COMPARISON OF GROWTH STAGE WITH CALENDAR DATE AS A BASIS FOR HARVESTING TWELVE IRRIGATED PASTURE GRASSES

by

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COMPARISON OF GROWTH STAGE WITH CALENDAR
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INTRODUCTION

The changing philosophy of agriculture in the United States has resulted in a shift from cultivated crop production to the utilization of more soil conserving crops. This will likely have a positive influence on the amount of pasture acreage in the future. Oregon alone, from the years 1940 to 1950, experienced a 22.6 per cent acreage increase in the amount of irrigated pastures (17, p.23). The recommendation of the 1952 Oregon Agricultural Planning Conference that irrigated pasture acreage be increased over the next 25-year period indicates that this trend will likely continue.

This rapid expansion in pasture acreage has greatly emphasized the need for increased research in this field. It should be pointed out that the results obtained in any research will be only as reliable as the experimental techniques used. Techniques adequate for some phases of pasture research may not be adequate for others. It is necessary, therefore, that reliable experimental techniques be devised before work is initiated on a pasture problem.

One of the major phases of pasture research deals with the evaluation of forage species and strains in small plot experiments. Techniques used in such evaluations should simulate as nearly as possible conditions which might be expected under actual field use. Such factors as clipping height and interval of time between harvestings should be considered. It is possible that the different forage species and strains would react differently under the various heights and intervals used.

This research was undertaken to study techniques of evaluating grass species and strains based on differences in yield performance. The two techniques used were growth stage and calendar date as a basis for harvesting. The main objective of the experiment was to determine whether or not there was any significant difference in yield performance of twelve irrigated pasture grasses when harvested on a growth stage and calendar date basis at two mower bar heights.

REVIEW OF LITERATURE

Pasture research utilizes both livestock and mechanical equipment in measuring results. However, it is recognized that animals graze preferentially and affect the sward in a manner which cannot be duplicated by mechanical harvesting (1, p.241).

Pasture research methods have been adequately reviewed by Ahlgren (1, pp.240-259), by Linehan (15, pp.1328-1333), and in a report by a joint committee of the American Society of Agronomy, the American Dairy Science Association, the American Society of Animal Production, and the American Society of Range Management (19, pp.39-50). For clarification, certain of these research methods will be briefly reviewed. They will be discussed from the standpoint of animal grazing trials, clipping methods supplemental to grazing trials, and small plot clipping experiments.

Grazing Trials

Grazing trials have as their objectives the measurement of the quality of the herbage and the output or yield of pasture per unit area. Some investigators consider only quality or only yield, whereas others give attention to both aspects (17, p. 1380).

According to Mott and Lucas (17, p.1383), quality in forage crops is the function of the nutritive value of the forage plus the rate of forage intake by the animals. The measurement of quality in grazing trials is the output per animal which may be expressed in terms of daily gains in weight, daily milk production, or some other unit of measurement.

In grazing trials the output or yield per acre of pasture may be expressed in various ways. In general, it may be expressed in terms of animal days per acre as suggested by Knott, et al. (14, pp.1-20); livestock production per acre which may be evaluated in terms of milk production or animal weight gains as reviewed by Ahlgren (1, pp.244-245); or by some appropriate feed unit per acre, such as the yield of the total digestible nutrients as discussed by Hodgson, et al. (11, pp.1-31).

The chief advantage of the grazing method is the measurement of results under actual grazing conditions. It is desirable, though, that the kind of animals for which the results of the experiment are to apply be used in the experimentation (1, p.245; 17, p.1380; and 19, p.41).

One of the limitations of grazing trials is the high cost factor due to the necessity of livestock. The grazing trial also requires comparatively larger experimental areas than other pasture research methods (1, p.253 and 17, pp. 1380-1385).

Green, Langer, and Williams (7, p.1379) stated that the experimental errors experienced in grazing trials are quite formidable. This is mainly attributed to the large variation between animals. It is important, therefore, that special attention be given to the proper selection of experimental animals. Such factors as uniformity in respect to age, weight, and stage of lactation if cows are used, should be considered (19, p.41).

According to Ahlgren (1, p.245), less difficulty is likely to be encountered in conducting grazing trials with dairy heifers, beef cattle, or sheep, than with lactating dairy animals. As stated in the January, 1952, Agronomy Journal (19, p.41), in experiments with animals not primarily kept for milk, castrated males are preferred to females so as to eliminate disturbances due to oestrus or carrying or suckling their young. Of course, if the objective of the grazing trial is to investigate the effects upon the animals during successive lactations or upon the birth and performance of the offspring, this would not be true.

The main factors which one must consider in the design of grazing experiments, as stated by Mott and Lucas (17, p.1380), are (a) the treatment variables to be studied, (b) the precision or sensitivity needed, and (c) the cost involved in conducting the experiment.

Clipping Methods Supplementary to Grazing Trials

In grazing experiments it is usually desirable to take herbage yields in order to estimate the herbage production of a particular pasture or treatment, or the herbage consumed by the animals (7, pp.1374-1379; 19, pp.39-50; 22, pp.349-359; and 29, pp.487-491).

There are a number of reasons why herbage production estimates based only on the performance of grazing livestock may not be sufficient and will need to be supplemented with clipping methods. One is that animals may avoid much forage due to differential palatability of species or to droppings and urine spots. Much herbage may escape evaluation due to the wastes by tramping. Also, certain animals, especially sheep, may utilize only the leaves of the herbage and reject the stems (1, pp.240-259, and 19, p.45).

According to Linehan (15, p.1328), the clipping methods rely on clippings of a number of sample plots in order to obtain an estimate of the quantity of herbage present on the field before, during, or after grazing.

Different sampling methods may be used (1, pp.240-259; 3, pp.451-452; 6, pp.202-217; 9, pp.566-574; 12, pp.420-421; 15, pp.1328-1333; 18, pp.171-185; 19, pp.39-50; 22, pp.349-359; and 29, pp.487-491). They may be classed as either the single clip method or the difference method.

The single clip method estimates the herbage yield of one clipping only, usually taken just before the livestock are turned into the pasture. The difference method, on the other hand, usually consists of two clippings which are taken at different times, with the yield difference between the two clippings representing the herbage production or animal feed consumption for a given pasture.

Both methods may utilize either mower strips or cages (3, pp.451-452; 6, pp.202-217; 12, pp.420-421; 15, pp.1328-1333; 18, pp.171-185; 22, pp.349-359; and 29, pp.487-491). The cage method, according to Linehan (15, p.1328) and the joint committee report of the American Society of Agronomy, et al. (19, p.45), involves the use of some type of wire enclosure which is placed over the herbage in the grazing pasture. It is from these protected areas that the herbage yield estimates are derived. The mower strip method involves clipping a specified area of pasture in order to determine the yield according to the amount of forage obtained.

The mower strip method is preferred to the cage method where pastures are rotationally grazed, whereas the cage method is more desirable under continuous pasturing conditions (19, p.45). The clipping methods in use today generally show higher yields than those obtained from actual grazing (19, p.43, and 29, pp.487-491).

Small Plot Clipping Experiments

According to McIntyre and Griffiths (16, p.1361), small plot trials are commonly used as a basis of assessment or for selection of treatments to be tested further by grazing. As no animals are required, the cost factor is greatly reduced.

Small plot experiments may be used to test the performance of species and strains, and to study management, fertilization, and other cultural practices (16, pp.1361-1366, and 19, p.47). McIntyre and Griffiths (16, p.1362) stated that when pure stands of forage which are close genetically and in growth characteristics are clipped to simulate grazing, they can be expected to show differences which would be similar to those obtained if actual grazing had been used.

