occurred either in heavy downpours or very light showers.

Plant counts were made in November 1953, and yields were taken in May 1954 (table 4). Dry-matter yields were somewhat lower than those of the 1952 seeding; however, the results of the two seedings were very similar. Band seeding at the high rate of seed and fertilizer was again the highest yielding treatment, with 2,063 pounds of dry matter. The same amount of seed and fertilizer broadcast, using the corrugated roller-seeder for seeding, produced only 1,238 pounds of dry matter. The same amount of seed and fertilizer broadcast on top of the soil and then rolled yielded 1,955 pounds. This treat-

ment was the second highest yielding and was almost as high as band seeding.

The 1953 experiment included additional treatments in which the individual fertilizer elements alone or in various combinations were compared. All rates of nitrogen and potash, alone or in combination, either banded 1 inch below the seed or in contact with the seed, had a very depressing effect on stands and yield. Phosphorus, however, was almost as stimulating as the complete fertilizer where banded 1 inch below. Where P_2O_5 was applied in combination with N or K_2O in a band 1 inch below the seed, the depression in yield was not nearly so great as when N or K_2O was applied alone.

The detrimental effect of N and K_2O alone and in combination was not indicated in early stand counts on grasses. There was a small decrease in the number of clover plants in some of these treatments (table 4). The main effect, however, was indicated rather clearly in the development of the plants as measured by the number of tillers and height of tall fescue plants. Plants in these treatments remained very small, with many of them dying during the winter and following spring. Even those that survived did not develop normally the following spring, thus the extremely low yields of dry matter.

The extremely dry conditions produced results somewhat different from those of 1952. Early stand counts indicated that band-seeded plots with higher rates of fertilizer produced fewer plants than did lower rates. The development of the plants in high-fertilizer plots, however, was considerably better. This increased development was reflected in the first year dry-matter yields as well as in final establishment.

The third in this series of experiments was divided into two separate experiments. The area was seeded on Sept. 7, 8, and 9, 1954, on a Keyport silt loam soil. Plant counts were made on October 25, 1954. Dry-matter yields were not taken in the following year, as was the procedure in previous experiments. Extremely dry weather in the fall of 1954 eliminated clover stands and an unusually large and variable weed population in the spring of 1955 made yield data almost impossible to evaluate. A total of 1.87 inches of precipitation was recorded in September 1954 as compared with a longtime average of 3.80 inches.

Experiment 1 included variations in seed rates and complete fertilizer rates along with seed and fertilizer placement variables (table 5). Moisture was unusually low during most of the early development of the plants; therefore, stands were considerably reduced in all treatments. The best stands of fescue in experiment I were obtained on those band-seeded plots in which low rates of fertilizer had been used or where the fertilizer was broadcast or placed to the side of the drilled seed. The only treatment in which the high rate of fertilizer banded gave a high plant count was where the narrow 1-inch press wheel was used. A very high plant count was also obtained with drilled seed and no fertilizer. These results indicate that under conditions of limited moisture some reduction can be expected in initial emergence of seedlings where complete fertilizers are placed in too great a concentration near the seed. The narrow press wheel apparently creates a condition conducive to good moisture retention in the bottom of the narrow furrow it creates. Under the conditions encountered in 1953, it appears that the narrow band, with low fertilizer

TABLE 5.—*Plant count and seedling development of tall fescue and ladino clover under different seeding and fertilizing treatments, experiment I, Beltsville, Md., 1954*

[Seeded in September 1954; plant counts made on October 25, 1954]

Treatment		Plants per square foot			Seedling development	
Seeding rate and method ¹	Fertilizer rate and placement ²	Fescue	Clover	Weeds	Tillers per plant in fescue	Trifoliate leaves per plant in clover
High:	High:	Number	Number	Number	Number	Number
Drilled	Band, 1-b.	7.9	2.1	4.8	1.37	1.71
Do.	Contact.	5.9	2.5	3.1	1.29	2.48
Drilled, alt.	Band, 1-b.	4.7	1.3	3.7	1.19	2.62
Drilled	Band, 1-b, 1-s.	8.8	1.3	3.5	1.08	1.02
Do.	Bc.	8.9	2.7	3.0	1.10	1.59
Bc.	Bc.	8.1	1.2	7.6	1.02	1.67
Bc (com.)	Band, 1-b.	5.9	1.5	5.0	1.07	2.47
Do.	Bc.	4.7	1.2	6.0	1.09	1.08
Drilled	Low:					
Do.	Band, 1-b.	10.0	1.5	4.3	1.27	3.20
Low:	High:					
Drilled	Band, 1-b.	2.6	.7	.9	1.27	2.86
Do.	Band, 1-b, 1-s.	3.4	.8	3.4	1.03	1.88
Do.	Bc.	3.4	1.8	2.2	1.03	1.17
Bc (com.)	Bc.	2.2	.3	2.9	1.14	.67
Do.	Band, 1-b.	2.4	.5	2.2	1.04	2.60
Drilled	Band, 1-b.	2.0	1.6	2.0	1.20	2.63
Do.	Band, 1-b.	2.0	.5	5.3	1.40	2.80
Drilled	Low:					
Do.	Band, 1-b.	3.8	1.5	1.4	1.32	3.40
Drilled, alt.	Contact.	4.1	2.6	2.4	1.05	1.88
Drilled	Band, 1-b.	2.0	.8	4.7	1.10	2.38
Drilled	Band, 1-b, 1-s.	3.0	.8	1.2	1.07	1.25
Bc (com.)	Band, 1-b.	1.4	.3	1.8	1.21	1.33
Drilled	Bc.	4.2	1.0	4.9	1.05	2.20
Bc (com.)	Bc.	2.4	.9	4.0	1.00	1.56
Drilled	Band, 1-b.	2.3	.9	6.4	1.09	1.44
Drilled, alt.	Band, 1-b.8	.2	1.5	1.38	4.00
High:	None	10.0	2.4	3.2	1.03	.75
Drilled	High:					
Com. band seeder.	Band, 1-b.	4.8	1.1	2.2	1.44	2.09
Com. band seeder (reverse). ³	Band, 1-b.	5.2	.6	6.2	1.17	2.33
Drilled	Narrow press wheel.	10.9	2.3	2.9	1.34	2.39
Low:	do.	4.4	.8	2.8	1.36	2.63
Drilled						
Standard error of mean.82	.18	.39	.10	.15

¹ High rate—8 pounds of tall fescue and 2 pounds ladino clover per acre; low rate—4 pounds of tall fescue and 1 pound of ladino clover per acre, except as indicated; drilled—in rows, 8 inches apart; drilled, alt.—alternate-row planting of fescue and clover; Bc—broadcast and seedbed rolled after Bc; Bc (com.)—broadcast as corrugated roller rolled seedbed.

