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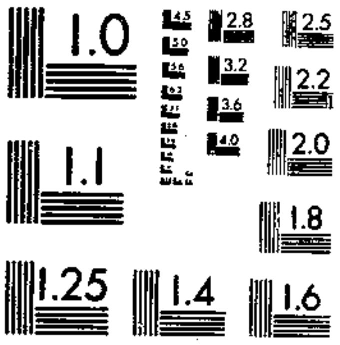

MICROCOPY RESOLUTION TEST CHART
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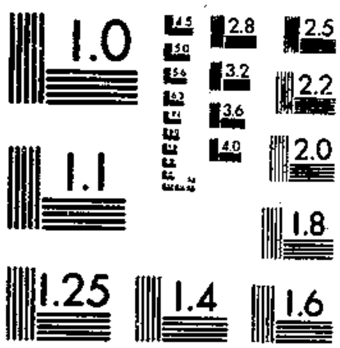

MICROCOPY RESOLUTION TEST CHART
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Yields and Botanical Composition of Four Grass-Legume Mixtures Under Differential Cutting[1]

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INTRODUCTION

Grazing or cutting management is one of the most important factors influencing productivity and maintenance of stands of grasses and legumes grown for pasture, silage, or hay. The ultimate in management assures continued survival of the seeded species in desirable proportions and the most efficient production possible not only for the season as a whole but during unfavorable periods of the season. In practice, grazing or cutting tends to be a

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destructive process at best, since it periodically removes much of the photosynthetic area of the plants and an abrupt decrease in the photosynthetic activity ordinarily reduces both top and root growth. Knowledge of the effects of different intensities and times of defoliation on the development of forage plants is essential to good grazing and haying practices.

Because of the diversity of growth characteristics of pasture and hay plants, the management requirements for best establishment and optimum growth of various species differ markedly. Habit and rate of growth, season of maximum production, and length of the period over which active growth occurs are all important factors in the reaction of a species, variety, or strain to grazing or cutting. Grasses ordinarily require different management practices than legumes. Different grass species, or different legume species, in many cases respond differently to defoliation treatments. Even strains within the same species of grass or legume often must be managed differently in order to assure maximum production and survival. Problems in management are complicated by the fact that grasses and legumes are normally seeded in mixtures for pasture in the humid regions.

Grasses and legumes growing together are constantly competing for space, light, water, and plant nutrients. These, together with soil and air temperatures, humidity, insects, and diseases, are the principal environmental factors determining the performance of a growing plant. Within the broad limits set by nature, a powerful factor in forage-plant performance is grazing or cutting management. This directly affects the carbohydrate reserves of the plants, and thus ultimately affects the plants' vigor. Also, it can affect the vigor and persistence of plants by influencing to a marked degree the incidence of disease. If a seeded mixture is left to nature alone, one of the seeded species or else one or more species of weeds or other undesirable plants will normally tend to predominate. Grazing or cutting, depending upon how it is regulated, may be either detrimental or beneficial to the persistence, total yield, distribution of production, botanical composition, and feeding value of the mixture.

Frequently the treatment that would be best for any one of the component species of a mixture is not best for the mixture as a whole. Thus proper management of a given species growing in mixture with other plants may be a quite different thing from proper management of the same species growing alone. In some mixtures it may be necessary to abuse the grass in order to maintain the legume; less frequently, the grass must be favored.

There is less basic information on the responses of various forage species to management when two or more are grown in association than on the responses of the individual species in pure stands. The botanical composition of the mixed stands, the trends in their composition through the season and from year to year, and the reasons for such trends have not been widely studied. It is particularly important to be able to relate management

practices to trends in the proportion of grass to legume and to the ingress of weeds. Differences in inherent compatibility of different strains of grasses and legumes in mixed seedings need thorough study. The effects of intensity of defoliation and time of defoliation on distribution of production are very important. It was principally for the purpose of obtaining information on these items that the present studies were undertaken.

In the eastern part of the United States, particularly in the Middle Atlantic States, it is often difficult to obtain or maintain stands of bromegrass (*Bromus inermis*) and alfalfa (*Medicago sativa*) either alone, together, or in combinations with other species. Because of the interest of farmers in growing these species, especially for hay and silage, it seemed desirable to try to find some method or combination of methods of management which would make it possible for each of these species to persist and produce advantageously in the East.

Orchard grass (*Dactylis glomerata*) with Ladino clover (*Trifolium repens* "Var. Ladino") is the outstanding pasture mixture for the Middle Atlantic States. A number of important problems exist with respect to management of this mixture. The exceptionally vigorous, rapid, and sometimes coarse growth of orchard grass in the spring of the year is considered by some to be undesirable, because this characteristic results in relatively unpalatable forage at times and presents certain problems in maintaining the associated legume. Others believe that, under proper management, this characteristic is not a serious draw-back and may even be an advantage in some respects. The "hard to manage" reputation of orchard grass has probably been the greatest single deterrent to its more widespread use.

Only recently has the importance of management of orchard grass pastures been recognized. Little information is available on management requirements of this grass, which is very well adapted to the broad central zone reaching from Missouri eastward, to the Northeast, and to the irrigated areas of the West. Little attention in the form of well-controlled management studies has been given to Ladino clover. Its increasing importance warrants much more intensive study.

The studies reported in this publication were conducted in the field at the Plant Industry Station, Beltsville, Md., in 1947–49, on seeded stands of the mixtures orchard grass-Ladino clover, bromegrass-Ladino clover, orchard grass-alfalfa, and bromegrass-alfalfa. Particular attention was given to the effects of the time and frequency of cutting on (1) total dry-matter production, (2) distribution of production through the growing period, (3) weed encroachment, and (4) trends in botanical composition through the season and from year to year.

REVIEW OF LITERATURE

The divergent views which prevailed about 50 years ago, and to a lesser extent prevail today, on proper methods of forage-crop

management indicate the complexity of the problems involved. In 1897 Crozier (*22*) reported that orchard grass clipped seven times in a 43-day period produced only 29 percent as much cured hay as comparable orchard grass cut only at the end of the period. About 5 years later Bennett (*10*) presented a different view regarding alfalfa. He said, in part:

> The first summer is the critical time in the life of alfalfa. Mowing must be done, and done often, without waiting for blooms to appear. Cut when 8 to 10 inches high—or oftener, if weeds and grass are growing and alfalfa is not. Cut at this stage the growth and vigor of the plants have not been checked by efforts to form or make seed. Seed making is very exhausting on the entire plant, and when permitted to bloom or form seed before mowing the vitality of the plants is largely subdued for the season, and crab grass and weeds then get in their good work of extermination. . . . Under extra favorable conditions mowing every 2 weeks may be necessary. Frequent mowing checks the growth of weeds and grass and causes alfalfa to branch or multiply new stalks and increase its vigor, and [is] essential, especially if growing slowly. . . .
>
> The second year the same precaution in mowing and clipping should be observed as during the first. But after the second year, when well established . . . , it is hardy, and crab grass and weeds cease to trouble.

Carrier and Oakley (*18*) reported larger gains per acre from heavy grazing of Kentucky bluegrass (*Poa pratensis*) pastures than from light grazing. Hutcheson and Wolfe (*39*) supported the earlier findings of Carrier and Oakley. On the other hand, Cotton (*21*) emphasized that in New York and New England the deterioration of pastures was due primarily to overgrazing, which prevented perennial plants from storing the food necessary for starting growth in the spring. Ellett and Carrier (*26*) concluded 35 years ago from trials made on an old bluegrass pasture that the total yield of dry matter varied inversely with the number of cuttings during the growing season. About the same time Waters (*69*), of Missouri, made reference to the importance of maturity of top growth prior to cutting on subsequent yields and permanence of stands of timothy (*Phleum pratense*). He pointed out that many farmers had noted that early cutting materially shortened the life of timothy meadows, causing the stand soon to become thin and the plants so weak that they started slowly in the spring, made poor growth, and were crowded out by weeds early in the season.

The theories held by some early workers that (1) frequent cuttings of perennial plants stimulate continued vigor and increase subsequent yields and (2) late cutting exhausts the plants and reduces the stand have usually not been upheld by more recent and thorough studies. Frequent defoliation is detrimental to most forage plants that have been studied.

The effects of various cutting treatments on forage yield and quality and on the longevity and vigor of forage plants are perhaps best understood in the case of alfalfa. Notable contributors to research on management of alfalfa have been Graber et al. (*31*), Salmon et al. (*58*), Willard (*70*), Rather and Harrison (*56*), and Tysdal and Kiesselbach (*68*). These workers agree that the

vigor and productivity of alfalfa are greatly reduced, weed infestations are encouraged, and both winter and summer mortality of alfalfa plants are increased by frequent and early removals of top growth and by cutting late in the fall before growth has ceased. Recently Dotzenko and Ahlgren (*25*) reported that in New Jersey frequent and early cutting reduced the yields of a bromegrass-alfalfa mixture. Maximum yields of alfalfa were obtained by harvesting at the half-bloom stage, and bromegrass produced its largest total yield at the full-bloom stage.

Contrary to most of the results in the literature, those of a study in the Yakima Valley recently reported by Jackobs (*40*) indicated that the vigor of alfalfa is not reduced seriously by frequent cutting or by cutting in the fall. Furthermore, they indicated that spring cutting had little or no effect on seasonal yields of the current year or subsequent years. Jackobs stated that alfalfa cut every 25 days during the 1947 and 1948 seasons produced 90.5 percent as much dry matter in 1949 as that cut at 41-day intervals in 1947 and 1948. The date of the last cutting in the fall had a pronounced effect on early growth the following spring, but this effect diminished rapidly as the season progressed.

Tysdal and Kiesselbach (*68*) studied the differential responses of a number of alfalfa varieties to various times of cutting. They stated, in part:

> The response of Ladak to different times of cutting is so great that it may almost be said that this variety can be made the lowest or highest yielding in a series of standard varieties through change in the time of cutting. . . . In contrast to this, Nebraska Common was not significantly different in yield from Grimm under any cutting treatment, and Hardistan reacted rather similarly to Grimm, although somewhat lower in yield under some treatments than others. Early cutting appears to handicap Hardistan slightly in comparison to Grimm.

The effect of grazing and cutting treatments on Kentucky bluegrass was studied before 1920 by Cotton (*21*), Carrier and Oakley (*18*), Ellett and Carrier (*26*), and Hutcheson and Wolfe (*39*). Graber et al. (*31*) reported that after 2 years of frequent cuttings, the productivity of a well-established bluegrass sod was less than one-fourth that of adjacent bluegrass cut only once annually, at maturity. Subsequently, Graber (*29*) reported that not only did amount of subterranean growth and total weight of herbage tend ultimately to vary inversely with frequency of defoliation but excessive defoliations were sometimes followed by reductions in growth persisting for several months. In later studies, Graber (*30*) found that a much larger current production of bluegrass was obtained with frequent and close defoliations than with tall defoliations of the same frequency made at the same times. The following year, bluegrass was less productive and weeds were five to seven times as abundant on the closely clipped as on the tall-clipped plots. However, the difference in second-year productivity associated with difference in clipping practice was limited almost entirely to the first cutting.

Harrison (*33*) reported that cutting at different heights affected the amount of both roots and tops produced by Kentucky bluegrass. The shorter the grass was cut and the more the leaf area was reduced, the smaller was the quantity of roots produced. Harrison pointed out that among the different grass species some can maintain themselves under short and frequent clipping by which others are nearly destroyed. In his tests, colonial bent (*Agrostis tenuis*) and red fescue (*Festuca rubra*) survived severe clipping which almost destroyed bluegrass. Harrison emphasized that deficiencies in organic-food reserves brought about by repeated defoliation are likely to weaken some plants to such an extent that they can no longer survive drought, disease, extremes of heat or cold, or the competition of plants which can escape close cutting by tillering or by growing almost flat on the ground surface, such as white clover, dandelion, crabgrass, knotweed, and plantain. In later studies, Harrison (*34*) showed that the rhizomes and a large proportion of the roots of vegetative cultures of bluegrass were killed by short and frequent defoliations.

Mortimer and Ahlgren (*50*) reported in 1936 that when bluegrass was cut to ground level, higher seasonal yields were obtained over a period of years than when it was cut to a level of 1½ inches. Cutting grass 8 to 10 inches high to ground level gave only slightly greater increases in yield than cutting grass 4 to 5 inches high to ground level. In an earlier experiment reported by Graber (*30*), current production of bluegrass cut to ½ inch was greater the first year than that of bluegrass cut to 1½ inches, but in the following year very substantial reductions occurred where the grass was never permitted to grow more than 2 or 3 inches tall before being clipped closely. In the trials reported by Mortimer and Ahlgren (*50*), no such reduction in yield occurred where the grass was allowed to grow to 4- to 5-inch heights before removal to ground level. Further studies by Ahlgren (*2*) indicated that cutting bluegrass to 1½ inches whenever it reached a 4- to 5-inch height was more productive than such cutting deferred until the plants were fully headed. In explanation, Ahlgren stated that the lower productivity on plots where cutting was deferred may have been due in part to the natural thinning of the turf which resulted from this type of management and the noticeably slower growth recovery following cutting.

Brown (*16*) found that lower herbage yields of Kentucky bluegrass were obtained by mowing semimonthly than by mowing only once or twice annually. In mowing at semimonthly intervals, larger yields were obtained by cutting to the 1-inch rather than the 2½-inch level. Mowing semimonthly to the 1-inch level had very little (if any) effect on root growth in the upper 6 inches of sod, in comparison with mowing semimonthly to 2½ inches or mowing at the hay stage. Repeated defoliation materially affected the quantity of rhizomes, by retarding their development during the spring and by increasing the rate at which they lost weight during the summer. In autumn, however, the largest increase in rhizome weight occurred on plots mowed semimonthly

to the 1-inch level, provided the moisture supply was adequate during this period.