In small plot clipping experiments both the growth stage and calendar date bases for time-of-harvest have been used to evaluate species and strains, fertility, and management treatments. The joint committee of the American Society of Agronomy, et al. (19, p.45) states that it is more desirable to sample herbage on a growth stage basis than on a calendar date basis.

Hanson, et al. (8, pp.373-376), in evaluating Kentucky bluegrass strains grown in association with white clover, harvested on a growth stage basis. Whenever the plants were four to five inches high, they were clipped with a reel-type mower to one-half and one inch until July, and one inch thereafter. They found that the stubble heights used in this experiment did not produce differential strain responses.

Stitt (26, pp.200-203) also used growth stage as a basis for harvest in evaluating five strains of bromegrass grown in close-drilled row plots under irrigation. He used intensive clipping to simulate heavy grazing. This was achieved by clipping to a two-inch stubble height whenever the grasses attained a growth height of eight to ten inches.

In investigating the effects of irrigation, nitrogen fertilization, and clipping treatments on a clover-Kentucky bluegrass sod, Robinson, et al. (24, pp.239-244) used clipping treatments which involved cutting to stubble heights of one-half, one, and two inches when the herbage reached a height of four to five inches. The lowest yields were obtained on the higher-clipped plots. The highest yields were obtained by clipping to one-half inch, but this treatment was too drastic for maintenance of a good grass sod. Clipping to one inch resulted in high yields and at the same time was effective in maintaining a desirable balance between grass and clover.

Robinson and Sprague (23, pp.244-247) studied the response of orchardgrass-ladino clover to irrigation and nitrogen fertilization. They used three clipping treatments. One treatment simulated rotational grazing by cutting to two inches when ten to twelve inches high, and the other two were clipped at the early hay and aftermath stages of growth. All clipping treatments were based on rate of recovery rather than on calendar dates. The yields were consistently higher in the series cut for hay and aftermath.

Sherwood, et al. (25, pp.841-858) conducted a pasture fertility experiment in North Carolina. In this experiment plots were clipped on a calendar date basis at approximately monthly intervals from the latter part of April to late September.

Comstock and Law (5, pp.1074-1083) used both methods in studying the effects of clipping on alfalfa-grass mixtures. Their terminology differed in that the clipping treatments were termed as frequent clipping, deferred rotation, and hay stage.

Peterson and Hagan (20, p.287) concluded from their small plot clipping frequency study on irrigated pasture mixtures in California that grazing intensively at intervals of 25 to 28 days might be suitable for mixtures containing ladino clover as the primary legume. They felt that a slightly longer interval between grazings should prevail where trefoil or alfalfa is the dominant legume.

This review of literature has shown marked variation in the harvesting methods used by the numerous workers in small plot clipping experiments. Some preference has been expressed, but no detailed study has been made to authenticate the superiority of either the calendar date or growth stage basis of harvesting irrigated pasture grasses.

MATERIALS AND METHODS

The experimental plots were located on the Experiment Station South Farm, approximately one mile south of the Oregon State College campus. The soil type is an Amity silt loam.

The experiment was conducted on established stands of twelve different species and strains of grasses. These grasses along with seeding rates are listed in Table 1. The grasses were seeded in pure stands in May, 1952, and the experiment was initiated in April, 1953.

The plot area was plowed in the fall of 1951 and in the spring of 1952 was re-plowed and leveled. Calcium carbonate was applied at the rate of three tons per acre and disked into the soil to a four-inch depth. The land was then harrowed and fertilized with ammonium sulfate at the rate of 200 pounds per acre. The seedbed preparation was completed by once again harrowing the land and then rolling with a cultipacker.

All plots were seeded by hand. Since the volume of seed required per plot was small it would have been almost impossible to insure even distribution by hand seeding. This problem was overcome by mixing each allotment of seed with approximately three gallons of moist sawdust. The sawdust and seed were then uniformly spread by hand over the entire plot and lightly raked into the soil. Because

Table 1. List of grass species and strains and respective seeding rates for the twelve grasses used in this experiment.

Species and strains	Scientific Name	Seeding Rate lbs./A.
Tall fescue, Alta	*Festuca arundinacea*. Schreb.	15
Meadow foxtail, ordinary	*Alopecurus pratensis*. L.	10
Orchardgrass, Akaroa	*Dactylis glomerata*. L.	10
Orchardgrass, common	*Dactylis glomerata*. L.	10
Orchardgrass, Oregon 233	*Dactylis glomerata*. L.	10
Orchardgrass, S-143	*Dactylis glomerata*. L.	10
Perennial ryegrass, Oregon	*Lolium perenne*. L.	20
Perennial ryegrass, S-23	*Lolium perenne*. L.	20
Reed canarygrass, ordinary	*Phalaris arundinacea*. L.	10
Smooth bromegrass, Achenbach	*Bromus inermis*. Leyss.	20
Timothy, ordinary	*Phleum pratense*. L.	8
Tall oatgrass, Tualatin	*Arrhenatherum elatius* Var. (L.) Presl.	20

of the extremely dry season, light and frequent irrigation applications were made in order to obtain uniform germination and stand establishment. Excellent stands were obtained for all of the species and strains used in this experiment.

Experimental Design and Treatments

The experimental design was a split plot with four clipping treatments superimposed at random upon each of twelve grass species and strains, as shown in Figures 1 and 2. Four replications were used.

Individual grass plots were six feet wide and 25 feet long, whereas clipping treatment subplots were three feet wide and 12½ feet long.

The clipping treatments consisted of the following:

T_1. Plots clipped on a calendar date basis at two-inch mower bar height.

T_2. Plots clipped on a calendar date basis at four-inch mower bar height.

T_3. Plots clipped on a growth stage basis at two-inch mower bar height.

T_4. Plots clipped on a growth stage basis at four-inch mower bar height.

The calendar date clippings consisted of harvesting the plots at approximately 26-day intervals. Growth stage

Figure 1. General view of experimental plot area showing the grasses seeded in solid stands with clipping experiments superimposed. Note lack of vegetation between plots.

Figure 2. Close-up of a single plot showing clipping treatment subplots superimposed upon a single grass plot.

refers to that stage of plant development at which a species or strain was thought to be desirable for pasturing. The criterion for determining this stage was plant height, based on the average length of the longest blade for a number of observations.

Height Measuring Technique

At the initiation of the experiment, it was not known what height would represent a desirable pasturing stage. By consulting with various experiment station agronomists, and by observing and measuring the grasses in the early part of the season, height standards were developed which were thought to represent the optimum stage for pasturing. The height standards used for the various grasses throughout the season are given in Table 2.

The plant height was determined, as illustrated in Figure 3, by taking ten height measurements in centimeters at random from each plot for all treatments prior to clipping. In general, the following steps were involved:

1. Meter rule placed at random in plot.
2. Forage at base of rule grasped in hand.
3. Forage lifted upright by sliding up rule.
4. Length of the longest blade, measured from the soil surface to blade tip, and recorded.

Following the establishment of the height at harvest

Table 2. Average length of longest leaf blade used as criterion for harvest of the twelve grasses on a growth stage basis.

Species and strains	Average height in cm. at cutting	
	T_3	T_4
Tall fescue, Alta	57.5	61.0
Meadow foxtail, ordinary	36.0	41.25
Orchardgrass, Akaroa	54.5	57.4
Orchardgrass, common	53.25	55.0
Orchardgrass, Oregon 233	52.5	55.2
Orchardgrass, S-143	55.0	55.6
Perennial ryegrass, Oregon	52.0 *	53.0 *
Perennial ryegrass, S-23	39.5	43.5
Reed canarygrass, ordinary	58.0	57.0
Smooth bromegrass, Achenbach	60.0	60.0
Timothy, ordinary	55.5 **	55.5 **
Tall oatgrass, Tualatin	61.5	65.0

* Based only on first two clippings because of profuse heading.