² High rate—750 pounds of 3-12-6 fertilizer per acre; low rate—250 pounds of 3-12-6 fertilizer per acre; band—in rows, 8 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed; Bc—broadcast and disked in before planting.

³ 2 pounds tall fescue and 1 pound ladino clover per acre.

⁴ 3 pounds of tall fescue and $\frac{1}{2}$ pound of ladino clover per acre.

⁵ Arrangement of the pucker wheels was reversed in position and a small spreader was added to the seed-tube opening to sow 2 rows of seed about 1 inch on each side of the fertilizer band.

rate, might have given some of the highest plant counts if this treatment had been included in the experiment. Development of the plants as measured by the number of tillers or trifoliate leaves, however, was much better in treatments where fertilizer was banded either below or in contact with the seed. This early-seedling development was an excellent measure of final stand establishment. The year following seeding, those treatments that made the most rapid early development had the best stands, although initial emergence was somewhat lower than that in some of the other treatments (figs. 25 and 26).

Experiment II included band seeding at the high seed rate with individual fertilizer elements in various combinations (table 6). The highest plant counts for fescue were obtained in the plots that received (1) 60 pounds of P_2O_5 banded 1 inch below seed (fig. 27), (2) 30 pounds of P_2O_5 in contact with seed, (3) 30 pounds of P_2O_5 banded 1 inch below seed, (4) 90 pounds of P_2O_5 banded 1 inch below seed, and (5) 90 pounds of P_2O_5 in contact with seed. Stands were all about the same with these five treatments. Clover stands were also better in plots fertilized with P_2O_5 alone except for the 90 pound rates, which depressed clover stands. Stands were reduced sharply where N and K were applied either alone or in combination. These, along with the no-fertilizer treatments, were almost completely bare in the spring of 1955 (figs. 25-28). This was attributed to low moisture in the fall along with retardation in development of the plants by N and K_2O or no fertilizer. Plant development was also best in the P_2O_5 treatments in general; however, the complete fertilizer showed good development and a fair stand.

The plots in the fourth in the series of fall-seeded experiments were seeded on September 21, 1955. The experiment consisted of 27 treatments. Plant counts were made in October 1955 and yield data taken in 1956 (table 7).

Moisture conditions after this seeding were excellent and all plots had adequate stands of both grass and legumes. Differences in emergence under the various treatments were not so great as in drier years, but there were still some significant differences. Differences in the development of plants, as measured by the number of tillers in tall fescue and the number of trifoliate leaves in ladino clover, under the various treatments were also significant. The lowest plant counts of tall fescue seemed to be from the lower seeding rate and the corrugated-roller method of seeding. Plots with the no-fertilizer treatment, complete fertilizer in contact with the seed, and nitrogen with phosphorus banded 1 inch below the seed were also low in plant count of tall fescue. Plots seeded with the commercial band seeder with normal attachments (packer wheels) also showed some reduction in number of fescue plants.

The number of clover plants appeared to be reduced by lower seed rate, high rate of P_2O_5 in contact, and contact placement of either or both N and K_2O in combination with phosphorus.

Fescue plants developed significantly better where 90 pounds of P_2O_5 alone and where 22.5 pounds of N with 90 pounds of P_2O_5 were banded 1 inch below the seed. The greatest suppression of development appeared to be caused by a lack of fertilizer. Grass development was the lowest where seed was (1) broadcast and fertilizer banded, (2) drill-seeded without fertilizer, and (3) drill-seeded with 22.5 pounds of N placed 1 inch below and 1 inch to the side of the seed.

TABLE 6.—*Place count and seedling development of tall fescue and ladino clover under different seeding and fertilizing treatments, experiment II, Beltsville, Md., 1954*

[Seeded with 8 pounds tall fescue and 2 pounds ladino clover in September 1954; plant counts made on October 25, 1954]

Treatment			Plants per square foot			Seedling development	
Seeding method	Fertilizer		Fescue	Clover	Weeds	Tillers per plant in fescue	Trifoliolate leaves per plant in clover
	Rate and mixture	Placement					
8-inch drills, alternate rows	None	8-inch band, 1 inch below seed.	Number 3.3	Number 0.8	Number 0.1	Number 1.00	Number 0.63
Do	22.5 lb. N	do	3.1	.8	.6	1.03	1.00
Do	90 lb. P ₂ O ₅	do	5.9	.2	.1	1.24	.50
Do	60 lb. P ₂ O ₅	do	6.6	1.2	.5	1.39	.75
Do	30 lb. P ₂ O ₅	do	6.0	1.3	1.3	1.25	1.85
Do	45 lb. K ₂ O	do	5.7	.7	1.0	1.02	1.00
Do	90 lb. P ₂ O ₅ , 45 lb. K ₂ O	do	4.1	.2	1.4	1.27	0
Do	22.5 lb. N, 90 lb. P ₂ O ₅	do	2.6	.3	.9	1.31	1.67
Do	22.5 lb. N, 45 lb. K ₂ O	do	3.1	.3	.5	1.03	1.00
Do	22.5 lb. N, 90 lb. P ₂ O ₅ , 45 lb. K ₂ O	do	5.3	.4	.8	1.57	2.75
Do	90 lb. P ₂ O ₅	Contact	5.8	.6	1.9	1.33	1.83
Do	60 lb. P ₂ O ₅	do	4.4	.5	1.8	1.14	1.80
Do	30 lb. P ₂ O ₅	do	6.3	1.4	1.5	1.25	1.36
Open press wheel	750 lb. 3-12-6	8-inch band, 1 inch below seed.	3.8	.6	1.2	1.34	.67
Narrow press wheel	750 lb. 3-12-6	do	1.7	0	.7	1.47	0
Standard error of mean			.74	.14	.21	.12	.11

TABLE 7.—*Plant count, seedling development, and dry-matter yield of tall fescue and ladino clover under different seeding and fertilizing treatments, Beltsville, Md., 1955-56*

[Seeded in September 1955; plant counts made in October 1955; harvested July 31, 1956]