Harrison and Hodgson (*35*) compared the responses of Kentucky bluegrass, orchard grass, timothy, smooth bromegrass (*Bromus inermis*), and quackgrass (*Agropyron repens*) to cutting treatments in the greenhouse. The grasses were cut weekly to three different heights for about 2 months or were cut only once, at the end of the trial. In nearly every case the greatest yields both of herbage and of roots and rhizomes were obtained from the plants that were cut only once. In general, the shorter a given grass was cut, the less herbage it produced. Bluegrass withstood close cutting better than the other grasses, because it produced the most green leaves below the cutting heights.

Brown and Munsell (*15*) found that such turf-forming grasses as Kentucky bluegrass and Rhode Island bentgrass (*Agrostis tenuis*) maintained better stands and yielded more under mowing (cutting at a height of 4 inches to one of 1 inch) than other grasses tested, including Canada bluegrass (*Poa compressa*), tall oatgrass (*Arrhenatherum elatius*), meadow fescue (*Festuca elatior*), perennial ryegrass (*Lolium perenne*), smooth bromegrass, orchard grass, and timothy.

At Beltsville, Md., Hein and Cook (*36*) concluded from grazing studies of a complex mixture that different rates and methods of grazing have a pronounced effect on plant population. Kentucky bluegrass and white clover predominated under heavy, continuous grazing; orchard grass, Canada bluegrass, timothy, and the annual lespedezas (*Lespedeza stipulacea* and *L. striata*) were most common under light, continuous grazing. Later, Henson and Hein (*37*) found that Kentucky bluegrass persisted better than orchard grass, timothy, or redtop (*Agrostis alba*) when cut frequently to a height of 1¼ inches over a 4-year period, and that timothy was the least persistent of the species tested.

Lovvorn (*47*) studied Kentucky bluegrass, Dallis grass (*Paspalum dilatatum*), carpet grass (*Axonopus affinis*), and Bermuda grass (*Cynodon dactylon*) in the greenhouse. His data showed that both Kentucky bluegrass and Dallis grass were affected more by frequent cutting than either carpet grass or Bermuda grass. Frequent cutting was most harmful to Dallis grass and least harmful to carpet grass. According to his conclusions Dallis grass and Kentucky bluegrass appear to warrant more careful management than either carpet grass or Bermuda grass. He noted that frequent cuttings reduced root yields more than top yields. Earlier Lovvorn (*46*) had found that cutting a Dallis grass-carpet grass mixture every 2 weeks was very unfavorable for Dallis grass. In his tests omitting either the first two spring cuttings or the last two fall cuttings proved most favorable for Dallis grass, and under such systems of management the quantity of the two grasses was approximately the same. He commented that the differential behavior of the two grasses could perhaps be explained on both morphological and physiological grounds. Dallis grass is a bunchgrass. After frequent close cuttings it retains very little photo-

synthetic area and cannot make new growth except by expending previously stored root reserves. Carpet grass, a decumbent, sod-forming grass, retains considerable leaf surface after frequent cutting.

After making a comparative study of grazing systems on unimproved bluegrass pasture in Iowa, Peterson (*55*) reported that yearling steers made lower gains if grazed continuously at a moderate intensity than if grazed heavily in spring and early summer and again in late summer and fall with no grazing for about 2 months in midsummer. He concluded, however, that continuous grazing is preferable to early- and late-season grazing only, as the absence of summer grazing favors the development of annual weedy species which might otherwise be eaten when in the most succulent stages of their growth. Peterson emphasized that heavy infestation of weedy grasses was the most serious consequence of deferred grazing, the weeds crowding and shading the bluegrass more and more.

Kennedy and Russell (*42*) found from cutting trials on a mixture of Kentucky bluegrass and wild white clover that cutting about every 8 weeks gave higher yields of forage than cutting at either shorter or longer intervals. In general, the more frequently the pasture herbage was cut, the lower was the quantity of dry matter from roots and other plant residues in the surface soil.

Except for the previously cited studies of Crozier (*22*), most of the early work with orchard grass was done at the Welsh Plant Breeding Station, Aberystwyth, Wales. In accord with Crozier, Stapledon and Beddows (*62*) reported that "pasture" cutting of orchard grass resulted in considerably less production of both tops and roots than cutting at the hay stage and only once thereafter. Moreover, they found that the plants permitted to develop to the hay stage before cutting produced considerably more growth early in the spring of the following year. They pointed out that different strains of orchard grass reacted very differently to cutting treatments.

After studying the effects of different cutting treatments on 22 species and strains of grasses and legumes including orchard grass, Stapledon and Davies (*63*) concluded that the seasonal distribution of herbage production is affected to a pronounced degree by the date at which cutting or pasturing begins. They stated that when cutting does not begin until late May, the May-to-November growth curve is much more level than when cutting begins earlier in the year. High yields of aftermath in orchard grass were reported. After a study of spaced plants of orchard grass, Stapledon and Milton (*64*) reported that those cut 8 times a season to 6 inches outyielded those cut 10 times to ground level. Plants cut twice (once as hay and once as aftermath) outyielded those cut under the other systems. Tiller and root development were nearly as good under the 6-inch cutting schedule as under the hay-and-aftermath system. When cuttings were made to ground level, however, both tiller and root development were much

reduced. The results obtained by Tincker (*67*) with orchard grass and timothy in pots, also, showed that cutting at 8-week intervals reduced the total dry weight produced.

In Virginia, Wolfe (*74*) reported higher yields from orchard grass under a hay system of cutting than under pasture conditions. Harrison and Hodgson (*35*) concluded from greenhouse studies of top and root development of perennial grasses that orchard grass and timothy were injured more by continuous close cutting than were Kentucky bluegrass, quackgrass, and bromegrass. These workers discounted the fact that orchard grass produced higher yields than bromegrass, on the basis that the entire set of bromegrass cultures was located in a shadier part of the greenhouse than were those of the other grasses.

Contrary to these results, Brown and Munsell (*15*) reported that orchard grass and timothy in mixtures with Ladino clover withstood simulated grazing management with lawnmowers much better than bromegrass, Canada bluegrass, tall oatgrass, meadow fescue, and perennial ryegrass. Furthermore, orchard grass maintained better stands than timothy and in most cases outyielded it, especially in late summer. All grasses were injured by frequent close cutting. Orchard grass recovered rapidly after cutting in comparison with other grasses, especially in the summer months. Brown and Munsell stated that weather, fertilization, time of year, and kind and proportion of grass in a mixture all have a pronounced part in determining what cutting or grazing schedule is the best. At Beltsville, Md., Henson and Hein (*37*) found that orchard grass was more persistent under cutting treatment than timothy but less so than Kentucky bluegrass.

Comstock and Law (*20*) studied the effects of different cutting treatments on various grass-alfalfa mixtures and on alfalfa grown in pure stand on field plots at Pullman, Wash. All plantings produced higher forage yields under deferred rotation cutting or cutting at the hay stage than under frequent cutting. Alfalfa in pure stand and alfalfa-orchard grass mixture produced highest yields under the deferred rotation system; all other mixtures produced best when cut at the hay stage. Alfalfa-orchard grass-bromegrass and alfalfa-bromegrass-crested wheatgrass (*Agropyron cristatum*) were most productive under the hay cutting treatment. When cut by a method simulating grazing (two or three times during the season), alfalfa-big bluegrass (*Poa ampla*) and alfalfa-bromegrass-crested wheatgrass produced higher yields than any of the other mixtures tested. Frequent cutting reduced root yields in all cases. In these studies the grass species competed more successfully with alfalfa when the mixture was cut more frequently. It was observed that the second and later cuttings tended to yield lower proportions of grass than the first cutting of each season.

Working with orchard grass-Ladino clover and bromegrass-Ladino clover mixtures, Sprague and Garber (*61*) found that the time of removal of the first crop in the spring was an important factor in the persistence of Ladino clover. Good yields were

obtained and a better stand of clover maintained by making the first cut when the herbage was 8 inches high than by making it when the grass had reached the "early head" or "full bloom" stage. Higher yields and a greater proportion of clover were obtained when cuttings were made closer to ground level. The 2-inch height of cut was more satisfactory than the 3-inch. In comparison with bromegrass-Ladino clover, orchard grass-Ladino clover produced a smaller first spring crop of herbage when cut at either of the two grass heading stages but provided one additional midsummer cutting and slightly more herbage when cut throughout the season under an 8-inch-back-to-2-inch system.

Only in recent years has much attention been given to the management of bromegrass. Harrison and Hodgson (*35*) concluded in 1939 that bromegrass, quackgrass, and Kentucky bluegrass were better adapted to close and frequent cutting than orchard grass and timothy, because the amounts of roots produced were greater. Bromegrass, however, produced lower yields of herbage than orchard grass or timothy receiving corresponding treatments. On the other hand, Brown and Munsell (*15*) found that the stands of bromegrass in Ladino clover mixtures under frequent cutting were very poor even before the end of the first season, whereas orchard grass under comparable conditions maintained good stands.

Bird (*11*) emphasized that stage of growth at time of cutting is one of the most important considerations in harvesting forage crops. He stated further that stage of growth at the time of the first cutting determines the period over which aftermath growth may take place and, together with weather and soil conditions, the extent of this growth. The four grass species used in his studies varied considerably as to the time at which they reached corresponding stages of growth in the spring. Bluegrass was the first to reach the end-of-bloom stage, and was followed by bromegrass, timothy, and redtop in that order. Bromegrass appeared especially sensitive to adverse conditions at the beginning of bloom. It was superior in yield to the other species if cut only at advanced stages of maturity, but not if cut at immature stages. If cut at the beginning of heading, bromegrass produced significantly lower yields and redtop significantly higher yields than the other species. If not cut until after seed had formed, however, bromegrass was the highest yielding and redtop the lowest yielding of the four species.

In studies by Ahlgren and Burcalow (*6*) at the Wisconsin Agricultural Experiment Station, bromegrass grazed whenever the forage reached a height of 2 to 3 inches produced only 54 percent as much pasturage as bromegrass harvested at the hay stage. On the other hand, bromegrass grazed when 6 to 10 inches tall produced 90 percent as much as bromegrass harvested at the hay stage. These investigators warned that bromegrass and alfalfa should remain ungrazed from mid-September or early October until growth has been checked by frost or cold weather, after which light grazing will cause little or no damage.

From trials conducted in Michigan, Rather and Harrison (*57*) concluded that returns from rotation grazing and from continuous grazing of bromegrass-alfalfa mixtures were nearly identical, although the alfalfa persisted somewhat better under rotation grazing. Neither early spring grazing nor close grazing was practiced in these trials. In studies on the effect of cutting treatment on the proportions of bromegrass and alfalfa in mixed stands of the two species, Wilsie et al. (*73*) reported that cutting four times per season resulted in a more rapid increase in the percentage of bromegrass, with a corresponding decrease in alfalfa, than harvesting at the normal hay stage (two or three times per season). With either cutting treatment, a satisfactory stand of both alfalfa and bromegrass remained at the end of 3 years. These workers stated that the grazing of bromegrass should be managed in such a way as to maintain the herbage at a height of not less than 6 to 8 inches. They emphasized that "bromegrass will not remain productive when grazed as closely as is ordinarily practiced with Kentucky bluegrass."

Newell and Keim (*52*) tested a number of cool-season and warm-season grasses in Nebraska under two systems of mowing. One plot series was mowed once each season at the hay stage, and another was mowed several times each season to simulate grazing. All grasses produced lower yields under the frequent-mowing treatment except Russian wild-rye (*Elymus junceus*), which showed no effect of mowing on yield, and buffalo grass (*Buchloë dactyloides*), yields of which on frequently mowed plots were higher than those on hay plots. Yields of the taller or higher-yielding grasses were more consistently reduced by increased severity of mowing treatment, even though the short grasses were mowed more closely. The best stands were maintained by bromegrass, crested wheatgrass, Russian wild-rye, and Kentucky bluegrass among the cool-season grasses and by blue grama (*Bouteloua gracilis*) and big bluestem (*Andropogon gerardi*) among the warm-season grasses. Switchgrass (*Panicum virgatum*) was most severely damaged by the mowing treatments and by invasion of weeds. Western wheatgrass (*Agropyron smithii*) and sideoats grama (*Bouteloua curtipendula*) were intermediate in their response to frequent mowing. Newell and Keim stated that bromegrass gave the best performances among all the grasses, particularly among the cool-season grasses.

Comstock and Law (*20*) found that mixtures of alfalfa-bromegrass-crested wheatgrass withstood cutting simulating grazing (two or three cuttings during the season) better than alfalfa mixtures including orchard grass, tall fescue, tall oatgrass, or intermediate wheatgrass (*Agropyron intermedium*). All mixtures produced higher forage and root yields under less severe cutting treatments.

There have been very few fundamental studies under controlled conditions to determine the management requirements of Ladino clover. The work of Brown and Munsell (*15*) is probably the most extensive for this species. These investigators

found that in mixtures of Ladino clover with orchard grass and timothy, height of cutting had a greater effect on first-year yields of the clover than frequency of cutting. Much larger yields were obtained where the mower was set to cut 2 inches rather than 4 inches above the ground. However, according to their 1941 findings cutting to 2 inches had a marked adverse effect on stands of Ladino clover the following year, because it resulted in more winter killing than higher but more frequent cutting. Brown and Munsell concluded at that time that continuous or close grazing, especially late in the fall, with only short rest periods, is not conducive to the persistence and continued high yield of Ladino clover. They stated the opinion that grazing five or six times per season and removing the stock whenever the forage has been grazed to a height of 4 inches should maintain vigorous stands for 5 or more years. However, they suggested that in good stands of orchard grass and Ladino clover frequent cuttings or grazings in the spring months might be necessary to prevent the grass from reaching a much less nutritious and more competitive condition. In a 1951 report (*14*) Brown stated that according to more recent results from these experiments Ladino clover not only gives higher yields of dry matter and protein but also survives longer when mowed to a height of 2 inches rather than 4 inches above the ground, regardless of whether the mowing is done when the Ladino is 6, 8, or 10 inches high.