** Based only on first two clippings because of profuse heading and rust.

Figure 3. Technique used in taking height measurements.

for the growth stage treatments, it was necessary to duplicate this as nearly as possible throughout the remainder of the clipping season. To achieve this, frequent measurements between clippings were required. When any two plots of a given grass reached the prescribed height, all four plots were clipped.

Clipping Dates

The first calendar date and growth stage clippings were made on April 25, 1953, and continued through October 25, 1953. There were eight successive calendar date clippings, one taken on each of the following dates: April 25, May 21, June 19, July 15, August 13, September 8, October 3, and October 25. Harvesting dates for the growth stage treatments are presented in Table 3.

Harvesting Procedure, Equipment, and Yield Determinations

Clipping treatments for each species and strain were evaluated on the basis of the total yield of dry matter per plot. Dry matter yield was determined by clipping a swath twenty inches wide and 12½ feet long through the middle of each treatment subplot with a Scythette mower. This mower, as shown in Figure 4, was equipped with a pan to catch the clipped forage and with a pair of wheels mounted in such a way as to facilitate the rapid adjustment

Table 3. Harvesting dates and total number of clippings for plots clipped on a growth stage basis at both two-inch (T_3) and four-inch (T_4) mower bar heights.

Species and strains	Treat-ment	Clipping Number and Harvesting Dates 1	2	3	4	5	6
Tall fescue, Alta	T3	Apr 26	Jun 2	Jul 28	Oct 8	Oct 25	
	T4	Apr 26	May 26	Jul 7	Sep 4	Oct 25	
Meadow foxtail, ordinary	T3	Apr 29	Jun 2	Jul 10	Sep 4	Oct 25	
	T4	Apr 29	May 26	Jul 1	Aug 18	Oct 25	
Orchardgrass, Akaroa	T3	Apr 25	Jun 2	Jul 10	Sep 4	Oct 25	
	T4	Apr 26	May 28	Jul 1	Aug 18	Sep 24	Oct 25
Orchardgrass, common	T3	Apr 25	Jun 2	Jul 10	Sep 24	Oct 25	
	T4	Apr 25	May 26	Jun 23	Aug 18	Oct 25	
Orchardgrass, Oregon 233	T3	Apr 25	Jun 2	Jul 10	Sep 4	Oct 25	
	T4	Apr 26	May 26	Jun 23	Jul 28	Sep 24	Oct 25
Orchardgrass, S-143	T3	May 5	Jun 23	Aug 18	Oct 8	Oct 25	
	T4	May 5	Jun 2	Jul 1	Aug 18	Oct 8	Oct 25
Perennial ryegrass, Oregon	T3	Apr 25	Jun 11	Sep 4	Oct 25		
	T4	Apr 25	Jun 4	Aug 18	Oct 25		
Perennial ryegrass, S-23	T3	May 9	Jul 1	Oct 25			
	T4	May 9	Jun 23	Aug 18	Oct 25		
Reed canarygrass, ordinary	T3	May 7	Jul 7	Oct 25			
	T4	May 7	Jun 23	Oct 25			
Smooth bromegrass, Achenbach	T3	May 5	Jul 7	Oct 25			
	T4	May 5	Jun 23	Oct 25			
Timothy, ordinary	T3	May 9	Jul 1	Oct 8	Oct 25		
	T4	May 9	Jun 23	Oct 8	Oct 25		
Tall oatgrass, Tualatin	T3	Apr 25	Jun 11	Jul 20	Sep 24	Oct 25	
	T4	Apr 25	Jun 4	Jul 7	Sep 4	Oct 25	

Figure 4. Front view of the Scythette mower used for clipping the plots. Note the forage catching pan and the manner in which the wheels are mounted to facilitate adjustment of the mower bar height.

of the mower bar cutting height. When clipping, it was necessary to sweep the forage back from the mower bar into the pan, in the manner illustrated in Figure 5, in order to obtain a clean job of cutting.

All the clipped forage from each individual plot was placed in a cotton cloth bag and weighed immediately, as shown in Figures 6 and 7. Forage samples were then taken to a forced air drier and dried down to a point where they no longer lost weight. Final dry weights were immediately recorded for each particular plot.

Following harvesting of the plots, the borders of each plot were also clipped to the same stubble height as that of the harvested area and the resulting forage discarded.

Plot Management

During the summer of 1952 the plots were clipped for weed control, and in the fall of 1952 were sprayed with 1½ pounds of 2,4-D per acre for control of the broadleaf weeds. Adequate weed control was obtained. Plot borders were sterilized with a CMU chlorate-borate mixture in order to prevent the more aggressive species from spreading into adjacent plots. This technique also allowed for easy identification of plots as shown in Figure 1. All plots received uniform treatment in regard

Figure 5. The clipping operation, showing how the clipped forage was swept back from the mower bar into the pan. This technique prevented piling up of the clipped forage over the mower bar.

Figure 6. The bagging operation, in which all the clipped forage of a plot was placed in a cotton cloth bag for weighing purposes.