TREATMENTS COMPARING DIFFERENT RATES AND METHODS OF SEEDING AND DIFFERENT RATES AND PLACEMENT OF FERTILIZER

Treatment			Plants per square foot		Seedling development		Dry-matter ⁴ yield (weed-free)
Seeding rate and method ¹	Fertilizer		Fescue	Clover	Tillers per plant in fescue	Trifoliate leaves per plant in clover	
	Rate ²	Placement ³					
High:			<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Pounds per acre</i>
Drilled-----	High-----	Band, 1-b-----	15. 75	13. 31	1. 14	1. 38	2, 000
Do-----	do-----	Bc-----	14. 75	15. 81	1. 22	1. 30	1, 620
Bc (com.)-----	do-----	Band, 1-b-----	10. 25	10. 69	1. 03	1. 51	1, 580
Bc-----	do-----	Bc-----	19. 25	15. 13	1. 11	1. 54	2, 160
Bc (com.)-----	do-----	Bc-----	11. 50	14. 56	1. 17	1. 47	1, 920
Com. band seeder-----	do-----	Band, 1-b-----	13. 25	11. 81	1. 20	1. 46	1, 900
Com. band seeder (reverse). ⁵ -----	do-----	Band, 1-b-----	17. 00	12. 69	1. 12	. 97	1, 340
Drilled-----	Low-----	Band, 1-b-----	17. 50	14. 75	1. 20	1. 45	1, 940
Low:							
Drilled-----	High-----	Band, 1-b-----	13. 75	8. 19	1. 14	1. 48	1, 740
Do-----	Low-----	Band, 1-b-----	11. 00	6. 44	1. 19	1. 59	1, 420

TREATMENTS COMPARING DIFFERENT FERTILIZER ELEMENTS ALONE AND IN VARIOUS COMBINATIONS UNDER VARIOUS METHODS OF APPLICATION

Treatment			Plants per square foot		Seedling development		Dry-matter ⁴ yield (weed-free)
Seeding rate and method ¹	Fertilizer		Fescue	Clover	Tillers per plant in fescue	Trifoliolate leaves per plant in clover	
	Rate and kind	Placement ³					
High:			<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Pounds per acre</i>
Drilled, alt.	No fertilizer		13. 25	12. 63	1. 07	1. 48	880
Do	22.5 lb. N	Band, 1-b	14. 50	14. 38	1. 15	1. 02	880
Do	22.5 lb. N	Band, 1-b, 1-s	20. 25	16. 63	1. 05	. 84	620
Do	90 lb. P ₂ O ₅	Band, 1-b	16. 75	16. 75	1. 23	1. 44	1, 600
Do	60 lb. P ₂ O ₅	Band, 1-b	15. 50	12. 75	1. 13	1. 53	1, 340
Do	30 lb. P ₂ O ₅	Band, 1-b	16. 75	14. 19	1. 16	1. 59	1, 320
Do	45 lb. K ₂ O	Band, 1-b	18. 75	13. 75	1. 10	1. 03	1, 020
Do	22.5 lb. N, 90 lb. P ₂ O ₅	Band, 1-b	13. 00	10. 75	1. 32	1. 65	1, 680
Do	22.5 lb. N, 45 lb. K ₂ O	Band, 1-b	14. 75	13. 44	1. 15	1. 09	960
Do	90 lb. P ₂ O ₅ , 45 lb. K ₂ O	Band, 1-b	20. 75	20. 25	1. 19	1. 67	1, 500
Do	22.5 lb. N, 90 lb. P ₂ O ₅ , 45 lb. K ₂ O	Band, 1-b	16. 25	13. 69	1. 16	1. 51	1, 740
Do	90 lb. P ₂ O ₅	Contact	16. 25	9. 63	1. 16	1. 47	1, 580
Do	60 lb. P ₂ O ₅	do	16. 75	12. 69	1. 19	1. 33	1, 500
Do	30 lb. P ₂ O ₅	do	23. 25	13. 31	1. 10	1. 15	1, 460
Do	22.5 lb. N, 90 lb. P ₂ O ₅	do	15. 50	5. 63	1. 17	1. 45	980
Do	90 lb. P ₂ O ₅ , 45 lb. K ₂ O	do	16. 75	5. 81	1. 11	1. 08	1, 620
Do	22.5 lb. N, 90 lb. P ₂ O ₅ , 45 lb. K ₂ O	do	13. 00	7. 94	1. 17	1. 55	1, 320
Standard error of mean			2. 21	1. 67	. 04	. 16	141. 8

¹ High rate—8 pounds of tall fescue and 2 pounds ladino clover per acre; low rate—4 pounds of tall fescue and 1 pound of ladino clover per acre; drilled—in rows, 8 inches apart; Bc—broadcast and seedbed rolled after Bc; Bc (com.)—broadcast as corrugated roller rolled seedbed; drilled, alt.—alternate-row planting of grass and clover.

² High rate—750 pounds of 3-12-6 fertilizer per acre; low rate—250 pounds of 3-12-6 fertilizer per acre.

³ Band—in rows, 8 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed;

Bc—broadcast and disked in before planting.

⁴ Data based on the second cutting. First cutting was made as a weed-control measure.

⁵ Arrangement of the packer wheels was reversed in position and a small spreader was added to the seed-tube opening to sow 2 rows of seed about 1 inch on each side of the fertilizer band.

The other treatments could be grouped as intermediate with no differences indicated among them.

The development of the clover plants, however, appeared to be depressed by nitrogen and potassium alone or in combination as well as by contact placement of certain of the fertilizer ratios.



FIGURE 25.—Tall fescue and ladino clover drilled in alternate rows, at the high rate: (Left) 750 pounds of 3-12-6 fertilizer banded 1 inch below seed; (right) no fertilizer applied. Planted September 1954; photographed July 1955.



FIGURE 26.—Tall fescue and ladino clover drilled in alternate rows, at the high rate, and fertilizer banded 1 inch below seed: (Left) 750 pounds of 3-12-6; (right) 45 pounds K_2O . Planted September 1954; photographed July 1955.



FIGURE 27.—Tall fescue and ladino clover drilled in alternate rows, at the high rates, and fertilizer banded 1 inch below seed: (Left) 60 pounds of P_2O_5 ; (right) 45 pounds of K_2O . Planted September 1954; photographed July 1955.

