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The Establishment and Management of Ladino Clover In Missouri

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SUMMARY

Experiments were conducted in the field and in the greenhouse. Objectives were to determine the possibilities of establishing ladino clover in grass sods and to develop and refine some of the cultural and management practices for its production. This work shows:

1. Ladino clover can dependably be established in grass sods with little or no tillage.
2. Italian imported ladino clover seed was equal or superior to the certified domestic seed tested from the standpoint of type purity but uncertified commercial seed was not consistently pure as to type.
3. Grass-ladino clover plantings produced better stands when made in late summer than when made in the spring.
4. Ladino clover seedlings which grew in the row of associated grass heaved less than those growing between the grass rows.
5. Clipping for weed control was essential for establishment of ladino clover on prepared seedbeds in the spring.
6. Ladino clover was well established and it produced well in redtop, tall fescue, orchard grass, bromegrass, and Kentucky bluegrass.
7. Ladino clover seedings in grass sods were more successful when made in the spring than when made in late summer.
8. Tillage of sods was helpful but not essential for the establishment of ladino clover.
9. Clipping for the control of the growth of associated grass was necessary for satisfactory ladino clover establishment in sods.
10. A temperature of 80° F was more favorable than cooler temperatures for the growth of ladino clover tops; 65° and 80° were about equally better than 50° for ladino clover root growth. Top growth of tall fescue increased with each 15° increase in temperature from 50° to 80° F. Sixty-five degrees Fahrenheit was more favorable than 50° or 80° for tall fescue root growth.
11. Frequency of defoliation had a much greater influence on the growth of ladino clover than height of defoliation.
12. Frequency of defoliation produced a more marked influence on the growth of ladino clover than on bromegrass or tall fescue.

These studies and the literature cited indicate that the botanical composition of grass-ladino clover swards can be influenced by:

1. Rates of seeding.
2. Time defoliation is initiated in the spring.
3. Level to which defoliation is made.
4. Frequency of defoliation.
5. Use of nitrogen fertilizers.

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O. Hale Fletchall and E. Marion Brown

INTRODUCTION

Ladino clover, *Trifolium repens* L. var. Ladino, is the most widely used legume in new permanent pasture seedings in Missouri. By 1947, when this study began, tests in Missouri and other states showed that the crop had promise for pasture. However, little was known about the best cultural practices for ladino clover under Missouri conditions. It is estimated that ladino clover was growing on only a few hundred acres in Missouri in 1947, and most of that was seeded on prepared seedbeds. It was first recommended by the College of Agriculture for inclusion in permanent pasture seed mixtures and for renovating old pastures in 1948.

The renovation of permanent pastures by heavy fertilization, seedbed preparation, and reseeding is expensive. Farmers are often unwilling to destroy a serviceable pasture and sacrifice the use of it for several months to establish a new one even with reasonable assurance of a substantial increase in production. In many instances it seems desirable to establish ladino clover in old grass pastures with little or no tillage. But is this practice dependable? An answer to this question is one of the objectives of the study reported here.

There is another instance in which it would be desirable to get a stand of ladino clover in established grasses. Many legumes, including ladino clover, are less hardy than the common pasture grasses. Therefore, it is not uncommon for a farmer to invest in a complete pasture renovation only to find that his legumes have succumbed to unfavorable weather conditions, insects, or other hazards, leaving a stand of almost pure grass. Ladino clover in such a pasture sward would contribute to the yield, improve its quality, and, through symbiotic nitrogen-fixing bacteria, release nitrogen for the grass.

Other pasture land is too steep, rocky, or stumpy for normal seedbed preparation. Annual lespedeza has performed very well as a pasture legume on this kind of land, as well as on tillable land, and probably should continue to be used where the fertility is too low to support ladino clover. However, ladino clover would be a more productive legume on soil fertile enough to support it. If ladino clover is to be grown on such pasture land, it must be established with little or no tillage of the sod.

Missouri Pasture Grasses

About 10 million of the 35 million acres of land in farms in Missouri are pasture land. Over half of this is unimproved and in a state of low productivity. Kentucky bluegrass, *Poa pratensis* L., is the most abundant grass in the northern part of the state while redtop, *Agrostis alba* L., is the most prevalent one in the southern part. Increasing amounts of tall fescue, *Festuca arundinacea schreb.*, and orchard grass, *Dactylis glomerata* L., are being planted. Southern strains of smooth bromegrass, *Bromus inermis* Leyss, although poorly adapted to the soil on which this study was made, are well adapted to deep, fertile, well-drained soils in Missouri. This study includes these five leading pasture grasses.

Bromegrass a Special Problem

Experience has shown that brome grass, because it is poorly adapted to the soil, is a weak competitor on the Missouri Agricultural Experiment Station South Farms. Tall fescue, however, has been found to be well adapted and a strong competitor on such soil (5).* To predict more accurately how well ladino clover would compete with bromegrass on more favorable soil, a study was made in the greenhouse with fertile topsoil in pots to compare bromegrass with tall fescue as an associated grass for ladino clover.

Effect of Temperature on Competitive Ability of Ladino Clover

The whole problem of associated crops is one of competition which is influenced by many factors. One of these is temperature. The growth of ladino clover alone and with grass was studied under controlled temperatures.

Ladino Clover Seed

The seed of ladino clover, the giant variety of white clover, cannot be distinguished from that of the intermediate or small types. Ladino crosses readily with varieties of the smaller types and the progeny is usually of intermediate size and vigor. Mechanical mixtures of seed from different types are possible. Ladino clover seed from many sources is offered for sale to Missouri farmers. One phase of this study was to determine the relative purity of seed from several sources.

When to Plant Ladino Clover

Pasture and meadow crops are usually most satisfactorily planted in Missouri either in late summer or in the spring. New seedings of most crops on prepared seedbeds are more successful in late summer, but the advantage of more efficient use of the land sometimes encourages spring planting. The planting of perennial legumes in grass sods is a relatively new practice in Missouri. Little is known about the best time of year for planting. Langford (7) recently found that the best time to plant birdsfoot trefoil, *Lotus corniculatus* L., in Kentucky bluegrass is late winter or early spring. However, the seedlings of Ladino clover

*Reference is made by number to the Bibliography.

are much more vigorous than those of birdsfoot trefoil so an assumption of coincidence of their optimum seeding dates might be open to question.

In these studies, seedings were made in the spring two years and in the late summer three years to compare these planting times for ladino clover in grass sods.

The Ratio of Ladino Clover to Grass in Pastures

Although it is traditionally difficult to establish and maintain legumes in grass pastures, the problem is not always one of establishing and maintaining the maximum proportion of ladino clover to grass. Under favorable conditions, ladino clover is aggressive. Conditions relative to bloat, winter injury, longevity of stand, and sometimes yield are better when grass makes up a substantial part of the herbage. This suggests a problem in acquiring and maintaining a balance between the legume and the non-legume components of the sward. No accurate optimum ratio of the two components has been established. However, ladino clover in excess of 50 percent of the grazed herbage is generally considered a bloat hazard, and this proportion is probably near the optimum from the other standpoints. An experiment was conducted to determine the effect of varying the seeding rates of grasses and ladino clover upon the subsequent botanical composition of the sward.

The clipping treatments applied to various experiments reveal some effects of management upon the maintenance of a desirable botanical composition.

Longevity and Production of Ladino Clover

Wide variations in the persistence of ladino clover stands have been obtained. Some of the losses of stands have been difficult to explain. The frequency of short lived stands is one of the most serious defects of this perennial pasture legume.

Different clipping treatments were applied to grass-ladino clover mixtures to obtain an indication of the influence of different grazing managements on the longevity of stands.

Determinations also were made of the productivity of grass-ladino clover mixtures as influenced by clipping treatment and associated species of grass.

MATERIALS AND METHODS

The influence of clipping treatment on the growth of ladino clover in pure stand and in association with varying stands of bromegrass and tall fescue was studied in the greenhouse. The effect of temperature on the growth of ladino alone and with tall fescue was also studied in temperature-controlled greenhouse compartments.

The establishment and maintenance of ladino clover was studied in the field on sods of five grasses with varying seasons, seedbed preparations, and subsequent clippings. Other field experiments included studies of seed sources, rates of planting, rate of seedling development, heaving, longevity of stand, and productivity of ladino clover.

Greenhouse Studies

Plans of Experiments

Series A: The study was begun June 20, 1948, and terminated October 11, 1948. Ladino clover was grown in pots in pure stand and with two stands each of bromegrass and tall fescue. The mixtures studied are shown in Table 1. The four clipping treatments which were given each mixture and the management each clipping treatment was designed to simulate are shown in Table 2. The

TABLE 1--FIVE MIXTURES USED IN GREENHOUSE SERIES A

Kinds of Plants	Number of Plants per 7.5-Inch Pot	Number of Plants per Square Foot
Ladino clover alone	32	92
Ladino clover plus	32	92
Bromegrass	6	17
Ladino clover plus	32	92
Bromegrass	37	106
Ladino clover plus	32	92
Tall fescue	6	17
Ladino clover plus	32	92
Tall fescue	37	106

TABLE 2--FOUR CLIPPING TREATMENTS APPLIED IN GREENHOUSE SERIES A

Clipping Treatment	Management Simulated
Clipped to 1.5 inches semi-monthly	Close continuous grazing
Clipped to 1.5 inches monthly	Close rotational grazing
Clipped to 3.0 inches monthly	Lenient rotational grazing
Not clipped	Cut as hay

cultures were grown in triplicate. Their random positions were changed about once a week.

Series B: The study was begun November 19, 1948, and terminated May 5, 1949. Thirty-two ladino clover plants per culture were grown (a) in pure stand and (b) with 12 tall fescue plants per culture. These stands are equivalent to 104 ladino clover plants and 39 tall fescue plants per square foot. Each mixture was subjected to two degrees of defoliation—(a) clipped to a height of 1.5 inches weekly and (b) not clipped. Each clipping treatment of each mixture was grown at temperatures of 80°, 65°, and 50° F. Actually, the temperature rose somewhat above 50° in the coolest chamber on a few hot, sunny days. The cultures were grown in triplicate.

Equipment

Pots: The cultures in series A were grown in two-gallon, glazed, earthenware pots, 8 inches in diameter and 8 inches deep. Each container, when filled to within about 1 inch of the top, holds approximately 6.3 kilograms of firmed, dry soil.

The cultures in series B were grown in galvanized truncated cones with both ends open. The containers were 7.5 inches in diameter at the top, 7 inches in diameter at the bottom, and 10 inches deep. The tapered construction facilitated the removal of the mass of soil and roots. The galvanized bands were placed in 2-gallon pots. Each container, when filled to within about 1 inch of the top, holds about 6.7 kilograms of firmed, dry soil.

Thermo-regulated Growth Chambers: The equipment which was used in one phase of these investigations to study the growth of plants at controlled temperatures has been described by Brown (2). It consists of three growth chambers

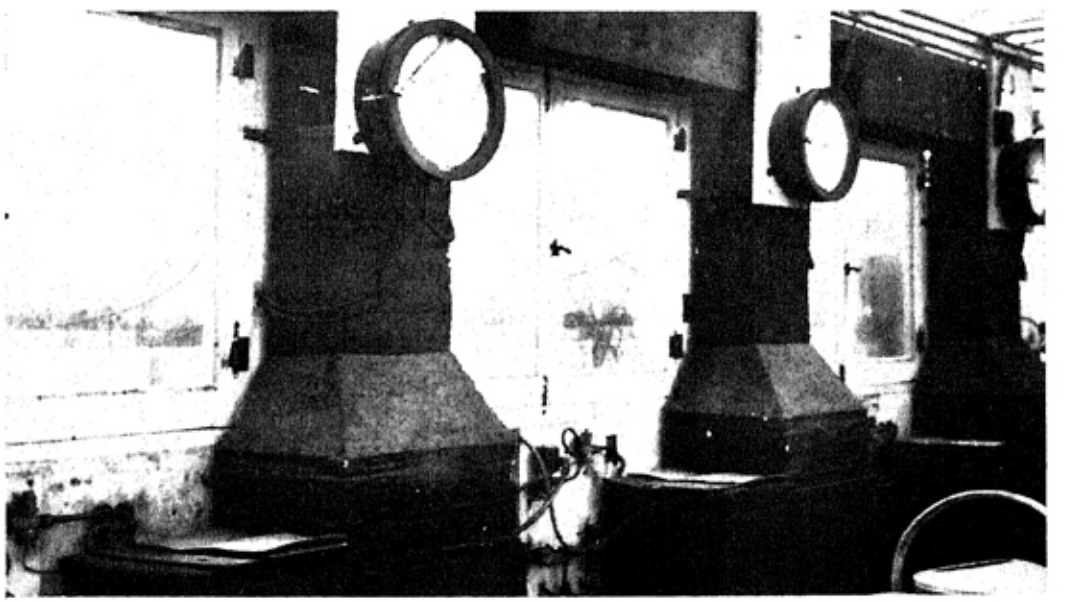

Figure 1—The thermo-regulated growth chambers used to study the growth of ladino clover.

equipped so that they can be operated simultaneously at independently controlled temperatures (Figure 1). Although the equipment permits independent control of air and soil temperatures, the cultures in this study were grown on platforms above the soil temperature tanks with the pots exposed to the same surrounding air temperatures as the aerial portions of the plants.

The thermo-regulated growth chambers are located within and along the south side of a greenhouse. The arrangement and construction of the growth chambers is such that the intensity of light admitted is at least equal to that admitted by an ordinary greenhouse and the three compartments are comparable with respect to light.

Materials

Soil: The soil for both greenhouse series was virgin Mexico silt loam topsoil. No nutrient or physical conditioning substances were added. The natural vegetation on the site from which the soil was obtained was a lush growth of Kentucky bluegrass and white clover.

Plants: All plant cultures used in these investigations were started from commercial seed of good quality.

Methods

Potting the soil: The soil was well mixed and screened through ¼-inch mesh hardware cloth. It was added to the pots in rotation about 1 kilogram at a time. Each increment of soil was pressed down firmly before the next was added and care was taken to obtain a high degree of uniformity of packing. The pots received equal weights of soil. Samples were taken for moisture determinations so that the weight of dry soil per pot could be determined.

Establishing the plants: Holes of uniform size and distribution for each species were made in the moistened soil in the pots. Extra seeds were dropped in each hole to allow for imperfect germination. They were covered with dry soil of the same origin as the potting soil, but it was passed through an 18 x 14 mesh screen. This dust made good contact with the seed without packing and within a few minutes it absorbed sufficient moisture from the potted soil to support germination. This eliminated the necessity of watering the cultures after planting to get good contact between the seed and the soil—a practice which usually results in many of the seeds floating to the surface and being displaced from their planned positions. After they emerged, the plants were thinned to one per hill. Where missing hills occurred, plants thinned from other hills were transplanted to them. Extra cultures were planted and those with poor initial stands or unthrifty seedlings were discarded.

In greenhouse series A, involving four clipping treatments applied to ladino clover grown alone and with varying stands of bromegrass and tall fescue, the ladino and the grasses were seeded at the same time.

In the greenhouse series B, with two clipping treatments given to ladino alone and with tall fescue at three temperatures, the grass was established first.

It was planted November 19, 1948, and kept in the greenhouse outside the thermo-regulated chambers. By February 15, 1949, when it was clipped to a height of 1.5 inches, the tall fescue had made a good growth, yielding an average of 4.5 grams of dry matter per pot (equivalent to 1400 pounds per acre).

The following day, the ladino clover was planted in both the mixed-culture pots and the ladino-alone pots. The ladino established very well in the tall fescue cultures but about 20 percent of the seedlings from plantings in the bare soil were killed by damping-off disease. Although disease necessitated the transplanting of many clover plants and the discarding of the most severely damaged cultures, perfect stands were obtained in those pots used in the experiment. The tall fescue cultures were again clipped to a height of 1.5 inches—just above the tops of the ladino clover plants—on March 15, 1949. The cultures were placed in the thermo-regulated growth chambers on March 17, 1949, after which they received the differential clipping treatments.

Watering: The soil moisture was maintained by weighing cultures periodically and adding sufficient water to the surface of the soil to bring the soil moisture content to 20 percent (Figure 2).

Figure 2—Weighing the cultures and adding water to bring the soil moisture content to 20 percent.

Measuring Growth: The herbage clipped from each culture was separated as to species, dried, and stored in separate containers. Material from successive clippings was dried and added to that of the previous clippings. In series B, the herbage clipped from the tall fescue cultures before they were placed in the growth chambers was not included in the yields. At the end of the experiment, the grasses were cut at the base of the crowns and the ladino clover was cut at the surface of the ground. This herbage was separated as to species, washed to remove adhering soil, and dried together with the corresponding herbage clipped previously.

The mass of soil and roots from each pot was placed on 3/16-inch mesh hardware cloth and the soil was washed from the roots with water under pressure. Foreign matter which could not be washed from the roots was picked out by hand. The ladino clover roots were separated from the grass roots and each was dried separately.

All dry weights or quantities of dry matter were determined by weighing the plant material after it had been oven-dried for about 24 hours at approximately 170 degrees Fahrenheit.

Field Studies

Plans of the Experiments

Seed sources: Up to 25 widely spaced plants of ladino clover from each of 13 lots of seed were classed as to size as giant, intermediate, and small.

Rates of Seeding: Ladino clover was seeded by itself at two rates and with two rates each of bromegrass and tall fescue. The grasses also were seeded alone at each of two rates (Table 3). The plots which were 5 feet wide and 18 feet long were grown in triplicate.

TABLE 3--MIXTURES OF LADINO CLOVER, BROMEGRASS, AND TALL FESCUE USED IN THE EXPERIMENT ON RATES OF SEEDING

Mixture	Grass	Pounds Grass Seed per Acre	Pounds Ladino Seed per Acre
1	bromegrass	10	0
2	bromegrass	10	2
3	bromegrass	10	5
4	bromegrass	25	0
5	bromegrass	25	2
6	bromegrass	25	5
7	tall fescue	10	0
8	tall fescue	10	2
9	tall fescue	10	5
10	tall fescue	25	0
11	tall fescue	25	2
12	tall fescue	25	5
13	none		2
14	none		5

Rate of Seedling Development: The rate of seedling development of ladino clover was compared with that of birdsfoot trefoil; Korean lespedeza, *Lespedeza stipulacea* Maxim.; common lespedeza, *Lespedeza striata* (Thunb.) H. & A.; red clover, *Trifolium pratense* L.; and alsike clover, *Trifolium hybridum* L. Each legume was seeded on duplicate plots 3½ feet wide and 5 feet long on a prepared seedbed and in Kentucky bluegrass sod in March, 1949. Air dry weights of 50 plants from each plot (reported here as air dry weights per 100 plants) were determined in July, 1949.

In another test the oven dry weights of 100 ladino clover seedlings were determined June 23, 1949, from stands seeded April 22, 1949. These seedings had been made on a prepared seedbed and on disked and untilled sods of redtop, of tall fescue, of orchard grass, of smooth bromegrass, and of Kentucky bluegrass.

Establishment in Grass Sods: Each late summer and each spring from the summer of 1948 to the summer of 1950, inclusive, ladino clover was seeded across one block each of redtop, tall fescue, orchard grass, and smooth bromegrass. The contiguous blocks of grass, each 100 feet wide and 260 feet long, were on relatively uniform land of the same cropping history. A block of Kentucky bluegrass which was located about 300 yards from the other grasses on soil of identical type and topography was included in the experiment in all except the late summer seeding in 1948. In the summers of 1949 and 1950, the seedings on prepared seedbeds were also made on separate, near-by areas.

Three degrees of tillage of the sods were tested: (a) plowed and worked down to a normal seedbed, (b) disked, to kill about half of the stand of grass, and (c) not tilled.

The summer, 1948, seeding received no clipping treatments because the stands survived the winter of 1948-49 so poorly. The summer, 1950, seeding was not subjected to differential clipping treatments because the investigator was recalled to active duty with the Army early in 1951. The seedings made in the spring of 1949, summer of 1949, and spring of 1950 received the clipping treatments shown in Table 4. Most of the clipping treatments were replicated four times on each tillage of each grass for each seeding. In a few cases space permitted only three replications and, in rare instances, two. However, since the sods (except orchard grass and bromegrass) thickened up rapidly after disking and observations did not disclose interactions between tillage treatments and clipping treatments, the numbers of replications of clipping treatments are, in most cases, twice the numbers mentioned above. The clipped plots were 6 feet wide and 40 feet long.

Heaving Observations: Studies were made in the winter of 1949-50 of the effect of the location of ladino clover seedlings with respect to the drilled rows of associated grass on the heaving of the clover plants. Tall fescue was seeded at 10 pounds per acre and ladino clover at 1.8 pounds per acre August 25, 1949, on 2.7 acres. The grass was drilled in rows 8 inches apart, from the grain box of a

TABLE 4--CLIPPING TREATMENTS APPLIED TO PLOTS OF LADINO CLOVER AND GRASS IN THE EXPERIMENT ON ESTABLISHMENT IN GRASS SODS

Time of Seeding	Clipping Treatments Applied in the Year: 1949	1950
Spring, 1949	Clipped to 1.5 inches weekly	Clipped to 1.5 inches weekly
	Clipped to 2 inches semi-monthly	Clipped to 2 inches semi-monthly
	Clipped to 4 inches monthly	Clipped to 4 inches monthly
	Clipped as hay and aftermath removed	Clipped as hay and aftermath removed
	Clipped to 2 inches monthly	
Summer, 1949 and Spring, 1950		Clipped to 2 inches semi-monthly
		Clipped to 4 inches monthly
		Cut as hay and aftermath removed

grain drill, with 500 pounds per acre of 0-14-7 fertilizer drilled in the row. The clover was scattered ahead of the disks of the drill by removing the spouts of the grass seeding attachment from the boots.

Two techniques were used to measure the heaving of the ladino clover seedlings.

In one case 50 pairs of ladino clover plants uniformly distributed over the field were individually marked with wire stakes. One of each pair was located in the row of tall fescue near a grass plant. The other member of each pair was selected to be the same size with respect to number of leaves; it also had to be within 1 foot of the seedling in the row, but from 1.5 to 3.5 inches from the row of grass. Observations were made on the amount of heaving April 14, 1950.

The other technique employed chart quadrats on the same field. The vegetation on 20 systematically located areas, each 1 decimeter wide and 1 meter long, was charted. The heaving of the charted ladino clover seedlings within the rows of grass and between the rows was observed the same day the staked pairs were observed.

Longevity and Production: Stands and yields of pure grass and of grass-ladino clover associations involving smooth bromegrass, Kentucky bluegrass, orchard grass and redtop were measured from 1948 to 1950 inclusive. The legume-free plots used in the 1950 studies had grown grass-sweet clover from establishment until 1949 when seedings of sweet clover in the grass were discontinued.

The soil was limed and fertilized with 500 pounds per acre of 0-14-7 fertilizer and one block 140 feet long of each grass was planted in August, 1943.

The grasses were well established when the legumes were seeded in March, 1945, in strips 6 feet wide and 140 feet long. Each strip was divided into three plots 6 feet wide and 40 feet long with two 3-foot alleys and two 7-foot borders. The three plots of each grass-legume mixture received the following three clipping treatments: (a) mowed semi-monthly to a height of 1.5 inches; (b) mowed monthly to a height of 3 inches; and (c) mowed to the 3-inch level in mid-June.