Tesar and Ahlgren (*66*), experimenting with Ladino clover seeded in 1946, cut it two, four, and six times to heights of 1 and 3½ inches in 1947 and measured the residual effects of the six cutting treatments by making two uniform cuttings to a height of 1 inch in 1948. They found that stands cut four times to a height of 3½ inches in 1947 produced high yields in 1947; had relatively high yields of stolons per unit area in the fall of 1947 and the spring of 1948; and produced the highest average yield of forage, which contained comparatively little Kentucky bluegrass and the smallest proportion of annual weeds, in 1948. They concluded that this treatment appeared to simulate the type of grazing management necessary to maintain high production of Ladino clover over a period of years.

Mott (*51*), experimenting with a Ladino clover-Kentucky bluegrass mixture, found that the legume yield of stands cut to ½ inch when 4 to 6 inches high was more than four times as great as that of stands cut to ½ inch every week. Ahlgren and Burcalow (*5*), Ahlgren and Sprague (*1*), Colby (*19*), Dickey (*24*), Hollowell (*38*), and Midgley (*49*) also reported that continuous or close grazing, especially in the fall, is hazardous to Ladino clover.

Recently Blaisdell and Pechanec (*13*) reported on studies in which they gave particular attention to the effects of time of cutting in the spring on growth of bluebunch wheatgrass (*Agropyron spicatum*) and arrowleaf balsamroot (*Balsamorrhiza sagittata*). They said, in part:

> In general all clippings reduced the following year's herbage and flower stalk production, and average leaf height. The reduction due to the first

spring clipping was small; the effect became more pronounced from clippings made as the growing season advanced. The greatest reduction resulted from clippings made in late May and early June. The reduction from later clippings was progressively less, and the effect of the late fall clipping was slight.

Parker and Sampson (*54*) obtained smallest yields of grasses when they removed herbage at the time of most rapid growth. Similarly, McIlvanie (*48*) reported that with bluebunch wheatgrass the most vulnerable point in the seasonal development was at the middle of the vegetative stage, and that cutting intensified maximum vulnerability and prolonged its duration.

The effects of defoliation practices on a number of other species have been reported by various workers, including Aldous (*7*), Parker and Sampson (*53*), Biswell and Weaver (*12*), Leukel and Barnette (*45*), Dexter (*23*), Gernert (*28*), Johnson and Dexter (*41*), Wilsie et al. (*71*), Hanson and Stoddart (*32*), Stoddart (*65*), Baker et al. (*9*), Smith and Graber (*59*), and Wilsie and Hollowell (*72*). Generally, in the studies reported by these workers close and frequent cutting proved more detrimental than less close and less frequent cutting to both top and root growth. Other pertinent information of a more general nature relative to management of grasses and legumes is given in recent contributions by Ahlgren (*3, 4*), Brown (*17*), Garber et al. (*27*), and Sprague (*60*).

A few exceptions have been reported, in addition to those already cited, in which frequent and close cuttings apparently were not the most harmful. Lang and Barnes (*44*) observed on the eastern Wyoming plains that short grasses produced greater yields when cut frequently to ground level than when cut only once at the end of the season. Over a 2-year period, no decrease in density was observed where heavy cutting was practiced. Archibald et al. (*8*), in eastern Canada, under conditions of high precipitation, found continued close cutting did not reduce the yield of bluegrass pasture. Laird (*43*), who worked in the sandy soils of Florida, stated that "the largest and deepest root system of sod-forming grasses is not necessarily associated with the best and most vigorous top growth." Mowing of centipede grass (*Eremochloa ophiuroides*) and Bermuda grass increased the root growth, but this was not the case with St. Augustine grass (*Stenotaphrum secundatum*).

EXPERIMENTAL METHODS AND CONDITIONS

The studies reported here were conducted in 1947, 1948, and 1949 on field plots on the South Farm, Plant Industry Station, Beltsville, Md. The field used had a cover crop of Italian ryegrass (*Lolium multiflorum*), perennial ryegrass (*L. perenne*), and volunteer red clover (*Trifolium pratense*) from the spring of 1943 to the summer of 1945. The experimental area was limed in the summer of 1944 at the rate of 2 tons per acre of ground limestone and again at the same rate on January 16, 1946. In addition, 12 tons of barnyard manure and 300 pounds of superphosphate were applied in 1944, and 800 pounds of 4–12–7 per acre just before

seeding in 1945. A top dressing of 500 pounds per acre of 0–14–14 was applied on March 15, 1948, and again on April 5, 1949.

Mixtures of orchard grass and Ladino clover, orchard grass and alfalfa, bromegrass and Ladino clover, and bromegrass and alfalfa were seeded September 26, 1945. A small proportion of red clover was included in the Ladino clover mixtures. Orchard grass was seeded at the rate of 6 pounds per acre; bromegrass, 10 pounds per acre; alfalfa, 10 pounds per acre; Ladino clover, 2 pounds per acre; and red clover, 3 pounds per acre.

Each of the 4 mixtures was scheduled for 18 different cutting treatments; thus 72 plots were required for each replication. Five replications, 360 plots, were seeded in a combination two-way whole-plot, split-plot design. Plots of the Ladino clover mixtures were 6 by 25 feet and the alfalfa-mixture plots were 10 by 25 feet in size. Alfalfa plots were made wider than Ladino clover plots in order to allow for encroachment of Ladino clover from adjacent plots.

Excellent stands of all species were obtained in the fall of 1945. The stands of legumes were somewhat reduced by heaving early in the following spring. To improve these stands, the legumes were reseeded on March 29 and 30, 1946, by broadcasting on the surface without disturbing the plots. Only the alfalfa stands remained less than would have been desirable.

Cutting Treatments

The only treatment given the plots during 1946 consisted in uniformly mowing the entire area three times to remove weeds and volunteer ryegrass.

Beginning in 1947, each mixture was given a variety of cutting treatments. Cutting started at three different dates in the spring, was repeated at two different frequencies, and ended at three different dates in the fall, which were approximately the same for all the beginning dates. The schedules were as follows:

Beginning date and frequency of cutting	*Ending date*
April 15:	
6-inch height	September 15
	October 15
	November 15
12-inch height	September 15
	October 15
	November 15
May 5:	
6-inch height	September 15
	October 15
	November 15
12-inch height	September 15
	October 15
	November 15
June 1:	
6-inch height	September 15
	October 15
	November 15
12-inch height	September 15
	October 15
	November 15

The dates for the various treatments are approximate; at times it was necessary to vary them a few days one way or the other. In any event, an effort was made to obtain first cuts at an early, a medium, and a hay stage in the spring and last cuts at an early, a medium, and a late date in the fall.

Cutting heights were established arbitrarily at 6 and 12 inches. The less frequently cut stands of the Ladino clover mixtures were sometimes cut at heights less than 12 inches because they did not reach that height during the summer and fall. The growth intervals, however, averaged about twice as long for the less frequent cuttings as for the more frequent. All stands were cut to a height of 2 inches on each harvest date.

Differential cutting treatments were continued throughout the seasons of 1947, 1948, and 1949.

Determining Yields of Forage and Weeds

Yield samples were taken in 1947 and 1948 from all plots and in 1949 from the Ladino clover-mixture plots only. In 1949 most of the alfalfa-mixture plots were very weedy and were overrun with a volunteer growth of white clover.

Yield samples were taken by mowing a strip through the center of each plot with a 36-inch sickle-bar power mower. The herbage harvested from such strips was weighed green and that from the October-last-cutting series of plots of all five replications was subsampled at each cutting during the season for determination of dry-matter percentages and for botanical estimations. When herbage on a September- or November-last-cutting series of plots appeared to differ significantly in botanical composition from that of the regularly subsampled plots, it likewise was subsampled. In addition, all cuttings made in November were subsampled. Thus, samples were saved from more than one-third of all the plots cut.

Each subsample was weighed immediately after harvest, placed in a cloth bag, dried in a forced-draft hay drier at approximately 180° F., and then weighed again in order to compute the percentage of dry matter.

In calculating acre yields of dry matter, the dry-matter percentages obtained for the October-last-cutting series of plots were applied to data for herbage from the September- and November-last-cutting plots which had not been subsampled.

In 1947 the yield of weeds on the plots was estimated just before each cutting, on all five replications of each treatment. In 1948 and 1949 estimates of weed content were made on all the dried herbage samples from each of the five replications. The 1948 and 1949 weed estimates were applied in the same manner as dry-matter percentages, because corresponding plots of different last-cutting-date series appeared to be similar in yield of weeds in most cases. When the herbage on a September- or November-last-cutting plot appeared to differ significantly from that of the regularly subsampled plots in weed content, it was sampled for a weed

estimation. On the basis of this estimation, acre yield of weeds was calculated from total dry matter harvested.

Data on seasonal yields of both forage and weeds were subjected to an analysis of variance.

Dry-matter yields of forage are reported on a weed-free basis. Weed yields, also, are reported.

Determining Botanical Composition

Botanical estimates were made on all the herbage samples saved and dried in the seasons of 1948 and 1949. In most instances independent estimates were made by two individuals and averages of the two readings were recorded. A number of samples were separated by hand after the estimating, to check its accuracy; prevailingly, the estimates were found to be accurate.

Botanical analyses for all plots were made, also, by the point-quadrat method in the spring and fall of 1947 and in the falls of 1948 and 1949. The needles of the point quadrat were pushed through the herbage to ground level, and a hit was recorded for an individual species each time a needle touched a plant of that species—except that only one hit was recorded for a species on any one needle, even if the needle had come in contact with a plant of that species more than once. If no plant was hit, bare ground was recorded. To calculate the percentage of plot area covered by each of the various species and the percentage of bare ground, the number of hits recorded for each species or for bare ground was divided by the total number of hits.

Weather Conditions

Rainfall on the experimental area in 1947 and 1948 was favorable for crop production. Precipitation for 1947 amounted to 43.41 inches, compared with a local average of 41.94 inches. That for 1948 amounted to 54.62 inches. Distribution for both these years was good, with above-average precipitation during the growing season. In 1949 precipitation was much less favorable, particularly during the summer and fall; it totaled 38.69 inches, and was average or above average only in January, February, and May.

Unusually warm weather had an adverse effect on production during a part of the 1949 growing period.

RESULTS AND DISCUSSION

Comparative Responses of Mixtures

Orchard grass-Ladino clover proved to be outstanding, under the conditions of these studies, among the four mixtures tested. In comparison with the others it was less exacting in management requirements, more productive under a variety of cutting treatments, superior in distribution of production through the growing season, less subject to weed encroachment, and in most cases

superior in maintaining a desirable grass-legume balance through the growing season. Bromegrass-Ladino clover was superior to the alfalfa combinations. Bromegrass-alfalfa proved the least desirable of the four mixtures, particularly under the more severe systems of cutting.

For the Ladino clover mixtures, proper methods of management were determined largely by the grass component. Orchard grass was extremely aggressive, and tended to crowd out Ladino clover under the less severe cutting systems. Bromegrass was much less aggressive and was sensitive to time and frequency of cutting. The problem was to maintain bromegrass in the mixture, particularly during the summer and fall. Therefore, the most satisfactory cutting treatments for bromegrass-Ladino clover were those that favored the grass. Cutting procedures essential to maintenance of production and continued survival of the alfalfa mixtures were largely determined by the needs of the legume. Alfalfa was less tolerant of cutting than any of the other species studied. It tended to be similar to bromegrass in its management requirements.

Where each mixture was given the kind of management that proved best for it, the four differed from one another very little in total forage production. Proper management had a marked influence, also, in leveling out differences with regard to summer production, weed encroachment, and the grass-legume balance.

Of the different features of cutting treatment studied, frequency of cutting had the greatest over-all influence on total yield, distribution of production, ingress of weeds, and balance between grasses and legumes. Time of first cutting was nearly as important, particularly in the case of bromegrass-Ladino clover and the alfalfa mixtures. Apparently, under the conditions of this investigation, time of last cutting was the least important of the variables of treatment studied.

That time of last cutting appeared to be less important than time of first cutting was somewhat surprising; much of the forage-crop literature has emphasized the necessity of careful fall grazing or cutting management, and in practice greater attention has usually been given to fall than to spring management. Perhaps the importance of proper spring management to the production and maintenance of grass-legume stands has been underrated. Much of the research on grazing and cutting management has been done in the Northern States, where fall management may well be more important than farther south.

Under the hay system of management followed—cutting in early June and allowing the aftermath to reach a 12-inch height before each subsequent harvest—bromegrass-Ladino clover equaled orchard grass-Ladino clover in productivity (table 1). The alfalfa mixtures, likewise, were favored by this less severe type of management; over the 2 years in which their yields were taken they averaged about as productive under it as the Ladino mixtures, whereas under all the other cutting systems the average yields were distinctly less.