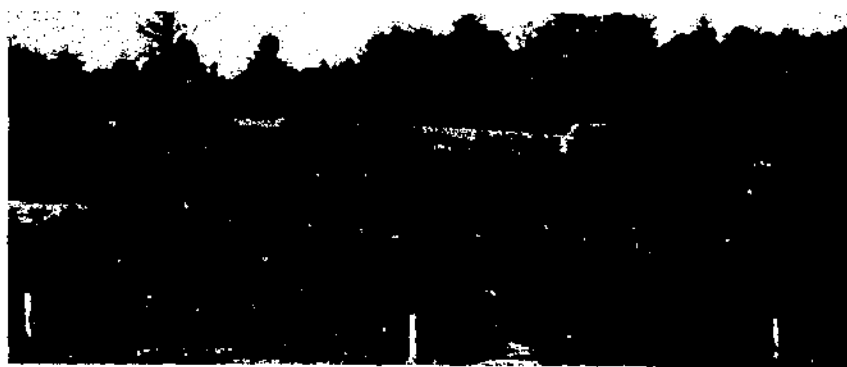


FIGURE 28.—Tall fescue and ladino clover drilled in alternate rows, at the high rate, and fertilizer banded 1 inch below seed: (Left) 22.5 pounds of N and 45 pounds K_2O ; (right) 22.5 pounds of N and 90 pounds of P_2O_5 . Planted September 1954; photographed July 1955.

These data indicate that caution must be exercised on the choice of fertilizer ratios in band seeding of legumes even where excellent moisture conditions prevail.

Yields were taken in June 1956 after a clipping for weed control in late April. Yields therefore were not so high as they would have been had this June cutting been the first. Very little difference between plots was observable before harvesting and, as was expected, the differences in yield were not nearly so great as in previous years. The greatest yield reduction appeared to be from the no-fertilizer treatment and from that in which the fertilizer band was placed 1 inch to the side of the seed. The use of N and K alone or in combination again depressed yields even in this year of adequate moisture.

Experiments on Early-Summer Seeding of *Sericea* *lespedeza* and Orchardgrass

Studies on the establishment of *Sericea lespedeza* (*Lespedeza cuneata* (Dumont) G. Don) and orchardgrass (*Dactylis glomerata* L.) were initiated in 1953. The objects and procedures of these studies were similar to those of the fescue-clover experiments. Seedings were made in June of 1953, 1954, and 1955 at the Agricultural Research Center on silt loam soils of very low fertility that had not been cropped for many years. These experiments, in addition to providing a study of additional species, provided a study of early-summer seeding problems, which may be expected to be somewhat different from fall seedings.

Data on plant counts made in 1953 and yield data taken in 1954 are presented in table 8. Because of extremely dry conditions at the time of and after seeding, stands and development of seedlings were for the most part very poor in the 1954 experiment. These plots were not harvested, but plant-count data were taken (table 8).

Results of the 1953 and 1954 seedings were essentially the same. Responses to placement differentials and fertilizers were almost identical although emergence was somewhat lower in 1954. Usually the best stands were obtained by drilling seed at higher rates and broadcasting a complete fertilizer at the higher rate. Banding the fertilizer 1 inch below the seed usually resulted in considerably

TABLE 8.—*Plant count and dry-matter yield of Sericea lespedeza under different seeding and fertilizing treatments, Beltsville, Md., 1953-54*

[Seeded in June 1953 and in June 1954]

Treatment			Sericea lespedeza plants per square foot in 1953 seeding on—		Dry- matter yield of Sericea lespedeza in 1953 seeding	Sericea lespedeza plants per square foot in 1954 seeding, counted July 1954
Seeding rate and method ¹	Fertilizer		July 8, 1953	Aug. 26, 1953		
	Rate and kind	Placement ²				
8 lb. Sericea lespedeza:			<i>Number</i>	<i>Number</i>	<i>Pounds per acre</i>	<i>Number</i>
Bc.....	200 lb. 10-14-14.....	Bc.....	9	11	138	4
Bc.....	200 lb. 10-14-14.....	Band, 1-b.....	9	13	180	6
Bc.....	400 lb. 5-14-14.....	Bc.....	9	8	83	5
Bc.....	400 lb. 5-14-14.....	Band, 1-b.....	8	5	167	5
8-inch drills.....	200 lb. 10-14-14.....	Bc.....	22	19	481	4
Do.....	200 lb. 10-14-14.....	Band, 1-b.....	6	5	489	1
Do.....	400 lb. 5-14-14.....	Bc.....	20	19	901	4
Do.....	400 lb. 5-14-14.....	Band, 1-b.....	5	6	173	2
24 lb. Sericea lespedeza:						
Bc.....	200 lb. 10-14-14.....	Bc.....	33	30	299	9
Bc.....	200 lb. 10-14-14.....	Band, 1-b.....	30	23	193	7
Bc.....	400 lb. 5-14-14.....	Bc.....	30	21	538	8
Bc.....	400 lb. 5-14-14.....	Band, 1-b.....	37	31	807	11
8-inch drills.....	200 lb. 10-14-14.....	Bc.....	32	35	942	20
Do.....	200 lb. 10-14-14.....	Band, 1-b.....	33	36	1,405	10
Do.....	400 lb. 5-14-14.....	Bc.....	44	39	1,666	13
Do.....	400 lb. 5-14-14.....	Band, 1-b.....	13	10	730	1
8 lb. Sericea lespedeza and 3 lb. orchardgrass:						
Bc.....	200 lb. 10-14-14.....	Bc.....	9	12	112	3
Bc.....	200 lb. 10-14-14.....	Band, 1-b.....	10	11	82	2
Bc.....	400 lb. 5-14-14.....	Bc.....	8	8	44	3