Weather and Soil

The Soil: The field work was performed on the University of Missouri South Farm about three miles southeast of Columbia. The soil is Mexico silt loam which characterizes the slightly rolling prairies of Northeast Missouri (9). The dark gray silty surface soil is characteristically 6 to 10 inches deep. The 4- to 8-inch thick sub-surface layer which is somewhat lighter is extremely acid. The true subsoil has a high content of colloidal clay making it almost impervious to water. In general, crop yields are lower on Mexico silt loam than they are on other soils in Northeast Missouri. On areas where surface drainage is poor, crops often suffer from excessive moisture. Periods of low rainfall are particularly hazardous to crops due to the sub-surface claypan. Under conditions of ideal moisture, this soil is highly productive.

The Weather and the Soil Moisture: The monthly precipitation, the mean temperatures, and the departures of the precipitation and temperatures from normal for the years 1948 to 1953, inclusive, are presented in Tables 5, 6, 7, 8, 9, and 10. The periodic soil moisture content for the years 1948, 1949, 1950, and 1951 is shown in Tables 11, 12, 13, and 14.

TABLE 5--MONTHLY PRECIPITATION AND TEMPERATURE AND DEPARTURES FROM NORMAL AT COLUMBIA, MISSOURI, 1948

	Temperature in °F.		Precipitation in Inches	
Month	1948 Mean	Departure From Normal	1948 Total	Departure From Normal
January	25	-5	1.15	- .65
February	33	-1	2.04	+ .47
March	42	-1	3.72	+ .71
April	61	+6	.82	-2.98
May	64	0	2.85	-1.99
June	74	+1	6.53	+1.63
July	78	0	6.67	+3.66
August	76	0	2.14	-1.75
September	70	+1	1.78	-2.84
October	56	-2	2.94	- .27
November	46	+3	4.21	+1.60
December	37	+4	1.46	- .61
Annual	55	0	36.31	-3.02

TABLE 6--MONTHLY PRECIPITATION AND TEMPERATURE AND DEPARTURES FROM NORMAL AT COLUMBIA, MISSOURI, 1949

Month	Temperature in °F. 1949 Mean	Temperature in °F. Departure From Normal	Precipitation in Inches 1949 Total	Precipitation in Inches Departure From Normal
January	30	0	6.29	+4.49
February	34	0	1.95	+ .38
March	43	0	2.03	- .98
April	54	-1	2.01	-1.79
May	68	+4	5.42	+ .58
June	76	+3	6.43	+1.53
July	80	+2	7.71	+4.70
August	76	0	4.05	+ .16
September	63	-6	4.82	+ .20
October	60	+2	2.80	- .41
November	48	+5	.50	-2.11
December	37	+4	3.55	+1.48
Annual	56	+1	47.56	+8.23

TABLE 7--MONTHLY PRECIPITATION AND TEMPERATURE AND DEPARTURES FROM NORMAL AT COLUMBIA, MISSOURI, 1950

Month	Temperature in °F. 1950 Mean	Temperature in °F. Departure From Normal	Precipitation in Inches 1950 Total	Precipitation in Inches Departure From Normal
January	35	+5	2.05	+ .25
February	36	+2	1.45	- .12
March	40	-3	1.74	-1.27
April	50	-5	2.98	- .82
May	66	+2	3.59	-1.25
June	73	0	3.36	-1.54
July	73	-5	1.74	-1.27
August	71	-5	5.19	+1.30
September	67	-2	1.36	-3.26
October	64	+6	1.23	-1.98
November	39	-4	1.16	-1.45
December	30	-3	.20	-1.87
Annual	54	-1	26.05	-13.28

TABLE 8--MONTHLY PRECIPITATION AND TEMPERATURE AND DEPARTURES FROM NORMAL AT COLUMBIA, MISSOURI, 1951

Month	Temperature in °F. 1951 Mean	Temperature in °F. Departure From Normal	Precipitation in Inches 1951 Total	Precipitation in Inches Departure From Normal
January	31	+1	2.70	+ .90
February	35	+1	4.00	+2.43
March	39	-4	4.77	+1.76
April	51	-4	2.22	-1.58
May	65	+1	3.80	-1.04
June	70	-3	6.44	+1.54
July	76	-2	3.47	+ .46
August	76	0	5.62	+1.73
September	65	-4	4.90	+ .28
October	58	0	3.27	+ .06
November	38	-5	1.94	- .67
December	31	-2	1.49	- .58
Annual	53	-2	44.62	+5.29

TABLE 9--MONTHLY PRECIPITATION AND TEMPERATURE AND DEPARTURES FROM NORMAL AT COLUMBIA, MISSOURI, 1952

Month	Temperature in °F.		Precipitation in Inches	
	1952 Mean	Departure From Normal	1952 Total	Departure From Normal
January	34	+4	.83	- .97
February	38	+4	2.05	+ .48
March	41	-2	3.39	+ .38
April	54	-1	2.72	-1.08
May	64	0	2.82	-2.02
June	81	+8	6.13	+1.23
July	79	+1	3.84	+ .83
August	75	-1	7.92	+4.03
September	68	-1	2.02	-2.60
October	53	-5	.20	-3.01
November	44	+1	4.20	+1.59
December	35	+2	1.62	- .45
Annual	56	+1	37.74	-1.59

TABLE 10--MONTHLY PRECIPITATION AND TEMPERATURE AND DEPARTURES FROM NORMAL AT COLUMBIA, MISSOURI JANUARY, 1953 TO FEBRUARY, 1954, INCLUSIVE

Month	Temperature in °F.		Precipitation in Inches	
	Monthly Mean	Departure From Normal	Monthly Total	Departure From Normal
1953				
January	34	+4	1.36	- .44
February	40	+6	1.51	- .06
March	46	+3	3.34	+ .33
April	51	-4	3.39	- .41
May	65	+1	3.23	-1.61
June	80	+7	.96	-3.94
July	79	+1	2.32	- .69
August	78	+2	1.98	-1.91
September	72	+3	2.47	-2.15
October	61	+3	2.44	- .77
November	47	+4	.54	-2.07
December	36	+3	.70	-1.37
Annual	57	+2	24.24	-15.09
1954				
January	30	0	1.17	- .63
February	43	+9	.90	- .67

TABLE 11--PER CENT SOIL MOISTURE UNDER BLUEGRASS SOD, 1948

Month and Day	0-6 Inch Zone	6-12 Inch Zone
April		
14	28	27
29	13	17
May		
3	23	18
7	26	22
17	25	24
31	13	17
June		
14	8	9
18	22	12
25	28	29
July		
3	27	28
10	23	25
17	19	21
21	29	28
30	28	28
August		
7	22	23
14	20	21
30	20	18
September		
9	18	16
24	16	14
29	12	13
October		
11	23	19
20	24	22

TABLE 12--PER CENT SOIL MOISTURE UNDER BLUEGRASS SOD, 1949

Month and Day	0-6 Inch Zone	6-12 Inch Zone
April		
21	33	30
30	30	28
May		
7	31	28
14	33	30
23	33	32
28	34	32
June		
3	33	32
10	33	32
18	32	30
26	35	33
July		
2	31	27
12	35	31
22	30	29
29	22	23

TABLE 12--CONTINUED

Month and Day	0-6 Inch Zone	6-12 Inch Zone
August		
5	27	26
12	25	21
20	29	27
26	23	23
September		
2	25	23
10	27	22
16	31	31
23	33	31
October		
1	27	26
7	31	28
14	30	27
22	35	32
31	34	29

TABLE 13--PER CENT SOIL MOISTURE UNDER BLUEGRASS SOD, 1950

Month and Day	0-6 Inch Zone	6-12 Inch Zone
April		
11	37	33
17	32	31
24	30	28
May		
1	38	31
6	29	26
15	26	25
20	29	24
June		
1	31	29
9	30	27
17	27	23
28	17	18
July		
7	14	13
15	9	10
19	24	15
29	15	14
August		
3	17	12
7	15	15
11	24	17
18	27	22
28	29	22
September		
2	30	27
9	24	22
15	24	23
25	24	21
October		
5	26	23
16	18	20
30	14	16

TABLE 14--PER CENT SOIL MOISTURE UNDER BLUEGRASS SOD, 1951

Month and Day	0-6 Inch Zone	6-12 Inch Zone
April		
25	35	30
May		
3	30	28
10	31	30
18	26	26
26	26	25
June		
2	26	22
9	28	21
15	20	18
26	36	31
July		
2	32	32
14	35	32
21	27	28
27	21	22
August		
2	18	19
10	29	25
17	31	29
September		
8	32	30
25	32	31

The temperatures are from the United States Weather Bureau Station at Columbia. The rainfall reported here for the period from April 1 to September 30 each year was measured on the Missouri Experiment Station South Farm near the experimental area. Data for the rest of the year are from the Columbia Weather Bureau Station.

Soil moisture samples were taken approximately once a week during the growing season from a bluegrass sod. They were taken from the top 6 inches of soil and from the 6- to 12-inch zone. The moisture content is the average of two samples expressed as percent of dry soil.

The growing seasons mentioned below are from the Columbia Weather Bureau Station. Before 1951, they were computed from the date of the last killing frost in the spring to the first killing frost in the fall, but in 1951 and subsequent years, the growing season was designated as the period from the last date in the spring with temperatures of 32° F. or lower to the first date in the fall with temperatures of 32° or lower.

The growing season in 1948 extended from April 1 to October 17. There were two drouthy periods that year. April, May, and the first half of June had about one-third normal rainfall. Soil moisture was replenished by adequate rainfall in the latter half of June and in July but it was inadequate to support germination of seeds in August and September when rainfall was less than one-half of normal.

Freezing rains produced an ice sheet which covered the land during much of January and February, 1949, but they did not smother perennial forage crops. A prolonged period of day temperatures above freezing and night temperatures below freezing without snow cover occurred in the latter part of the 1948-49 winter. The soil was quite wet and heaving was noticeably more severe that winter than in other years.

The 1949 growing season lasted from April 19 to October 26. Temperatures were moderate and rainfall was plentiful and well distributed. Established plants did not suffer from inadequate moisture at any time during the season.

Temperatures averaged above normal throughout the winter of 1949-50 but they fluctuated widely. Long periods of diurnal freezing and thawing without snow cover resulted in considerable heaving of seedlings from late summer plantings.

The 1950 growing season, extending from April 15 to November 3, was unusually cool with the temperature going above 90° F. only 6 days. Precipitation was below normal every month except August and much of the rain fell in light showers. There were only two rains in excess of 1 inch during the entire season, one of 2.20 inches on June 3 and one of 1.23 inches on August 8.

Soil moisture decreased rapidly in June and the first half of July. It was low enough toward the end of that period to retard plant growth. The light rains in the latter half of July and in August maintained adequate moisture in the top 6 inches of soil but they did not restore much moisture to the 6- to 12-inch zone. There was sufficient soil moisture from August 11 to October 5 but after that time the soil continued to dry until the first ground-soaking rain January 2, 1951.

December and January were marked by severe cold without snow cover in the 1950-51 winter. The cool weather in March and April retarded the early spring growth of pasture crops and the germination of early spring seedings in 1951.

The growing season in 1951 extended from April 17 to November 1. Temperatures were favorable for forage crops in late April and May. June and early July were unseasonably cool. The remainder of July and August were normally hot, but September was cool. Rainfall in 1951 was adequate except for brief periods in late May and early June and in late July and early August. Soil moisture toward the ends of these two periods was low enough to cause ladino clover to wilt slightly on hot days.

November and December were colder than normal and January and February were warmer than normal in the 1951-52 winter. Rainfall during the winter was low but fall rains had built up the soil moisture so that the soil was not dry.

The growing season in 1952 was from April 16 to October 6. Temperatures averaged about normal except in June and July. Poor distribution of otherwise

adequate rainfall together with high temperatures resulted in a shortage of moisture in June and October and dry topsoil in September.

The 1952-53 winter was mild and soil moisture was about average. Alternate freezing and thawing caused moderate heaving of some perennial plants.

The period between freezing temperatures in 1953 was from April 20 to October 29. April was cooler than normal but the remainder of the growing season was warmer than normal. The 1953 drouth began in April and continued through the winter of 1953-54. Fortunately, most of the rain that fell during the growing season was well distributed, but the drouth was so severe that the subsoil moisture, as well as that in the surface soil, was depleted. Many pastures and meadows—even trees—were badly damaged or killed.

The winter of 1953-54 was mild with very little snow. The soil was so dry that farmers were able to plow the land even when the temperature was below freezing.

Equipment

Sod Tillage Implements: The cut-away disk (bush and bog harrow) was somewhat more effective than an ordinary tandem disk for thinning stands of grass sods. Prepared seedbeds were made by the use of an ordinary plow, disk, spiketooth harrow, and corregated roller, as required.

Point Quadrat: The inclined point quadrat, pioneered by Levy and Madden (8), and modified by Tinney, Aamodt, and Ahlgren (17), was used to estimate relative stands of ladino clover and associated grasses. An inclined point quadrat is shown in Figure 3. It consists of a frame supporting ten small wire shafts in

Figure 3—The inclined point quadrat used for measuring relative stands.

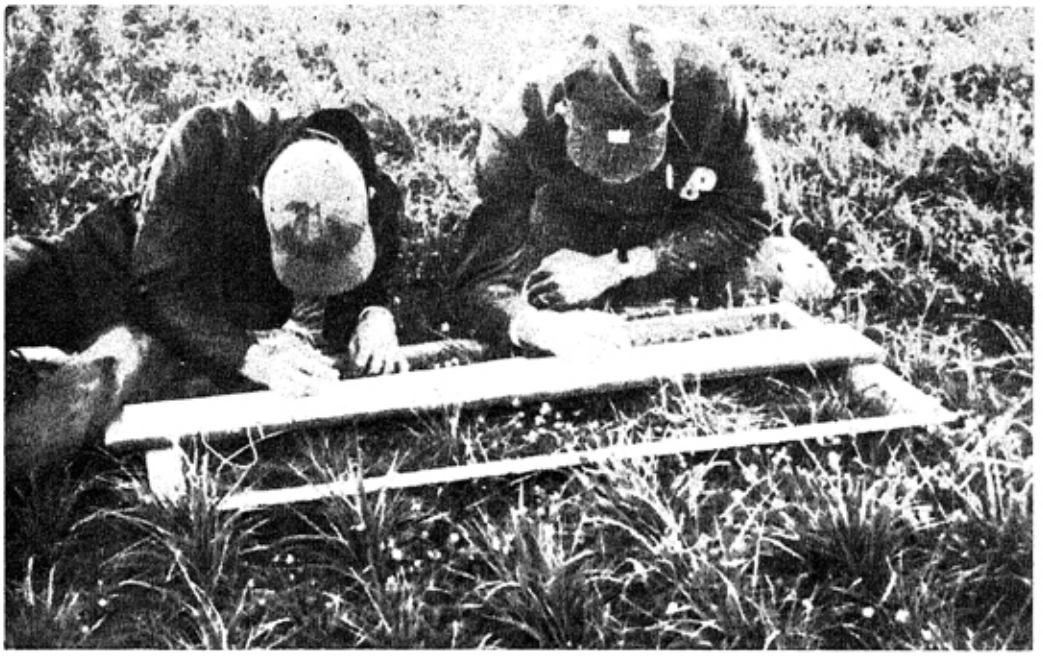

Figure 4—The construction of a chart quadrat of tall fescue-ladino clover planted August 26, 1949, on a prepared seedbed. Photographed October 24, 1949.

a line, parallel, 2 inches apart. Each shaft, which is free to move endwise in the frame, is pointed on the lower end. The line of shafts, in this case, is inclined 30 degrees from the vertical.

Area Quadrats: A square metal frame with an inside area of one square foot was used in determining the number of plants and the number of leaves per unit area.

Chart quadrats 1 decimeter wide and 1 meter long were plotted to a scale of 1:1 on strips of ordinary white wrapping paper. The plotting paper was cross-lined with a 1-decimeter grid to facilitate plotting, and thumbtacked to a board for ease of handling in the field. The area to be plotted was delineated by a metal frame equipped with small wires to form a grid matching the grid system on the plotting paper. Figure 4 shows a chart quadrat being constructed. This is a modification of some of the equipment and methods discussed by Oosting (10).

Materials

Except in the case of the seed source study, all the plants used were established from commercial seed of good quality.

Methods

Establishing Spaced Plants: The spaced plants for evaluating seed sources of ladino clover were started in the greenhouse. Sheet metal bands, 2 inches square and 3.5 inches long, were placed on end in an ordinary greenhouse flat and filled

with soil. On March 3, 1950, one ladino clover seed was planted in each metal band. Forty seeds from each source were planted, except in the case of the two Missouri samples, which contained less than 40 seeds each. When the plants reached the 6- to 8-leaf stage they were transplanted in the field after removing the metal bands without disturbing the soil surrounding the roots. The plants were planted three feet apart each way.

Determining Types of White Clover: On October 9, 1950, the white clover plants in the seed source study were classified, according to the judgment of the investigator, as giant, intermediate, or small. The classification was based on spread of plants, size of leaflets, length of petioles, and diameter of stolons.

Establishing the grasses: The grasses which were used to study the establishment of ladino clover in grass sods, and the rates at which they were planted were: redtop, 13 pounds per acre; tall fescue, 41; orchard grass, 35; and bromegrass, 20. All were planted September 20, 1947.

The land had been limed a few years before and cropped with small grain and lespedeza for several years with moderate amounts of mixed fertilizers applied with the small grains. The seedbed, although very dry and somewhat cloddy, was well worked down and firm. Five hundred pounds of 0-14-7 fertilizer and 150 pounds of 32.5 percent ammonium nitrate were applied at the time of seeding.

A soaking rain fell the day after planting and excellent stands of all four grasses were obtained. The grasses were clipped leniently in 1948 and they provided dense vigorously growing sods for the first ladino clover seedings on August 30, 1948. Figure 5 illustrates the stands of two of the grasses.

The Kentucky bluegrass used in the ladino clover establishment studies was a good native stand on virgin soil.

Smooth bromegrass, Kentucky bluegrass, orchard grass, and redtop were seeded in August, 1943, to study the persistence of the ladino clover and the productivity of the grass-legume mixtures under three systems of management. The land was limed and fertilized with 500 pounds per acre 0-14-7 fertilizer. Excellent stands were obtained and the grasses were well established when the legumes were seeded in March, 1945.

Tillage: Prepared seedbeds were made by plowing, followed by such other cultural operations as required for a good seedbed. Seedbeds which were prepared for late summer seedings were rolled with a corregated roller, but those prepared for spring seedings were not rolled.

Disking, where applied, was planned to reduce the stands of grass 50 percent. This required from one to eight tillage operations with a cut-away disk or a tandem disk, depending upon the species of grass and the conditions of the land. Since the effectiveness of the tillage operations in reducing grass stands is influenced by subsequent weather conditions, the objective of a 50 percent reduction in stand was only approximated. Table 15 shows the relative stands of disked and untilled grasses as determined by the inclined point quadrat about

Figure 5—Bromegrass (above) and tall fescue (below) used in studies of the establishment of ladino clover in grass sods. Photographed October 13, 1949.

TABLE 15--THE INFLUENCE OF DISKING ON THE STANDS OF GRASSES COUNTED ON SEPTEMBER 28, 1948 FOLLOWING DISKING ON AUGUST 30, 1948

Grass	Hits per 100 Points With Point Quadrat	
	Untilled	Disked
Redtop	84	33
Tall fescue	90	57
Orchard grass	88	50
Bromegrass	90	58

one month after the land preparation for the late summer, 1948, seeding of ladino clover. The results obtained at that time were observed to be representative of those obtained from disking for the four subsequent ladino clover seeding dates.

Seeding: Except for spaced plants and for plots used to study rates of seeding, ladino clover was seeded at the rate of 1.8 pounds per acre. In the studies of rates of seeding, rate of seedling development, and longevity and production, the seed was broadcast by hand. The ladino clover for studying establishment in grass sods and heaving was seeded from the grass seed attachment of an ordinary horse-drawn grain drill. To prevent the grain drill from covering the seed too deeply on the prepared seedbeds, the lower ends of the flexible spouts leading from the grass seedbox were removed from the boots and allowed to dangle beneath the box, broadcasting the seed in front of the drill disks. The dates on which ladino clover was seeded for the various studies reported here are shown in Table 16.

TABLE 16--DATES ON WHICH SEEDINGS OF LADINO CLOVER WERE MADE IN FIVE SEASONS ON PREPARED SEEDBEDS AND ON DISKED AND UNTILLED SODS OF FIVE GRASSES

Season	Date Seeded
Summer, 1948	August 30, 1948
Spring, 1949	April 22, 1949
Summer, 1949	August 26, 1949
Spring, 1950	April 10, 1950
Summer, 1950	September 12, 1950

Clipping: The spaced plants for studying ladino clover from different seed sources were not clipped in 1950. The plots which were seeded with different rates of ladino clover and associated grasses were clipped leniently during the period of observation. The clipping schedules for the studies on establishment of ladino clover in grass sods and the longevity and production of ladino clover are presented above under plans of experiments.

Clipping was performed with a sickle type or a reel type mower, as appropriate. The sickle type was more satisfactory for a tall growth of herbage. Except when small quantities of top growth were clipped and yields of forage were not being measured, the clipped herbage was removed from the plots.

Yields were determined from one mower swath down the middle of each plot.

After the yield samples had been taken, the remaining herbage of the plots was clipped to the appropriate height. The harvested material was collected in a "grass catcher" on the reel mowers. The clippings were carefully raked with hand rakes after clipping with the sickle type mower.

Determining Stands: The first one or two stand counts made after planting were made in ten systematically located foot-square quadrats per plot. After the ladino clover plants had spread to the extent that the areas covered overlapped, this system was no longer practical. A few counts of leaves per unit area were made, but this technique was abandoned as too time consuming.

The point quadrat was used to measure relative stands of associated grass and, after ladino clover passed the seedling stage, of the clover. Ten systematically located settings per plot were made, giving a total of 100 point samples per plot. Each shaft of the quadrat was pushed through the vegetation until it hit the ground or until it hit a plant of each species being counted. Not more than one count of each species was recorded per point even if the shaft of the quadrat hit vegetation of that species more than once. This resulted in not more than 100 hits on any one species per 100 points, regardless of the density of the stand.

Determining Yields: Yield samples were weighed in the field at the time of harvesting. Moisture samples were taken, percent dry matter was determined, and the yields of dry matter were computed.

RESULTS

Greenhouse Studies

Series A

The average herbage and root yields of three cultures of each treatment grown in the greenhouse are shown in Tables 17 and 18. Figure 6 shows that smooth bromegrass produced about 50 percent more plant material than tall fescue at the two more lenient clipping treatments but both produced about the same when clipped to a height of 1.5 inches either monthly or semi-monthly. The herbage yields were not greatly affected by clipping treatments.