TABLE 1.—*Summaries of mean annual acre yields of forage, by cutting frequency, species mixture, and date of first cutting*

2-YEAR PERIOD 1947–48 [1]

Frequency (cutting height) and species mixture	Dry matter produced per acre, by approximate date of first cutting		
	April 15	May 5	June 1
	Tons	*Tons*	*Tons*
6 inches:			
Orchard-Ladino	2.61	2.83	2.81
Brome-Ladino	2.52	2.52	3.05
Orchard-alfalfa	1.68	1.78	2.03
Brome-alfalfa	1.31	1.39	1.85
12 inches:			
Orchard-Ladino	2.83	2.86	2.91
Brome-Ladino	2.92	2.61	3.09
Orchard-alfalfa	2.19	2.15	2.75
Brome-alfalfa	2.14	2.19	2.73
3-YEAR PERIOD 1947–49 [2]			
6 inches, Ladino mixtures	2.51	2.62	2.85
12 inches, Ladino mixtures	2.75	2.65	2.90
Both frequencies:			
Orchard-Ladino	2.63	2.79	2.85
Brome-Ladino	2.63	2.48	2.90

[1] Least significant difference at 5-percent level: Between mixtures within a date within a frequency, 0.29 ton; between frequencies within a mixture within a date, 0.17 ton; between dates within a mixture within a frequency, 0.31 ton.

[2] Least significant difference at 5-percent level: Between frequencies within a date, 0.07 ton; between dates within a frequency, 0.26 ton; between mixtures within a date, 0.13 ton; between dates within a mixture, 0.28 ton. The interaction of dates × frequencies × mixtures was not significant.

The alfalfa combinations did not differ from one another in productivity under the 12-inch cutting frequency. However, within the April- and May-first-cutting series of plots cut at the 6-inch stage of growth, orchard grass-alfalfa was more productive than bromegrass-alfalfa over the period 1947–48. The Ladino clover mixtures did not differ from one another in total forage production where cutting began in April or June, whether the forage was cut at the 6-inch or at the 12-inch height. Where cutting began in May, orchard grass-Ladino clover produced more than bromegrass-Ladino clover over the period 1947–49, regardless of cutting frequency.

Although the differential effects of last-cutting treatments on forage production were less apparent, in 1947 and over the 2- and 3-year periods forage production usually averaged less where cutting ended in September than where it ended in October or November (table 2). The effect of time of last cutting was essentially the same for all mixtures; in no case was the interaction of last cutting dates × mixtures significant. In 1948 the Novem-

ber-last-cutting treatment resulted in higher yields than either of the others. In 1949, when yield data were taken for the Ladino clover mixtures only, differences in last-cutting treatments produced no differences in yield of forage.

Yield summaries roughly indicating the distribution of production by the various mixtures through the season are presented in tables 3 and 4. The mixtures including Ladino clover produced more uniformly through the growing period than those including alfalfa. While the differences in yields between the two Ladino clover mixtures were not large under the systems of management favoring bromegrass, orchard grass-Ladino clover was a more certain and consistent producer of forage during midsummer than bromegrass-Ladino clover. This was especially true in 1949, and in the May-first-cutting series in 1947 and 1948. Orchard grass-alfalfa was superior to bromegrass-alfalfa in distribution of yield.

TABLE 2.—*Summary of mean annual acre yields of forage* [1] *by last cutting date, for all mixtures and all first cutting dates, in 1947–49*

Period and frequency (cutting height)	Dry matter produced per acre, by approximate date of last cutting		
	September 15	October 15	November 15
	Tons	*Tons*	*Tons*
1947, both frequencies	2.53	2.76	2.74
1948, both frequencies	2.07	2.11	2.24
1947–48:			
Both frequencies	2.30	2.44	2.49
6-inch frequency	2.13	2.20	2.27
12-inch frequency	2.46	2.67	2.71
1947–49,[2] both frequencies	2.62	2.73	2.79

[1] Least significant difference at 5-percent level: Between dates, 0.13 ton for 1947, 0.12 ton for 1948, 0.11 ton for 1947–48 and for 1947–49; between frequencies within a date, 0.07 ton; between dates within a frequency, 0.13 ton. The interaction of dates × mixtures was not significant.

[2] Yield data of 1947–49 are for Ladino clover mixtures only.

Orchard grass ordinarily started growth in the spring from 10 days to 2 weeks earlier than bromegrass and maintained much more active growth during the summer. Orchard grass also made greater growth in the fall. Bromegrass, once it had begun active growth, grew rapidly for a period of 4 to 6 weeks, very often reaching a higher peak of production by the first of June than orchard grass. Probably the greatest weaknesses of bromegrass noted in these trials were its pronounced lack of growth during the summer and fall and its susceptibility to *Rhizoctonia solani*.

The orchard grass-Ladino clover mixture maintained a higher proportion of grass throughout the season than the bromegrass-

TABLE 3.—*Mean annual acre yields of forage produced by species mixtures before and after July 1 in 1947–48, by cutting frequency and times of first and last cuttings*

Frequency (cutting height) and times of first and last cuttings	Dry matter produced per acre							
	Orchard-Ladino		Brome-Ladino		Orchard-alfalfa		Brome-alfalfa	
	Before July 1	After July 1	Before July 1	After July 1	Before July 1	After July 1	Before July 1	After July 1
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1947								
6 inches:								
April-September	1.62	0.91	1.80	0.97	1.42	0.63	1.44	0.31
April-October	1.77	1.09	1.65	1.07	1.24	.65	1.72	.37
April-November	1.80	1.13	1.85	1.21	1.36	.65	1.48	.33
May-September	1.76	1.12	1.44	1.13	1.37	.70	1.44	.47
May-October	1.81	1.23	1.57	1.33	1.25	.82	1.55	.46
May-November	1.73	1.28	1.46	1.27	1.52	.91	1.42	.45
June-September	1.87	.82	2.08	1.04	1.74	.70	2.05	.40
June-October	1.90	.90	2.06	1.12	1.73	.71	2.06	.41
June-November	1.89	.87	2.14	1.20	1.74	.66	2.16	.40
12 inches:								
April-September	1.39	1.29	1.49	1.27	1.13	.94	1.29	.90
April-October	1.38	1.84	1.50	1.70	1.08	1.27	1.46	1.45
April-November	1.43	1.67	1.49	1.62	1.25	1.21	1.43	1.02
May-September	1.70	1.10	1.78	1.04	1.47	.80	1.59	.69
May-October	1.78	1.58	1.86	1.15	1.44	1.15	1.90	.81
May-November	1.69	1.44	1.78	1.05	1.55	1.06	1.58	.65
June-September	1.49	1.38	1.70	1.28	1.46	1.35	1.80	1.17
June-October	1.47	1.78	1.61	1.69	1.38	1.51	1.77	1.23
June-November	1.48	1.60	1.73	1.66	1.50	1.55	1.97	1.36
1948								
6 inches:								
April-September	1.44	0.72	1.55	0.61	0.81	0.51	0.42	0.18
April-October	1.28	1.08	1.28	.83	.73	.63	.55	.31
April-November	1.71	1.09	1.54	.76	.79	.66	.48	.29
May-September	1.92	.83	1.58	.67	.86	.50	.62	.23
May-October	1.81	.90	1.72	.70	.81	.51	.64	.21
May-November	1.82	.90	1.52	.69	.94	.52	.62	.25
June-September	1.93	.96	1.93	.93	1.03	.58	.81	.38
June-October	1.65	1.15	1.56	1.10	.95	.65	.75	.49
June-November	1.70	1.20	1.91	1.21	1.04	.68	.76	.46
12 inches:								
April-September	1.06	1.43	1.15	1.50	.77	1.16	.60	.89
April-October	.82	1.93	.97	1.82	.59	1.46	.69	1.22
April-November	1.01	1.75	1.18	1.83	.77	1.55	.71	1.15

TABLE 3.—*Mean annual acre yields of forage produced by species mixtures before and after July 1 in 1947–48, by cutting frequency and times of first and last cuttings*—Continued

1948

Frequency (cutting height) and times of first and last cuttings	Dry matter produced per acre							
	Orchard-Ladino		Brome-Ladino		Orchard-alfalfa		Brome-alfalfa	
	Before July 1	After July 1	Before July 1	After July 1	Before July 1	After July 1	Before July 1	After July 1
12 inches:	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
May-September	1.49	1.38	1.23	.8[illegible]	.87	.82	.96	.67
May-October	1.11	1.47	1.31	1.05	.74	1.01	1.15	1.04
May-November	.98	1.44	1.40	1.14	.93	1.10	1.08	1.02
June-September	1.27	1.46	1.40	1.50	1.32	1.43	1.23	1.20
June-October	.97	1.78	1.16	1.65	.88	1.39	.99	1.11
June-November	1.08	1.68	1.37	1.82	1.13	1.59	1.18	1.38

Ladino clover mixture (tables 5 and 6). Under some of the less severe cutting systems, the orchard grass tended to predominate in this mixture at the expense of the Ladino clover. Summer and fall production of the bromegrass-Ladino clover mixture under the more severe cutting treatments was provided almost entirely by the Ladino clover.

One of the outstanding differences that appeared among mixtures was in their capacity to compete with weeds. During the first year of the studies weeds were sufficiently abundant to be of practical importance in only one mixture—bromegrass-alfalfa. Throughout the course of the studies weeds were of major importance in the bromegrass-alfalfa mixture, but they were usually much less important in the other mixtures (tables 5–8). They were of minor importance in the orchard grass-Ladino clover mixture except on a few of the plots in 1949. The average yields of weeds in the Ladino clover mixtures in 1948–49 and in the alfalfa mixtures in 1948 are given in table 9. In 1948 the orchard grass-alfalfa mixture tended to be intermediate in weed yield between the two Ladino clover mixtures. In 1949 and over the 2-year period 1948–49 there were more weeds in bromegrass-Ladino clover than in orchard grass-Ladino clover under all systems of cutting except the hay system.

The responses of the different mixtures to cutting treatments were influenced to a considerable degree by the prevalence of weeds and the succession of weedy species through the season. The appearance of weeds was one of the first indications of mismanagement.

Of the weeds that occurred in the spring and fall the most common were chickweeds (*Cerastium arvense, C. vulgatum,* and

TABLE 4.—*Mean acre yields of forage produced by Ladino clover mixtures before and after July 1 in 1949, by cutting frequency and times of first and last cuttings*

Frequency (cutting height) and times of first and last cuttings	Dry matter produced per acre			
	Orchard-Ladino		Brome-Ladino	
	Before July 1	After July 1	Before July 1	After July 1
6 inches:	*Tons*	*Tons*	*Tons*	*Tons*
April-September	1.71	0.50	1.96	0.49
April-October	1.69	.67	1.83	.58
April-November	1.92	.64	1.84	.59
May-September	1.82	.65	1.82	.59
May-October	1.73	.75	1.77	.70
May-November	1.83	.84	1.78	.64
June-September	2.21	.49	2.10	.44
June-October	2.12	.66	2.01	.49
June-November	2.27	.69	2.09	.59
12 inches:				
April-September	1.46	1.00	1.55	.84
April-October	1.33	1.17	1.46	.93
April-November	1.53	1.18	1.64	.99
May-September	1.80	.95	1.51	.77
May-October	1.61	1.09	1.44	.84
May-November	1.70	1.12	1.40	.71
June-September	1.75	1.16	1.63	.96
June-October	1.59	1.23	1.48	1.04
June-November	1.63	1.22	1.59	.99

C. viscosum), sheep sorrel (*Rumex acetosella*), curled dock (*Rumex crispus*), buckhorn plantain (*Plantago lanceolata*), common plantain (*P. major*), dandelion (*Taraxacum officinale*), wintercress (*Barbarea vulgaris* and *B. verna*), mayweed (*Anthemis cotula*), field peppergrass (*Lepidium campestre*), low sedge (*Kyllinga pumila*), and speedwell (*Veronica serpyllifolia*). The chickweeds were probably the most prevalent of this group; wintercress, sheep sorrel, plantain, and curled dock occurred frequently. The plantains occurred to some extent throughout the year—probably surpassing any other weeds in this regard. Plantains were most prevalent during late summer and fall.

Although many different weed species were present in the spring and fall, their combined effects on the performance of the seeded mixtures were not so great as those of the principal summer species, crabgrass (*Digitaria sanguinalis*) and foxtails (*Setaria* spp.). Nutgrass (*Cyperus esculentus*) was present during the summer on some of the plots. Among all the weeds present, crab-

grass probably had the most important effect on the sown species. Ordinarily it started to germinate and emerge in late April and early May. However, it was usually not until mid-July that crabgrass made sufficient growth to appear in the harvested forage.

TABLE 5.—*Botanical composition of herbage harvested in 1948–49 from orchard grass-Ladino clover plots, as estimated from dried samples* [1]

1948

Frequency (cutting height), cutting period, and date of cutting	Composition of herbage harvested			
	Orchard	Ladino	Bluegrass	Weeds
	Percent	*Percent*	*Percent*	*Percent*
6 inches:				
April-October:				
April 22	78	21	1	Tr
May 12	68	25	4	3
June 10	62	33	3	1
June 28	64	34	2	Tr
July 21	44	54	1	1
August 26	49	35	8	8
October 14	29	51	3	17
May-October:				
May 5	71	28	1	Tr
June 7	67	28	5	0
June 28	62	37	1	0
July 21	52	46	1	0
August 17	63	33	3	1
September 14	49	38	0	13
October 14	36	61	0	3
June-October:				
May 25	91	8	1	1
June 17	61	36	3	Tr
July 8	50	48	1	Tr
August 6	66	31	2	Tr
September 3	54	42	1	4
October 14	51	38	2	9
12 inches:				
April-October:				
April 22	84	16	0	Tr
May 27	79	19	1	1
July 12	85	13	2	0
September 3	84	13	2	1
October 14	57	42	1	1
May-October:				
May 5	79	19	1	1
June 10	76	22	1	1
July 21	87	13	Tr	Tr
September 14	85	10	2	3
October 14	41	57	Tr	1
June-October:				
May 25	91	8	Tr	Tr
July 8	79	17	4	Tr
September 3	85	12	2	1
October 14	61	37	1	1

[1] Tr = trace.