Bc.....	400 lb. 5-14-14.....	Band, 1-b.....	12	10	96	3
8-inch drills.....	200 lb. 10-14-14.....	Bc.....	22	18	406	5
Do.....	200 lb. 10-14-14.....	Band, 1-b.....	7	10	258	1
Do.....	400 lb. 5-14-14.....	Bc.....	18	16	528	5
Do.....	400 lb. 5-14-14.....	Band, 1-b.....	4	4	152	1
24 lb. Sericea lespedeza and 6 lb. orchardgrass:						
Bc.....	200 lb. 10-14-14.....	Bc.....	27	18	419	10
Bc.....	200 lb. 10-14-14.....	Band, 1-b.....	27	14	650	7
Bc.....	400 lb. 5-14-14.....	Bc.....	20	10	537	7
Bc.....	400 lb. 5-14-14.....	Band, 1-b.....	21	16	505	7
8-inch drills.....	200 lb. 10-14-14.....	Bc.....	70	47	677	19
Do.....	200 lb. 10-14-14.....	Band, 1-b.....	19	29	267	4
Do.....	400 lb. 5-14-14.....	Bc.....	62	37	509	22
Do.....	400 lb. 5-14-14.....	Band, 1-b.....	7	18	300	2
8-inch drills, alt. rows.....	No fertilizer.....		38	32	369	10
Do.....	20 lb. N.....	Band, 1-b.....	6	14	184	1
Do.....	56 lb. P ₂ O ₅	do.....	28	32	345	8
Do.....	56 lb. K ₂ O.....	do.....	11	24	236	3
Do.....	56 lb. P ₂ O ₅ , 56 lb. K ₂ O.....	do.....	4	7	287	4
Do.....	20 lb. N, 56 lb. P ₂ O ₅	do.....	6	14	261	2
Do.....	20 lb. N, 56 lb. K ₂ O.....	do.....	1	2	53	5
Do.....	20 lb. N, 56 lb. P ₂ O ₅ , 56 lb. K ₂ O.....	do.....	3	7	281	1
Standard error of mean.....			4. 80	3. 39	182. 8	1. 57

¹ Bc—broadcast and seedbed rolled after Bc.

² Bc—broadcast and disked in before planting; band—in rows, 8 inches apart; 1-b—1 inch below seed.

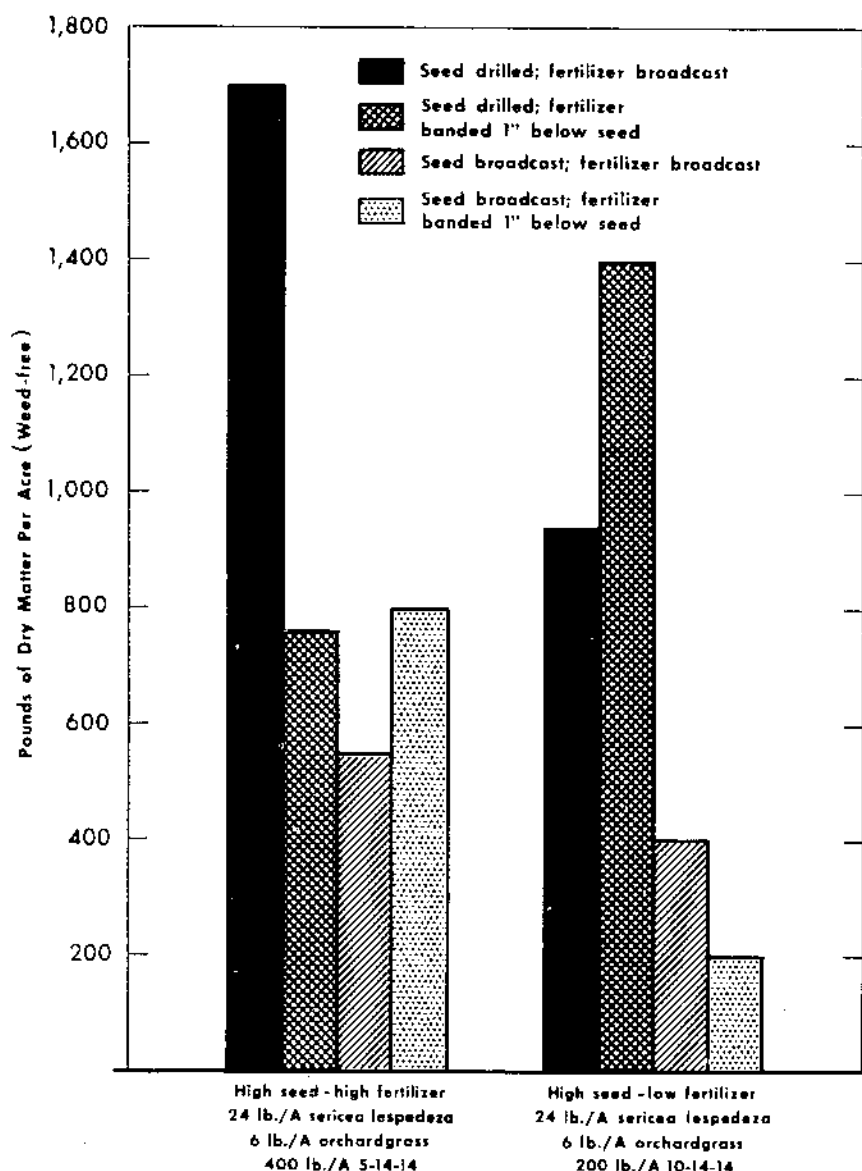


FIGURE 29.—Yield of weed-free dry matter of *Sericea lespedeza* and orchardgrass under different seeding and fertilizer treatments, planted in spring of 1953, Beltsville, Md.

reduced stands at high rates of fertilizer. In 1953, where lower rates of fertilizer were used, stands and yields were generally about the same in both banded- and broadcast-fertilizer plots. In 1954, which was an extremely dry year, however, at the low rate the broadcast-fertilizer plots showed initial plant counts about double that of comparable banded-fertilizer plots. Plants that did survive in the band-seeded plots, however, generally made better growth than those in the plots where the seed was drilled and the fertilizer broad-

cast. This is very obvious in the dry-matter yields taken 2 years after seeding (fig. 29). Where *Sericea lespedeza* was drill seeded alone and fertilizer was broadcast, both at the high rates, the dry-matter yield was 1,666 pounds per acre. The treatment in which seed was drilled and fertilizer banded yielded 730 pounds, or less than 50 percent of the comparable broadcast-fertilizer treatment. When only half the amount of fertilizer was used, this relationship was reversed. The same relationship was also shown at the low rate of seeding. This strongly indicates the adverse effect of too great a concentration of fertilizer on this species under relatively low moisture conditions. Banded fertilizer, however, stimulated production where rates were low enough so that stands were not reduced significantly.

Where the elements N and K, either alone or in combination, were banded below the seed, stands were very poor; but P_2O_5 apparently did not damage the seedlings at the rate used (56 pounds per acre). Stands were also very good in the plots receiving no fertilizer; however, growth was very poor as reflected by yield of dry matter (table 8).