The root growth of tall fescue increased from 1.5 grams per culture with the most severe defoliation to 3.4 grams when not clipped. The ratio of root yields to herbage yields of tall fescue was 0.62 when the plants were clipped to

TABLE 17--THE INFLUENCE OF CLIPPING AND OF SPECIES AND STAND OF ASSOCIATED GRASS ON THE HERBAGE YIELD OF CULTURES CONTAINING THIRTY-TWO LADINO CLOVER PLANTS GROWN IN THE GREENHOUSE

Height of Clipping	Number of Clippings per Month	Stand and Species of Associated Grass	Grams of Dry Herbage per Culture		
			Ladino	Grass	Total
1.5 in.	2	37 bromegrass	9.8	5.5	15.3
		37 tall fescue	11.5	6.7	18.2
		6 bromegrass	12.5	1.2	13.7
		6 tall fescue	10.9	1.5	12.4
		None	17.3		17.3
1.5 in.	1	37 bromegrass	20.3	4.4	24.7
		37 tall fescue	19.4	5.4	24.8
		6 bromegrass	18.8	2.0	20.8
		6 tall fescue	24.9	1.7	26.6
		None	24.9		24.9
3.0 in.	1	37 bromegrass	19.3	5.5	24.8
		37 tall fescue	20.6	4.4	25.0
		6 bromegrass	23.0	1.8	24.8
		6 tall fescue	22.1	1.5	23.6
		None	27.2		27.2
Not clipped		37 bromegrass	19.0	5.5	24.5
		37 tall fescue	29.5	5.3	34.8
		6 bromegrass	31.8	2.4	34.2
		6 tall fescue	30.1	1.5	31.6
		None	25.5		25.5

TABLE 18--THE INFLUENCE OF CLIPPING AND OF SPECIES AND STAND OF ASSOCIATED GRASS ON THE ROOT GROWTH OF CULTURES CONTAINING THIRTY-TWO LADINO CLOVER PLANTS GROWN IN THE GREENHOUSE

Height of Clipping	Number of Clippings per Month	Stand and Species of Associated Grass	Grams of Dry Roots per Culture		
			Ladino	Grass	Total
1.5 in.	2	37 bromegrass	1.2	3.5	4.7
		37 tall fescue	1.1	1.7	2.8
		6 bromegrass	1.4	.6	2.0
		6 tall fescue	1.0	1.2	2.2
		None	1.9		1.9
1.5 in.	1	37 bromegrass	3.1	4.5	7.6
		37 tall fescue	2.6	3.4	6.0
		6 bromegrass	2.8	1.4	4.2
		6 tall fescue	3.2	1.5	4.7
		None	4.0		4.0
3.0 in.	1	37 bromegrass	3.0	5.9	8.9
		37 tall fescue	2.9	2.7	5.6
		6 bromegrass	2.8	1.3	4.1
		6 tall fescue	2.7	1.1	3.8
		None	4.0		4.0
Not clipped		37 bromegrass	4.0	9.1	13.1
		37 tall fescue	7.4	5.3	12.7
		6 bromegrass	7.3	3.3	10.6
		6 tall fescue	6.7	1.5	8.2
		None	4.8		4.8

1.5 inches semi-monthly and 0.98 when not clipped. The two intermediate defoliation treatments, clipped to 1.5 inches monthly and to 3 inches monthly, resulted in tall fescue root/top ratios of 0.76 and 0.74, respectively. These data indicate that the frequency of clipping had more effect on the root growth and the root/top ratios of tall fescue than the height of clipping.

The root yields of bromegrass were 2.0, 3.0, 3.6, and 6.2 grams per culture for the progressively more lenient defoliations. The corresponding root/top ratios were 0.58, 0.88, 0.89, and 1.56. In the case of bromegrass, as of tall fescue, there was little difference in root development between cultures clipped to 1.5 inches and 3.0 inches monthly, but those clipped to 1.5 inches semi-monthly made the least root growth.

The herbage yields of the two grasses were not greatly different. There was a tendency for bromegrass to out-yield tall fescue at the more lenient clippings and for the tall fescue to yield more at the shorter heights of clipping. Bromegrass consistently produced higher root yields than tall fescue—about 85 percent more at the two more lenient clippings.

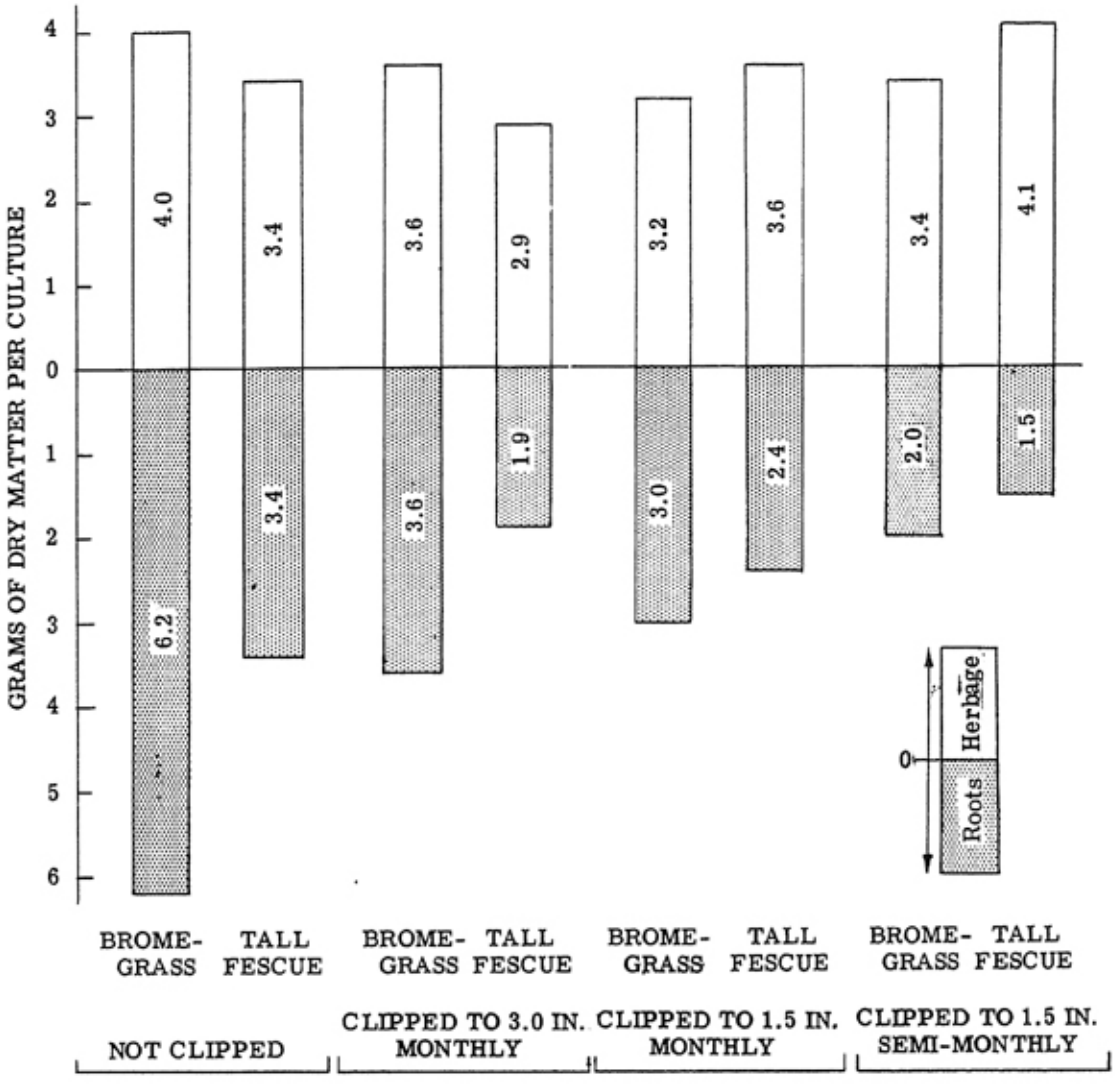

Figure 6—A comparison of the growth of bromegrass and tall fescue grown with ladino clover in the greenhouse as influenced by clipping *(average of both stands).*

Figure 7 shows that the herbage yields of bromegrass and tall fescue were similar in each density of stand. In both stands, bromegrass produced more root growth than tall fescue. The root/herbage ratio of bromegrass increased with thickness of stand from 0.89 to 1.12 for six plants and 37 plants per culture, respectively; while that of tall fescue decreased from 0.81 to 0.60. The average ratio for bromegrass was about 1.00 and for tall fescue about 0.70. In general, the yield per plant of herbage and of roots was about twice as great with six plants per culture as with 37 in the case of each grass.

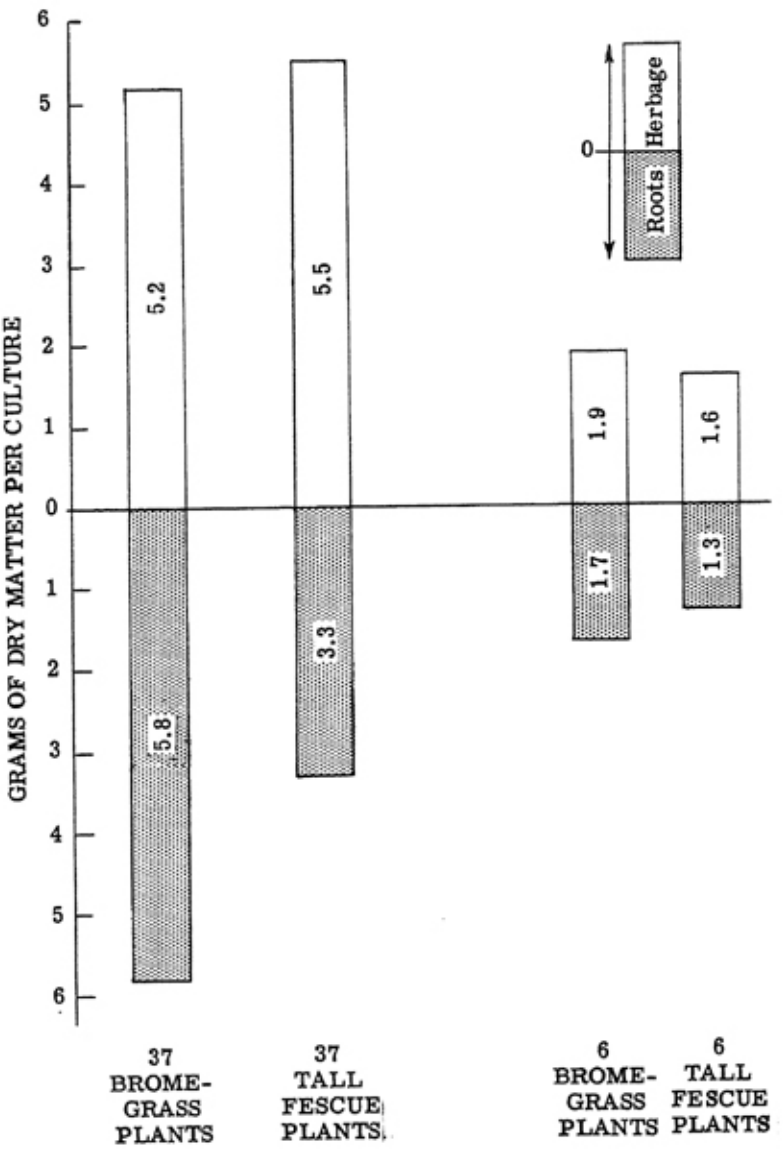

Figure 7—A comparison of the growth of bromegrass and tall fescue grown with ladino clover in the green house as influenced by stand *(average of all clippings).*

Figure 8 shows that stands of both 37 and six plants of bromegrass per culture reduced the total dry matter production of ladino clover more than comparable stands of tall fescue. It should be noted, however, that the greatest reduction of ladino, obtained with 37 bromegrass plants, was only 27 percent when compared with ladino grown alone. Six bromegrass plants reduced the ladino herbage yield almost as much as 37 tall fescue plants and reduced the root yield more.

Thirty-seven tall fescue plants reduced the ladino clover root growth no more than six tall fescue plants, but the thick stand of bromegrass resulted in the smallest ladino clover root yield of any mixture. When both stands and all

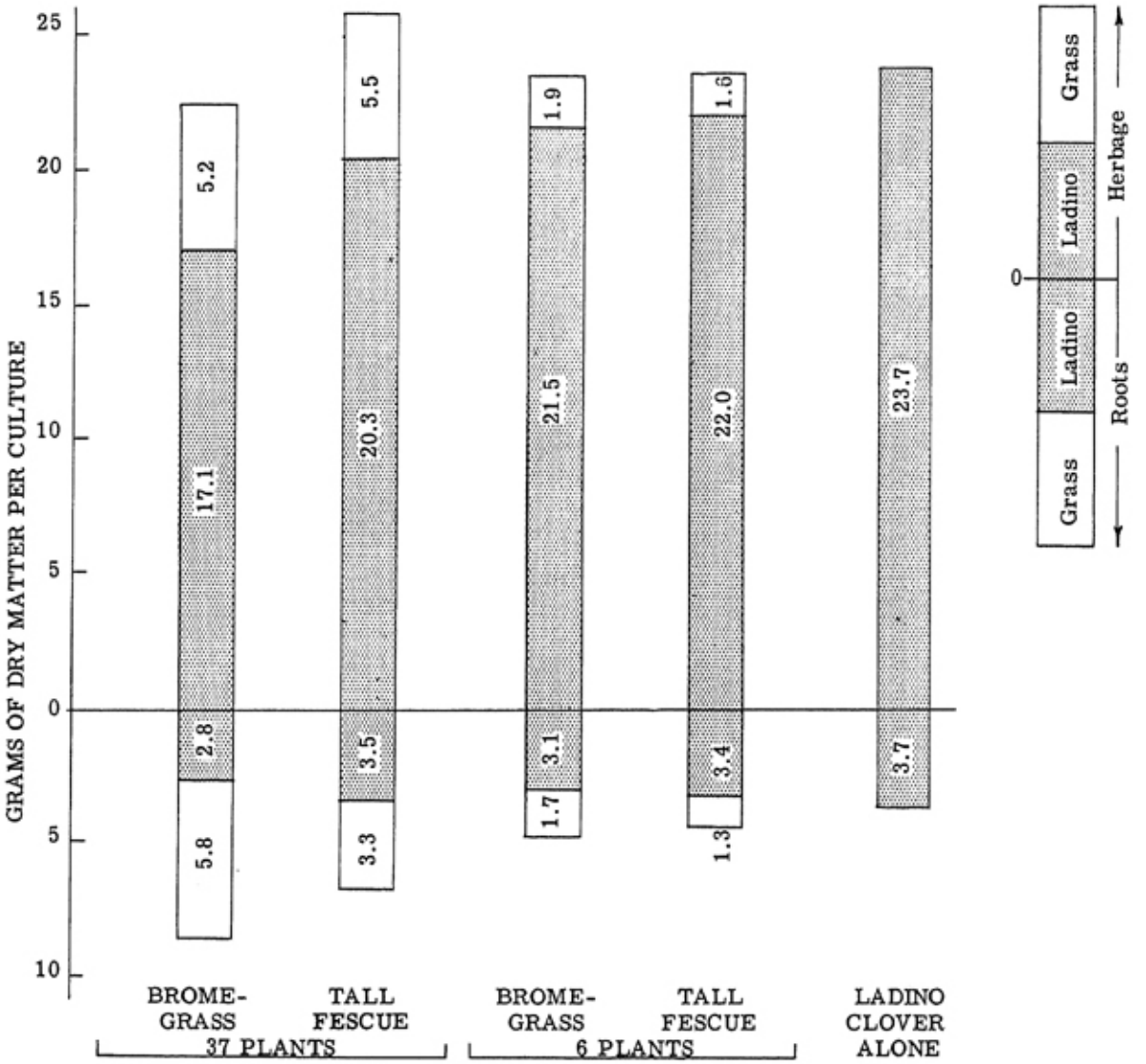

Figure 8—The influence of species and stand of associated grass on the yields of cultures containing 32 ladino clover plants grown in the greenhouse (average of all clippings).

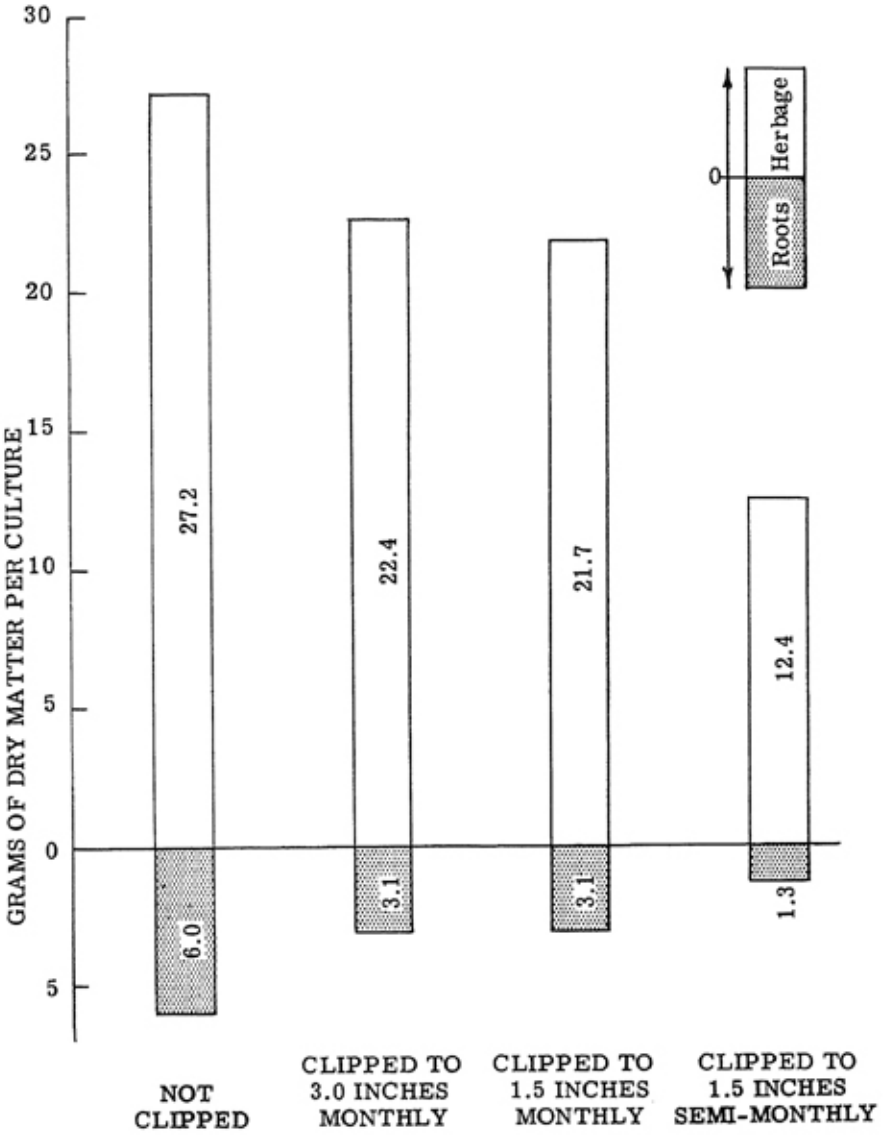

Figure 9—The influence of clipping on the growth of ladino clover in the greenhouse (average of all mixtures).

clipping treatments are averaged, it is found that ladino clover grown with bromegrass produced 14 percent less herbage and 19 percent less roots than when grown alone. Tall fescue grown with ladino clover reduced the herbage yield 11 percent and the root yield 8 percent.

Averages of both species and all clippings show that cultures with six grass plants produced 8 percent less ladino clover herbage and 13 percent less ladino roots than those with ladino alone. Thirty-seven grass plants suppressed the ladino clover herbage yield 21 percent and the ladino root yield 13 percent.

Figure 9 shows that the growth of ladino clover was considerably reduced by defoliation. Compared with the dry matter produced by the unclipped cul-

tures, those clipped to 3 inches monthly produced 18 percent less herbage and 48 percent less roots; those clipped to 1.5 inches monthly produced 20 percent less herbage and 48 percent less roots, and those clipped to 1.5 inches semi-monthly produced 54 percent less herbage and 78 percent less roots.

There was no difference in ladino root growths and little difference in ladino herbage yields between the cultures clipped short monthly and those clipped high monthly. However, the semi-monthly clipping to 1.5 inches resulted in 43 percent less ladino clover herbage and 58 percent less roots than the monthly clipping to 1.5 inches. Thus the frequency of defoliation had much more effect on ladino clover herbage yields and root growth than height of clipping. The influence of clipping on the growth of tall fescue-ladino clover cultures is illustrated in Figure 10.

Frequent clipping reduced the root/herbage ratio of ladino clover from about 0.20 in the unclipped cultures to 0.15 in the ones clipped monthly and 0.10 in those clipped semi-monthly.

The herbage and root yields of ladino clover-grass mixtures are compared with those of ladino grown alone under each clipping treatment in Figure 11. In the case of these newly established plants, the grass herbage in the three groups of clipped cultures shown in Figure 11 did not compensate for the suppression of ladino clover herbage, so the total herbage yield of the mixed cultures was not as great as the yield of the pure ladino cultures.

Frequent clipping reduced the yield of ladino clover roots, grass roots, and therefore total roots. Only in the clipped cultures did ladino roots in the mixed stands out-yield those in pure stand. Under every clipping treatment, contrary to the relative herbage yields, the mixed cultures produced more total roots than

Figure 10—Thirty-two ladino clover plants with 37 tall fescue plants planted June 20, 1948, and photographed October 14, 1948. Pot 1: clipped to the 1.5-inch level semi-monthly; pot 2: clipped to the 1.5-inch level monthly; pot 3: clipped to the 3-inch level monthly; pot 4: not clipped. Pots 1, 2, and 3 were last clipped October 2, 1948.

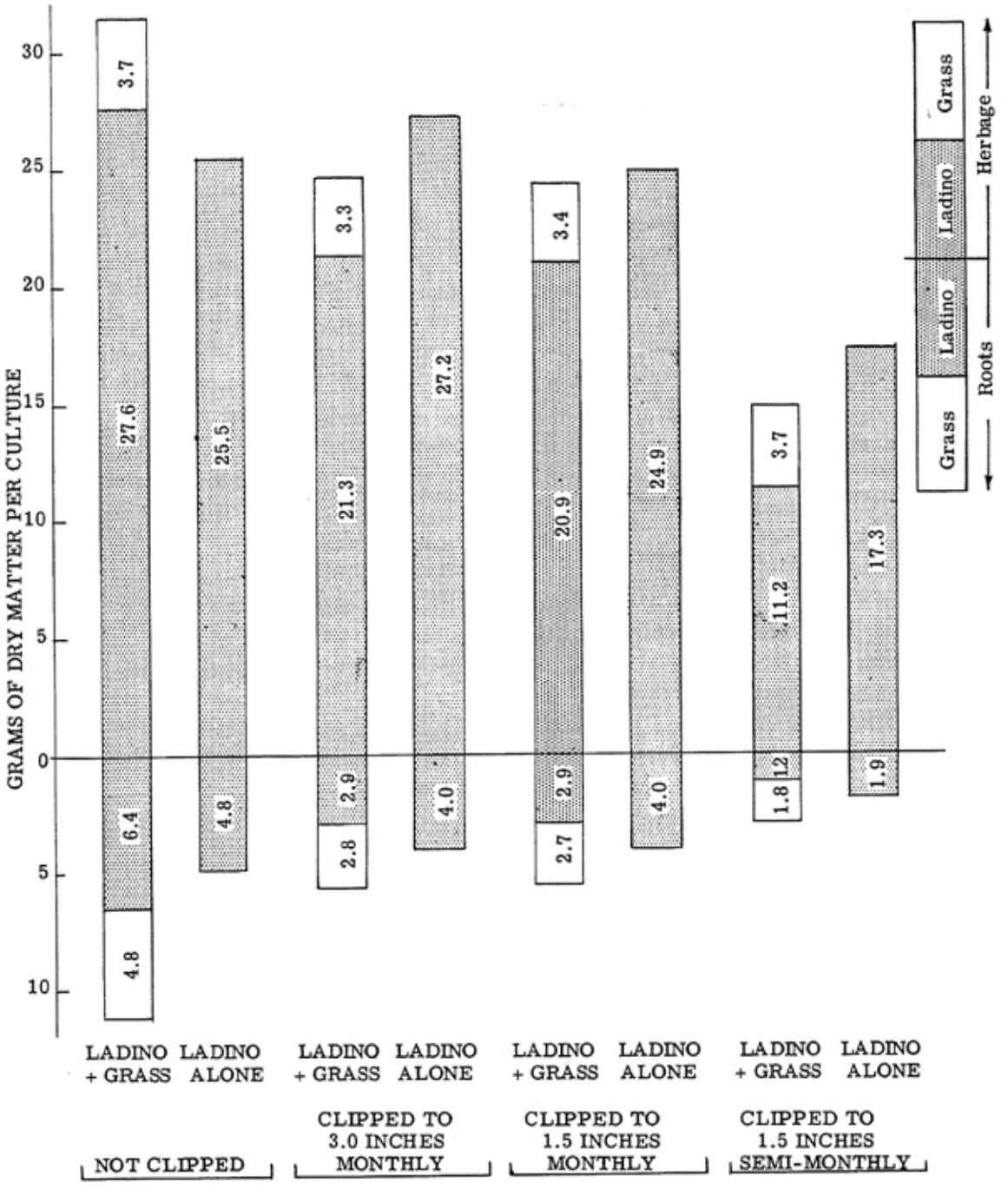

Figure 11—The influence of clipping on yields of cultures containing 32 ladino clover plants grown alone and with grass (ladino-grass cultures are averages of both stands and both species).

the pure ladino cultures; that is to say, the production of roots by grass plants was greater than their reduction of ladino clover roots.