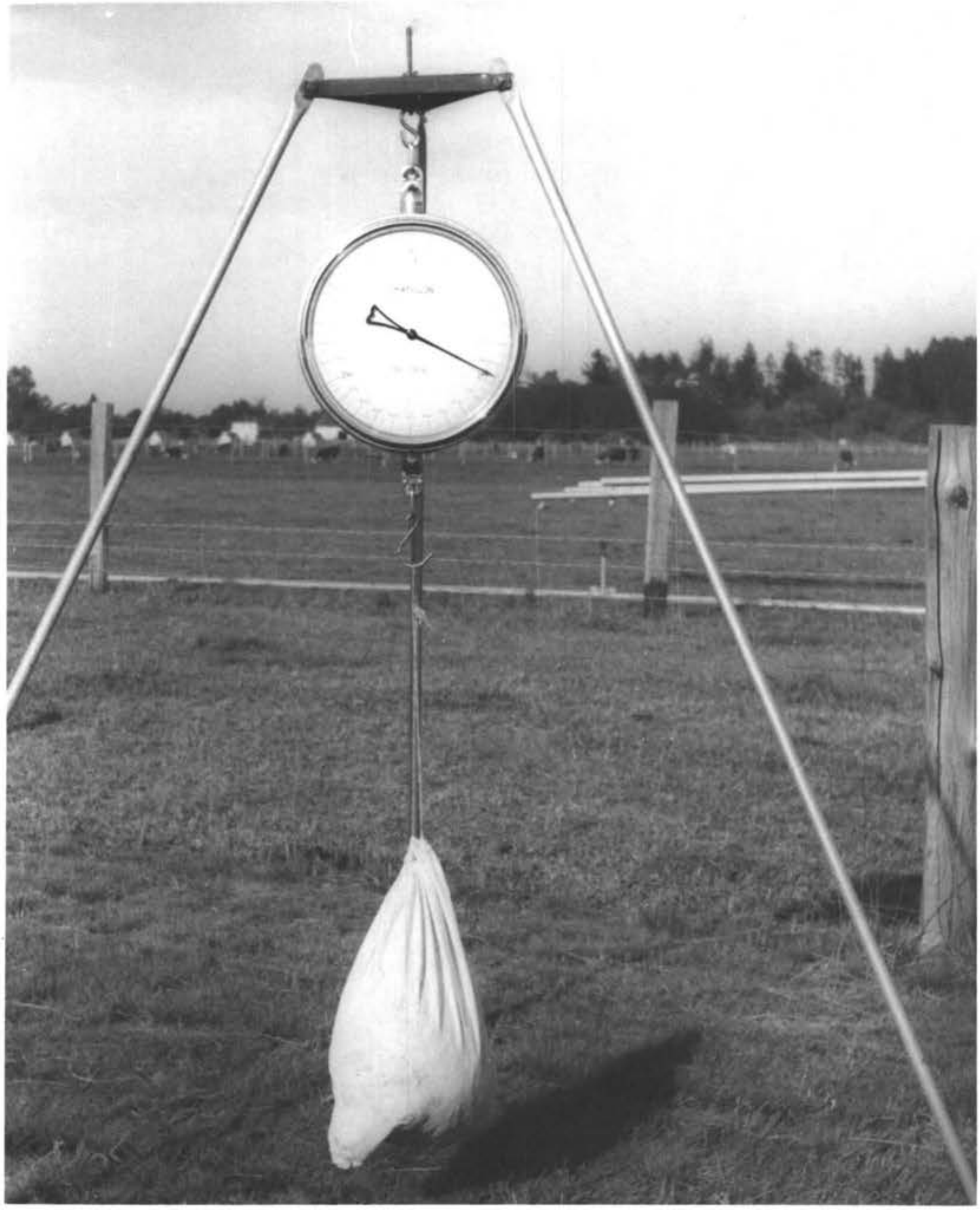

Figure 7. Weighing, in gram weight units, immediately following clipping the green forage from one plot.

to fertilization and irrigation. The dates of application and amounts of each for 1953 were as follows:

Fertilization:

Date	Pounds of Nitrogen per Acre	Kind of Fertilizer
March 27	80	$(NH_4)_2 SO_4$
May 30	40	$(NH_4)_2 SO_4$
July 17	45	$(NH_4)_2 SO_4$
August 25	40	$NH_4 NO_3$

Irrigation: (sprinkler irrigation was used)

Date	Inches of Water
June 27	3.00
July 17	2.13
July 27	3.00
August 10	3.00
September 17	3.50

EXPERIMENTAL RESULTS

Dry matter yields for the twelve grass species and strains harvested on a calendar date basis are presented in Tables 4 and 5 for the two-inch and four-inch mower bar heights, respectively. These data, along with the mean difference between treatments, are summarized in Table 7.

The analysis of variance of yields for the calendar date treatments, T_1 and T_2, is presented in Table 6. Statistical results indicate highly significant differences between replications, between species and strains, between clipping treatments, and between clipping dates. Significant interactions for clipping dates X species and strains, and for clipping dates X clipping treatments also are indicated. The clipping dates X species and strains interaction may be interpreted by the use of the growth curves in Figure 8. If, for example, Alta fescue and meadow foxtail are compared, it can be seen that the magnitude of yield difference on the various clipping dates was not the same. This is also the situation for the other grasses. The clipping date X clipping treatment interaction also shows that at the various clipping dates the yield responses of the various grasses to the two clipping treatments were not of the same magnitude.

Table 4 shows that Oregon 233 orchardgrass was the highest-yielding grass at the two-inch mower bar height,

Table 4. Dry matter yields for twelve grass species and strains according to clipping dates when harvested on a calendar date basis at a two-inch mower bar height (Treatment T_1).

Species and strains	Yield in grams for each clipping date								Total yield in grams, all dates
	April 25	May 21	June 19	July 15	Aug. 13	Sept. 8	Oct. 3	Oct. 25	
Tall fescue, Alta	546	176	271	103	147	151	52	31	1477
Meadow foxtail, ordinary	234	251	317	86	139	128	20	6	1181
Orchardgrass, Akaroa	473	158	294	103	225	194	30	9	1486
Orchardgrass, common	468	139	319	108	182	164	33	15	1428
Orchardgrass, Oregon 233	388	191	330	114	206	208	33	18	1488
Orchardgrass, S-143	385	210	333	96	214	191	36	15	1480
Perennial ryegrass, Oregon	401	148	148	25	76	80	17	12	907
Perennial ryegrass, S-23	219	214	194	28	85	101	29	16	886
Reed canarygrass, ordinary	245	166	250	77	238	141	35	18	1170
Smooth bromegrass, Achenbach	466	112	287	67	169	131	25	10	1267
Timothy, ordinary	296	195	205	42	150	132	18	10	1048
Tall oatgrass, Tualatin	400	75	407	50	294	125	53	31	1435
Total yield in grams, all species	4521	2035	3355	899	2125	1746	381	191	15253

Table 5. Dry matter yields for twelve grass species and strains according to clipping dates when harvested on a calendar date basis at a four-inch mower bar height (Treatment T_2).

Species and strains	Yield in grams for each clipping date: April 25	May 21	June 19	July 15	Aug. 13	Sept. 8	Oct. 3	Oct. 25	Total yield in grams, all dates
Tall fescue, Alta	421	171	220	117	149	169	78	36	1361
Meadow foxtail, ordinary	114	301	246	73	106	83	20	8	951
Orchardgrass, Akaroa	351	143	229	99	166	152	43	13	1196
Orchardgrass, common	339	177	234	83	179	135	51	14	1212
Orchardgrass, Oregon 233	227	211	261	113	173	188	53	22	1248
Orchardgrass, S-143	242	213	254	99	186	163	55	15	1227
Perennial ryegrass, Oregon	336	163	126	37	60	55	15	11	803
Perennial ryegrass, S-23	106	212	166	25	52	49	18	17	645
Reed canarygrass, ordinary	205	173	232	82	178	112	38	7	1027
Smooth bromegrass, Achenbach	269	186	218	84	121	91	31	11	1011
Timothy, ordinary	181	239	155	39	95	68	25	6	808
Tall oatgrass, Tualatin	364	85	362	83	224	121	57	20	1316
Total yield in grams, all species	3155	2274	2703	934	1689	1386	484	180	12805

Table 6. Analysis of variance of dry matter yields for calendar date treatments (T_1 and T_2) for twelve grass species and strains.

Variation due to:	Degrees of freedom	Mean square
Replications	3	24,528**
Species and strains	11	51,424**
Error (a)	33	2,481
Treatments	1	125,129**
Treatments X species and strains	11	1,047
Error (b)	36	4,442
Dates	7	1,057,556**
Dates X species and strains	77	18,967**
Dates X treatments	7	45,922**
Dates X treatments X species and strains	77	1,223
Error (c)	504	1,668
Total	767	

**Exceeds the 1% level of significance.

Table 7. Summary of total dry matter yields for twelve grass species and strains clipped on a calendar date basis at two-inch and four-inch mower bar heights (Treatments T_1 and T_2, respectively).

Species and strains	Total yield in grams according to mower bar height: 2 inches	4 inches	Average yield in grams 1/	Mean difference between treatments 2/
Tall fescue, Alta	1477	1361	1419	116*
Meadow foxtail, ordinary	1181	951	1066	230**
Orchardgrass, Akaroa	1486	1196	1341	290**
Orchardgrass, common	1428	1212	1320	216**
Orchardgrass, Oregon 233	1488	1248	1368	240**
Orchardgrass, S-143	1480	1227	1354	253**
Perennial ryegrass, Oregon	907	803	855	104*
Perennial ryegrass, S-23	886	645	766	241**
Reed canarygrass, ordinary	1170	1027	1099	143**
Smooth bromegrass, Achenbach	1265	1011	1138	254**
Timothy, ordinary	1048	808	928	240**
Tall oatgrass, Tualatin	1435	1316	1376	119*

1/ Least significant difference (.05) for average of treatments T_1 and T_2 is 144 grams.