In the 1955 studies on establishment of *Sericea lespedeza* and orchardgrass, initial emergence was exceptionally uniform. Good moisture conditions prevailed throughout the 1955 growing season. Seeding rate only had highly significant effect upon the number of plants emerged (tables 9 and 10). Although not significant, the reduction in the number of *Sericea lespedeza* plants where 112 pounds P_2O_5 was placed in contact with the seed strongly indicates that even phosphorus may be detrimental at very high rates. Highly significant differences between treatments were obtained in early growth and development of both the lespedeza and orchardgrass as measured by height of lespedeza and number of tillers on orchardgrass. Equally good growth responses were obtained with a complete fertilizer banded 1 inch below drilled seed and with phosphate fertilizer banded 1 inch below (figs. 30 and 31) or in contact with drilled seed. Nitrogen and potash fertilizers, alone or in combination, placed 1 inch below drilled seed resulted in poorest development; the P_2O_5 treatment resulted in good development (figs. 32 and 33). Seedlings showed little initial response to fertilizers placed 1 inch below and 1 inch to the side of the



FIGURE 30.—*Sericea lespedeza* and orchardgrass drilled in alternate rows, at the high rate: (Left) 400 pounds of 5-14-14 banded 1 inch below seed; (right) no fertilizer. Planted May 1955; photographed July 1955.



FIGURE 31.—*Sericea lespedeza* and orchardgrass drilled in alternate rows, at the high rate, and fertilizer banded 1 inch below seed: (Left) 10 pounds of N; (right) 56 pounds of P_2O_5 . Planted May 1955; photographed July 1955.



FIGURE 32.—*Sericea lespedeza* and orchardgrass drilled in alternate rows, at the high rate, and fertilizer banded 1 inch below seed: (Left) 56 pounds of P_2O_5 ; (right) 56 pounds of K_2O . Planted May 1955; photographed July 1955.



FIGURE 33.—*Sericea lespedeza* and orchardgrass drilled in alternate rows, at the high rate, and fertilizer banded 1 inch below and 1 inch to side of seed: (Left) 20 pounds of N; (right) 56 pounds of P_2O_5 . Planted May 1955; photographed July 1955.

TABLE 9.—*Plant count, height, and dry-matter yield of orchardgrass and Sericea lespedeza under different seeding and fertilizing treatments, experiment I, Beltsville, Md., 1955-56*

[Seeded on June 2, 1955; plant counts and measurements made on July 5, 1955; harvested July 17, 1956]

Seeding method ¹	Treatment		Plants per square foot		Height		Dry-matter yield (weed-free)
	Fertilizer		Orchard-grass	Sericea lespedeza	Orchard-grass	Sericea lespedeza	
	Rate and kind	Placement ²					
12 lb. Sericea lespedeza and 6 lb. orchardgrass:			<i>Number</i>	<i>Number</i>	<i>Inches</i>	<i>Inches</i>	<i>Pounds per acre</i>
Bc.....	200 lb. 10-14-14	Bc.....	18. 25	24. 00	1. 75	0. 63	1, 140
Bc.....	200 lb. 10-14-14	Band, 1-b.....	24. 25	25. 00	1. 38	. 44	1, 320
Bc.....	400 lb. 5-14-14	Bc.....	23. 00	24. 75	2. 25	. 66	1, 100
Bc.....	400 lb. 5-14-14	Band, 1-b.....	20. 75	24. 50	1. 63	. 41	1, 100
8-inch drills.....	200 lb. 10-14-14	Bc.....	19. 25	19. 75	2. 75	. 63	500
Do.....	200 lb. 10-14-14	Band, 1-b.....	18. 00	23. 25	3. 13	. 94	1, 020
Do.....	400 lb. 5-14-14	Bc.....	19. 75	22. 25	3. 25	1. 00	880
Do.....	400 lb. 5-14-14	Band, 1-b.....	22. 50	22. 00	2. 88	. 88	1, 320
24 lb. Sericea lespedeza and 6 lb. orchardgrass:							
Bc.....	200 lb. 10-14-14	Bc.....	21. 25	46. 25	2. 38	. 63	1, 460
Bc.....	200 lb. 10-14-14	Band, 1-b.....	15. 25	51. 00	2. 13	. 69	1, 500
Bc.....	400 lb. 5-14-14	Bc.....	23. 25	51. 25	2. 63	. 63	1, 560
Bc.....	400 lb. 5-14-14	Band, 1-b.....	25. 00	48. 00	1. 63	. 44	1, 440
8-inch drills.....	200 lb. 10-14-14	Bc.....	19. 75	44. 25	2. 88	. 69	1, 060
Do.....	200 lb. 10-14-14	Band, 1-b.....	20. 00	39. 75	3. 38	1. 13	1, 360
Do.....	400 lb. 5-14-14	Bc.....	24. 00	45. 00	3. 75	1. 00	1, 060
Do.....	400 lb. 5-14-14	Band, 1-b.....	19. 75	39. 00	3. 63	. 94	1, 420
Standard error of mean.....			(*)	3. 67	. 25	. 142	84. 2

¹ Bc—broadcast and seedbed rolled after Bc.

² Bc—broadcast and disked in before planting; band—in rows, 8 inches apart; 1-b—1 inch below seed.

*Not significant.

TABLE 10.—*Plant count, seedling development, and dry-matter yield of orchardgrass and Sericea lespedeza under different fertilizing treatments, experiment II, Beltsville, Md., 1955-56*

[Seeded with 24 pounds *Sericea lespedeza* and 6 pounds orchardgrass in 8-inch drills, alternate rows, on June 2, 1955; plant counts and measurements made on July 17, 1955; harvested July 17, 1956]