TABLE 5.—*Botanical composition of herbage harvested in 1948–49 from orchard grass-Ladino clover plots, as estimated from dried samples* [1]—Continued

1949

Frequency (cutting height), cutting period, and date of cutting	Composition of herbage harvested			
	Orchard	Ladino	Bluegrass	Weeds
	Percent	*Percent*	*Percent*	*Percent*
6 inches:				
April-October:				
April 19	43	50	5	2
May 9	38	47	13	2
May 31	29	54	15	1
June 27	26	57	16	1
July 19	26	62	11	0
August 25	29	39	10	23
October 12	32	20	16	32
May-October:				
May 5	73	15	7	5
May 31	52	42	4	2
June 24	38	56	4	1
July 19	36	55	9	Tr
August 25	43	44	6	7
October 12	45	19	6	30
June-October:				
May 25	84	7	8	1
June 27	36	57	6	1
July 19	38	57	4	Tr
August 25	59	34	3	3
October 12	64	22	3	10
12 inches:				
April-October:				
April 19	80	19	1	1
May 31	81	12	8	0
July 13	62	30	9	0
October 12	89	2	7	1
May-October:				
May 5	88	10	2	Tr
June 13	67	29	4	1
August 9	91	6	3	1
October 12	91	5	3	2
June-October:				
May 25	88	7	4	Tr
July 13	70	28	2	0
October 12	86	7	5	2

[1] Tr = trace.

During the next 2 or 3 weeks this weed developed very rapidly. Heads began to appear during or soon after the first week in August. Crabgrass was extremely competitive during August and September. Its growth rate declined sharply in early October, or earlier when frost occurred.

The trends in weed populations during the season and from year to year are shown in tables 5–8. Of particular interest is the fact that neither the spring and fall weeds nor the summer weeds were

much in evidence during June or early July of any year. At that time only small quantities of weeds were present even on the most severely cut plots, which had the poorest stands of the seeded

TABLE 6.—*Botanical composition of herbage harvested in 1948–49 from bromegrass-Ladino clover plots, as estimated from dried samples* [1]

1948

Frequency (cutting height), cutting period, and date of cutting	Composition of herbage harvested				
	Brome	Ladino	Bluegrass	Orchard	Weeds
6 inches:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
April-October:					
April 22	56	40	Tr	0	3
May 12	36	57	5	0	2
June 10	20	74	5	0	1
June 28	13	86	Tr	0	Tr
July 21	7	82	0	0	11
August 26	5	49	Tr	0	46
October 14	4	49	0	0	48
May-October:					
May 5	23	66	8	0	2
June 7	19	74	6	0	1
June 28	5	89	6	0	Tr
July 21	3	93	1	0	3
August 17	3	78	3	0	17
September 14	1	20	2	0	77
October 14	2	70	0	0	28
June-October:					
May 25	69	28	2	0	2
June 17	15	82	2	0	1
July 8	19	79	2	0	Tr
August 6	13	76	0	0	11
September 3	4	64	0	0	32
October 14	5	59	0	0	36
12 inches:					
April-October:					
April 22	51	47	1	0	1
May 27	67	31	Tr	0	1
July 12	50	47	2	0	Tr
September 3	40	50	Tr	0	10
October 14	10	82	Tr	0	7
May-October:					
May 5	22	72	6	0	1
June 10	25	70	3	0	1
July 21	12	79	3	0	6
September 14	5	43	1	0	51
October 14	5	91	Tr	0	4
June-October:					
May 25	70	27	2	0	1
July 8	37	60	3	0	0
September 3	33	58	Tr	0	9
October 14	10	83	Tr	0	7

[1] Tr = trace.

TABLE 6.—*Botanical composition of herbage harvested in 1948–49 from bromegrass-Ladino clover plots, as estimated from dried samples* [1]—Continued

1949

Frequency (cutting height), cutting period, and date of cutting	Composition of herbage harvested				
	Brome	Ladino	Bluegrass	Orchard	Weeds
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
6 inches:					
April-October:					
April 19	9	83	2	2	5
May 9	7	87	4	1	1
May 31	2	94	2	1	1
June 27	4	90	4	1	1
July 19	3	90	1	1	4
August 25	1	36	Tr	1	62
October 12	6	37	1	1	56
May-October					
May 5	14	62	5	7	12
May 31	4	89	5	2	1
June 24	5	88	1	5	1
July 19	4	83	8	3	2
August 25	1	39	4	1	55
October 12	6	42	5	Tr	47
June-October:					
May 25	56	30	4	5	6
June 27	13	84	1	2	0
July 19	5	92	1	1	1
August 25	2	42	1	Tr	56
October 12	4	33	Tr	Tr	62
12 inches:					
April-October:					
April 19	41	51	1	1	6
May 31	63	32	2	Tr	3
July 13	31	65	3	Tr	1
October 12	35	36	2	Tr	28
May-October:					
May 5	19	63	1	5	12
June 13	9	79	1	5	6
August 9	29	48	1	13	9
October 12	24	44	Tr	13	18
June-October:					
May 25	68	27	1	2	2
July 13	34	63	2	Tr	Tr
October 12	39	47	1	Tr	13

[1] Tr = trace.

species, and herbage harvested from the well-managed plots was practically weed-free. Apparently, late June and early July formed a transition period for the spring and summer weeds, at which the former had passed their peak of growth and the latter had not yet reached the stage of rapid development.

TABLE 7.—*Botanical composition of herbage harvested in 1948 from orchard grass-alfalfa plots, as estimated from dried samples* [1]

Frequency (cutting height), cutting period, and date of cutting	Composition of herbage harvested				
	Orchard	Alfalfa	Bluegrass	White clover	Weeds
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
6 inches:					
April-October:					
April 22	85	3	0	9	3
May 12	80	0	1	16	2
June 10	69	Tr	0	28	3
June 28	87	1	0	10	2
July 21	82	Tr	0	14	4
August 26	72	1	0	14	13
October 14	42	Tr	0	21	37
May-October:					
May 5	88	Tr	2	6	4
June 7	87	1	Tr	6	5
June 28	84	1	1	11	3
July 21	89	1	0	9	2
August 17	93	Tr	0	3	3
September 14	20	Tr	0	1	78
October 14	28	1	0	5	65
June-October:					
May 25	87	1	1	7	4
June 17	88	2	0	9	1
July 8	91	1	0	7	1
August 6	91	1	0	6	2
September 3	89	1	0	5	6
October 14	55	2	0	13	30
12 inches:					
April-October:					
April 22	76	19	0	4	1
May 27	68	17	2	10	2
July 12	80	8	1	9	3
September 3	80	14	0	3	3
October 14	52	27	0	11	10
May-October:					
May 5	81	11	Tr	6	2
June 10	77	12	0	4	6
July 21	79	6	0	11	4
September 14	36	19	0	5	39
October 14	52	33	0	8	7
June-October:					
May 25	78	16	1	4	1
July 8	66	25	1	7	1
September 3	72	25	0	2	2
October 14	56	40	0	3	1

[1] Tr = trace.

TABLE 8.—*Botanical composition of herbage harvested in 1948 from bromegrass-alfalfa plots, as estimated from dried samples* [1]

Frequency (cutting height), cutting period, and date of cutting	Composition of herbage harvested				
	Brome	Alfalfa	Bluegrass	White clover	Weeds
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
6 inches:					
April-October:					
April 22	35	3	0	23	39
May 12	31	Tr	1	29	38
June 10	20	Tr	Tr	51	29
June 28	34	1	2	47	16
July 21	26	Tr	Tr	43	30
August 26	7	Tr	0	6	87
October 14	4	Tr	0	10	86
May-October:					
May 5	39	Tr	4	13	44
June 7	39	1	4	13	43
June 28	49	1	2	37	10
July 21	32	Tr	1	42	25
August 17	10	1	0	6	84
September 14	4	Tr	0	3	93
October 14	3	Tr	0	7	90
June-October:					
May 25	51	3	4	12	29
June 17	30	5	Tr	49	16
July 8	52	4	0	34	11
August 6	29	1	0	13	57
September 3	6	1	0	16	77
October 14	6	1	0	13	80
12 inches:					
April-October:					
April 22	28	57	0	2	13
May 27	36	28	2	11	22
July 12	34	24	4	22	17
September 3	10	10	0	2	78
October 14	11	30	0	7	52
May-October:					
May 5	40	40	10	5	6
June 10	30	58	1	5	6
July 21	48	19	3	10	21
September 14	8	21	0	2	69
October 14	8	76	0	2	14
June-October:					
May 25	47	26	12	4	12
July 8	23	50	10	7	9
September 3	8	12	0	3	77
October 14	8	30	0	5	57

[1] Tr = trace.

TABLE 9.—*Summary of mean annual acre yields of weeds, by cutting frequency, mixture, and date of first cutting, in 1948 and in 1948–49*

Frequency (cutting height), and species mixture	Dry matter produced per acre, by approximate date of first cutting					
	1948 [1]			1948–49 [2]		
	April 15	May 5	June 1	April 15	May 5	June 1
6 inches:	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Orchard-Ladino	0.07	0.04	0.03	0.12	0.08	0.04
Brome-Ladino	.46	.41	.26	.43	.40	.32
Orchard-alfalfa	.18	.27	.09			
Brome-alfalfa	.94	1.17	.81			
12 inches:						
Orchard-Ladino	.01	.03	.02	.01	.02	.02
Brome-Ladino	.09	.38	.07	.13	.32	.08
Orchard-alfalfa	.06	.32	.04			
Brome-alfalfa	1.00	.95	.99			

[1] Least significant difference at 5-percent level: Between mixtures within a date within a frequency, 0.26 ton; between frequencies within a mixture within a date, 0.14 ton; between dates within a mixture within a frequency, 0.15 ton.

[2] Least significant difference at 5-percent level: Between mixtures within a date within a frequency, 0.09 ton; between frequencies within a mixture within a date, 0.07 ton; between dates within a mixture within a frequency, 0.10 ton.

ORCHARD GRASS-LADINO CLOVER

Orchard grass-Ladino clover was much less exacting in its management requirements than any of the other mixtures (table 1). Frequent cutting reduced the yield only where it began in April.

Production under frequent cutting tended to be less where cutting began in April than where it began in June, although the differences were not always statistically significant (table 1). Where the aftermath was permitted to reach a height of 12 inches before being harvested, yield was unaffected by time of first cutting.

In general, orchard grass-Ladino clover was more productive where cutting continued beyond September (table 2). It appeared to make little difference whether the cutting ended in November or in October.

Distribution of production through the season was influenced markedly by frequency of cutting and to a lesser extent by time of first cutting (tables 3 and 4). Yield of forage after July 1 was nearly always greater on plots cut at the 12-inch stage than on those cut frequently; in 1949 it was in several instances about twice as great. Where cutting was begun in May rather than in

April or June there was a tendency for summer and fall yields to be depressed on plots cut when the herbage was 12 inches tall. In 1948 summer yields on plots infrequently cut were greatest, by a small margin, where cutting began in April. In 1949 summer yields under this system were slightly exceeded by those under the hay system of management.

Where cutting ended in September, early-spring yields of the following year tended to be greater than where cutting had continued into October or November—particularly under the 12-inch frequency. Any advantage in yield associated with September ending of the preceding year's cutting usually disappeared by midseason.

According to point-quadrat determinations, the ground cover of the orchard grass-Ladino clover plots at the beginning of the investigation was about 50 percent orchard grass and 30 percent Ladino clover, the remainder consisting primarily of red clover (table 10). Figure 1 illustrates the condition of some of these

FIGURE 1.—Orchard grass-Ladino clover cut first in early May and thereafter whenever the forage reached a height of 6 inches (left foreground) or 12 inches (right foreground), as it appeared on June 5, 1947, and bromegrass-Ladino clover (far right) which was to be cut for the first time on that day.

plots on June 5, 1947. During the first season very little change occurred in composition of ground cover except that red clover almost completely disappeared and under frequent cutting weeds slightly increased. In 1948 there were no marked changes; the proportion of orchard grass slightly decreased, that of Ladino clover increased, the weed percentage changed very little, and some bluegrass appeared. In the ground-cover determinations

made in October 1947 and October 1948, the smallest proportion of orchard grass (35 percent) was found on plots where cutting had been started in April and repeated at the 6-inch frequency (table 10). Ladino clover covered 49 percent of the area of plots that had been so treated. On most of the plots in 1948, orchard grass covered about 50 percent of the ground area and Ladino clover about 40 to 49 percent. Thus, according to the October determinations, differences in cutting treatment had only limited effect on botanical composition of ground cover on the orchard grass-Ladino clover plots in 1947 and 1948.