2/ "t" test of the mean difference between treatments T_1 and T_2.

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

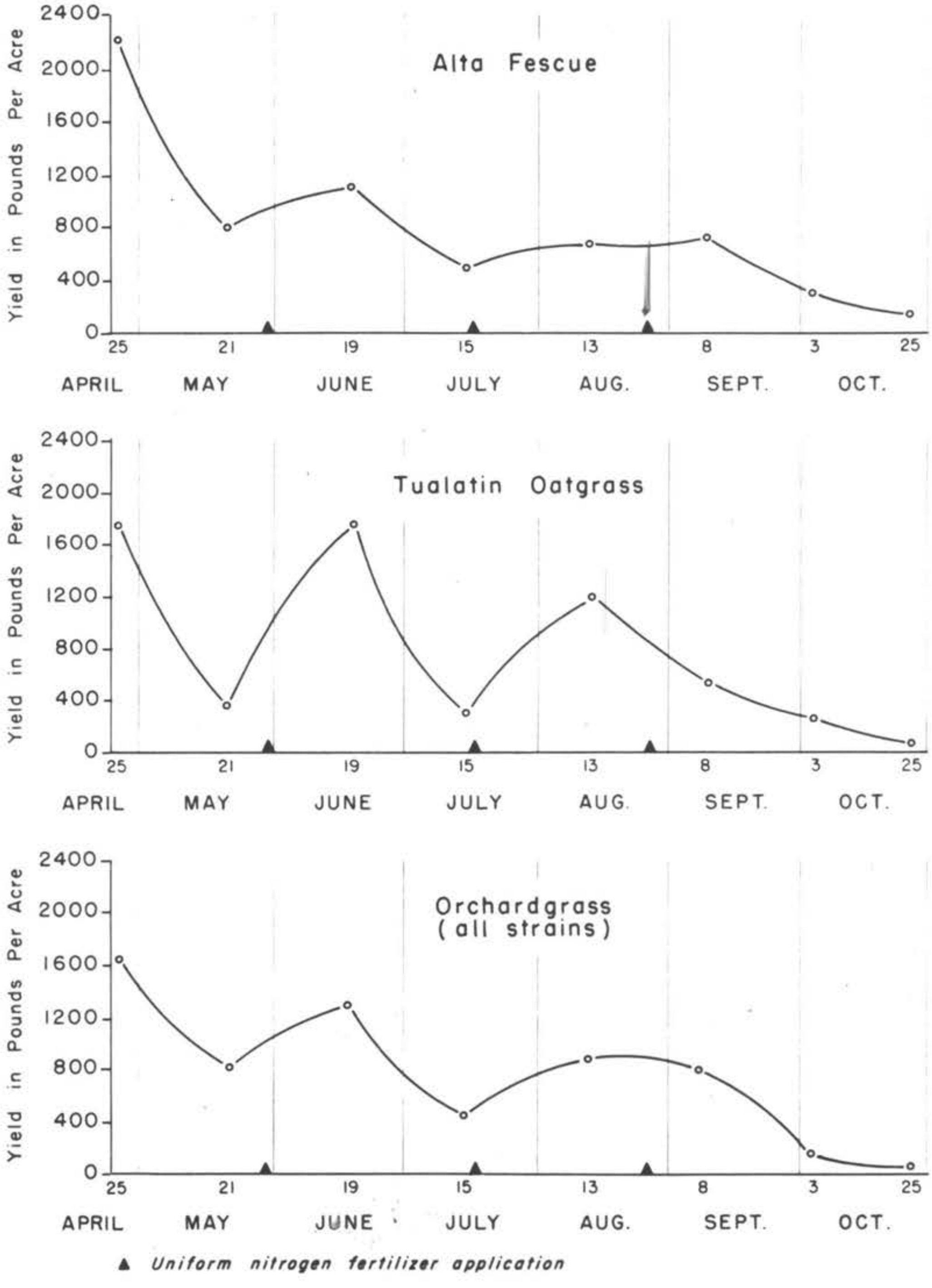

Figure 8. The seasonal growth curves for various grasses as determined by clipping on a calendar basis at a two- and four-inch mower bar height (treatments T_1 and T_2 combined) in 1953