Treatment		Plants per square foot		Seedling development		Dry-matter yield (weed-free)
Fertilizer		Orchard- grass	Sericea lespedeza	Tillers per plant in orchard- grass	Height of Sericea lespedeza plants	
Rate and kind	Placement ¹					
No fertilizer		Number	Number	Number	Inches	Pounds per acre
10 lb. N	Band, 1-b	18.0	50.8	1.25	1.00	1,300
20 lb. N	do	15.0	48.5	1.22	.69	1,400
28 lb. P ₂ O ₅	do	19.5	48.0	1.29	.89	1,100
56 lb. P ₂ O ₅	do	21.3	52.5	1.78	1.47	1,740
112 lb. P ₂ O ₅	do	20.0	51.5	1.77	1.30	1,700
28 lb. K ₂ O	do	21.3	46.0	1.93	1.58	1,780
56 lb. K ₂ O	do	21.5	46.3	1.44	.92	1,560
56 lb. P ₂ O ₅ , 56 lb. K ₂ O	do	17.8	39.8	1.43	.81	1,360
20 lb. N, 56 lb. P ₂ O ₅	do	21.8	49.8	1.84	1.60	2,040
20 lb. N, 56 lb. K ₂ O	do	19.5	52.3	2.02	1.32	1,560
200 lb. 10-14-14	do	19.3	41.3	1.48	1.00	1,680
400 lb. 5-14-14	do	19.8	50.0	1.86	1.39	1,940
200 lb. 10-14-14	Band, 1-b, 1-s	21.8	42.0	2.09	1.46	1,600
400 lb. 5-14-14	do	20.0	42.5	1.40	.94	1,320
20 lb. N	do	19.8	52.0	1.73	1.05	1,500
56 lb. P ₂ O ₅	do	19.8	46.5	1.28	.96	1,600
56 lb. K ₂ O	do	17.0	48.3	1.41	.97	1,600
56 lb. P ₂ O ₅ , 56 lb. K ₂ O	do	18.0	49.3	1.32	.91	1,180
20 lb. N, 56 lb. P ₂ O ₅	do	20.5	55.3	1.29	.92	1,600
20 lb. N, 56 lb. K ₂ O	do	20.0	46.8	1.30	.85	1,640
28 lb. P ₂ O ₅	Contact	23.0	49.5	1.34	.88	1,580
56 lb. P ₂ O ₅	do	21.3	51.3	1.61	1.25	1,840
112 lb. P ₂ O ₅	do	18.3	43.5	1.75	1.18	1,580
	do	18.3	27.0	1.86	1.11	1,440
Standard error of mean		(*)	(*)	.123	.132	163.1

¹ Band—in rows, 8 inches apart; 1-b—1 inch below seed; 1-s—1 inch to side of seed.

*Not significant.

seed in 1955, regardless of rate or ratio (fig. 32). This treatment was not included in the 1953 and 1954 seedings.

Data on plant development (table 9) indicate that, even in a year of high moisture, banded complete fertilizer at high rates appears to have some adverse effect on development of *Sericea lespedeza*. First-year yields, however, were stimulated by this high rate of fertilizer. Retardation in development apparently was not serious enough to significantly reduce stands.

Species competition was indicated very strongly in these studies with mixtures of *Sericea lespedeza* and orchardgrass. Yields were generally higher where the lespedeza and orchardgrass were seeded in alternate rows rather than in the same row. In comparable treatments, *Sericea lespedeza* seeded alone, in the 1953 study, at 24 pounds per acre yielded higher generally than 24 pounds of *Sericea* with 6 pounds of orchardgrass.

Experimental Results and Discussion

The results of these studies provided very valuable information on seed and fertilizer placement, fertilizer rates and ratios, and the effect of climatic and environmental conditions on establishment. Since these studies included both fall and early-summer seedings of different species, they provided an opportunity to study problems common to each type of seeding. These studies also provided information on evaluating establishment methods.

Response to seed and fertilizer placement was very striking in these experiments. The method of seeding now commonly known as band seeding was superior to broadcast seeding in all the fall seedings. The advantage of band seeding apparently lies in the placement of both seed and fertilizer in proper relation to each other. In the fall seeding of tall fescue and ladino clover, drilling fertilizer appeared to have little advantage where seed was broadcast. However, drilled seed appeared to have a distinct advantage even where fertilizer was broadcast. The maximum advantage, however, appeared to be where both seed and fertilizer were drilled in proper relation to each other.

Fertilizer placed in a band to the side of the seed generally did not result in so high production as that placed directly below. This side placement, however, showed considerable advantage over broadcast fertilizer. Uptake of fertilizer placed to the side is apparently delayed to some extent; however, the plants apparently are able to utilize this fertilizer soon enough to aid in establishment. This type of placement may have advantages during drier seasons.

Early-summer seeding of *Sericea lespedeza* and orchardgrass mixtures responded differently to fertilizer than the fall-seeded tall fescue and ladino clover mixtures. Maximum establishment and yield response was due to broadcasting fertilizer and drilling seed. Banding fertilizer seriously damaged establishment in these seedings in 2 out of 3 years. In 1955, when moisture conditions were very good, banded complete fertilizer still had a slight adverse effect on seedling development. The effect was not serious enough in this year, however, to reduce stands, and first-year yields were stimulated by banded fertilizer.

The differential response of fall and early-summer seedings to fertilizer placement may be explained, at least partially, on the basis of salt concentration. Fall seedings were generally followed by

cooler weather and more uniform rainfall. Soil-moisture evaporation was considerably less during the fall. The early-summer seedings were usually followed by hot and relatively dry weather. Rains occurring after these seedings were generally followed by extended periods of hot, dry weather. These conditions were conducive to considerable soil-moisture evaporation. Evaporation caused an upward movement of water, which moved fertilizer salts toward the soil surface. As moisture evaporated, the solution became more concentrated, which restricted moisture availability through higher osmotic pressures, plasmolysis, or possibly salt toxicity. Of the fertilizer elements used in the early-summer seedings, especially in the drier years, only phosphorus could be banded with comparative safety. This could possibly be attributed to low solubility and slow movement of phosphates in soil.

Species response to banded fertilizer was somewhat different in these experiments although not so great as might be expected. Ladino clover and *Sericea lespedeza* were more sensitive than grasses to banded applications of potassium and nitrogen. However, the development of both grasses and legumes was retarded by these two elements when used alone or in combination. Phosphorus stimulated development even in the drier years.

These studies indicated that fertilizers commonly used in the maintenance of forages in the Eastern United States may be entirely different from those that stimulate establishment. Wagner (19) in an earlier report of these studies stated:

It is of unusual significance that fertilizer requirements for establishment and maintenance appear to be two distinctly different things. Phosphorus for both the grasses and legumes used in these studies was the key element in early establishment. The use of some nitrogen and potassium along with phosphorus appeared to be beneficial. On the other hand, potassium and nitrogen either alone or in combination with one another were definitely detrimental to young seedlings. Yet both nitrogen and potassium in relatively large quantities are known to be important for the maintenance and continued productivity of forage crops in this area.

The soils used in most of these studies were relatively low in available plant nutrients. This may partially explain the striking response to fertilizer placement; however, other advantages in addition to fertility were clearly evident in these studies.