In both grass-ladino mixtures and pure ladino cultures, varying the height of monthly clippings produced almost no difference in root growth.

There was striking uniformity of total herbage yields among the mixtures shown in Figure 8. The cultures containing ladino clover alone, those with six associated tall fescue plants, and those with six associated bromegrass plants produced almost equal yields of herbage. The mixture including 37 bromegrass plants yielded about 6 percent less than these three mixtures; the one including 37 tall fescue plants yielded about 9 percent more.

Total root yields exhibit much less uniformity then herbage yields. Compared with the pure ladino clover culture, the one including six tall fescue plants produced 27 percent more, and the one with six bromegrass plants yielded 30 percent more. Thirty-seven associated tall fescue plants and an equal stand of associated bromegrass resulted in total root yields exceeding the pure ladino cultures 84 percent and 132 percent, respectively.

In general, ladino clover was more sensitive than grass to frequency of clipping. Contrary to some field studies (3) (14), in this greenhouse study with young plants, species of neither family were particularly differential in response to varying heights of monthly clipping.

There was a striking difference between the grasses and the ladino clover in the ratio of root to herbage yields. The root/herbage ratio of the grasses averaged about 0.85 and that of ladino clover, about 0.15.

Series B

The herbage and root yields shown in Figures 12 and 13 are averages of three observations per treatment. These yields are the total weights of dry matter harvested while the cultures were under treatment plus that remaining in the cultures at the close of the experiment. They do not include the weight of two harvests of grass prior to subjecting the cultures to controlled temperatures.

The average yield of total plant material (roots plus herbage) of unclipped tall fescue (Figure 12) was more than twice as much as that of the clipped grass —12.3 grams per culture compared to 5.5 grams. Clipping resulted in a reduction in herbage yield of 45 percent and a reduction in root yield of 67 percent. Thus, the root/herbage ratio was reduced from an average of 0.79 to 0.51 by clipping.

Differences in total tall fescue yields resulting from temperature treatments were small. The 80° temperature resulted in the highest yield among the unclipped cultures and the 65° temperature resulted in the highest yield among the clipped ones. Fifty degrees produced the lowest yield under both clipping treatments. The average yields of tall fescue herbage at 50°, 65°, and 80° were 4.6, 5.2, and 6.2 grams per culture, respectively. The unclipped cultures yielded more

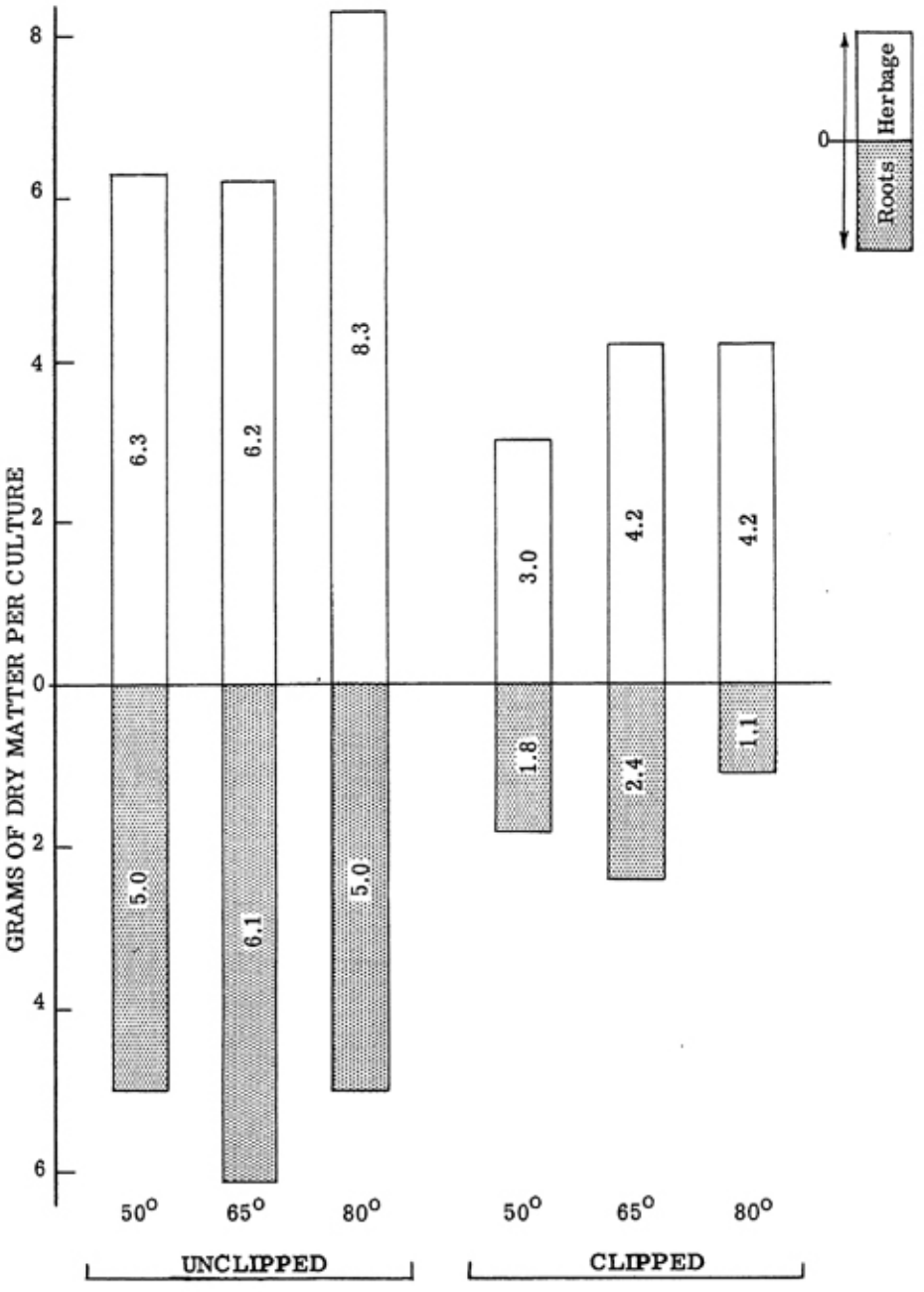

Figure 12—The influence of clipping and temperature on the yield of tall fescue grown in association with ladino clover in the greenhouse.

herbage at 80° F. than at 50° or 65°. The two lower temperatures resulted in nearly equal yields of herbage. Among the clipped cultures, those growing at the lowest temperature yielded the least herbage and the yields at the two high-

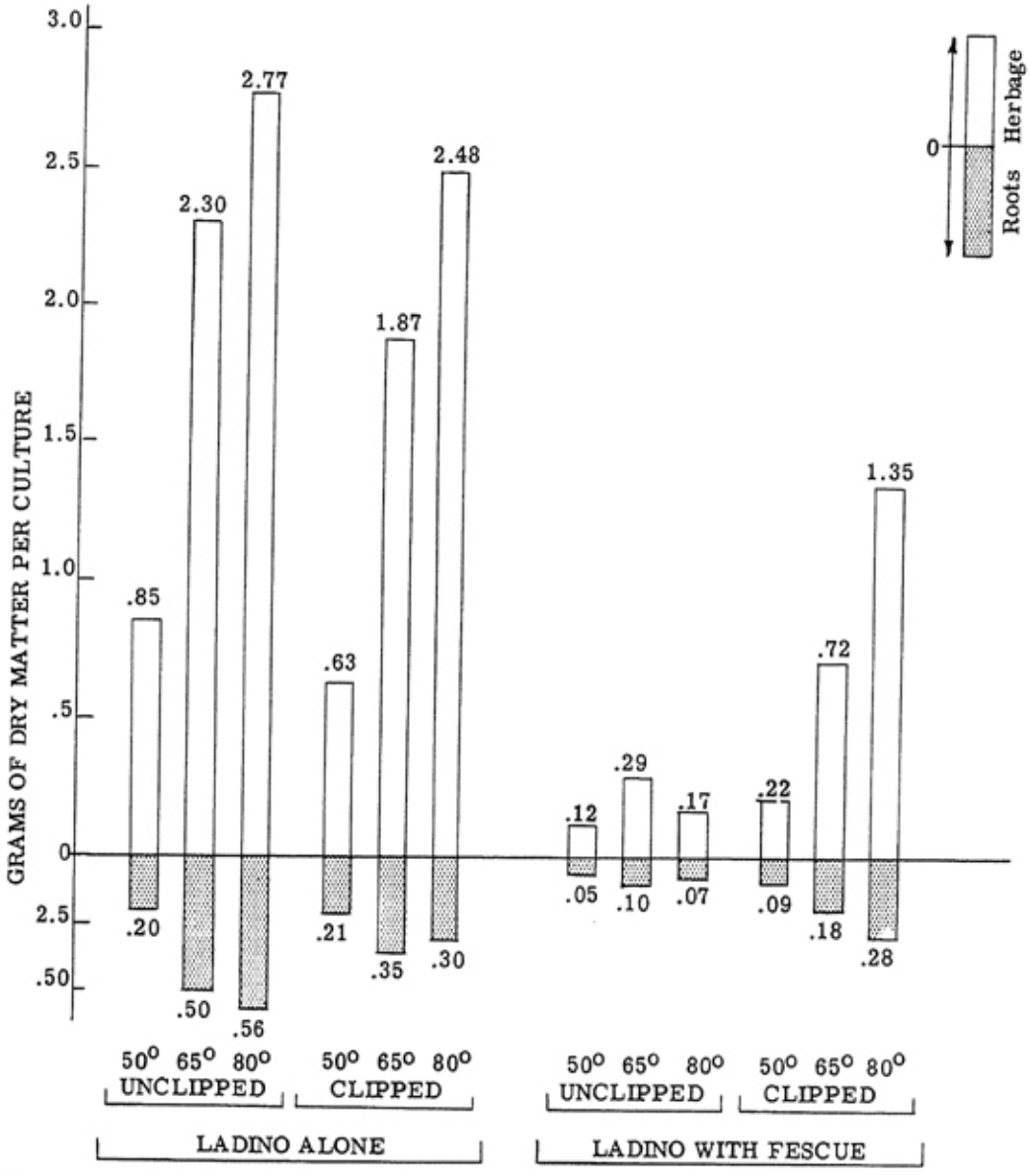

Figure 13—The influence of associated grass, clipping, and temperature on the growth of ladino clover seedlings in the greenhouse.

er temperatures were the same. Sixty-five degrees resulted in the highest yield of tall fescue roots, an average of 4.2 grams per culture. Root yields at 50° exceeded those at 80° 3.4 to 3.1 grams. The differences in root/herbage ratios between cultures grown at 50° and 65° were small. The average ratios were 0.69 and 0.76, respectively. However, the 80° temperature resulted in a root/herbage ratio considerably less than these (0.49).

The growth of ladino clover seedlings was greatly retarded by tall fescue

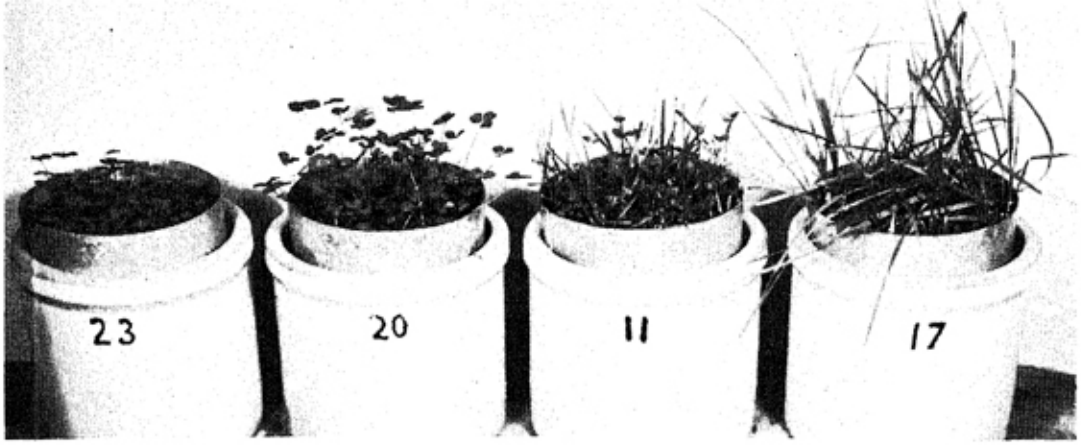

Figure 14—Ladino clover photographed April 25, 1949, after growing for 39 days in a thermo-regulated growth chamber at 80° F. Pot 23—ladino alone, clipped; pot 20—ladino alone, unclipped; pot 11—ladino with tall fescue, clipped; pot 17—ladino with tall fescue, unclipped.

sod as shown in Figure 13. The average yield of total plant material in pure ladino clover cultures was 2.17 grams; that in tall fescue sod was 0.61 grams. Associated tall fescue reduced the herbage yield of ladino clover from an average of 1.82 grams per culture to 0.48 grams, a reduction of 74 percent. Ladino roots yielded 65 percent less dry matter in tall fescue sod than in pure stand. The average yields were 0.35 grams and 0.13 grams. The root/herbage ratios for ladino clover grown alone and with tall fescue were 0.22 and 0.36, respectively.

The ladino clover seedlings were greatly affected by defoliation. Clipping reduced the yields of total plant material of the pure ladino cultures, but it increased the yield of the ladino plants in the mixed cultures. Unclipped, pure ladino cultures averaged 2.39 grams of plant material per culture while clipped ones averaged 1.95 grams, a reduction of 14 percent. Unclipped, mixed cultures produced an average of 0.27 grams of ladino clover, and clipped cultures produced 0.95 grams, over three and one-half times as much. These figures show that in the unclipped cultures, ladino clover associated with tall fescue yielded about one-ninth as much total plant material as ladino in pure stand, but in the clipped cultures, the ladino in mixed stands yielded almost one half as much as that in pure stands.

Clipping affected the herbage yields of ladino much the same as it did total plant growth. Clipped, pure stands of ladino yielded 17 percent less herbage than unclipped, pure stands. Ladino clover in clipped, mixed cultures yielded four times as much herbage as that in unclipped, mixed ones. The roots of ladino clover grown alone were more markedly affected by clipping than the tops. The defoliated cultures produced 41 percent less roots than the unclipped ones. Clipping stands of tall fescue-ladino clover resulted in an average ladino root yield two and one-half times that of the unclipped, mixed cultures. The pure ladino cultures had an average root/herbage ratio of 0.20 when clipped and 0.24 when not clipped. The mixed cultures had a ratio of 0.30 when clipped and 0.42 when not clipped. Figure 14 shows the effects of clipping and of associated tall fescue on the growth of ladino clover.

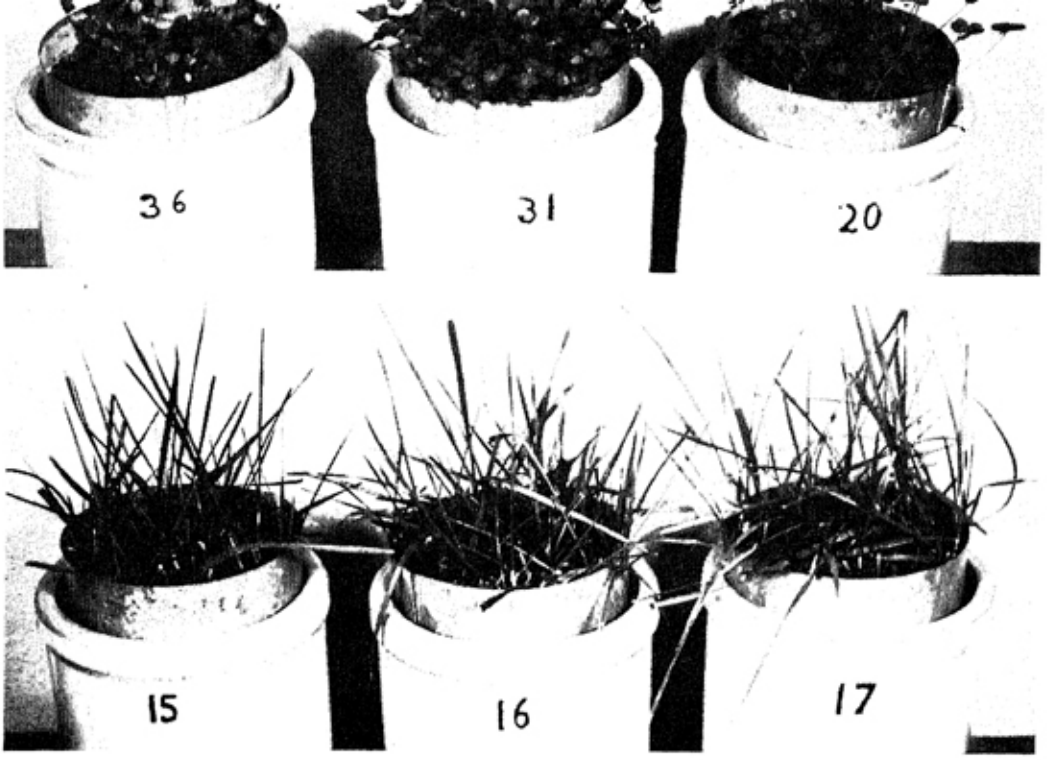

Figure 15—Unclipped ladino clover alone (above) and with tall fescue (below) grown in thermo-regulated growth chambers at (left to right) 50°, 65°, and 80° F. Photographed April 25, 1949, after exposure to controlled temperatures for 39 days.

The highest temperature used in this study, 80° F., gave the greatest average yield of total ladino clover—2.00 grams per culture. Sixty-five and 50° were accompanied by yields of 1.58 and 0.59 grams, respectively. Only the ladino clover grown in association with tall fescue in unclipped cultures failed to yield most at 80°. This combination of treatments produced the most ladino clover growth at 65°. This is the clipping treatment, as pointed out above, under which tall fescue produced the greatest yield at 80°. The least favorable temperature for growth of both herbage and roots of ladino clover in every combination of mixtures and clipping treatments was 50° F.

The herbage yield of ladino clover exhibited about the same response to varying temperatures as the production of total plant material mentioned above. The 15° increase in temperature from 50° to 65° resulted in an average increase in herbage yield of 0.83 grams per culture, or 180 percent, while the increase in temperature from 65° to 80° resulted in an increase in herbage yield of only 0.40 grams, or 31 percent.

More herbage was produced at 65° than at 80° by unclipped ladino clover in association with tall fescue. Figure 15 illustrates the influence of temperature on the growth of unclipped ladino clover and tall fescue.

The most unfavorable temperature studied for ladino clover root growth was 50°, which resulted in an average of only 0.14 grams of dry roots per cul-

ture. The 65° temperature was accompanied by twice that weight, 0.28 grams. However, 80° cultures produced only 0.30 grams. The largest yield of ladino clover roots was produced at 65° in the pure, clipped cultures and in the mixed, unclipped ones. The average root/herbage ratios of ladino clover grown at 80° and 65° were identical—0.25. The average for 50° was 0.37.

Field Studies

Seed Sources

Although small numbers of plants were used in the study of seed sources, Table 19 indicates that some imported Italian seed is at least equal to certified domestic seed in purity as to type. The imported Italian seed produced 4 percent off-type plants; while the certified domestic seed produced 8 percent off-type plants. Uncertified domestic seed was much inferior to either of these sources producing an average of 38 percent intermediate and small plants. There was greater variation between samples of uncertified domestic seed than between any of the other categories tested.

TABLE 19--THE OCCURRENCE OF GIANT, INTERMEDIATE, AND SMALL WHITE CLOVER PLANTS FROM LADINO CLOVER SEED OF DIFFERENT SOURCES

Nature of Seed	Origin	Number Plants Observed	Number Giant Plants	Number Intermediate Plants	Number Small Plants
Certified	California	23	19	4	0
	Idaho	23	23	0	0
	Oregon	25	23	2	0
Total, certified		71	65	6	0
Imported	Italy	22	22	0	0
	Italy	24	22	2	0
Total, Italian		46	44	2	0
Uncertified	Unknown	24	12	12	0
	California	21	16	4	1
Total, uncertified domestic		45	28	16	1
Experimental	California	21	20	1	0
	domestic	25	20	5	0
	domestic	25	22	3	0
Total, experimental selections		71	62	9	0
Outcrossed	Missouri (a)	19	7	9	3
	Missouri (b)	11	6	3	2
Total, freely outcrossed		30	13	12	5
Intermediate	Kentucky (c)	25	1	23	1

(a) Seed gathered from a closely grazed bluegrass-ladino pasture.

(b) Seed gathered from superior ladino clover plants growing near volunteer white clover.

(c) Green Acres White Clover--not ladino clover.

It is interesting to note that the experimental selections tested were no more pure for type than the imported or the certified domestic seed.

The white clover obtained from seed grown near volunteer white clover and from seed produced in a closely grazed pasture where conditions were favorable for white clover to volunteer consisted of a high percentage of intermediate and small types. Seed harvested from superior ladino clover plants growing near volunteer white clover produced almost 50 percent off-type plants.

Rates of Seeding

The data in Table 20 presents accurate comparisons between stands of ladino clover and between stands of grasses. Due to the great differences in form between ladino clover and grass plants, percentage herbage composition is indicated much less accurately by the point quadrat; however, from many observations, it was judged that swards giving equal numbers of hits per 100 points on grass and ladino contained an ideal balance of clover and grass. Table 20 shows that the only seed mixture which gave this estimated optimum grass-legume balance was 25 pounds of tall fescue and 2 pounds of ladino clover.

TABLE 20--INFLUENCE OF SEEDING RATES ON THE STANDS OF GRASS-LADINO CLOVER MIXTURES SEEDED APRIL 24, 1948 AND COUNTED OCTOBER 20, 1949

Species of Grass	Lbs. Grass Seed per Acre	Hits per 100 Points When Ladino Clover Was Seeded at the Rate of: 0 Lbs./Acre Hits on Grass	2 Lbs./Acre Hits on Grass	2 Lbs./Acre Hits on Ladino	5 Lbs./Acre Hits on Grass	5 Lbs./Acre Hits on Ladino
None	0		0	58	0	67
Bromegrass	10	20	14	51	9	67
Bromegrass	25	35	18	41	15	61
Tall fescue	10	47	26	43	17	51
Tall fescue	25	53	32	32	26	51

Figure 16 illustrates varying stands of ladino clover resulting from varying seeding rates with bromegrass. Bromegrass did not grow vigorously on this soil. By the end of the growing season in 1949, it was dominated by the vigorously growing ladino clover even where it was seeded at 25 pounds per acre with 2 pounds per acre of ladino clover.