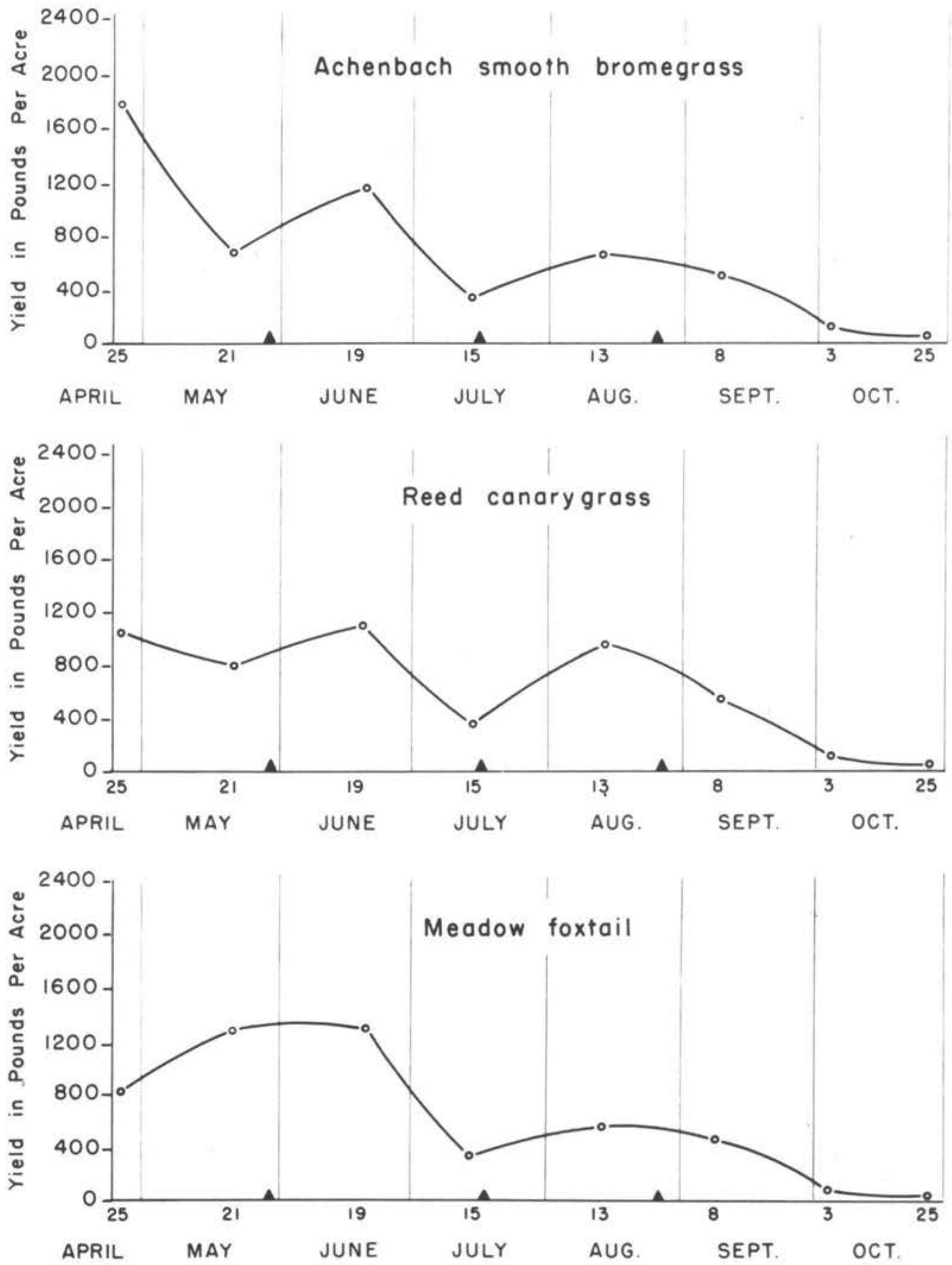

Figure 8 continued

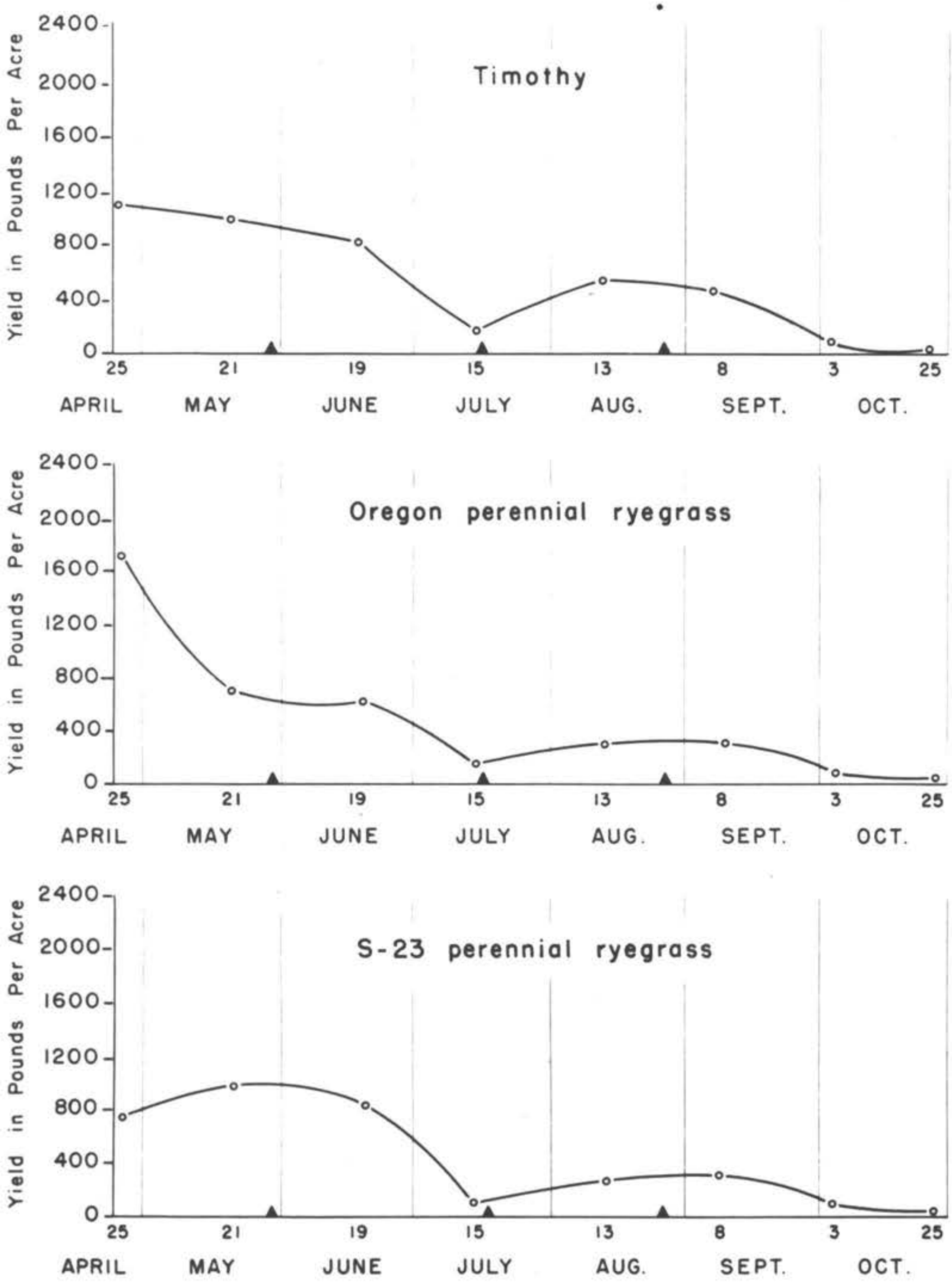

Figure 8 continued

followed closely by the other orchardgrass strains, Alta fescue, and Tualatin oatgrass. Alta fescue and Tualatin oatgrass were the highest-yielding grasses for the four-inch mower bar height treatment as shown in Table 5. The perennial ryegrass strains were the lowest-yielding grasses for the calendar date treatments at both the two-inch and four-inch mower bar heights. Total yields for each clipping date for both mower bar heights exhibited the same general trends of increases and decreases throughout the season. The highest seasonal yield of forage for all species and strains was produced by the two-inch clipping treatment; however, the total yield for all species and strains at the four-inch clipping height surpassed the yields of the two-inch treatment on May 21, July 15, and October 3.

The summary of the calendar date treatments in Table 7 shows that each of the twelve grasses produced significantly higher yields when clipped at the two-inch than when clipped at the four-inch mower bar height. Considering the average yield of the two clipping heights for the calendar date harvest, Alta fescue was the highest-yielding grass, whereas S-23 perennial ryegrass was the lowest-yielding.

The average harvesting heights for the calendar date treatments are presented in Appendix Tables 1 and 2.

Yields of the calendar date treatments were positively correlated with plant height. A correlation coefficient of .9604 was obtained when considering all grass species and strains.

Mean yield differences between calendar date treatments, as given in Table 7, showed wide fluctuation between species and strains. The low yield mean differences for Oregon perennial ryegrass, Alta fescue, and Tualatin oatgrass would indicate that these grasses were not as greatly influenced by differential mower bar cutting heights as were the nine other grasses. It would appear that Akaroa orchardgrass yields were most influenced by different cutting heights, as indicated by the large mean difference.

Yield data for the twelve grass species and strains when clipped on a growth stage basis at two-inch and four-inch mower bar heights are presented in Tables 8 and 9, respectively. It should be noted that frequency of clipping for the various grass species and strains varied between as well as within treatments, even though clippings were spread throughout the entire season. In general, more clippings were taken for the four-inch than for the two-inch mower bar height. Fewer clippings were made for the ryegrasses, Reed canarygrass, Achenbach smooth bromegrass, and timothy, than for the other grasses.

Table 8. Dry matter yields for twelve grass species and strains according to clipping numbers when harvested on a growth stage basis at a two-inch mower bar height (Treatment T_3).

Species and strains	Yield in grams for each clipping					Total yield in grams, all clippings
	1	2	3	4	5	
Tall fescue, Alta	598	330	593	545	96	2162
Meadow foxtail, ordinary	250	367	308	318	60	1303
Orchardgrass, Akaroa	489	244	389	483	63	1668
Orchardgrass, common	458	249	357	635	42	1741
Orchardgrass, Oregon 233	401	306	402	496	121	1726
Orchardgrass, S-143	618	522	572	432	52	2196
Perennial ryegrass, Oregon	396	440	440	77		1353
Perennial ryegrass, S-23	376	477	474			1327
Reed canarygrass, ordinary	496	710	591			1797
Smooth bromegrass Achenbach	714	625	468			1807
Timothy, ordinary	523	554	374	46		1497
Tall oatgrass, Tualatin	386	359	331	672	44	1792

Table 9. Dry matter yields for twelve grass species and strains according to clipping numbers when harvested on a growth stage basis at a four-inch mower bar height (Treatment T_4).