Drilling seed and compacting soil in the drill row without regard to fertilizer placement showed a very decided advantage over broadcast seeding. Lack of competition from weeds was one of the big advantages in band-seeded plots. Weed populations, when measured by plant counts, ground cover, or by hand separation from harvested forage, were always much lower in band-seeded plots than in broadcast plots. In band-seeded plots the surface soil is compacted only over the narrow bands. Emergence of weeds between the bands is less, since weeds respond very much like crop plants to seedbed preparation. Fertilizers are not available to the weed seedlings that do emerge between the bands; therefore, they are at a further disadvantage. Figures 21 and 22 illustrate these differences very clearly.

Seeding of grasses and legumes in alternate rows appears to offer several advantages over mixed seedings. Competition for nutrients and light is one of the serious drawbacks in the establishment of mixed grass-legume pastures. Often clovers are completely eliminated from the mixture by competition before becoming established. In

such cases it appears that alternate row seeding would offer an opportunity to overcome this disadvantage at least during establishment. Where the two species require different fertilizer elements for establishment they could be applied separately with the proper equipment. In these studies *Sericea lespedeza* produced higher dry-matter yields when seeded in alternate rows with orchardgrass than when seeded together in the same row.

These studies indicated that initial plant counts often are not a very accurate evaluation of establishment. This further emphasizes the necessity of evaluating establishment methods on the basis of rate of seedling development as well as initial plant counts and yields.

If yield of weed-free dry matter in the first year of production can be assumed to be the final evaluation of establishment, then a test of the reliability of various measurements is possible. Therefore, correlation coefficients of the various measurements used in these experiments on yield of weed-free dry matter in the 1952 seeding of tall fescue and ladino clover were computed.

The correlation values indicated that, of the measurements used, only percent trifoliolate leaves in clover and number of tillers in grasses gave significant correlation with first-year yields. Both measurements gave very high correlation values (.6382 for trifoliolate leaves and .5369 for tillers⁵). Initial numbers of plants (.2346 and -.0169) and height of grasses (.0543) gave very low nonsignificant values.

The nonsignificant negative correlation (-.0169) of the number of clover plants on yield indicated a possible decrease in emergence of clover where fertilizer was banded. Data (tables 1 and 3) indicated that there was a slight negative trend between these two measurements.

The rapidity of development of the plant, therefore, is the key to final establishment.

Summary

Studies on the seeding and establishment of forage species were conducted at Beltsville, Md., from 1952 to 1955. Objectives of the studies were to determine the methods of establishment that would require less seed for satisfactory stands, eliminate or lessen the hazards of stand failures, and promote faster development and growth of the seedlings that would assure earlier utilization of the pasture, and, consequently, more production.

Precision equipment for the establishment of forages on prepared seedbeds in field experiments has been developed by Agricultural Research Service research engineers. The special drills were comparable to farm machines, but they were not prototype field implements as their prime objective was to facilitate the accurate determination of basic information regarding seeding and fertilizing methods. Seed and fertilizer can be metered accurately at various rates and applied in broadcast patterns or in drilled rows to plots approximately 5 feet wide. These special machines and some new techniques in handling field plots were developed primarily for the work reported in this bulletin. However, owing to the great interest by research workers of State agricultural experiment stations, more than 100 cooperative

⁵ The number of tillers was computed from the 1953 seeding of tall fescue and ladino clover.

experiments in 18 States were conducted during the first 8 years of the study with the seven special drills devised by this research unit.

The Beltsville experiments included early-summer mixed seedings of orchardgrass (*Dactylis glomerata* L.) and Sericea lespedeza (*Lespedeza cuneata* (Dumont) G. Don) and fall mixed seedings of tall fescue (*Festuca arundinacea* Schreb.) and ladino clover (*Trifolium repens* L. var. *ladino*). Experimental variables included seed rates and placement and fertilizer rates, ratios, and placement. In the evaluation and analysis of these experiments particular attention was given to initial emergence of seedlings, early growth and development, survival, production of forage, and weed populations.

The more significant results of these studies may be summarized as follows:

1. In the fall seeding of grassland species (tall fescue and ladino clover) on prepared seedbeds, better establishment resulted in 3 out of 4 years, 1952-55, by banding fertilizer below the drilled seed. Usually poor moisture conditions reduced stands materially in broadcast treatments. In the fall of 1955, excellent moisture conditions prevailed and little differences in emergence were indicated; however differences in development of seedlings due to treatments were noted. In no instance were broadcast stands superior to band-seeded ones within the same groups of fertilizer and seed rates.

2. In early-summer seeding of grassland species (orchardgrass and Sericea lespedeza) drilling fertilizer below drilled seed had a depressing effect on establishment in 2 out of 3 years, 1953-55, except with phosphate fertilizer alone. When poor moisture conditions prevailed after planting, the best establishment was obtained by drilling seed and broadcasting fertilizer at the higher rates. Complete fertilizers banded at the lower rate, however, were equal to, or better than, the same amount of fertilizer broadcast.

3. Band seeding produced better early development of plants than other methods under adverse seeding conditions except where nitrogen and potassium were used alone or in combination. With good-to-fair moisture, the use of nitrogen and potash alone or in combination produced fair stands of grass but reduced legume stands and development of seedlings in both species. In very dry seasons these treatments produced little or no stands of either species.

4. Among the broadcast treatments, better stands were obtained where seed was deposited ahead of a double corrugated roller instead of between the rollers (common farm practice). This treatment did not produce adequate stands in the drier years, but with adequate moisture it was one of the best treatments.

5. Phosphorus and complete fertilizers stimulated early growth; but nitrogen and potash, either alone or in combination, had a depressing effect on stands, development, and yield.

6. The importance of proper placement of fertilizer in relation to the drilled seed is very clearly demonstrated in these studies. In practically all instances, a band of fertilizer placed 1 inch below the drilled seed stimulated development significantly, the exceptions being nitrogen and potassium fertilizers alone or in combination. Except for lower rates of phosphorus alone, contact placement of fertilizer was detrimental in most instances. Banding of fertilizer 1 inch to the side of the seed delayed stimulation of seedlings. However, in general, this delay was not long enough to cause serious damage. This may be

an effective method of banding fertilizer in drier years and on legume seedings.

7. Weed populations usually were reduced considerably in band-seeded plots. Two reasons are thought to be responsible for this: (1) fertilizer is available only to those plants directly over the band; and (2) compaction of the soil occurs only over the band, which leaves a poor seedbed between the drilled rows.

8. Early-seedling development, as measured by percent trifoliate leaves in clover and number of tillers in grass, appears to be one of the best indicators of establishment used in these experiments.

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