Competition from ladino clover reduced the amount of grass in the mixtures compared to the pure grass stands. When ladino clover was seeded at the rate of 2 pounds per acre the grass competition also reduced the amount of ladino clover; however, when ladino was seeded at 5 pounds per acre, neither rate of bromegrass appreciably affected the amount of ladino clover. Tall fescue tended to reduce the amount of ladino clover seeded at 5 pounds per acre, but 25 pounds of tall fescue were no more effective than 10.

Figure 16—Ladino clover seeded at 2 pounds per acre (left) and 5 pounds per acre (right) with bromegrass seeded at 10 pounds per acre. Planted April 24, 1948. Photographed April 23, 1949.

Rate of Seedling Development

The growth of ladino clover was compared with that of five other legumes in studies made jointly with Langford (7). As seen in Table 21, red clover seedlings were the only ones which appreciably outgrew ladino clover on the pre-

TABLE 21--A COMPARISON OF THE RATES OF SEEDLING GROWTH OF SIX LEGUMES PLANTED MARCH, 1949 ON A PREPARED SEEDBED AND IN UNTILLED KENTUCKY BLUEGRASS SOD. HARVESTED JULY, 1949

Species of Legume	Air Dry Weight of 100 Plants, Grams		
	Prepared Seedbed	Untilled Sod	Average for Each Species
Ladino clover	19	9	14
Birdsfoot trefoil	20	1	11
Korean lespedeza	11	3	7
Common lespedeza	15	10	13
Red clover	27	13	20
Alsike clover	18	9	14
Average for each tillage	18	8	

pared seedbed. Rate of ladino clover seedling growth was about equal to that of birdsfoot trefoil and of alsike clover, and somewhat superior to that of Korean and common lespedezas.

In untilled Kentucky bluegrass sod all legumes grew more slowly, acquiring an average size of only 44 percent of those on the prepared seedbed. Ladino clover was near average among the legumes tested in this respect. In untilled sod, as on the prepared seedbed, red clover seedlings reached the greatest weight. Ladino clover was about equal to alsike clover and common lespedeza in seedling weight, and it was much superior to Korean lespedeza and birdsfoot trefoil.

From the standpoint of percentage reduction in development resulting from lack of seedbed preparation, ladino clover was about average. Lack of seedbed preparation reduced the growth of common lespedeza seedlings least, 30 percent. Ladino clover, red clover, and alsike clover were reduced 53, 52, and 50 percent, respectively. Korean lespedeza was reduced 70 percent and birdsfoot trefoil only grew 5 percent as much in sod as on the prepared seedbed.

Another experiment tested the rate of growth of ladino clover seedlings growing in association with five grasses and with three degrees of seedbed preparation. Results of this study are shown in Table 22. The average weights of 100 seedlings grown on a prepared seedbed, disked sod, and untilled sod, were 30, 15, and 8 grams, respectively.

TABLE 22--INFLUENCE OF ASSOCIATED GRASS AND TILLAGE ON THE SEEDLING GROWTH OF LADINO CLOVER PLANTED APRIL 22, 1949. HARVESTED JUNE 23, 1949

Species of Associated Grass	Dry Weight of 100 Ladino Seedlings, Grams			
	Prepared Seedbed	Disked Sod	Untilled Sod	Average for Each Species
None	30			30
Redtop		18	8	13
Tall fescue		8	3	6
Orchard grass		13	10	12
Bromegrass		28	16	22
Bluegrass		8	4	6
Average for each tillage	30	15	8	

Ladino clover seedlings grew most rapidly in bromegrass, reaching an average weight of 22 grams per 100 plants. Redtop and orchard grass were about equal as associated grasses in this respect, resulting in ladino clover seedlings weighting 13 and 12 grams per 100 plants, respectively.

Bluegrass and tall fescue were equally competitive with 100 ladino clover seedlings grown in association with them weighing 6 grams. Disking the sod was very effective in increasing the rate of ladino clover seedling growth in the case of all grasses except orchard grass where it increased the growth rate only 30 percent. Ladino clover seedlings grew much larger on a prepared seedbed than on disked sod except on bromegrass sod.

Establishment in Grass Sods

The initial stands of ladino clover obtained from five seedings in three years on three types of seedbeds with five grasses are indicated in Table 23. The wide variations in stands between the different times of seeding reflect to a considerable extent the weather and the soil moisture following planting. The fall of 1948 was very dry and the few plants that emerged were small at the end of the growing season.

TABLE 23--INITIAL STANDS OF LADINO CLOVER SEEDED EACH LATE SUMMER AND EACH SPRING FROM SUMMER, 1948 TO SUMMER, 1950, INCLUSIVE ON PREPARED SEEDBEDS AND ON DISKED AND UNTILLED SODS OF FIVE GRASSES. PLANTS PER TEN SQUARE FEET

Associated Grass	Seedbed	Seeded Summer 1948 Counted Nov. 13, 1948	Seeded Spring 1949 Counted May 28, 1949	Seeded Summer 1949 Counted Nov. 15, 1949	Seeded Spring 1950 Counted May 22, 1950	Seeded Summer 1950 Counted Nov. 3, 1950
None	Prepared	22	73	107	33	86
Redtop	Disked	12	94	42	31	27
	Untilled	4	101	9	30	5
Tall fescue	Disked	18	111	23	32	6
	Untilled	10	108	7	23	2
Orchard grass	Disked	12	127	31	43	10
	Untilled	2	132	23	28	6
Bromegrass	Disked	16	168	41	153	48
	Untilled	8	111	12	41	21
Bluegrass	Disked		145	35	176	71
	Untilled		62	19	34	0
Avg., all grasses	Disked	15	129	34	87	33
	Untilled	6	103	14	31	7

Soil moisture was more plentiful following the 1949 summer seeding than that following the 1950 summer seeding. The result was better stands of ladino in 1949 than in 1950, especially in the more competitive grass sods. The spring of 1949 was moist and all of the ladino clover seedings made at that time were successful. Seedlings in the spring of 1950 grew in drier soil than those in 1949 and they were further hampered by more competition from the grass because clipping of the plots was begun at a later date that spring.

On sods, spring seedings were more successful than late summer seedings. The dense average stands from spring seedings, tabulated in Table 24, were influenced greatly by the stands obtained in the exceptionally favorable spring of 1949; however, seedings made in the less favorable spring of 1950 produced better stands of ladino clover in grass sods than any of the late summer seedings.

Delayed emergence of seedlings was not measured in this study, but a con-

TABLE 24--A COMPARISON OF INITIAL STANDS OF LADINO CLOVER RESULTING FROM SPRING AND LATE SUMMER SEEDINGS MADE ON PREPARED SEEDBEDS AND ON DISKED AND UNTILLED SODS OF FIVE GRASSES. PLANTS PER TEN SQUARE FEET

Associate Grass	Seedbed	Average Three Summer Seedings	Average Two Spring Seedings	Average All Seedings
None	Prepared	72	53	64
Redtop	Disked	27	63	41
	Untilled	6	66	30
Tall fescue	Disked	16	72	38
	Untilled	6	66	30
Orchard grass	Disked	18	85	45
	Untilled	10	80	38
Bromegrass	Disked	35	161	85
	Untilled	14	76	39
Bluegrass	Disked	53 (a)	138	73 (b)
	Untilled	10 (a)	48	23 (b)
Average all grasses	Disked	30	104	56
	Untilled	9	67	32

(a) Average of two seedings, 1949 and 1950.

(b) Average of four seedings spring, 1949 to summer, 1950, inclusive.

siderable number of spring seedlings were noted in plots planted the preceeding summer. On prepared seedbeds, late summer seedings produced better stands than spring seedings except in 1948 when the fall was very dry. The rolling, which the seedbeds for summer seedings received and which spring seedings did not receive, may account for some of this difference.

Table 25 gives counts made in April, 1951, of the stands of ladino clover which were finally obtained. In 1949, the summer, 1948, seeding was considered a failure due to poor emergence and to heaving, so the seedings on prepared seedbeds and disked sods were abandoned and the land was put to other uses. The untilled sods also contained almost no ladino clover in 1949, but they were not disturbed and by 1950 a good stand of ladino clover appeared. Smith, and others (13), report a similar experience in West Virginia. It is likely that this would also have happened on the disked sods and perhaps on the prepared seedbed if the land had not been disturbed. Dry weather and competition from grass retarded the thickening of ladino clover stands seeded in both spring and summer of 1950, especially in tall fescue, orchard grass and untilled bluegrass.

Although the intial stands of ladino clover varied among the species of associated grasses for the individual seedings, the differences were not consistent and the average initial stands from all seeding dates showed little advantage for any grass.

Disking consistently aided in getting stands of ladino clover in grass sods. This agrees with the report of Thatcher, Dodd, and Willard (16). In favorable

TABLE 25--RELATIVE STANDS OF LADINO CLOVER SEEDED EACH LATE SUMMER AND EACH SPRING FROM SUMMER, 1948 TO SUMMER, 1950, INCLUSIVE ON PREPARED SEEDBEDS AND ON DISKED AND UNTILLED SODS OF FIVE GRASSES. MEASURED WITH POINT QUADRAT OR AREA QUADRAT IN APRIL, 1951

Associated Grass	Seedbed	Hits per 100 Points, Seeded: Summer 1948	Spring 1949	Summer 1949	Spring 1950	Plants per 10 Sq. Ft. Seeded Summer 1950
None	Prepared		55	65	29	5
Redtop	Disked		73	52	13	7
	Untilled	39	22	46	14	2
Tall fescue	Disked		71	55	5	4
	Untilled	51	28	42	Trace	0
Orchard grass	Disked		53	54	Trace	5
	Untilled	39	23	58	Trace	Trace
Bromegrass	Disked		72	67	46	3
	Untilled	37	59	78	42	5
Bluegrass	Disked		31	56	26	5
	Untilled		37	25	Trace	5
Avg., all grasses	Disked		60	57	18	5
	Untilled	42	34	50	11	2

seasons disking was not necessary to obtain satisfactory stands of ladino (Figures 17, 18, 19, and 20); in unfavorable seasons the disking operation made the difference between success and failure. From the standpoint of obtaining satisfactory stands, disking was more beneficial to summer seedings than to spring seedings. Disked stands of redtop, tall fescue, and bluegrass thickened rapidly but orchard grass and bromegrass stands were permanently thinned by disking.

The influence of clipping during the year on establishment of ladino clover is indicated in Table 26. The spring seeding of 1949, which was a very favorable year for ladino clover, was favored by close, frequent defoliation. The proportion of ladino to grass in all of the mixtures was too high for safe grazing from the standpoint of bloat except perhaps bluegrass-ladino mixtures. Ladino clover did not establish well on the prepared seedbed when it was clipped only once in June because of a very rank growth of weeds.

The summer, 1949, seeding produced the most dense stands of ladino clover when clipped high monthly in 1950 except in the case of bluegrass where the response to clipping was rather inconsistent. In general, the proportion of ladino clover to grass was more nearly optimum after the first full growing season in the case of the summer, 1949, seeding than in the case of the preceding or succeeding seedings.

The spring, 1950, seeding, although it did not establish nearly as well, reacted to clipping in a manner similar to the spring, 1949, seeding. Observations

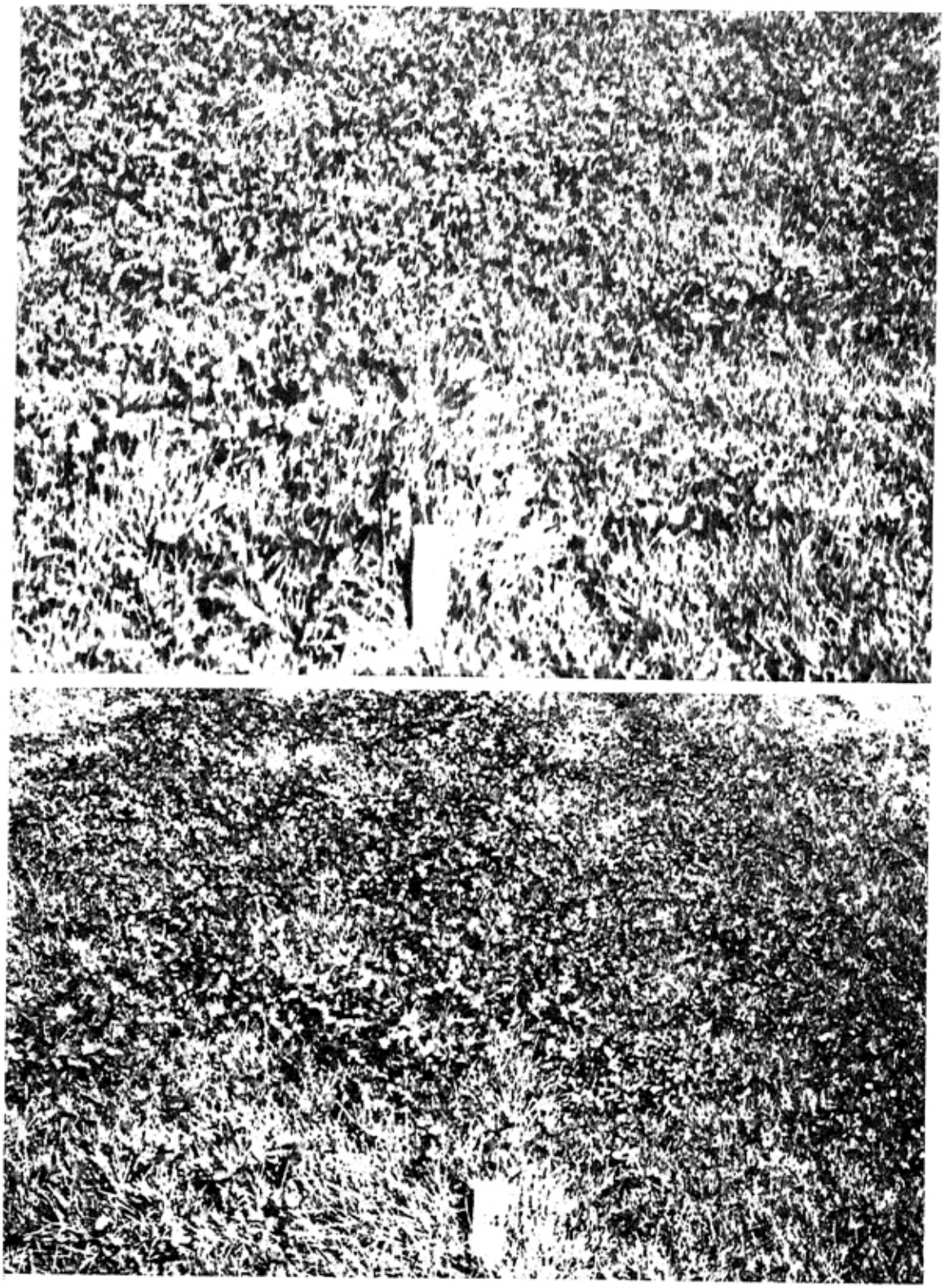

Figure 17—Ladino clover and redtop seeded April 22, 1949, on disked sod (above) and untilled sod (below). Plots left of stakes clipped to the 3-inch level monthly; plots right of the stakes mowed to the 1.5-inch level semi-monthly. Photographed October 8, 1949.

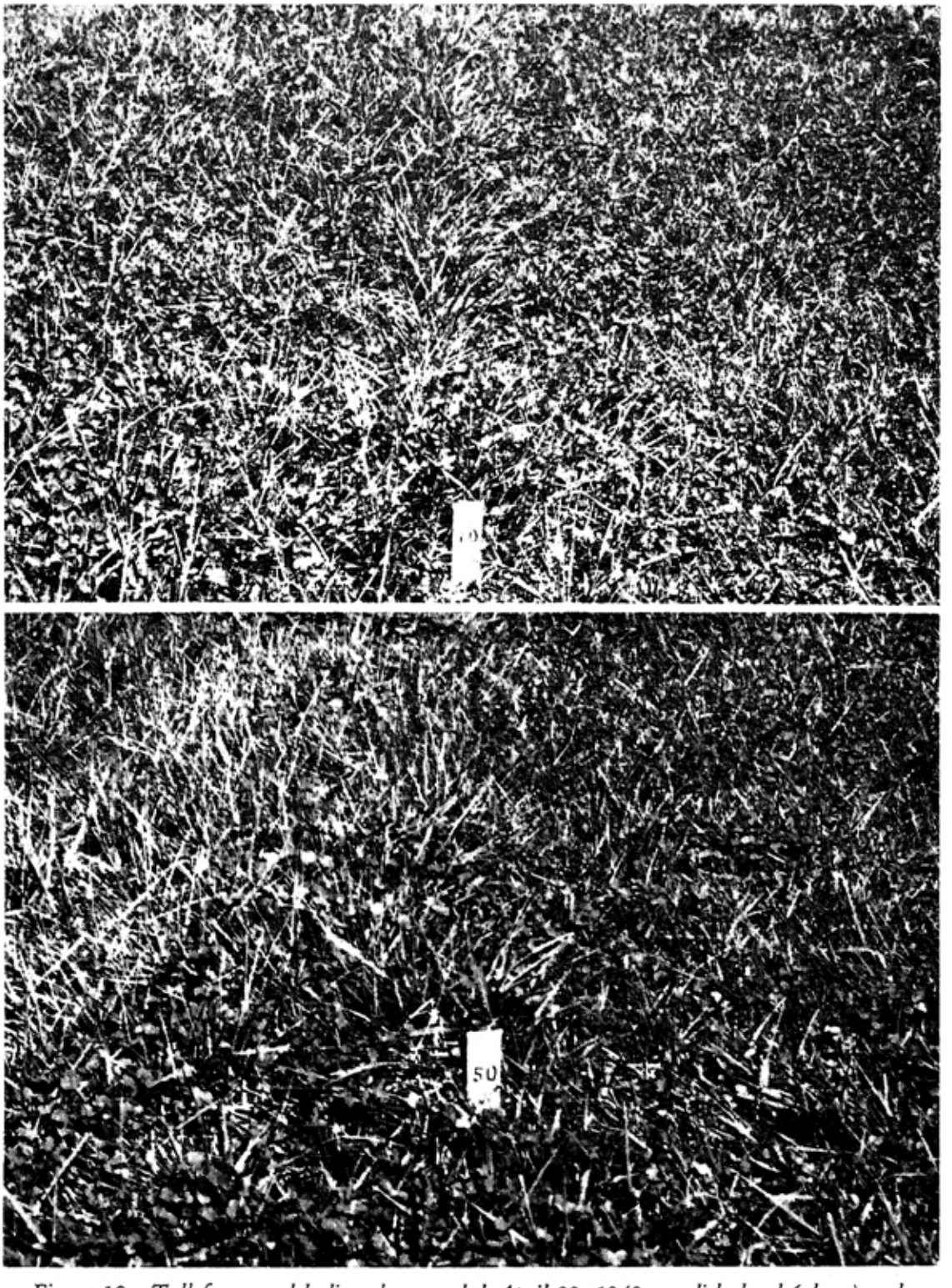

Figure 18—Tall fescue and ladino clover seeded April 22, 1949, on disked sod (above) and untilled sod (below). Plots left of stakes clipped to the 3-inch level monthly; plots right of the stakes mowed to the 1.5-inch level semi-monthly. Photographed October 8, 1949.

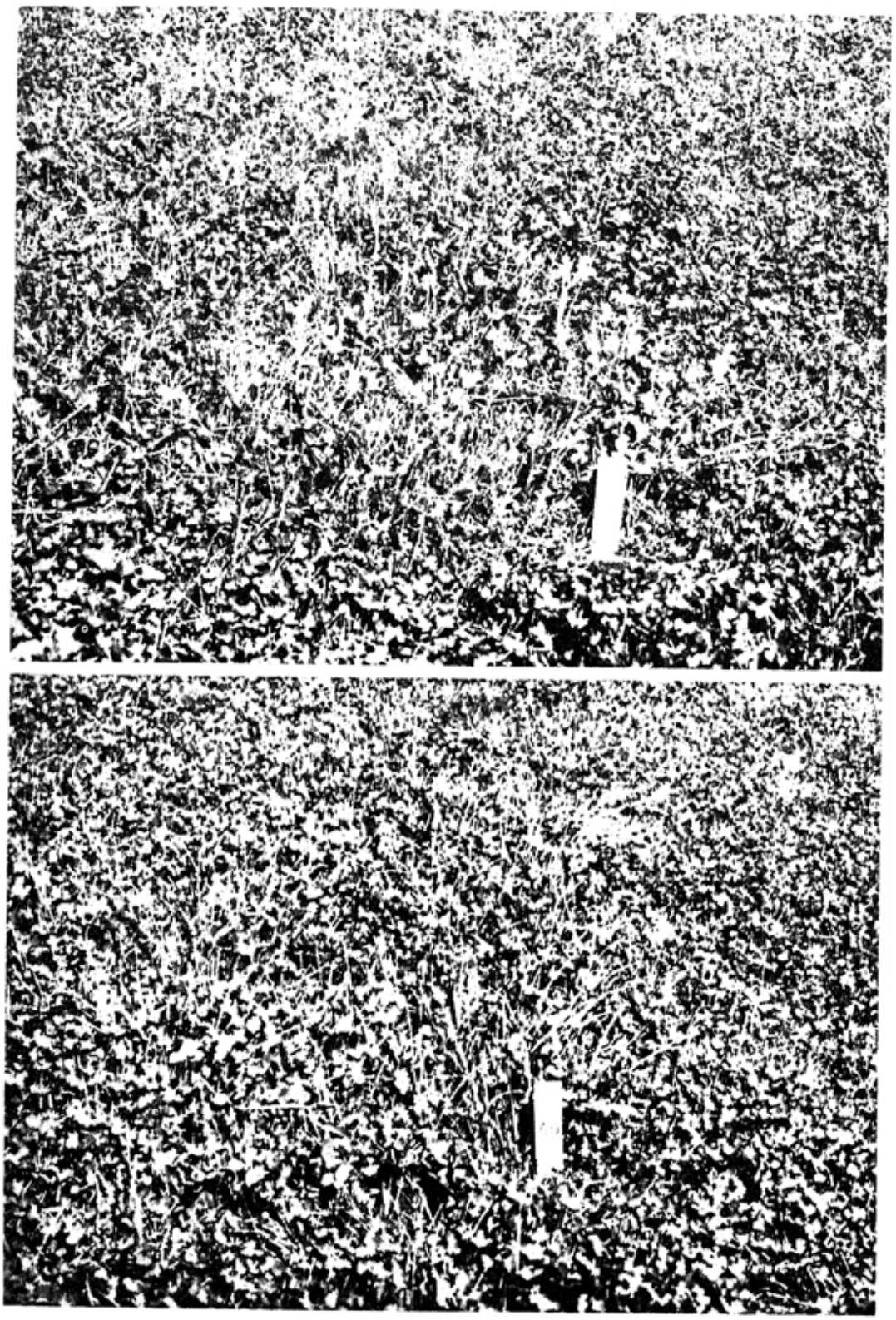

Figure 19—Ladino clover and orchard grass seeded April 22, 1949, on disked sod (above) and untilled sod (below). Plots left of the stake clipped to the 3-inch level monthly; plots right of the stake mowed to the 1.5-inch level semi-monthly. Photographed October 8, 1949.