Species and strains	Yield in grams for each clipping 1	2	3	4	5	6	Total yield in grams, all clippings
Tall fescue, Alta	392	186	362	453	159		1552
Meadow foxtail, ordinary	127	328	268	162	83		968
Orchardgrass, Akaroa	411	187	327	389	248	64	1626
Orchardgrass, common	317	195	217	325	285		1339
Orchardgrass, Oregon 233	266	255	264	294	368	81	1528
Orchardgrass, S-143	388	178	275	341	186	51	1419
Perennial ryegrass, Oregon	300	294	199	165			958
Perennial ryegrass, S-23	263	433	100	185			981
Reed canarygrass, ordinary	288	453	480				1221
Smooth bromegrass, Achenbach	518	461	396				1375
Timothy, ordinary	350	452	181	25			1008
Tall oatgrass, Tualatin	326	230	467	528	50		1601

As shown in Table 8, S-143 orchardgrass was the highest-yielding and meadow foxtail the lowest-yielding of the twelve grasses when clipped at the two-inch mower bar height. When clipped at the four-inch mower bar height, Akaroa orchardgrass was the highest-yielding, whereas Oregon perennial ryegrass was the lowest yielding of the twelve grasses, as shown in Table 9. The average height at harvest at each clipping date for the growth stage treatments is presented in Appendix Tables 3 and 4.

The analysis of variance of the yields for all calendar date and growth stage treatments is presented in Table 10. The analysis indicates highly significant differences between replications, between species and strains, and between treatments. The interaction of treatments X species and strains was also significant; however, for the calendar date treatments this interaction was not significant. It would seem then that this interaction could be attributed to the influence of the growth stage treatments.

Considering all grass species and strains, all clipping treatment yields except T_1 (calendar date at the two-inch mower bar height) and T_4 (growth stage at the four-inch mower bar height) were significantly different from each other.

Yields in pounds per acre for all treatments used in

Table 10. Analysis of variance of dry matter yields for calendar date and growth stage treatments for twelve grass species and strains.

Variation due to:	Degrees of freedom		Mean square
Replications	3		617,325**
Species and strains	11		899,721**
Error (a)	33		38,031
Treatments	3		3,340,832**
T_1 vs. T_2		1	1,001,030**
T_1 vs. T_3		1	4,366,512**
T_1 vs. T_4		1	18,151
T_2 vs. T_3		1	9,548,925**
T_2 vs. T_4		1	1,288,762**
T_3 vs. T_4		1	3,821,622**
Treatment X species and strains	33		46,693**
Error (b)	108		16,899
Total	191		

**Exceeds the 1% level of significance.

this study are summarized in Table 11. The data show that grasses harvested on a growth stage basis yielded consistently higher for the two-inch than for the four-inch mower bar height. Based on the average yield of the two clipping heights for the growth stage treatments, Alta fescue was the highest-yielding, and meadow foxtail the lowest-yielding of the grasses used.

Considering all treatments for each of the grass species and strains, the growth stage clippings at the two-inch mower bar height gave the highest total yields and the calendar date clippings at the four-inch mower bar height gave the lowest total yields. The average yields of all treatments combined show that Alta fescue produced the highest yields. This would indicate that it possesses high yielding ability under a number of varying conditions. S-23 perennial ryegrass gave the lowest yield when considering the average of all treatments combined.

Figure 8 shows the seasonal growth trends for the various grasses based on the average yields of calendar date treatments, T_1 and T_2, combined. The yield data from which Figure 8 is derived are shown in Appendix Table 5. The yields of the orchardgrass strains were combined and the average used to represent this species.

The general trend for the grasses is from higher yields in the early part of the season to lower yields

Table 11. Summary of dry matter yields in pounds per acre for twelve grass species and strains clipped on a calendar date and growth stage basis at two mower bar heights.

Species and strains	Yield in pounds per acre for various treatments: Calendar date 2"	4"	Average 1/ T_1 & T_2	Growth stage 2"	4"	Average T_3 & T_4	Average yield, all treatments 2/
Tall fescue, Alta	6808	6274	6541	9966	7154	8560	7550
Meadow foxtail, ordinary	5444	4384	4914	6006	4462	5234	5075
Orchardgrass, Akaroa	6850	5513	6181	7689	7495	7592	6887
Orchardgrass, common	6582	5587	6085	8025	6172	7098	6592
Orchardgrass, Oregon 233	6859	5753	6306	7956	7043	7499	6905
Orchardgrass, S-143	6822	5656	6241	10122	6541	8331	7285
Perennial ryegrass, Oregon	4181	3701	3941	6237	4416	5326	4633
Perennial ryegrass, S-23	4084	2973	3531	6117	4522	5319	4425
Reed canarygrass, ordinary	5393	4734	5066	8283	5628	6955	6011
Smooth bromegrass, Achenbach	5831	4660	5246	8329	6338	7333	6292
Timothy, ordinary	4831	3724	4278	6900	4646	5773	5024
Tall oatgrass, Tualatin	6615	6066	6343	8260	7380	7820	7080
Average yield, all species	5858	4919		7824	5983		

1/ Least significant difference (.05) for treatment T_1 and T_2 average is 664 lbs.

2/ Least significant difference (.05) for average yield of all treatments is 650 lbs.

near the end. Meadow foxtail and S-23 perennial ryegrass were the only grasses which produced more forage in the second clipping on May 21 than in the first clipping on April 25. Tualatin oatgrass, meadow foxtail, and Reed canarygrass were the only grasses to produce their highest yield of the season in the third clipping on June 19.

Fertilization responses by the grasses were indicated mainly for the May and June applications. It appeared that Tualatin oatgrass was especially responsive to fertilization as noted by the extreme fluctuation in yield. Timothy, Oregon perennial ryegrass, and S-23 perennial ryegrass did not show a yield increase following the May application of fertilizer, while all other grasses did. All grasses gave a yield increase following the July fertilization, but generally to a lesser extent than for the May fertilization. Only Alta fescue and the two perennial ryegrasses gave any indication of yield increases following the August fertilization.

DISCUSSION

This research showed a significant difference in the yield performance of the twelve grass species and strains depending upon the basis of harvest and the closeness of cut at time of harvest. Both of these factors exerted an influence on these yield differences.

The experimental data indicate that higher yields can be expected from grass species and strains when harvested on a growth stage basis at the two-inch mower bar height, and lowest yields when harvested on a calendar date basis at the four-inch mower bar height. It should be pointed out, however, that these results are for one year only and that different relationships might be established if the experiment were continued. Whether or not the same results would be obtained over a long period of time is a matter of speculation.

If the growth stage and calendar date basis of harvesting are compared for a given mower bar height, then the experimental results indicate that the growth stage harvesting will give the highest yields. It is reasonable to expect this trend to continue over several clipping seasons based on the findings of other workers. It has been previously pointed out that fewer clippings were taken over the season for the growth stage than for the calendar date basis of harvesting. Work done by Carter and Law (4, pp.1084-1091), Wagner (28, pp.578-584), and Aldous (2, pp.752-759) all showed that frequent defoliation of grass will cause reduced top and root growth. This in turn would adversely affect the longevity and vigor of the various grasses. The effects of frequent defoliation may also show up in livestock production as a result of decreased forage yields. For example, Jones (13, pp. 159-170) found that rotationally grazed pastures with a four-week rest period gave greater increases in live weight of sheep and had a greater carrying capacity than pastures with either a two-week or four-day rest period.