Greater changes in composition of ground cover on the plots took place in 1949 than in either 1947 or 1948 (table 10). This was probably due to the cumulative effects of the various

TABLE 10.—*Ground-cover composition on orchard grass-Ladino clover plots in 1947–49 as determined by the point-quadrat method*

Frequency (cutting height) and time of first cutting	Ground-cover composition on plots					
	Orchard	Ladino	Red clover	Blue-grass	Weeds	No cover
SPRING OF 1947						
6 inches:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
April	53	31	13	0	1	1
May	59	29	11	0	0	0
June	55	28	14	0	1	1
Average	56	29	13	0	1	1
12 inches:						
April	52	28	18	0	1	1
May	51	31	15	0	3	0
June	55	33	11	0	0	0
Average	53	31	15	0	1	1
General average	54	30	14	0	1	1
FALL OF 1947						
6 inches:						
April	50	33	1	0	10	8
May	55	32	0	0	1	12
June	56	29	1	0	6	8
Average	54	31	1	0	6	9
12 inches:						
April	54	40	1	0	2	3
May	61	27	1	0	3	8
June	62	28	3	0	1	6
Average	59	32	1	0	2	6
General average	56	32	1	0	4	8

TABLE 10.—*Ground-cover composition on orchard grass-Ladino clover plots in 1947–49 as determined by the point-quadrat method*—Continued

FALL OF 1948

Frequency (cutting height) and time of first cutting	Ground-cover composition on plots					
	Orchard	Ladino	Red clover	Bluegrass	Weeds	No cover
6 inches:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
April	35	49	0	3	13	1
May	49	38	0	2	7	4
June	47	43	0	2	4	4
Average	43	44	0	2	8	3
12 inches:						
April	50	46	0	1	2	1
May	52	40	0	2	4	2
June	49	46	0	2	3	1
Average	51	44	0	2	3	2
General average	47	44	0	2	5	2

FALL OF 1949

6 inches:						
April	28	20	0	18	32	3
May	37	18	0	12	31	3
June	45	24	0	7	16	7
Average	37	21	0	12	26	4
12 inches:						
April	54	22	0	7	10	8
May	61	23	0	2	6	7
June	60	25	0	5	4	5
Average	58	23	0	5	7	7
General average	48	22	0	8	17	6

cutting treatments and an abnormally dry late summer and fall. Ladino clover was reduced to about half the percentage recorded in 1948. The greatest changes occurred where harvesting began in April or May and was repeated at the 6-inch stage; under these conditions, both orchard grass and Ladino clover lost ground and bluegrass and weeds made rather large gains. On plots cut at the 12-inch stage, fewer weeds appeared. During 1949 orchard grass increased on the plots cut at the 12-inch stage to an average of 58 percent, whereas on plots cut at the 6-inch stage it decreased to an average of 37 percent.

Frequency of cutting had a marked effect on the proportions of grass and legume in the herbage harvested during the summer of 1948 (table 5). Early in the season, Ladino clover composed a

FIGURE 2.—Orchard grass–Ladino clover cut, each of the years 1947–49, first in early May and thereafter whenever the forage reached the height of 12 inches: *A*, On May 5, 1949, one day after the 1949 cutting; *B*, on May 31, 1949, about 4 weeks after the first cutting.

comparatively small part of the herbage from plots cut at both frequencies. The herbage cut at the 12-inch stage contained percentages of orchard grass much higher than those of Ladino clover until fall. In July and September it contained from 79 to 87 per cent orchard grass and from 10 to 17 percent Ladino clover. By the time of the last cutting, October 11, the clover had increased

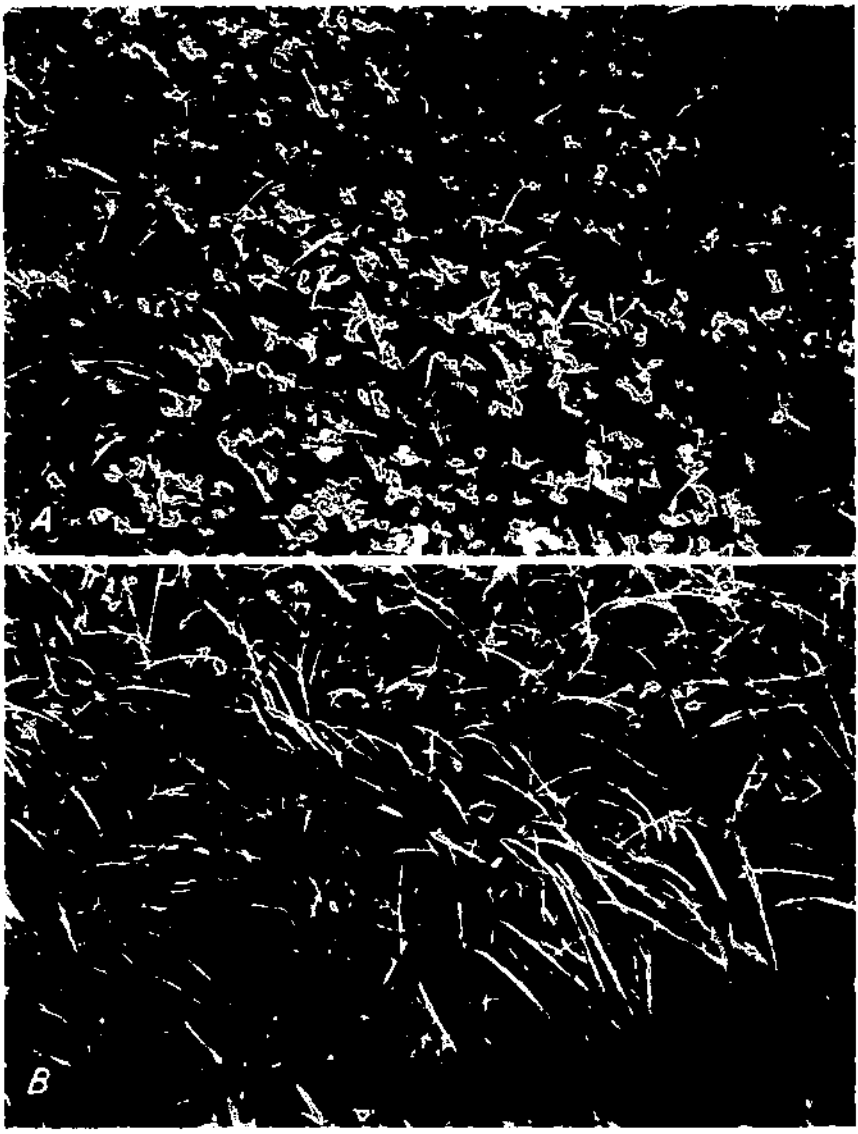

FIGURE 3.—The same stand of orchard grass-Ladino clover shown in figure 2 as it appeared (*A*) on June 24, 1949, 11 days after a cutting, and (*B*) on August 8, 1949, 8 weeks after a cutting.

under the 12-inch cutting frequency to such an extent that it formed 37 to 57 percent of the herbage harvested. On plots harvested at the 6-inch stage, by the middle of July the proportion of Ladino clover almost equaled that of orchard grass. A decrease in this proportion after July was followed by some increase before the final cutting on October 14. The late increase was much less

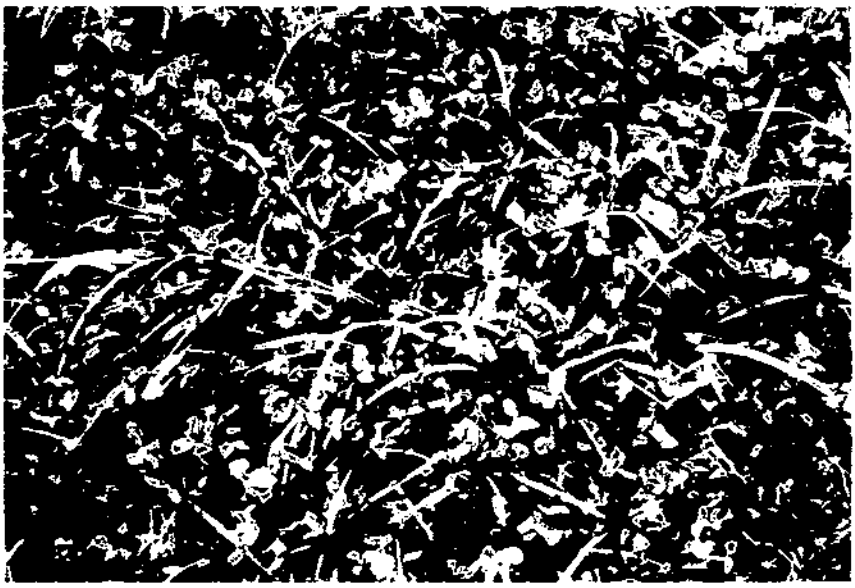

FIGURE 4.—Orchard grass-Ladino clover mat, in each of the years 1947-49, first in early June and thereafter whenever the forage reached a height of 12 inches, as it appeared August 8, 1949 about 4 weeks after a cutting.

striking than that observed on the infrequently cut plots. Differences in botanical composition of the herbage according to cutting frequency were much less at the end of the growing period than during the summer.

Time of beginning cutting affected the botanical composition of the forage of the first cutting and the last cutting of the season but appeared to have little effect on that of forage harvested during the summer (table 5). Where cutting was delayed until June, the first harvest contained a very high proportion of orchard grass and a correspondingly low proportion of Ladino clover. In 1948 the June first harvests of both frequency series contained 91 percent orchard grass and 8 percent Ladino clover. According to composition of forage of the last 1948 harvest, the plot series fell into two groups: the May-first-cutting plots clipped infrequently and the April- and May-first-cutting plots clipped frequently had from 29 to 41 percent orchard grass and from 51 to 61 percent Ladino clover, and the three other series had from 51 to 61 percent orchard grass and from 37 to 42 percent Ladino clover.

Although the proportion of Ladino clover was higher on all plots in midsummer of 1949 than it had been in 1948, it diminished substantially in the fall (table 5). At the time of the last 1949 cutting the percentage, by weight, of Ladino clover in the herbage ranged from 19 to 22 on the plots clipped at the 6-inch stage and from 2 to 7 percent on the plots clipped infrequently. Trends in

botanical composition of herbage harvested during 1949 are illustrated in figures 2–4.

As the 1949 season progressed, bluegrass developed rather prominently on the frequently cut plots of the April-first-cutting series (table 5). Weeds, until then prevailingly of little consequence, increased strikingly in 1949 on the frequently cut plots where cutting was not postponed until June. At the last harvest they composed 32 percent of the herbage from those first cut in April and 30 percent of the herbage from those first cut in May. The contrasting figure for the June-first-cutting series was 10 percent. At no time in 1949 did weeds compose more than 2 percent of the yield from any plot series cut at the 12-inch stage.

The average annual weed yield for 1948–49 was significantly greater under frequent than under infrequent cutting where harvesting began in April, but not where it was postponed until May or June (table 9).

There was a suggestion that weed yields of frequently cut plots were lower where cutting ended in September rather than in October or November; otherwise, no indication was found that weed content of orchard grass-Ladino clover forage varies with the time of last cutting.

Bromegrass-Ladino Clover

The bromegrass-Ladino clover mixture proved to be very sensitive to method of management (table 1). Where cutting began in April, higher average yields of this mixture were obtained in 1947–48 from the plots on which the aftermath was permitted to grow 12 inches tall than from those on which it was cut whenever it reached a height of 6 inches. Where cutting began in May or in June, 1947–48 yield averaged the same under frequent as under infrequent cutting. Under infrequent cutting, average annual yield for 1947–48 was lower where cutting began in May than where it began in June or in April; under frequent cutting, yield for the same period was lower where the first cut was made in April or in May than where it was deferred until June. Averages of yield under the 6-inch cutting frequency for 1947–49 gave evidence in favor of June rather than April as the time for the first cut, and strongly suggested that under this frequency greater yields are obtained by beginning cutting in June rather than in May.

Bromegrass-Ladino clover generally produced considerably more forage during the summer under infrequent than under frequent cutting (tables 3 and 4). Summer production of forage from plots cut at the 12-inch stage was greatly reduced, in all years, by beginning cutting in May rather than in April or June.

Bird (*11*) reported that bromegrass was superior in yield to certain other grass species when cut at advanced stages of development but not when cut at immature stages. He did not report evidence that early cuttings are less harmful to grasses than cuttings made at intermediate stages of growth. Recently Blaisdell

and Pechanec (*13*) reported that bluebunch wheatgrass was damaged more by cutting in midspring than by cutting at either earlier or later stages of development.

The reasons for lesser yields of forage from bromegrass-Ladino clover plots on which cutting began in May rather than in April or June are not entirely clear. Although carbohydrate reserves in the plants were not determined, a possible explanation is that such reserves in plants left uncut until May had by that time been drawn upon heavily for growth and the plants had not yet developed far enough to restore them in any appreciable degree. Plants cut for the first time in April probably could draw upon more ample reserves in making new growth. Furthermore, when bromegrass is cut or grazed in the early spring stages of development it can produce new herbage from the cut stems; but in later stages its regrowth must come to a large extent from new rhizomes —a fact that undoubtedly results in a heavier drain on reserves and also retards recovery. Where the aftermath was infrequently cut substantial storage of nutrients probably took place between a first cut made in April and the next cut. In the case of plants first cut in June, considerable storage undoubtedly occurred before cutting, as the bromegrass was fully headed.

Severe competition from crabgrass and foxtail affected the

FIGURE 5.—View on June 5, 1947, of bromegrass-Ladino clover (left) ready to be cut on that day for the first time and thereafter at the 12-inch stage, orchard grass-Ladino clover (center) cut for the first time in early May and thereafter whenever the forage reached a height of 6 inches, and orchard grass-Ladino clover (right) cut for the first time in early May and thereafter whenever the forage reached a height of 12 inches.

bromegrass-Ladino clover yields of plots first cut in May. The May cuttings were made at about the time crabgrass began its year's growth. By thus reducing some of the competition offered by the seeded species, the crabgrass was able to develop rapidly.

Another factor possibly limiting the yields from bromegrass-Ladino clover plots cut first in May and the proportion of bromegrass in the mixture on such plots is the rapid growth of Ladino clover in May. Particularly at that time, the clover recovers more rapidly from cutting than bromegrass and therefore tends, after a cutting, to increase at the expense of the grass.