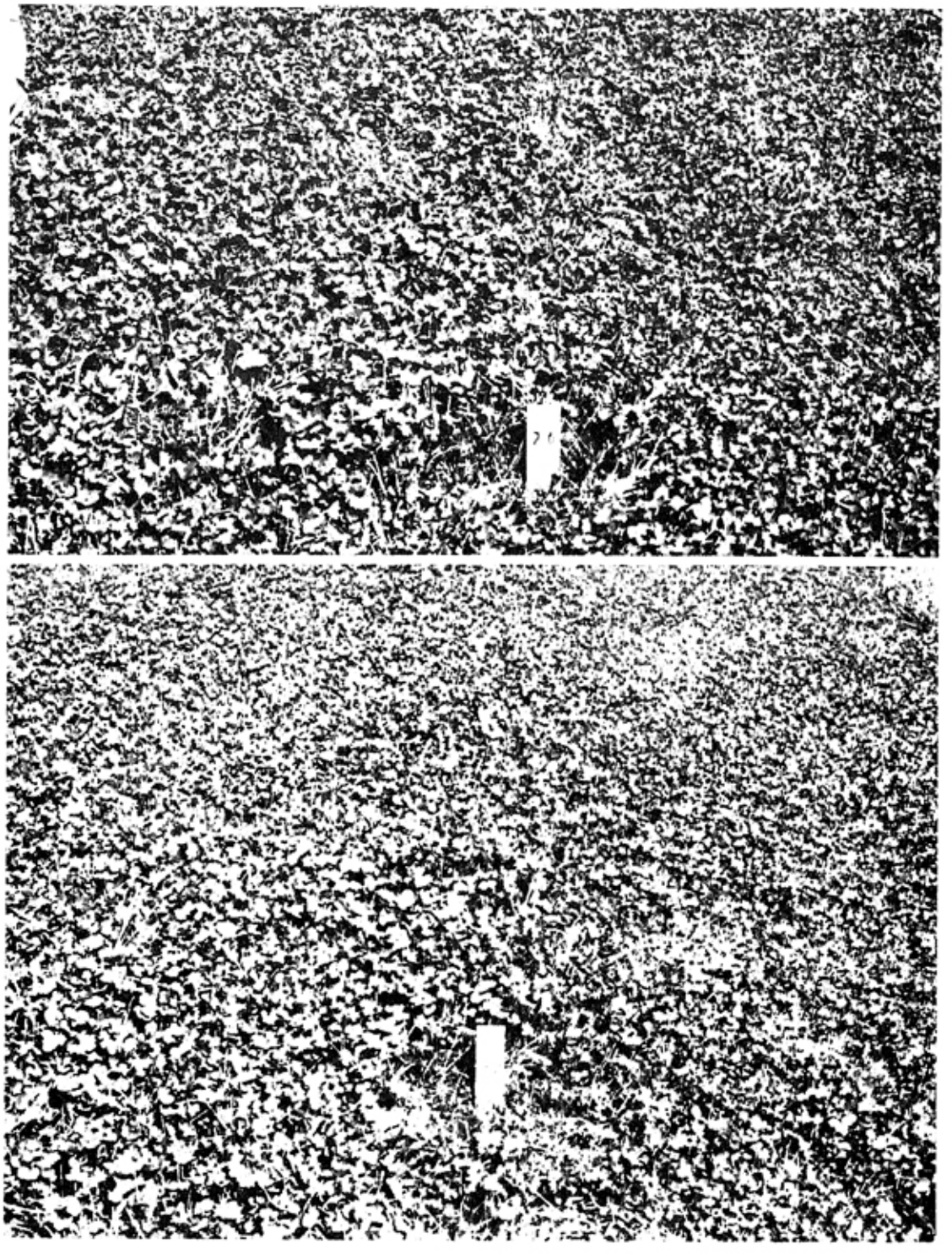

Figure 20—Bromegrass and ladino clover seeded April 22, 1949, on disked sod (above) and untilled sod (below). Plots left of stakes clipped to the 3-inch level monthly; plots right of

TABLE 26--INFLUENCE OF CLIPPING DURING THE FIRST FULL SEASON FOLLOWING SEEDING ON STANDS OF LADINO CLOVER. THE STANDS FROM THE SPRING, 1949 SEEDING WERE COUNTED IN MAY, 1950 AND THOSE FROM THE SUMMER, 1949 AND SPRING, 1950 SEEDINGS WERE COUNTED IN APRIL, 1951. HITS PER 100 POINTS WITH THE POINT QUADRAT

Associated Grass	Seedbed	Seeded Spring, 1949 and Clipped:			Seeded Summer, 1949 and Clipped:			Seeded Spring, 1950 and Clipped:		
		Short Semi-monthly	High Monthly	High Once in June	Short Semi-monthly	High Monthly	High Once in June	Short Semi-monthly	High Monthly	High Once in June
None	Prepared	92	76	26	65 (a)			38	44	11
Redtop	Disked	82	75		34	76	50	24	8	5
	Untilled				30	65	44	16	12	14
Tall fescue	Disked	80	71		54	68	48	16	Trace	Trace
	Untilled				31	71	31	Trace	Trace	0
Orchard grass	Disked	84	80		52	68	48	Trace	Trace	Trace
	Untilled				46	74	55	Trace	Trace	Trace
Bromegrass	Disked	90	87		57	76	68	50	41	48
	Untilled				65	92	77	33	52	40
Bluegrass	Disked	57	46	23	48	57	63	38	18	20
	Untilled	58	55	51	30	20	25	Trace	Trace	Trace

(a) Seeded as a tall fescue-ladino clover mixture and grazed closely in 1950.

of pure stands of ladino clover which were clipped to the 1.5-inch level weekly in both 1949 and 1950 revealed that the vigor of the ladino clover was considerably reduced but fairly good stands remained. In similar plots, differences in stand between plots clipped to the 2-inch level monthly and those clipped to the 4-inch level monthly were slight, both treatments resulting in almost 100 percent stands.

In other pure stands which were not mowed in the seedling year the initial ladino clover stand completely disappeared due to the competition from weeds (Figure 21).

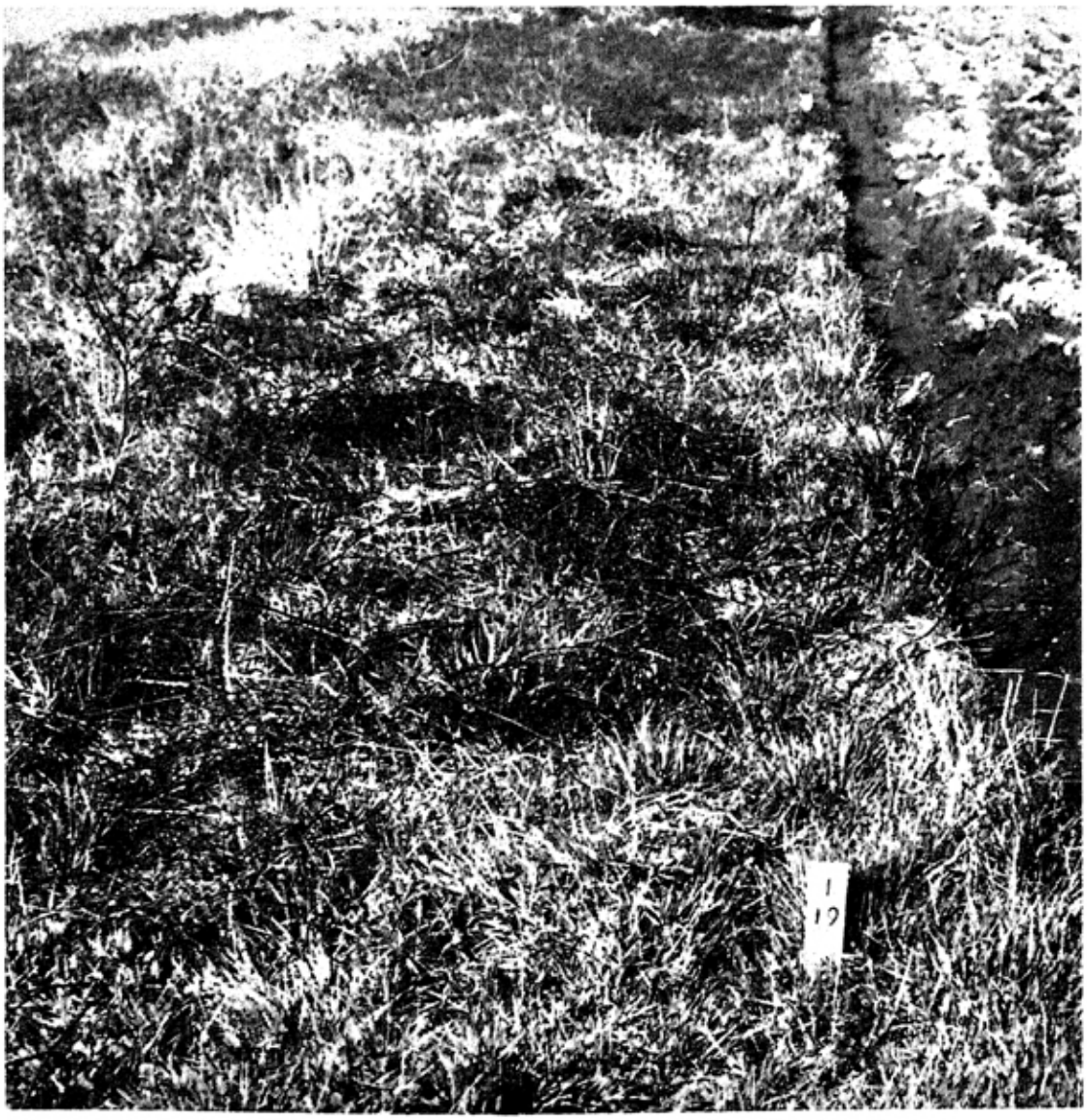

Figure 21 — Weeds crowded out ladino clover that was seeded on this plot April 22, 1949, on a prepared seedbed and not clipped. Photographed October 13, 1949.

Heaving

Most of the heaving of ladino clover in the winter of 1949-50 occurred in the late winter. Table 27 shows that 14.0 percent of the ladino clover plants which grew in the rows of grass (about 1 inch wide and 7 inches apart) were killed by heaving and 43.1 percent of those between the rows were killed by heaving. Within the grass rows, 53.5 percent of the ladino seedlings were undamaged; while, between the rows, only 20.5 percent were undamaged.

TABLE 27--INFLUENCE OF LOCATION WITH RESPECT TO THE ROW OF ASSOCIATED TALL FESCUE SEEDLINGS ON THE HEAVING OF LADINO CLOVER SEEDLINGS IN THE WINTER OF 1949-50

Condition of Plants	Growing Within the Rows of Grass		Growing Between the Rows of Grass	
	Number of Plants	Per Cent of Plants	Number of Plants	Per Cent of Plants
	Chart Quadrat Method of Study			
Normal	23	53.5	40	20.5
Heaved 1 cm. (alive)	10	23.3	26	13.3
Heaved 2 cm. (alive)	2	4.6	15	7.7
Heaved 3 cm. or more (alive)	2	4.6	30	15.4
Total living heaved	14	32.5	71	36.4
Heaved (dead)	6	14.0	84	43.1
Dead, not heaved	0	0.0	0	0.0
Total plants observed	43	100.0	195	100.0
	Paired Plants Method of Study			
Normal	42	84.0	11	22.0
Heaved 1 cm. (alive)	4	8.0	7	14.0
Heaved 2 cm. (alive)	1	2.0	11	22.0
Heaved 3 cm. or more (alive)	0	0.0	3	6.0
Total living heaved	5	10.0	21	42.0
Heaved (dead)	2	4.0	18	36.0
Dead, not heaved	1	2.0	0	0.0
Total plants observed	50	100.0	50	100.0

The ladino clover plants within the rows where fertilizer was applied were observed to average larger than those between the rows. However, this was not the only cause for the difference in heaving. When plant pairs of equal size were compared, 4.0 percent of the plants within the rows were killed by heaving and 36.0 percent of those between the rows were killed. The proportions of undamaged plants within the rows and between the rows were 84.0 percent and 22.0 percent, respectively. Figures 22 and 23 illustrate heaving of ladino clover in the winter of 1952-53 and the value of associated grass in reducing loss from heaving.

Figure 22—Tall fescue-ladino clover seeded August 26, 1949, and photographed April 24, 1950. Much of the ladino clover between the rows of grass was killed by heaving and the clover can be seen spreading from the rows.

Longevity and Production

A history of the ladino clover stands from each of the five dates of seeding is presented in Tables 28, 29, 30, 31, and 32. The very thin initial stands from the 1948 seeding which virtually disappeared during the 1948-49 winter and the very dense stands obtained from the spring, 1949, seeding were nearly equal in density in August, 1950. Ladino clover from the earliest seeding was extremely dense in orchard grass in August, 1950, but the vigor of the plants declined until by October only 31 hits per 100 points were scored on the clover.

Ladino clover which had become well established in bluegrass maintained good stands until it disappeared in almost all the plots in the winter of 1951-52. These bluegrass plots were badly infested with field mice and it is believed that they were responsible for the elimination of the ladino clover. Drouth, delayed clipping, and grasshoppers prevented the establishment of ladino clover seedlings which emerged from the spring, 1950, seeding on untilled bluegrass.

The ladino clover from the spring, 1950, seeding did not become well established in tall fescue, orchard grass, nor untilled bluegrass; however, the ladino clover in the tall fescue and orchard grass had begun to thicken by the spring of 1953.

Stand counts were not made in 1952; however, it was observed that the drouth reduced some stands of ladino clover. Figure 24 shows that ladino clover

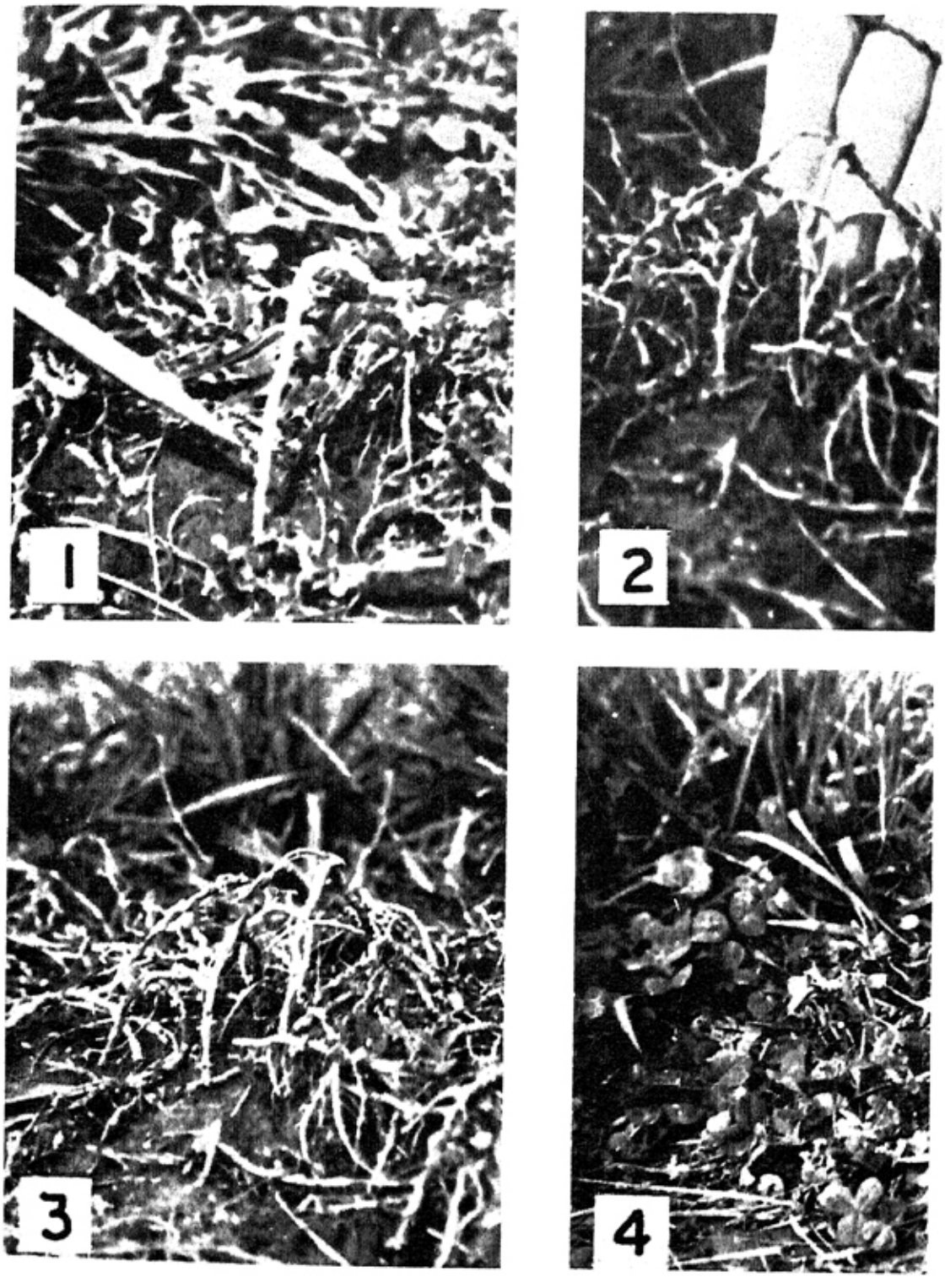

Figure 23—1, 2, and 3. Heaved ladino clover plants. 4. Ladino clover growing in the clump of tall fescue did not heave. Photographed April 18, 1953.

TABLE 28--STANDS OF LADINO CLOVER SEEDED IN THE LATE SUMMER, 1948 ON A PREPARED SEEDBED AND IN DISKED AND UNTILLED SODS OF FOUR GRASSES

Associated Grass	Seedbed	Plants per 10 Sq. Ft. 1948 Nov.	Hits per 100 Points in: 1950 Aug.	1950 Oct.	1951 Apr.	1953 Apr.	Est. Per Cent Stand Mar. 1954
None	Prepared	22					
Redtop	Disked	12					
	Untilled	4	16	19	39	41	1
Tall fescue	Disked	18					
	Untilled	10	40	41	51	55	0
Orchard grass	Disked	12					
	Untilled	2	78	31	39	34	Trace
Bromegrass	Disked	16					
	Untilled	8	55	49	37	54	10
Avg., all grasses	Disked	15					
	Untilled	6	47	35	42	46	3

TABLE 29--STANDS OF LADINO CLOVER SEEDED IN THE SPRING, 1949 ON A PREPARED SEEDBED AND IN DISKED AND UNTILLED SODS OF FIVE GRASSES

Associated Grass	Seedbed	Plants per 10 Sq. Ft. 1949 May	1949 Aug.	Hits per 100 Points in: 1950 May	1950 Aug.	1950 Oct.	1951 Apr.	1953 Apr.	Est. Per Cent Stand Mar. 1954
None	Prepared	73	82	83	69	75	54	49	20
Redtop	Disked	94	74		79	69	73	68	2
	Untilled	100	58		12		22	73	40
Tall fescue	Disked	111	71		75	70	71	45	0
	Untilled	108	102		37		28	56	Trace
Orchard grass	Disked	127	82		82	56	53	25	3
	Untilled	132	110		55		23	42	2
Bromegrass	Disked	168	81		88	80	72	58	15
	Untilled	111	129		48		59	57	30
Bluegrass	Disked	96	65	42	37	37	31	0	0
	Untilled	62	53	55	43	36	37	0	0
Avg., all grasses	Disked	119	75		72	62	60	39	4
	Untilled	103	90		39		34	46	14

TABLE 30--STANDS OF LADINO CLOVER SEEDED IN THE LATE SUMMER, 1949 ON A PREPARED SEEDBED AND IN DISKED AND UNTILLED SODS OF FIVE GRASSES

Associated Grass	Seedbed	Plants per 10 Sq. Ft. 1949 Nov.	Plants per 10 Sq. Ft. 1950 May	Hits per 100 Points in: 1950 Aug.	1950 Oct.	1951 Apr.	1953 Apr.	Est. Per Cent Stand Mar. 1954
None	Prepared	98				65	1	0
Redtop	Disked	42	29	82	82	53	65	20
	Untilled	9	13	27	29	46	61	5
Tall fescue	Disked	23	26	68	76	57	45	0
	Untilled	7	11	41	58	44	53	0
Orchard grass	Disked	31	39	84	60	56	29	3
	Untilled	23	27	66	40	58	32	3
Bromegrass	Disked	41	49	87	92	67	53	20
	Untilled	12	36	66	73	78	50	30
Bluegrass	Disked	35	84 (a)	36	40	56	0	0
	Untilled	19	24 (b)	24	32	25	0	0
Avg., all grasses	Disked	34	45	71	70	58	38	9
	Untilled	14	22	45	46	50	39	8

(a) Many spring seedlings.
(b) A few spring seedlings.

TABLE 31--STANDS OF LADINO CLOVER SEEDED IN THE SPRING, 1950 ON A PREPARED SEEDBED AND IN DISKED AND UNTILLED SODS OF FIVE GRASSES

Associated Grass	Seedbed	Plants per 10 Sq. Ft. 1950 May	Hits per 100 Points in: 1950 Aug.	1950 Oct.	1951 Apr.	1953 Apr.	Est. Per Cent Stand Mar. 1954
None	Prepared	33	15	43	29	45	5
Redtop	Disked	31	9	17	12	57	40
	Untilled	30	5	10	14	77	30
Tall fescue	Disked	32	6	11	5	28	0
	Untilled	23	1	1	Trace	8	0
Orchard grass	Disked	43	9	8	Trace	27	Trace
	Untilled	28	2	1	Trace	11	Trace
Bromegrass	Disked	153	21	47	46	60	20
	Untilled	41	13	49	41	54	10
Bluegrass	Disked	176	16	29	25	0	0
	Untilled	34	3	1	Trace	0	0
Avg., all grasses	Disked	87	12	22	18	34	12
	Untilled	31	5	12	11	30	8

TABLE 32--STANDS OF LADINO CLOVER SEEDED IN THE LATE SUMMER, 1950 ON A PREPARED SEEDBED AND IN DISKED AND UNTILLED SODS OF FIVE GRASSES

Associated Grass	Seedbed	Plants per 10 Sq. Ft. 1950 Oct.	Plants per 10 Sq. Ft. 1951 Apr.	Hits per 100 Points 1953 Apr.	Est. Per Cent Stand March 1954
None	Prepared	85	47		
Redtop	Disked	27	7	12	0
	Untilled	5	2	2	0
Tall fescue	Disked	6	4	9	0
	Untilled	2	0	1	0
Orchard grass	Disked	10	5	9	0
	Untilled	6	Trace	3	0
Bromegrass	Disked	49	33	33	Trace
	Untilled	21	5	10	0
Bluegrass	Disked		47	2	0
	Untilled		47	2	0
Avg., all grasses	Disked	23	19	13	Trace
	Untilled	9	11	4	0

which had been seeded on a prepared seedbed with tall fescue in late summer, 1949, was still present in September, 1952, but, as seen in Table 30, this ladino clover disappeared by April 18, 1953. The condition of four of the grasses on April 18, 1953, is shown in Figure 25.

Except where competition from grass was slight, ladino clover was virtually eliminated from all plots by the extreme drouth of 1953. As seen in Table 33, stands of redtop and bromegrass were thin and the redtop stands were very uneven by 1954; therefore, ladino clover was not as nearly eliminated from redtop and bromegrass as from the other grasses.

TABLE 33--STANDS OF FIVE GRASSES, MARCH, 1954. GRASSES SEEDED AUGUST, 1947

Grass	Estimated Per Cent Stand March, 1954
Redtop	15
Tall fescue	100
Orchard grass	80
Bromegrass	5
Bluegrass	95

The initial stands of ladino clover obtained from the summer, 1950, seeding were similar to stands on comparable plots from the summer, 1948, seeding, but the histories of the stands from these two seedings are very different. The 1948 seedings, which were followed by a favorable year for ladino clover in 1949, resulted in very satisfactory stands of ladino clover. The 1950 seeding, which was followed by less favorable management and weather, had not produced satisfactory stands of ladino clover at the end of three years. It should be noted,

Figure 24—Tall fescue and ladino clover pasture planted on prepared seedbed August 26, 1949. Photographed September 7, 1950 (above), and September 25, 1952 (below).

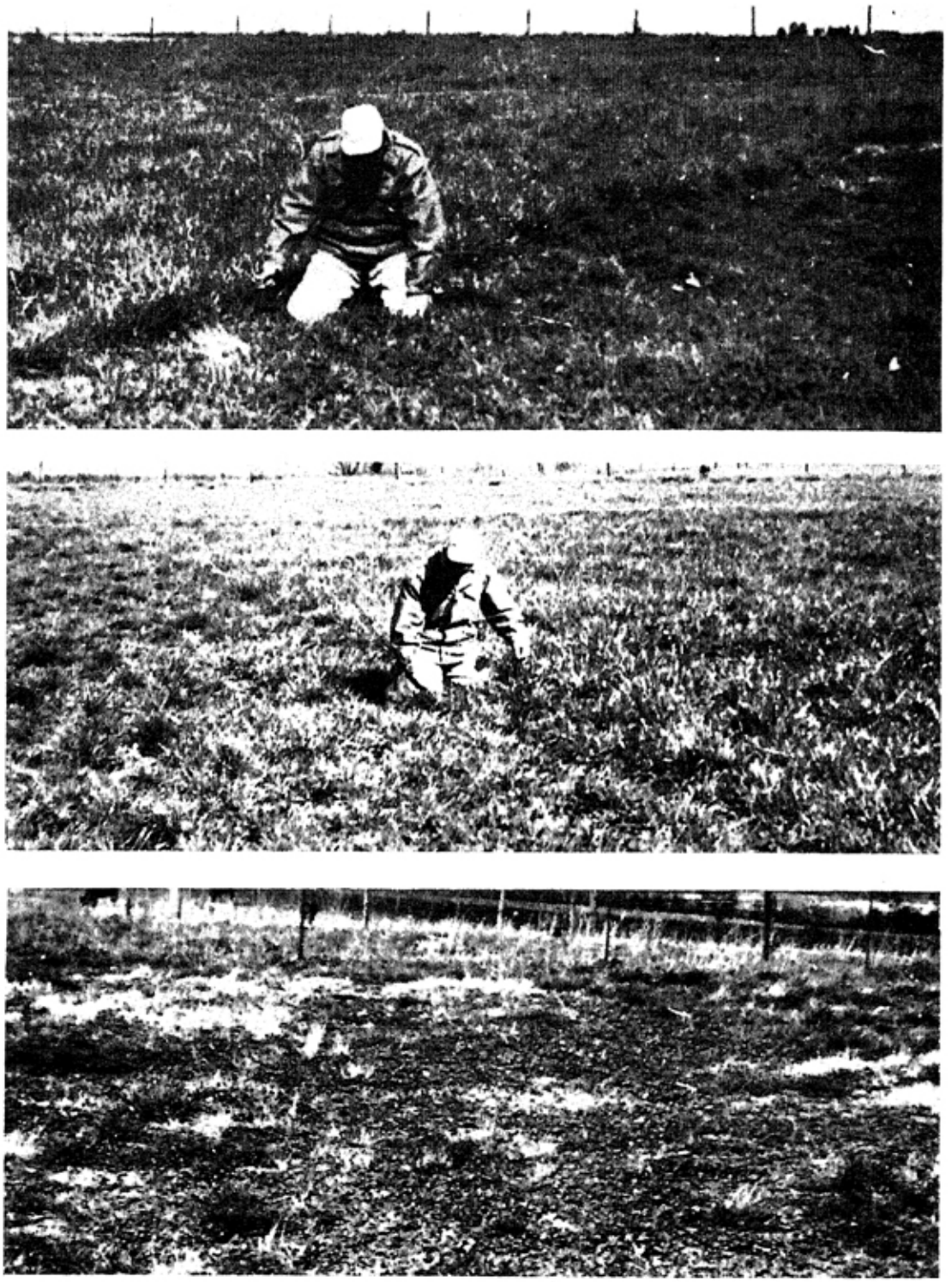

Figure 25—Condition of grasses used in establishment and longevity study, April 18, 1953. Top: Redtop (lower right) and tall fescue (upper left). Middle: Tall fescue (upper right) and orchard grass (lower left). Bottom: The bromegrass stand has virtually disappeared. Note the early growth made by tall fescue.

however, that the ladino clover from the summer, 1950, seeding was showing a tendency to thicken in April, 1953, at the beginning of the extreme drouth.

Disking sods prior to planting ladino clover did not appear to affect the longevity of the ladino clover stands in grasses.

In another study in which the yields of ladino clover-grass mixtures were compared with those of the grasses alone, ladino clover stands were maintained in bromegrass, bluegrass, orchard grass, and redtop for seven years (Table 34). Field mice are believed to be the cause of the disappearance of the ladino clover from these plots during the winter of 1951-52. The ladino clover was seeded in March, 1945.

TABLE 34--LADINO CLOVER STANDS IN FOUR ASSOCIATED GRASSES WITH THREE MOWING TREATMENTS. THE LADINO WAS SEEDED MARCH, 1945 IN SODS SEEDED AUGUST, 1943

	Hits per 100 Points Growing in Association With:											
Date Sampled	Bromegrass			Bluegrass			Orchard Grass			Redtop		
	A	B	C	A	B	C	A	B	C	A	B	C
1948												
June 7	87	63	50	24	29	74	65	14	10	49	44	17
July 23	99	94	46	33	24	64	70	41	10	70	53	24
Sept. 7	81	71	29	22	17	41	48	29	16	44	44	13
1949												
May 6	45	97		71	50		56	64		82	92	
July 19	70	73	73	86	58	57	80	75	59	82	78	55
Sept. 26	36	79	59	32	58	56	51	69	38	48	66	53
1950												
Aug. 14	50	53	63	59	67	92	26	41	46	57	62	68
Nov. 4	31	39	62	26	57	82	13	31	20	28	35	40
1951												
May 11	27	60	68	53	85	93	24	43	28	39	69	67
1953												
April 18	0	0	0	0	0	0	0	0	0	0	0	0

Clipping treatment:
A--Clipped to 1.5-inch level semi-monthly.
B--Clipped to 3.0-inch level monthly.
C--Clipped to 3.0-inch level once in June.

Good stands of bluegrass and redtop remained throughout the experiment; however, stands of closely clipped bromegrass were thin in 1948 (Figure 26) and the bromegrass which was clipped to the 3-inch level monthly was thin by the end of 1949 (Table 35). Stands of orchard grass, which were clipped to the 1.5-inch level semi-monthly, were thin by the fall of 1949.

Ladino clover stands suffered from heaving where poor stands of bromegrass and orchard grass afforded little winter protection. Close, frequent clipping

Figure 26—Bromegrass and ladino clover mowed to the 1.5-inch level semi-monthly (above) and to the 3-inch level monthly (below). Neither plot had been mowed in 1949 before this photograph was taken April 22.

TABLE 35--STANDS OF FOUR GRASSES WHICH WERE SEEDED AUGUST, 1943 AND GREW IN ASSOCIATION WITH LADINO CLOVER WHICH WAS SEEDED MARCH, 1945 UNDER THREE CLIPPING TREATMENTS

Date Sampled	Hits per 100 Points on: Bromegrass A	B	C	Bluegrass A	B	C	Orchard Grass A	B	C	Redtop A	B	C
Oct. 8, 1948	5	42	54	84	98	96	46	82	81	62	79	71
May 7, 1949	6	61		100	100		80	95		93	100	
Oct. 7, 1949	1	15	41	97	100	76	22	72	28	56	88	81
Aug. 14, 1950	0	18	30	97	95	81	37	84	79	35	64	53
May 11, 1951	58 (a)	50 (a)	67 (a)	99	100	78	65 (a)	97	73	85	98	94

(a) Mostly volunteer Kentucky bluegrass.

Clipping treatments:

A--Clipped to 1.5-inch level semi-monthly.
B--Clipped to 3.0-inch level monthly.
C--Clipped to 3.0-inch level once in June.

did not appear injurious to ladino clover except in years following severe heaving or during periods of dry, hot weather. Ladino clover suffered more from competition with the grass in the plots which were cut as hay in seasons of high rainfall and cool temperatures such as 1949.

Except for the case of bromegrass that was clipped high, monthly in 1949, grass-ladino clover mixtures out-yielded the corresponding grasses alone in every year with every species of grass and all clipping treatments (Table 36). Yields of grass-ladino clover mixtures averaged about one-third as high when cut once in June as when clipped semi-monthly or monthly from April to September. Differences in herbage yields between plots clipped to 1.5 inches semi-monthly and those clipped to the 3-inch level monthly were variable and no definite trends were indicated. For the three-year period, redtop-ladino clover was the highest yielding mixture, followed in order by mixtures including bluegrass, bromegrass, and orchard grass; however, the differences between yields resulting from different associated grasses were not great.

Since the mowing dates for each year were not the same and the semi-monthly and monthly growth periods were approximate, the averages for Figures 27, 28, 29, and 30 were obtained by computing average daily yields within each growth period, adding the average daily yields to determine the yield for each calendar month, and averaging the monthly yields for the years 1948, 1949, and 1950. These Figures show the average seasonal distributions of herbage yields, 1948 through 1950, from bromegrass, bluegrass, orchard grass, and redtop grown alone and with ladino clover and clipped at different heights and frequencies.

TABLE 36--ANNUAL YIELDS OF GRASSES AND GRASS-LADINO MIXTURES. POUNDS DRY HERBAGE PER ACRE

Grass and Clipping	Year and Crop					
	1948		1949		1950	
	Grass Alone	Grass + Ladino	Grass Alone	Grass + Ladino	Grass Alone	Grass + Ladino
Bromegrass						
Short semi-monthly	1310	2815	2919	3076	2071	4472
High monthly	921	3228	2492	2326	1927	2736
High once in June	680	2109	579	1476		
Bluegrass						
Short semi-monthly	1996	2575	3810	3885	1657	3364
High monthly	680	2219	939	4648	422	3890
High once in June	457	1334	613	1485		
Orchard Grass						
Short semi-monthly	1892	2789	3060	3306	1604	2690
High monthly	1028	1841	1264	3770	656	2976
High once in June	312	1372	312	1022		
Redtop						
Short semi-monthly	1850	2958	2920	3900	1996	4045
High monthly	1111	2762	2051	5017	924	3548
High once in June	1337	1919	748	1289		

These graphs further illustrate the superior yields from grass-ladino clover mixtures, compared to pure grass stands. This is in spite of a considerable contribution to the yields of some of the bromegrass and orchard grass plots by volunteer bluegrass and lespedeza. Although ladino growing in association with bromegrass, bluegrass, orchard grass, and redtop resulted in a large increase in the yields of herbage, it also resulted in a more uneven distribution of herbage yields than in the case of pure grass stands. In general, the production troughs of the mixtures were not as low as those of the grasses, but the production peaks, which frequently occurred later than the production peaks of the grasses, were much higher.

Bromegrass-ladino produced the most uniform herbage yield throughout the season with the peak of production from the plots which were cut high, infrequently, occurring in May, followed by a gradual decline throughout the season. The bromegrass-ladino clover which was cut short, frequently, increased in productivity to July and then declined. The bromegrass without ladino clover reached its peak of production in May when cut short, frequently, and in June when cut high, infrequently. The production of these plots was increased in the summer by the presence of volunteer lespedeza. Since the bromegrass did not grow vigorously on severely defoliated plots, the tendency for production of

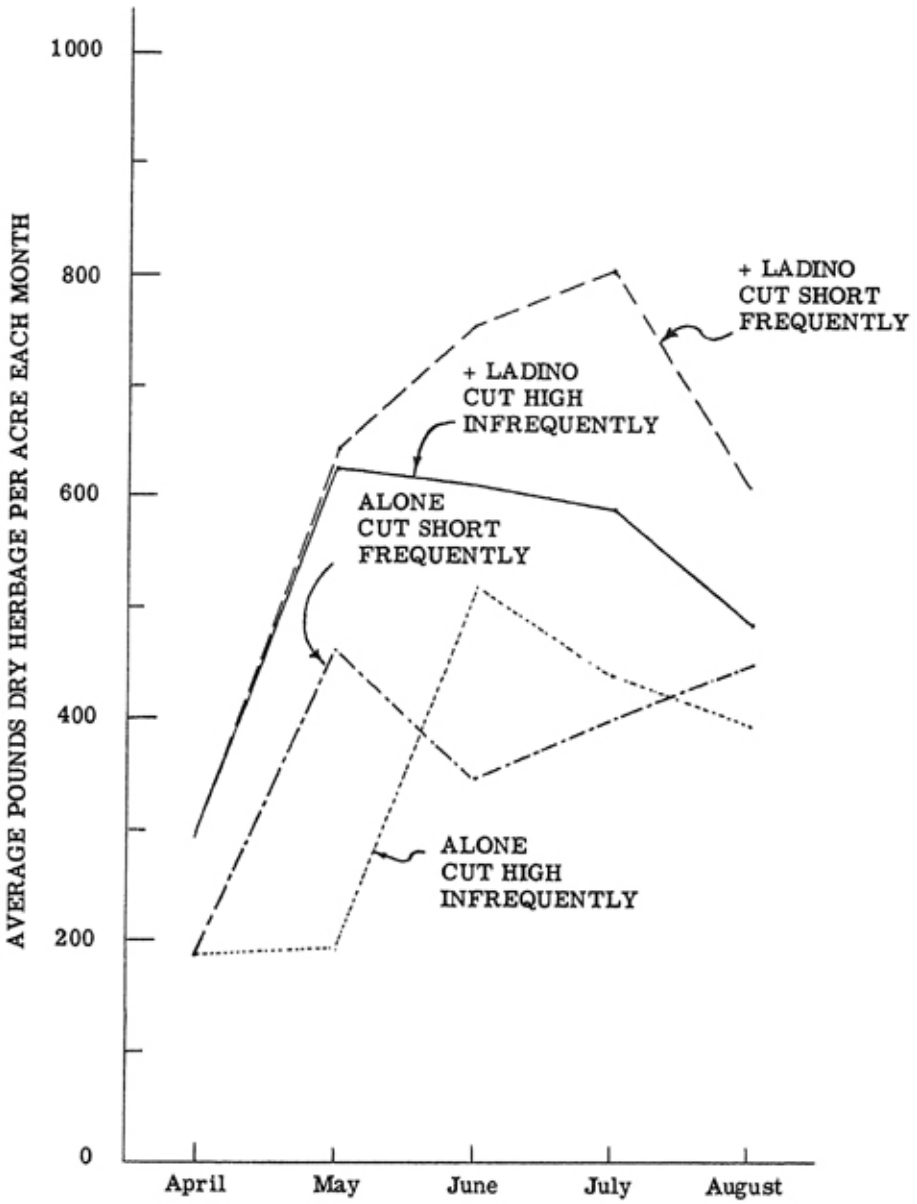

Figure 27—Seasonal distribution of herbage harvested from bromegrass growing alone and with ladino clipped to 1.5-inch level semi-monthly and 3-inch level monthly. Average 1948 to 1950, inclusive.

bromegrass-ladino clover mixtures to remain relatively high during July and August is prabably a reflection of the growth habit of ladino clover.

All of the bluegrass plots reached their peak of production in May except the bluegrass-ladino clover mixture that was cut high, infrequently. It reached its peak of production in June. Yields of bluegrass and ladino clover were favored somewhat by the more lenient clipping, but the lenient clipping of bluegrass alone yielded much less than the more severe defoliation.

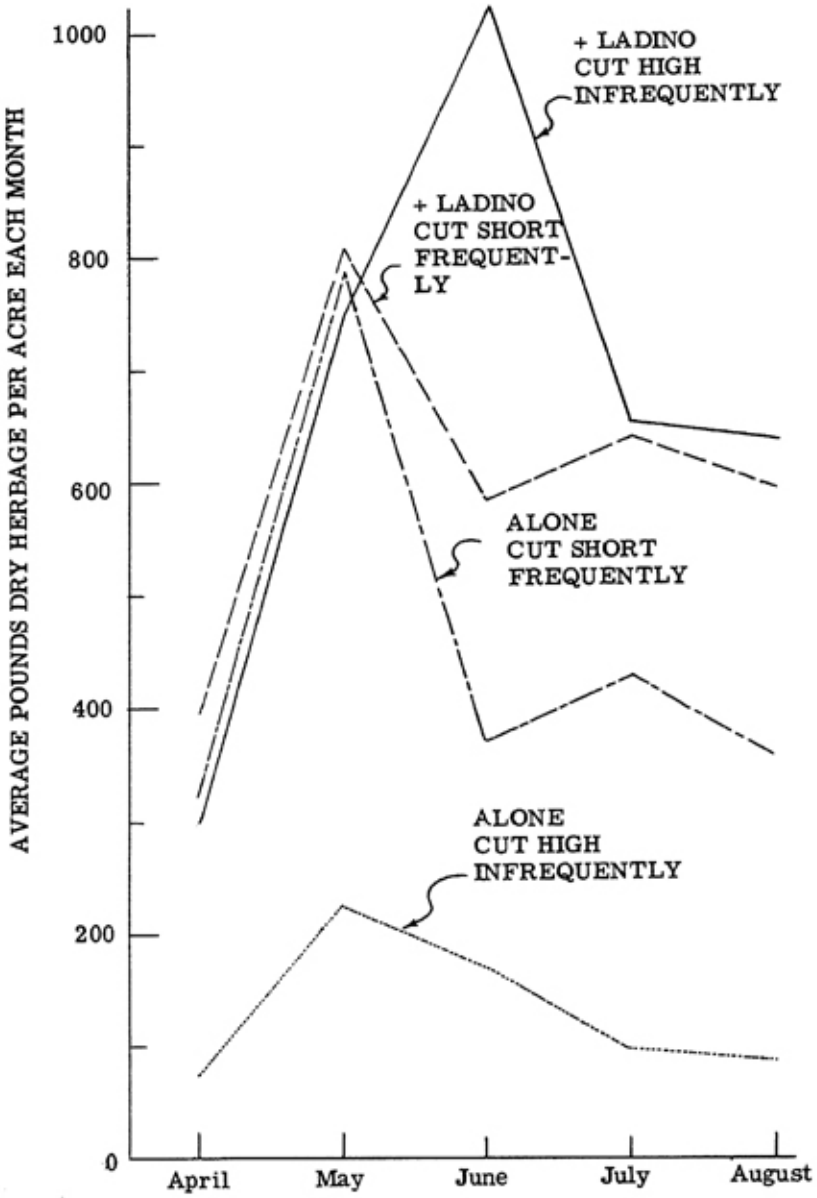

Figure 28—Seasonal distribution of herbage harvested from bluegrass alone and with ladino; clipped to 1.5-inch level semi-monthly and 3-inch level monthly. Average 1948 to 1950, inclusive.

The relatively low yields of orchard grass alone and with ladino clover were partly due to poor stands of orchard grass. The poor stand not only affected the yields directly, but resulted in some reduction in the vigor of ladino clover due to winter injury. The seasonal distributions of the yields of herbage from orchard grass alone and orchard grass-ladino clover were comparatively uniform. Although the more severe defoliation produced a more uniform distribution of herbage yields and the total yield was only slightly less than that of the mixture given the more lenient defoliation, the orchard grass stands thinned much

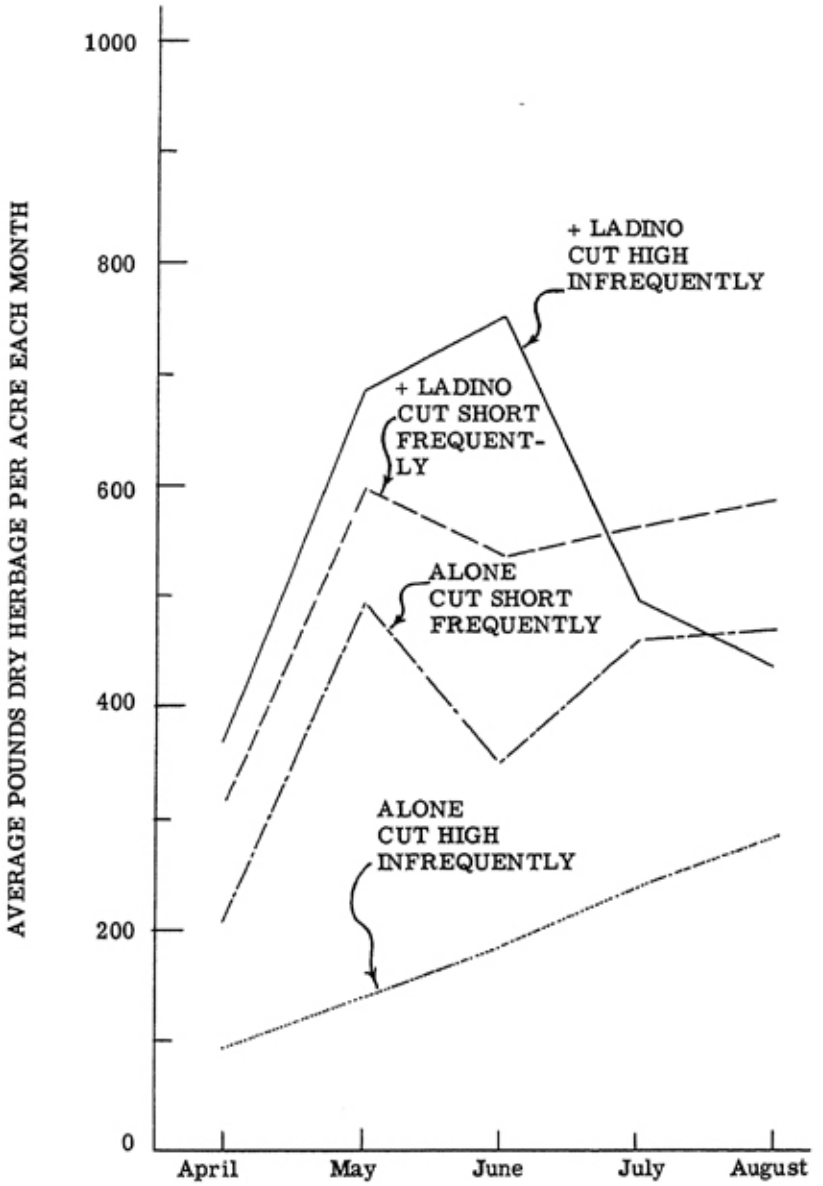

Figure 29—Seasonal distribution of herbage harvested from orchard grass growing alone and with ladino; clipped to 1.5-inch level semi-monthly and 3-inch level monthly. Average 1948 to 1950, inclusive.

more under the close, frequent mowing treatment.