In the spring of 1947 the cover on the bromegrass-Ladino clover plots was about 40 percent bromegrass and about 40 percent Ladino clover (table 11). Views of two of these plots as they appeared in June 1947 are shown in figures 5 and 6. During the

FIGURE 6.—Bromegrass-Ladino clover on plot shown in figure 5 as it appeared in late June, 1947, 3 weeks after the first cutting.

growing period of 1947 the percentage of bromegrass decreased markedly and that of Ladino clover increased by more than half. The 1947 decrease in the percentage of bromegrass was probably due to elimination of some plants and the marked tendency of this grass to grow slowly in the fall. During 1948 weeds increased greatly on the frequently cut plots but there was little change in the percentage of Ladino clover or in that of weeds on the infrequently cut plots. Bromegrass decreased slightly under frequent cutting, whereas on the infrequently cut plots of the April- and June-first-cutting series the percentage of bromegrass was greater in the fall of 1948 than in the fall of 1947. Under infrequent cutting, bromegrass was less abundant in 1948 on the May-first-cut-

ting plots than on the plots first cut in April or June. It increased on those plots in 1949.

In 1949 the weed percentage of the ground cover increased under all cutting treatments (table 11). By fall weeds covered, on an average, 51 percent of the area of the frequently cut plots and 20 percent of that of plots harvested at the 12-inch stage. Although Ladino clover decreased somewhat in 1949, in the fall of that year it still covered 45 percent of the area of plots clipped at the 12-inch stage and 36 percent of that of the frequently clipped plots. Bromegrass decreased slightly on the frequently cut plots and increased slightly on the plots harvested at the 12-inch stage.

The trends in botanical composition of the bromegrass-Ladino clover yields during the summers of 1948 and 1949 were influenced

TABLE 11.—*Ground-cover composition on bromegrass-Ladino clover plots in 1947–49 as determined by the point-quadrat method*

SPRING OF 1947

Frequency (cutting height) and time of first cutting	Ground-cover composition on plots					
	Brome	Ladino	Blue-grass	Red clover	Weeds	No cover
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6 inches:						
April	38	37	0	19	3	2
May	41	37	0	19	2	1
June	41	37	0	19	1	1
Average	40	37	0	19	2	2
12 inches:						
April	39	37	0	19	4	1
May	38	44	0	16	3	0
June	39	38	0	19	3	0
Average	39	39	0	18	3	0
General average	39	38	0	18	3	1

FALL OF 1947

6 inches:						
April	8	72	0	0	14	6
May	15	63	0	1	12	9
June	22	45	0	2	19	11
Average	15	60	0	1	15	9
12 inches:						
April	14	79	0	1	3	3
May	18	72	0	1	5	5
June	14	65	0	3	9	9
Average	15	72	0	2	6	6
General average	15	66	0	1	10	7

TABLE 11.—*Ground-cover composition on bromegrass-Ladino clover plots in 1947–49 as determined by the point-quadrat method*—Continued

FALL OF 1948

Frequency (cutting height) and time of first cutting	Ground-cover composition on plots					
	Brome	Ladino	Blue-grass	Red clover	Weeds	No cover
6 inches:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
April	11	57	0	0	31	1
May	10	56	0	0	30	3
June	13	54	0	0	31	1
Average	11	56	0	0	31	2
12 inches:						
April	28	65	1	0	4	2
May	18	70	0	0	11	1
June	23	71	2	0	3	1
Average	23	69	1	0	6	1
General average	17	62	1	0	19	1

FALL OF 1949

6 inches:						
April	5	37	1	0	55	2
May	11	39	1	0	46	4
June	13	33	2	0	50	2
Average	10	36	1	0	51	3
12 inches:						
April	30	45	1	0	20	3
May	26	41	1	0	26	6
June	25	48	7	0	14	5
Average	27	45	3	0	20	5
General average	18	40	2	0	35	4

by the frequency of harvest and the time of first cutting (table 6, figs. 7 and 8). In the first cuttings of 1948, bromegrass predominated except where harvesting began in May. There it composed a little less than 25 percent of the yield. The first cuts from the plots harvested at the 6-inch stage were very similar in botanical composition to those from the corresponding plots harvested at the 12-inch stage. Except where cutting began in May, later yields differed markedly in composition according to cutting frequency. Under frequent cutting the percentage of bromegrass declined sharply and that of Ladino clover increased. Under infrequent cutting the proportion of bromegrass decreased much less sharply; in the second 1948 harvest of the April-first-cutting series it actually increased, from 51 percent to 67 percent, and as

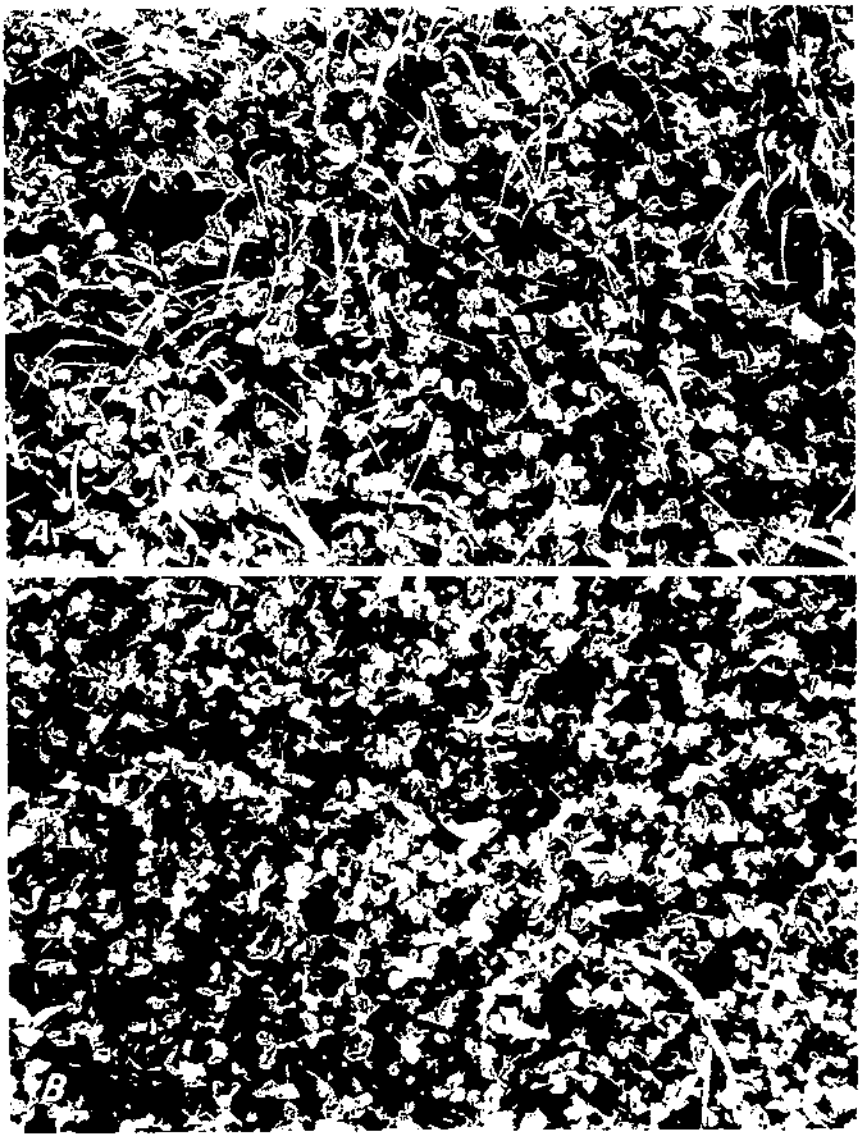

FIGURE 7.—Bromegrass-Ladino clover cut first in early June of each year and thereafter at the 12-inch stage (figs. 5, 6), as it appeared (*A*) in late June of 1949 and (*B*) on August 8, 1949, about 4 weeks after a cutting.

late as September 3 it averaged 40 percent for this series—still exceeding the maximum percentage of bromegrass contained at any time during the season in the herbage harvested from the plots first cut in May. On July 21, 1948, the herbage harvested on the plots first cut in May and thereafter cut frequently contained on an average 3 percent bromegrass and 93 percent Ladino clover.

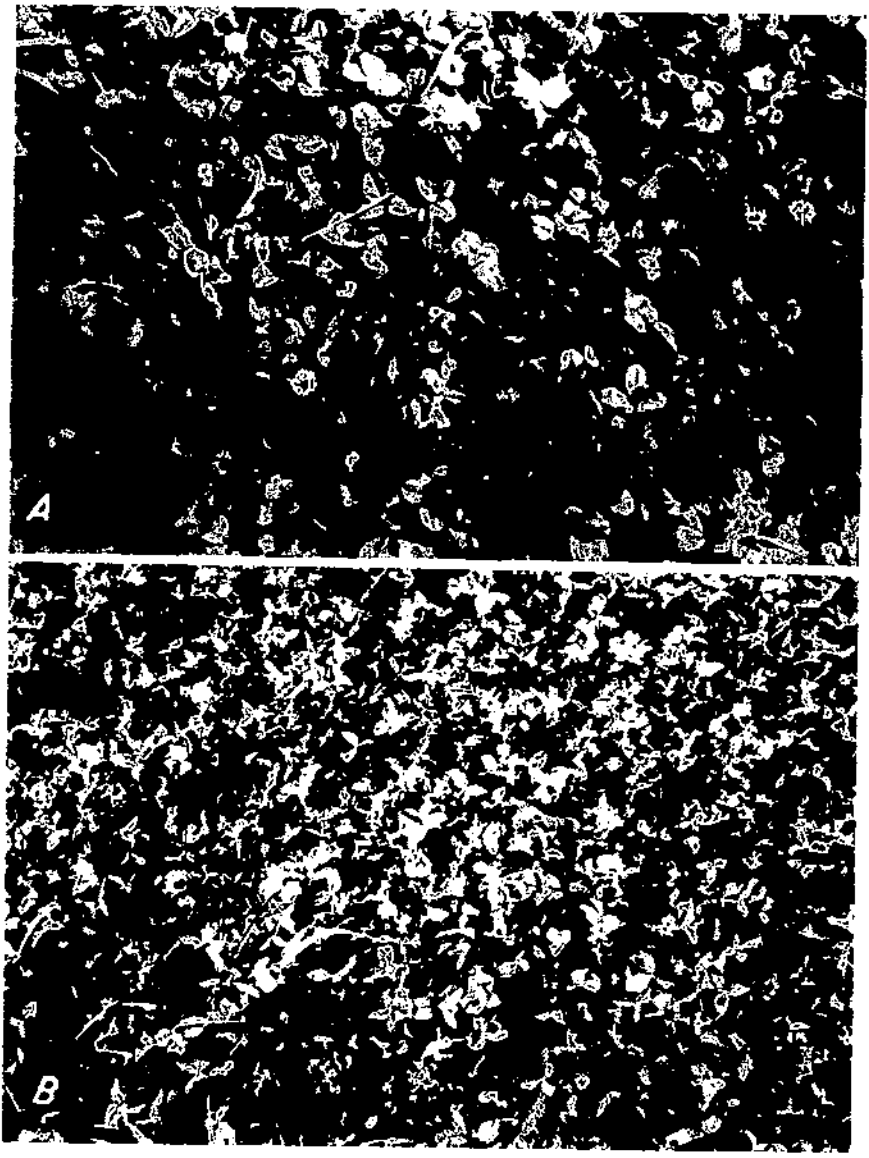

FIGURE 8.—Bromegrass-Ladino clover cut first in early May of each year and thereafter at the 12-inch stage, as it appeared (*A*) on May 31, 1949, about 4 weeks after the first cutting of that year, and (*B*) on August 8, 1949, 8 weeks after a cutting.

By the time of the last cutting of the season, the mixed herbage from all plots of both cutting-frequency series contained 10 percent or less bromegrass.

Weeds made up a substantial part of the herbage harvested in

1948 on all the frequently cut plots and on the May-first-cutting series of plots infrequently cut, from the latter part of July until late in the season (table 6). In that year weed yields under frequent cutting were less where cutting began in June than where it began in April or May (table 9).

General trends in the botanical composition of the forage of the frequently cut plots were much the same in 1949 as in 1948 (table 6). Proportionately much less bromegrass and in most cases more Ladino clover were present at early dates in 1949 than in 1948 on the frequently cut plots of the April- and May-first-cutting series (table 6). At the end of the season the percentages of Ladino clover were less and those of weeds were greater in 1949 than in 1948.

The first 1949 cut from the May-first-cutting series of plots harvested at the 12-inch stage contained only 19 percent bromegrass, compared with 41 percent for the April- and 68 percent for the June-first-cutting series (table 6). As in 1948, the second cut from the April-first-cutting series contained more bromegrass than the first. The bromegrass component of the herbage of the June-first-cutting series increased from 10 percent in the fall of 1948 to 68 percent in the first harvest of 1949. This increase, which resulted in a marked shift in the grass-legume balance from fall to spring, illustrates the growth cycle of bromegrass.

On plots harvested at the 12-inch stage the percentage of bromegrass in the forage at the end of the season was much higher in 1949 than in 1948 (table 6). On October 12, 1949, bromegrass composed 35 percent of the herbage for the April-, 24 percent for the May-, and 39 percent for the June-first-cutting series. These percentages are in contrast with 10, 5, and 10 percent, respectively, for 1948.

In the last cuttings of 1949 Ladino clover was somewhat reduced but still composed 33 to 47 percent of the forage from all plot series (table 6).

In 1949 the bluegrass percentages were slightly greater on the frequently cut plots and very slightly greater on the plots infrequently cut (table 6) than in 1948. In general, less bluegrass occurred in the bromegrass-Ladino clover than in the orchard grass-Ladino clover mixture, especially on the frequently cut plots of the April-first-cutting series.

The reason for this difference is not entirely clear. Ordinarily it would seem that bluegrass might be expected to encroach sooner on bromegrass-Ladino clover plots than on orchard grass-Ladino clover plots, since bromegrass is normally much less aggressive than orchard grass. Crabgrass apparently became well established in the bromegrass mixture before bluegrass could develop. Observations made outside these studies suggest that crabgrass is capable of competing vigorously with bluegrass, particularly when the latter is not already well established. Although orchard grass is highly competitive with bluegrass, a sod of orchard grass-Ladino clover is not nearly so dense at ground level as a heavy stand of crabgrass.

Weeds, although they generally increased in 1949, were actually less of a factor on the May-first-cutting plots under infrequent cutting in 1949 than in 1948 (table 6). Most of the 1949 increases in weed yield appeared late in the season. Over the 2-year period 1948–49 weed yields were greater under the 6-inch than under the 12-inch cutting frequency, regardless of when cutting began (table 9) or ended.

Weed yields in 1948–49 under frequent cutting were less where cutting was deferred until June than where it began in April (table 9). Under infrequent cutting, weed yields over this period were greatest where cutting began in May.

Over the period 1948–49, weed yield under either cutting frequency did not vary with the date of final cutting. In 1949, under frequent cutting the weed component of the yield was less where cutting ended in September and under infrequent cutting it was least where cutting continued into November.

Orchard Grass-Alfalfa

Frequent defoliations consistently reduced forage yields of the orchard grass-alfalfa mixture, regardless of time of first cutting (table 1). This result is in contrast with the fact that such defoliations consistently reduced yields of the orchard grass-Ladino clover mixture only where cutting began in April.

On the plots harvested at the 6-inch stage, 1947 yields were higher where cutting was delayed until June than where it began in April or May. In 1948 there were no differences in yield according to time of first cutting. The yield averages for 1947–48, however, were higher where cutting began in June than where it began in April (table 1). On the plots cut at the 12-inch stage, yields were higher where cutting began in June than where it began in either April or May. In general, where cutting ended in September less forage was produced than where cutting continued until October or November (table 2).

Forage production of the plots harvested at the 12-inch stage was better distributed through the season than that of the plots harvested frequently (table 3). In 1948, more than twice as much forage was produced after July 1 where cutting was infrequent. Under infrequent cutting, production after July 1 was favored by deferring first cutting until June.

Ground cover on the orchard grass-alfalfa plots in the spring of 1947 was more than 50 percent orchard grass, a little less than 25 percent red clover, and a little less than 15 percent alfalfa (table 12). Under frequent cutting the alfalfa component of the cover was almost eliminated in a single year. Where the herbage was permitted to grow to a height of 12 inches before defoliation, alfalfa formed about the same percentage of the ground cover at the end of 3 years as in the beginning.

White clover increased on the frequently cut plots to the extent that it covered about 20 percent of their area by the fall of 1948 (table 12). Very few weeds were present until late in 1947.

Weeds increased each year under frequent cutting until in the fall of 1949 they covered, on an average, 45 percent of the area of plots so treated. Under infrequent cutting weeds did not become abundant until the year 1949, when in the fall of that year they covered, on an average, 21 percent of the plot area.

Practically all the weeds were produced in the latter part of the season (table 7). Before late August, weeds composed only a small percentage of the herbage harvested from the plots cut at the 12-inch stage.

In 1948 the total yield of weeds produced under each of the two cutting frequencies was the same (table 9), although late in the season the proportion was higher in the herbage harvested from the frequently cut plots (table 7). Under the 6-inch frequency,

TABLE 12.—*Ground-cover composition on orchard grass-alfalfa plots in 1947–49 as determined by the point-quadrat method*

Frequency (cutting height) and time of first cutting	Ground-cover composition on plots						
	Orchard	Alfalfa	Bluegrass	Red clover	White clover	Weeds	No cover
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Spring of 1947							
6 inches:							
April	50	17	0	20	3	3	8
May	48	15	0	26	3	3	5
June	60	13	0	23	0	1	3
Average	52	15	0	23	2	2	5
12 inches:							
April	57	10	0	23	0	5	4
May	55	13	0	23	1	5	3
June	56	18	0	23	0	2	2
Average	56	14	0	23	0	4	3
General average	54	14	0	23	1	3	4
Fall of 1947							
6 inches:							
April	59	2	0	7	3	18	10
May	60	0	0	0	7	27	5
June	71	5	0	4	3	8	10
Average	63	2	0	4	5	18	9
12 inches:							
April	63	9	0	4	4	11	8
May	73	7	0	3	5	10	1
June	64	15	0	5	3	6	8
Average	67	11	0	4	4	9	6
General average	65	6	0	4	4	13	7

TABLE 12.—*Ground-cover composition on orchard grass-alfalfa plots in 1947–49 as determined by the point-quadrat method*—Continued

FALL OF 1948

Frequency (cutting height) and time of first cutting	Ground-cover composition on plots						
	Orchard	Alfalfa	Bluegrass	Red clover	White clover	Weeds	No cover
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6 inches:							
April	39	0	3	7	22	29	1
May	44	0	1	4	14	35	2
June	48	1	2	4	23	21	1
Average	43	1	2	5	20	28	1
12 inches:							
April	54	11	3	6	15	9	2
May	49	14	2	11	7	14	5
June	54	22	1	6	2	11	4
Average	52	16	2	8	8	11	4
General average	48	8	2	6	14	20	2

FALL OF 1949

6 inches:							
April	33	0	15	1	5	45	3
May	37	1	10	1	3	46	4
June	36	2	5	2	7	45	4
Average	35	1	10	1	5	45	4
12 inches:							
April	49	12	7	1	4	21	6
May	51	14	6	2	2	23	3
June	53	14	6	1	3	18	5
Average	51	13	6	1	3	21	5
General average	43	7	8	1	4	33	4

yield of weeds was higher where cutting began in May rather than in June; under the 12-inch frequency, it was higher where cutting began in May rather than in April or June (table 9). Weed yields were not affected by time at which cutting ended on the plots cut at the 12-inch stage, but on the frequently cut plots they were lower where cutting ended in September rather than in October or November.

BROMEGRASS-ALFALFA

The yields of the bromegrass-alfalfa mixture were affected by cutting treatment more than those of any of the other mixtures (table 1). Frequent cutting drastically reduced forage yields in

all cases. Even when cut infrequently beginning cutting before the first of June seriously reduced yields. Where cutting was delayed until June and was repeated at the 12-inch frequency, yields fairly comparable to the best of the other mixtures were obtained. Weeds were prevalent on all plot series, regardless of cutting treatment, in 1948 and 1949 (table 8, fig. 9).

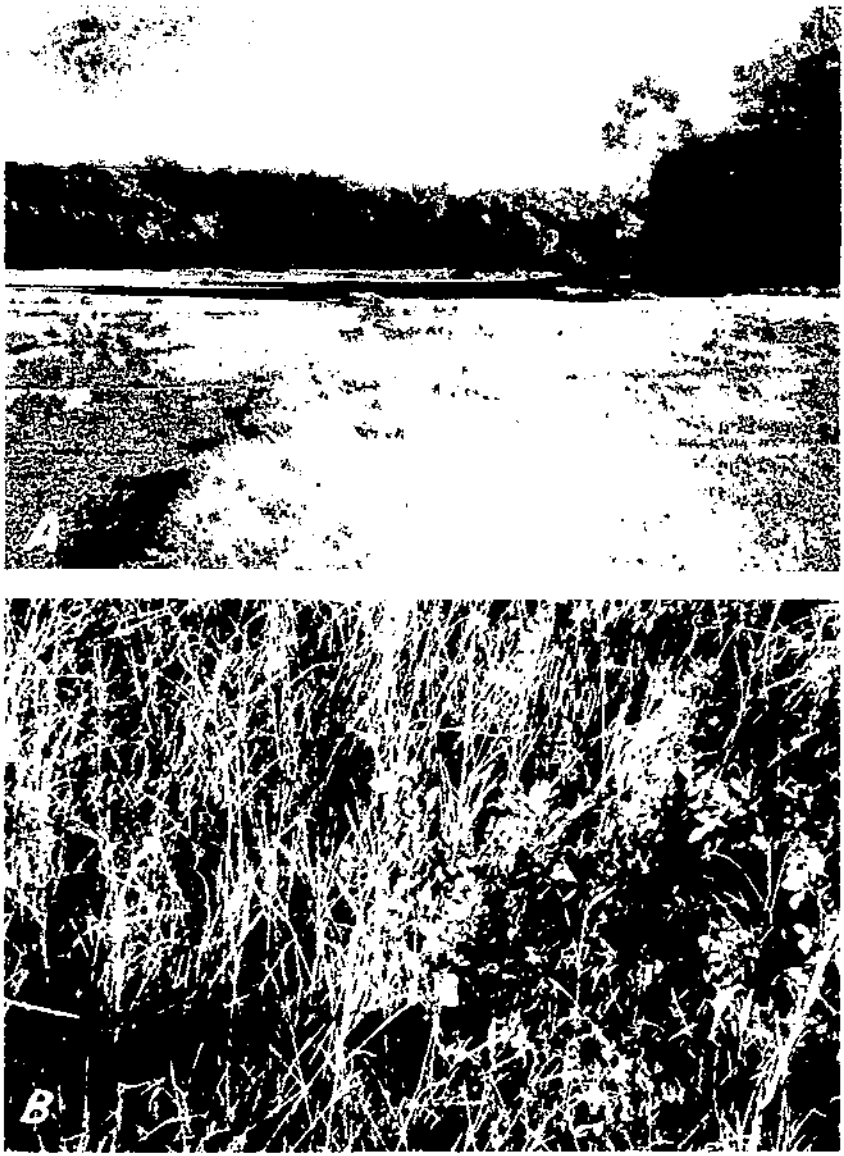

FIGURE 9.—*A*, Bromegrass-alfalfa stands (center) in typical condition on October 12, 1949. *B*, Close-up view, on the same date, of one of the bromegrass-alfalfa stands shown in *A*. Note the high proportion of crabgrass.

SUMMARY

Field studies were conducted during the 3-year period 1947–49 at the Plant Industry Station, Beltsville, Md., to determine the general behavior under differential cutting treatments of these four grass-legume mixtures: Orchard grass (*Dactylis glomerata*) and Ladino clover (*Trifolium repens* L. "Var. Ladino"), bromegrass (*Bromus inermis*) and Ladino clover, orchard grass and alfalfa (*Medicago sativa*), and bromegrass and alfalfa. Each year, cutting of stands of each mixture began at three different dates in the spring, was repeated during the season at two frequencies (the 6-inch and 12-inch heights), and ended at three different dates in the fall, which were approximately the same for all the beginning dates. In analyzing the results, particular attention was given to the effects of time and frequency of cutting on (1) total dry-matter production, (2) distribution of production through the growing season, (3) weed encroachment, and (4) trends in botanical composition through the season and from year to year. The results are as follows:

1. Orchard grass-Ladino clover proved to be outstanding among the four mixtures tested. In comparison with the others it was less exacting in management requirements, more productive under a variety of cutting treatments, superior in distribution of production through the growing season and in resistance to weed encroachment, and in most cases superior in maintaining a desirable grass-legume balance through the growing season.

2. Bromegrass-Ladino clover was superior in productivity to the alfalfa combinations.

3. Bromegrass-alfalfa was found the least desirable of the four mixtures, particularly under the more severe systems of cutting.

4. Frequency was the most important cutting factor in its overall influence on total yield, distribution of production, ingress of weeds, and grass-legume balance. Time of beginning cutting was almost as important as frequency, and was more important than time of ending cutting.

5. The only treatment that consistently reduced the yields of orchard grass-Ladino clover was making the first cut in April and cutting the aftermath whenever it reached a height of 6 inches. All other systems of cutting tested resulted in approximately the same yields of this mixture.

6. Bromegrass-Ladino clover required more careful management than orchard grass-Ladino clover. The yield was reduced when cutting was started in April under the 6-inch cutting frequency; and starting it in early May reduced yield regardless of cutting frequency. Highest yields were obtained by (1) delaying first cutting until June or (2) starting cutting in April and cutting thereafter only at the 12-inch stage.

7. Yields of orchard grass-alfalfa and of bromegrass-alfalfa comparable to the best yields of the Ladino clover mixtures were obtained only by delaying first cutting until June and letting the aftermath grow to a height of 12 inches. Under more severe treat-

ment, orchard grass-alfalfa was more productive than bromegrass-alfalfa.

8. The treatments that led to the highest total forage production also were generally superior as to distribution of production through the season, prevention of weed encroachment, and maintenance of a satisfactory grass-legume balance.

9. Production of forage tended to be greater, for all mixtures, where cutting ended in October or November rather than in September.

10. The Ladino clover mixtures were more consistently productive through the season than the alfalfa mixtures.

11. Ordinarily orchard grass, in comparison with bromegrass, started growth from 10 days to 2 weeks earlier in the spring and maintained much more active growth during the summer. It also made greater growth in the fall. Bromegrass, once it had begun active growth in the spring, grew rapidly for a period of 4 to 6 weeks, very often reaching a higher peak of production than orchard grass by the first of June.

12. In the orchard grass-Ladino clover combination a much higher proportion of the grass component was maintained during the summer than in the bromegrass-Ladino clover combination. Under the more severe cutting treatments summer production on the bromegrass-Ladino clover plots was provided almost entirely by the clover.

13. The mixtures differed strikingly in their capacity to compete with weeds, of which crabgrass (*Digitaria sanguinalis*) and foxtails (*Setaria* spp.) had the greatest effect on the sown species. Weed encroachment was greatest in the bromegrass-alfalfa plots and least in orchard grass-Ladino clover plots.

14. The ingress of bluegrass (*Poa pratensis*) was encouraged by early and frequent cutting. More bluegrass was noted in the orchard grass-Ladino clover than in the bromegrass-Ladino clover mixture.

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