Plots growing redtop alone and redtop with ladino clover out-yielded those growing other grasses with comparable treatments, except the closely defoliated plot of redtop alone which was exceeded in yield by the corresponding bluegrass plot. All of the redtop plots, regardless of associated legume or clipping treatment, produced very unevenly distributed yields. The leniently defoliated plots reached a production peak in June and fell off sharply in July and August, while the more severely defoliated plots reached a production peak in May with a marked reduction in yield in June which remained fairly constant the remainder of the summer. It should be noted, however, that the summer production of

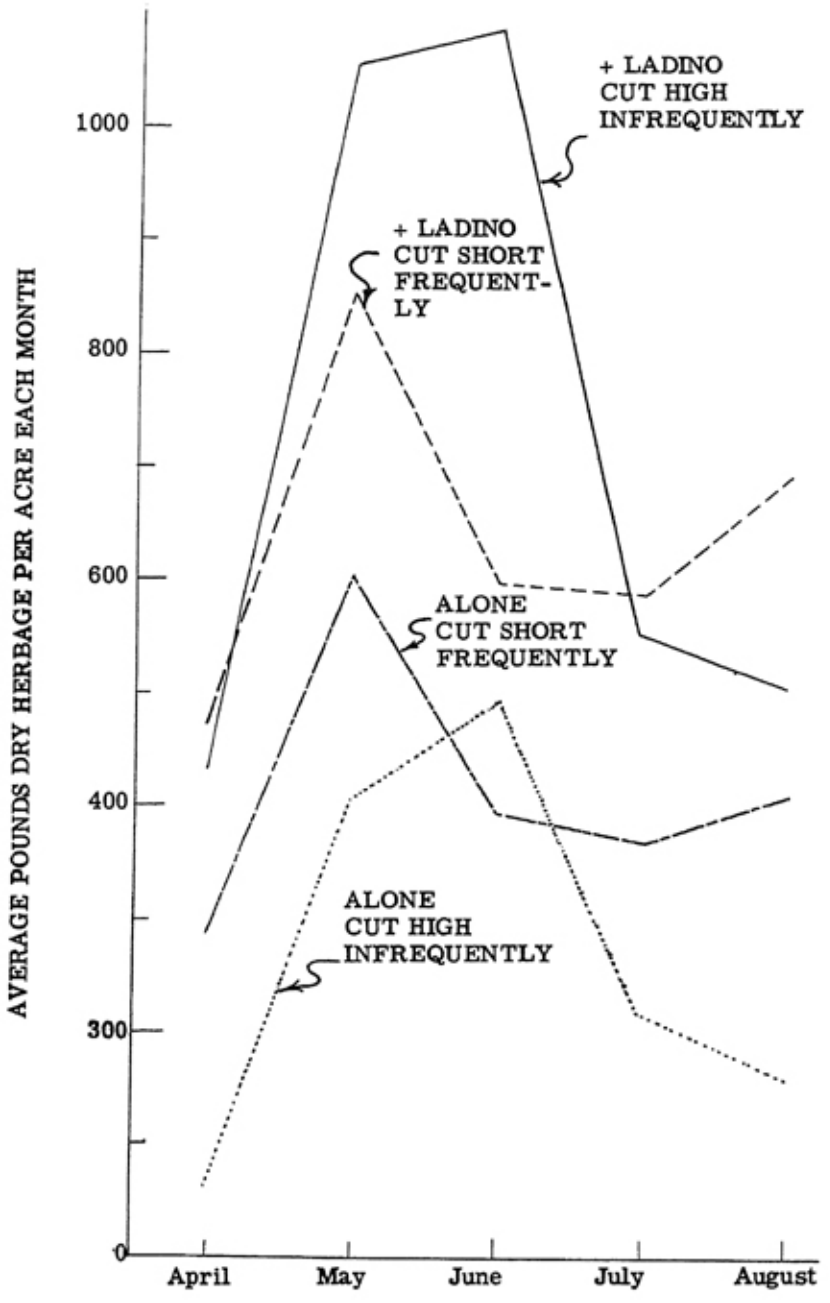

Figure 30—Seasonal distribution of herbage harvested from redtop growing alone and with ladino; clipped to 1.5-inch level semi-monthly and 3-inch level monthly. Average 1948 to 1950, inclusive.

herbage from the redtop plots compared favorably with the average production of comparable plots of the other grasses. Redtop alone, like the other three grasses, produced a considerably higher yield of forage when clipped to the 1.5-inch level semi-monthly than when clipped to the 3-inch level monthly.

DISCUSSION

A generally accepted method of producing high yields of nutritious forage is to apply the mineral nutrients in which the soil is deficient and to establish and maintain a legume in the sward (5). The ease and certainty with which a legume can be established in grass sod, its survival under grazing, and the grazing management required for its maintenance affect its value as a pasture legume.

The ideal legume for this purpose would be one that could be established without seriously disturbing the existing sod or interrupting grazing and that would survive and remain productive for many years. Ladino clover showed promise of approaching the ideal. Thus it was tested to determine what cultural practices and what grazing management were required for its establishment and maintenance. Measurements of productivity also were considered valuable in estimating the desirability of ladino clover for a pasture legume. Further studies are being conducted in Missouri, but this practice is already being recommended to farmers on the basis of the investigation reported here.

Competition Involving Ladino Clover, Bromegrass, and Tall Fescue

Although bromegrass does not grow vigorously in the field on Mexico silt loam soil, it was found to be slightly more aggressive than tall fescue from the standpoint of yields of grass and from the standpoint of suppression of associated ladino clover when grown in pots of virgin Mexico silt loam topsoil in the greenhouse. This differential response of the two grass species to the natural soil and the potted topsoil suggests a difference between the species in their tolerance to the claypan which underlies Mexico silt loam.

The hypothesis that this difference in soil adaptation is a result of an inherent difference between the root systems of the two grasses is supported by the consistently higher root yields from bromegrass cultures than from tall fescue cultures. Since bromegrass exceeded tall fescue more in root yields than in herbage yields, tall fescue roots apparently are more efficient than bromegrass roots in terms of weight of top growth produced per unit weight of roots. It also appears that where bromegrass out-yields tall fescue in herbage production, it does so at least in part by the development of a considerably more extensive root system.

The claypan of Mexico silt loam soil may be a limiting factor in the development of bromegrass roots. Tall fescue apparently is better adapted to this soil because of its more efficient root system and possibly because the claypan is not as great a deterrent to its root development.

Bromegrass yielded more herbage than tall fescue in cultures which were not clipped and in those which were clipped to the 3-inch level monthly, but tall fescue out-yielded bromegrass in cultures which were clipped to the 1.5-inch level monthly and in those which were clipped to the 1.5-inch level semi-monthly.

Bromegrass yielded more roots than tall fescue under all clipping treatments. The differences between species in root yields were greater in the unclipped cultures and in those clipped to the 3-inch level monthly than in those clipped to the 1.5-inch level monthly or those clipped to the 1.5-inch level semi-monthly.

This differential response of the two grasses to clipping is probably a result of their different habits of growth. Tall fescue has a high percentage of basal leaves, while bromegrass has more of its leaves distributed along the stem. This is further supported by the fact that among the monthly clipped cultures bromegrass produced more herbage than tall fescue when clipped to the 3-inch level and tall fescue produced more herbage than bromegrass when clipped to the 1.5-inch level. This indicates the differential response was due to height of clipping rather than frequency of clipping.

The herbage of all mixed cultures was predominantly ladino clover. The contribution of ladino clover to herbage yields varied from 64 percent in the cultures containing 37 bromegrass plants clipped to the 1.5-inch level semi-monthly, to 95 percent in the cultures containing six tall fescue plants, not clipped.

Ladino clover produced a much smaller proportion of the total root yields of the mixed cultures. It produced from 26 percent of the roots in the cultures containing 37 bromegrass plants that were clipped to the 1.5-inch level semi-monthly to 82 percent in the cultures containing six tall fescue plants that were not clipped.

Ladino clover appeared unusually aggressive in these greenhouse pots, but it should be remembered that (a) it was competing with cool-season grasses in a warm to hot environment, (b) it was a shallow-rooted crop competing with deeper-rooted crops in relatively shallow pots, and (c) ladino clover is sensitive to soil moisture deficiency which often occurs in the field but which did not exist to any appreciable extent in these cultures.

In the field, ladino clover seedlings were observed to be about average among those of the common legumes in competitive ability in bluegrass sod. When planted in different grass sods in the field, they developed most rapidly in bromegrass and least rapidly in tall fescue and bluegrass. They were intermediate in this respect when growing in association with redtop and orchard grass.

Ladino clover that was clipped monthly produced 19 percent less herbage and 48 percent less roots than the unclipped clover. Clipping semi-monthly produced 54 percent less herbage and 78 percent less roots than no clipping. Both herbage and root yields of monthly clipped ladino clover were practically equal

whether the clover was clipped to the 1.5-inch level or to the 3-inch level.

Thus, ladino clover growth was affected more by frequency of clipping than by height of clipping. This is reasonable when one considers the growth habit of ladino clover. The stems are stolons and the only plant parts that are harvested by clipping are the leaflets and a portion of the petiole. There is a tendency for the petioles of periodically clipped ladino clover to be about the same length, producing a distinct canopy of leaflets at a uniform height with few leaflets occurring at intermediate heights. From the standpoint of photosynthetic area removed from the plants, about the only difference between clipping to 1.5 inches and clipping to 3 inches is a 1.5-inch section of the slender petioles which naturally grow in considerable shade.

Influence of Temperature and Clipping on Competitive Ability of Ladino Clover Seedlings in Established Tall Fescue

Tall fescue herbage yields tended to increase with increases in temperature from 50° to 80° but the differences were small and they were not consistent within each clipping treatment. Clipped tall fescue yielded about one-half as much herbage and about one-third as much root material as unclipped tall fescue.

Pure stands of ladino clover increased in growth with each 15° increase in temperature. Herbage yields gave less response and root yields gave much less response to the increase in temperature from 65° to 80° than to the increase from 50° to 65°. Clipping resulted in smaller reductions in ladino clover yields than it did in tall fescue yields. This is probably because clipping to the 1.5-inch level caused a smaller percentage of defoliation of ladino clover seedlings than of established tall fescue plants.

Unclipped tall fescue competed as severely with ladino clover seedlings in pots of fertile, well-watered soil as it did in the field; however, when the cultures were clipped, the ladino clover seedlings averaged four times as large as when they were not clipped. Nutrients and moisture were not thought to be limiting. Thus the main benefit of clipping to ladino clover was the reduction of competition for light by the tall fescue.

Seed Sources

In this limited study, Italian imported ladino clover seed was equal to domestic certified seed from the standpoint of type purity. The genetic histories of the experimental selections are not known, but seed of those tested produced as great a percentage of off-type plants as certified commercial seed. It is indicated that uncertified domestic seed, seed produced under close grazing, and seed harvested from ladino clover plants in close proximity to volunteer white clover, are undependable sources of ladino clover.

Rates of Seeding

These studies indicate that botanical composition of the herbage can be influenced, at least for a time after seeding, by the relative rates of seeding grass and ladino clover. As much as 25 pounds of tall fescue seed and as little as 2 pounds of ladino clover seed produced herbage that was considered safe for grazing by animals subject to bloat. However, other observations suggest the hypotheses that (a) there may be a characteristic ecologic balance between ladino clover and each species of grass in a given environment, (b) mixed ladino-grass stands tend to approach that characteristic balance with the passage of time, (c) although stands of adapted grasses may change somewhat, most of the adjustments may be made by either thickening or thinning ladino clover stands, and (e) varying weather produces environments which change much more rapidly than the ecology of the swards.

It is doubtful if any productive mixture of bromegrass and ladino clover, growing on Mexico silt loam soil, would long remain safe for grazing from the standpoint of bloat.

Establishment in Grass Sods

When ladino clover was seeded in grass sods, the poorer initial stands from spring plantings were better than the best initial stands from late summer seedings. This is probably because the top fraction of soil is usually more moist in April and May than in September and October in Missouri; thus providing a more favorable medium for germination and early establishment of ladino clover. Many instances were noted of seedling emergence in the spring following late summer planting. It is not known whether or not these were only from hard seed, but there were cases in which the numbers of spring seedlings were considered too great to be explained on this basis.

In this study the land was not dry enough in the spring to work with disk or drill until April. It is likely that winter or early spring seeding in untilled sod or seeding after fall sod tillage would have been better. At least these times have been proven better for birdsfoot trefoil (7) and lespedeza (4).

Ladino clover proved highly sensitive to soil moisture conditions, especially during establishment. It established well in very heavy stands of grass without tillage when planting was followed by abundant, well distributed rainfall. It established poorly in heavy sod in dry weather. Tilling the sod almost invariably helped to get stands of ladino, but it was essential only when planting was followed by dry soil conditions.

In Missouri, surface soil moisture in sod is usually below optimum for establishment of ladino clover in the fall, and is sometimes too low in the spring. Results of this study show that tillage would be desirable for establishing ladino clover in late summer and that it would often be beneficial for spring planting. However, inability to till sod does not preclude the establishment of ladino

clover on the land. Spring appears to be a better season than late summer for planting ladino on untilled sod.

Ladino clover was satisfactorily established in all species of grass tested—redtop, tall fescue, orchard grass, bromegrass, and bluegrass. On the average, slightly better initial stands were obtained in untilled bromegrass and orchard grass than in untilled sods of the other grasses. Tillage gave larger increases in initial stands of ladino clover in Kentucky bluegrass and in bromegrass than it did in the other grasses. None of the measurements or observations in this study explain this. It is possible that, except for the rather strong competition for light, moisture, and nutrients, the plant interactions between ladino clover and the grasses are more beneficial to ladino clover seedlings growing with bromegrass and bluegrass than with the other grasses and that tillage decreased the competition allowing the beneficial interactions to be expressed.

Where grass or weed competition was great, short, frequent clipping during the first full year of establishment was more beneficial to ladino clover than more lenient defoliation. This was particularly true when soil moisture was high, indicating that light was the more limiting factor. Periodic clipping was more benefical to spring seedings in the year of planting than to late summer seedings in the year following planting. Delaying the beginning of periodic clipping until mid-June in a relatively dry year resulted in marked thinning of current spring seedlings, but it was not particularly harmful to vigorous plants established the summer before.

Results on prepared seedbeds substantiate the validity of the general recommendations for establishing perennial forage crops in Missouri (5). In general, better establishment was obtained from late summer seedings than from spring seedings. Clipping for weed control was essential for satisfactory ladino clover establishment in the spring on prepared seedbeds.

Winter Killing

The only important winter injury to ladino clover detected in these studies was caused by field mice and by heaving. Field mice were unusually numerous in the winter of 1951-52 in areas where there was abundant vegetative cover. In many of those areas the ladino clover stolons almost completely disappeared. This did not happen where there was little vegetative cover.

Ladino clover seedlings growing in the drill rows of tall fescue and underlain with bands of phosphate and potash fertilizer heaved much less than plants between the rows. The fertilizer stimulated the growth of the plants in the rows, resulting in larger plants at the beginning of winter, which appeared to reduce heaving. However, selection of pairs of equal sized plants—one plant in a grass row and one between the rows—indicated greater heaving losses among the plants between the rows than were indicated by the area quadrat method of study. Among those growing in the rows, the opposite was true.

Several factors probably were involved:

A. The average size of plants selected in the row was smaller than the average of the total population in the row because small plants were selected to match those between the rows.

B. Conversely, the average size of plants selected between the rows was larger than the average of the total population between the rows.

C. Plants in the rows were selected to be near grass plants, eliminating those plants growing in "skips" in the grass stands.

D. Plants between the rows were selected to be near the middle of the area between the rows, so they had a minimum of benefit from the grass and the fertilizer.

Longevity

These studies, as well as numerous observations on farmers' fields, show that ladino clover persists at least several years in sods unless it is killed by drouth, winter injury, or unfavorable management.

Ladino clover is more drouth tolerant in Missouri than common white clover, but it is relatively sensitive to dry soil conditions. It remained alive but appeared to grow little during short periods of low soil moisture. Periods of drouth lasting for a few weeks reduced the vigor of ladino clover. Successive periods with only short periods of plentiful moisture between had a cumulative, weakening effect. In a very dry growing season when a good rain fell about once per month, ladino clover almost completely disappeared from grass sods. The only survival was in thin stands of grass.

There is a possibility that ladino clover will become reestablished by natural reseeding where old stands are lost.

There was some indication, though inconclusive, that ladino clover in grass sods was benefited in dry years by high, infrequent clipping compared to short, frequent clipping. The frequency was probably more important than the height of clipping.

Limited vegetative cover prevented loss of ladino clover from field mice; however, reasonably good cover reduced heaving damage in years having long periods of diurnal freezing and thawing. Since, in the experience of the writers, winters conducive to heaving are quite common in Missouri and those with severe field mice infestation are not, it seems wiser to manage ladino clover so that it has a good vegetative cover at the end of the growing season. Although no comparisons with unrolled checks were made, rolling badly heaved ladino clover with a smooth roller in the early spring when the soil was quite moist was judged to benefit it. This pushed the stolons and roots down in contact with the soil, reducing damage from desiccation.

Production

Ladino clover seeded in grass sods greatly increased their total productivity, as wild white clover did in studies reported by Johnstone-Wallace (6).

In plots which were clipped to the 1.5-inch level monthly, the average increase was 47 percent. High, infrequent clipping represented much poorer utilization of the pure grasses from the standpoint of yield, but it was better management from the standpoint of grass stands, especially in the cases of bromegrass and orchard grass. Brown (3) also found that Kentucky bluegrass yielded more herbage but produced a smaller increment in rhizomes when clipped to the 1-inch level semi-monthly than when clipped to the 2.5-inch level semi-monthly.

When ladino clover was grown with the grasses, the more leniently clipped mixtures yielded, on the average, 98 percent as much herbage as the more severely clipped ones. Thus, by adding ladino to the sward and practicing more lenient defoliation, grass stands were better maintained and yields were increased 44 percent. On the average the presence of ladino clover in "hay cut" plots increased the yield from a single cutting in June 138 percent.

Good stands of bromegrass with ladino defoliated leniently were out-yielded by poor stands of bromegrass with ladino defoliated more severely. The same was true with orchard grass.

Bluegrass and redtop maintained good stands with ladino clover under both clipping treatments. The mixtures yielded somewhat more under the more lenient clipping.

Although yields were not measured on tall fescue-ladino mixtures, they were observed to be among the most productive ones.

Orchard grass suffered from heaving on the plots from which yields were taken. It has been judged to compare with the other grasses more favorably as an associated grass with ladino clover on soils less subject to heaving. Wagner (18) has also reported orchard grass-ladino clover to be an outstanding mixture from the standpoint of exactness of management requirements, yield, distribution of production, competition with weeds, and balance of botanical composition when compared with bromegrass-ladino clover, orchard grass-alfalfa (*Medicago sativa* L.), and bromegrass alfalfa mixtures at Beltsville, Md. Ladino clover in combination with any one of the five grasses studied produced relatively high yields.

Herbage production of grass-ladino clover mixtures was not well distributed throughout the growing season. Seasonal production peaks tended to be higher and somewhat later than those of pure grasses. This agrees with the report of Johnstone-Wallace (6) that the production of Kentucky bluegrass-wild white clover mixtures was less uniform than the production of pure stands of either species. Bromegrass-ladino clover and orchard grass-ladino clover gave the more uniform herbage production.

The severity of defoliation was inconsistent in its effect on the grass-legume balance of the herbage. This may be because of differential effects of height of clipping and frequency of clipping. Bromegrass and orchard grass tended to lose vigor under frequent clipping more than redtop, tall fescue, bluegrass, or ladino clover. Ladino clover was observed to grow more vigorously when the grass stands thinned, in spite of the more severe defoliation, except when it heaved in winter due to lack of protection by the grass or when soil moisture was deficient in the upper part of the soil.

The influence of height of clipping, independent of frequency of clipping, on the growth of grasses alone or in mixtures was not thoroughly studied; however, Brown (3) found that bluegrass rhizome development (and consequently stand) was favored by clipping to the 2.5-inch level compared to the 1-inch level. Robinson and Sprague (11) found that a 2-inch height of clipping resulted in more Kentucky bluegrass and less clover than shorter clipping heights (1 inch or ½ inch) in plots seeded to a mixture of bluegrass and several types of white clover, including ladino.

Ladino clover did not appear very sensitive to height of clipping except when the clipping treatment affected the vigor of competing grass.

There appears to be a differential response between some grasses and ladino clover to frequency of clipping when height of the stubble is constant. Brown and Munsell (1) reported no benefit in herbage yields from allowing either Kentucky bluegrass or Rhode Island bentgrass, which was fertilized with nitrogen and which contained little white clover, to reach a height of 4 inches instead of 3 before clipping to the 1.5-inch level. Their results showed that clipping bluegrass as frequently as it reached a height of 2 inches reduced the production only 15 percent below that of the grass which was clipped when it reached a 3-inch or a 4-inch height. Clipping only as frequently as the grass reached a height of 5 inches increased the productivity 32 percent and doubled the area occupied by volunteer white clover (an increase from 6 percent to 13 percent) compared to the plots clipped at the 3- or 4-inch height.

Tesar and Ahlgren (15) have reported the residual effects of six, four, and two clippings in one season on plots seeded the year before to ladino clover and in which Kentucky bluegrass was volunteering. They found that frequent clipping resulted in much higher yields of bluegrass and lower yields of ladino clover during the year after treatment.

Results of these studies also show that vigor of ladino clover is greatly reduced by frequent defoliation.

Delaying the first defoliation of grass-ladino clover mixtures in the spring was detrimental to ladino clover, with no apparent harm to the grass. This agrees with the report of Sprague and Garber (14).

The use of nitrogen fertilizers to influence the botanical composition of grass-legume mixtures was not studied, but it is well known that addition of nitrogen increases the vigor of grasses, making them stronger competitors with

legumes. This was reported by Brown and Munsell (1), Brown (3), Johnstone-Wallace (6), Robinson and Sprague (11) (12), and Sprague and Garber (14).

Application of Results to Commercial Production

Most of the following suggestions for establishment and management of ladino clover are made subject to confirmation by field-scale plantings, grazing trials, and cost-benefit studies.

New seedings of ladino clover are best made in late summer on a well firmed seedbed by "band" distribution of the fertilizer and ladino clover seed. Spring seedings without a companion crop should be clipped for weed control. A desirable ratio of grass to ladino clover in the forage during the first few years requires a rate of seeding of the grass about 50 percent higher than normal. Ladino clover should be seeded at about 1 pound per acre.

Ladino clover can be established in grass sods if deficiencies in soil nutrients are corrected. Success is more certain if plantings are made in the spring or possibly late winter on sods tilled to reduce the stands of grass to one-half of normal. Since orchard grass is permanently thinned by tillage, it should be tilled lightly, if at all, for ladino clover establishment. With less assurance of success, ladino can be established in grass in late summer and it can be established without tillage of the sod. The ladino should be seeded at the rate of 2 pounds per acre in established grasses.

Swards containing ladino clover seedlings in grass sod should be grazed or mowed. This defoliation should be to a height of 1.5-inches to 3 inches every two to four weeks, depending on the soil moisture. The close, frequent defoliation is better for moist conditions, and the high, less frequent defoliation is better for dry conditions.

Rotation grazing is preferable to continuous grazing for grass-ladino clover mixtures. Heavy stocking with short periods of grazing is best. Intervals between grazing should normally be two to four weeks.

The proportion of ladino clover to grass can be influenced by the grazing and clipping management and by fertilization. The tendency for excessive ladino clover can be reduced by delaying the initiation of clipping or grazing in the spring. It can also be held in check by shortening the intervals between grazing or by clipping once between grazing periods just below the canopy of ladino clover leaflets. If the clipping is made a few days prior to a grazing period the cured clippings will be consumed and they may reduce the bloat hazard. Defoliation to increase the ratio of grass to ladino clover in herbage should not be shorter than necessary to remove the ladino clover leaflets. Application of nitrogen fertilizer makes the grass more vigorous at the expense of the ladino clover.

Management to increase the ratio of ladino clover to grass in the forage should include early grazing or clipping followed by relatively long intervals be-

tween defoliations and each defoliation should be to as short a level as possible without appreciable damage to ladino clover stolons. Heavy application of nitrogen fertilizer should not be made. The sward should be managed so that it will have a good vegetative cover at the end of the growing season.

The proportion of ladino clover in forage can be regulated by management of grazing and clipping more satisfactorily when it is grown with a grass which has many of its leaves distributed along the stem than when it is grown with a grass which has almost entirely basal leaves.

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