The experimental results also indicate that the two-inch mower bar height could be expected to give the highest yields in any one clipping season for both methods of harvesting. Various workers, as previously referred to in the review of literature, have shown that low clipping heights, if continued over several years, reduce vigor and yields of certain forage grasses. The extent to which yields might be reduced, however, may depend upon the tolerance limit of a given species or strain to this kind of management. For example, at Pennsylvania State College it has been found that turf grasses, such as the bentgrasses, chewing fescue, or creeping red fescue, can survive frequent clipping to a height of 1 3/4 inches. Alta fescue, however, was killed if frequently clipped below a height of

2 1/4 inches.

There are several criticisms which can be directed toward both the growth stage and calendar date bases of harvesting.

The main criticism of the calendar date basis of harvest is the set interval of time between clippings. The 26-day interval which was used in this study appeared to be adequate during the first half of the clipping season, but inadequate for the last part of the season. As can be seen from Figure 8, there was much less regrowth between clippings in the last part of the clipping season. This is in agreement with Rappe (21, pp.309-338) who reported a natural lapse of production in grasses during midsummer as they prepared for their reproductive phase. He reported that this lag in plant growth took place irrespective of clipping treatment. Because of the slowing down of growth processes during the latter part of the harvest season, it seemed that it might have been more desirable to delay clipping until more growth was present. Lack of plant growth, and consequently a reduction in photosynthetic area, may prevent the replenishing of root reserves and subsequently affect the vigor of the grasses. The deleterious effects of this physiological phenomenon, if any, cannot be determined from this study.

The main criticism of the growth stage basis of harvesting is in the determination of the stage of plant development most desirable for pasturing. In this study, the height standards which seemed desirable in the first part of the season did not appear so as the season progressed. For example, some grasses such as meadow foxtail and the ryegrasses developed inflorescences without producing much leaf growth. Since these grasses were not harvested until the leaves attained the specified length, they may not have been in a stage of development most desirable for pasturing. Based on one season's observations, it appears that criteria should be developed which would assess proper plant growth stage more accurately than height alone. These criteria, whatever they may be, would have to be developed for each grass because of differences in seasonal production characteristics and variations in growth habits among grass species and strains.

The high correlation coefficient obtained for yields and heights for the calendar date treatments may have value in estimating yields based on plant height; however, this needs to be substantiated by further investigation.

In this study only quantity of forage was determined. Much would have been gained in evaluating the various treatments if chemical analyses of the forage samples had been conducted. This would have given a measurement of the quality of the forage in addition to the measurement of quantity of forage.

Based on the one season's results, it cannot be positively said that the growth stage or calendar date basis of harvesting is best. It would seem that both of these techniques have their place, not only in grass species and strains testing, but in other pasture studies as well. The choice of which technique is to be used in pasture research should depend upon the grazing management plan to be used ultimately in the field. If a calendar date grazing rotation is to be used, then the calendar date basis of harvesting should be employed in small plot clipping experiments. On the other hand, if forages are to be managed strictly on a growth stage basis in the grazing management plan, then the growth stage harvesting basis should be used to evaluate small plot experiments.

The calendar date and growth stage bases of harvesting may not necessarily be incompatible. Further study might result in the establishment of a variable calendar date basis of harvesting. This might be based on the growth stage which a particular grass could be expected to attain by a given date. Under such a technique, a clipping interval used at the start of the season could be lengthened or shortened to correspond with the growth rate for a particular grass as the season progressed.

This study has pointed out the need for additional research in the use of calendar date and growth stage bases of harvest. More attention should be given this problem by pasture research workers in the future.

SUMMARY AND CONCLUSIONS

The growth stage and the calendar date bases of harvesting were studied on established stands of twelve irrigated pasture grass species and strains grown on an Amity silt loam soil. The grasses were as follows: Alta fescue, meadow foxtail, Akaroa orchardgrass, common orchardgrass, Oregon 233 orchardgrass, S-143 orchardgrass, Oregon perennial ryegrass, S-23 perennial ryegrass, Reed canarygrass, Achenbach smooth bromegrass, timothy, and Tualatin oatgrass. Both the growth stage and calendar date bases of harvesting were clipped at two-inch and four-inch mower bar heights throughout the 1953 clipping season. The calendar date treatments were harvested at approximately 26-day intervals, whereas the growth stage treatments were harvested when each individual grass reached a height which was thought to represent a stage of plant development most desirable for pasturing.

All treatments were evaluated on the basis of the total dry matter yield of forage and analyzed by the analysis of variance. The principal results and conclusions of this study were as follows:

1. The growth stage basis of harvesting at the two-inch mower bar height produced the highest total yield based on the performance of all twelve grass species and strains combined.

2. The calendar date basis of harvesting at the four-inch mower bar height produced the lowest total yield based on the yield performance of all twelve grass species and strains combined.

3. The calendar date basis of harvesting at the two-inch mower bar height and the growth stage basis of harvesting at the four-inch mower bar height were intermediate in total yields, but not significantly different from each other.

4. The growth stage basis of harvesting produced the highest yields for a given mower bar height.

5. Fewer clippings were made for the growth stage than for the calendar date harvestings.

6. Each grass species and strain harvested on a calendar date basis produced significantly higher yields when clipped at the two-inch than when clipped at the four-inch mower bar height.

7. The outstanding grasses of this study based on yield performance for all treatments were Alta fescue, the four orchardgrass strains, and Tualatin oatgrass. The perennial ryegrass strains were consistently low in yielding ability for the various treatments.

8. Yields of the calendar date treatments were positively correlated with plant height. A correlation coefficient of .9604 was obtained for all grass species and

strains.

9. The selection of the harvesting basis to be used in small plot clipping experiments should depend on the ultimate grazing management practice to be used in the field.

10. With further study it might be possible to develop a variable calendar date basis of harvesting which would be comparable to the growth stage basis of harvesting.

11. Since this study was conducted for only one clipping season, the results obtained are only indicative and should not be used as the basis of major recommendations.

12. The use of the growth stage and calendar date bases of harvesting needs to be investigated further by pasture research workers in the future.

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APPENDIX

Appendix Table 1. Average height in centimeters of twelve grass species and strains for each clipping date when harvested on a calendar date basis at a two-inch mower bar height. 1/

Species and strains	Height in centimeters for each clipping date								Average height all dates
	April 25	May 21	June 19	July 15	Aug. 13	Sept. 8	Oct. 3	Oct. 25	
Tall fescue, Alta	65	46	41	33	29	29	23	16	35
Meadow foxtail, ordinary	28	33	40	25	23	22	14	10	24
Orchardgrass, Akaroa	59	42	45	35	34	34	20	14	35
Orchardgrass, common	56	42	48	36	33	31	21	15	35
Orchardgrass, Oregon 233	44	41	47	36	33	36	21	15	34
Orchardgrass, S-143	42	42	47	31	32	31	20	13	32
Perennial ryegrass, Oregon	55	32	25	15	19	21	17	14	25
Perennial ryegrass, S-23	30	30	27	14	17	20	15	13	21
Reed canarygrass, ordinary	46	34	36	22	29	29	16	12	28
Smooth bromegrass, Achenbach	49	31	39	21	24	27	20	13	28
Timothy, ordinary	38	38	31	18	23	25	16	11	25
Tall oatgrass, Tualatin	63	32	64	27	46	33	22	16	38

1/ Height based on the average distance from ground surface to longest blade tip.

Appendix Table 2. Average height in centimeters of twelve grass species and strains for each clipping date when harvested on a calendar date basis at a four-inch mower bar height. 1/

Species and strains	Height in centimeters for each clipping date								Average height all dates
	April 25	May 21	June 19	July 15	Aug. 13	Sept. 8	Oct. 3	Oct. 25	
Tall fescue, Alta	65	51	56	46	41	45	36	27	46
Meadow foxtail, ordinary	28	44	46	37	33	29	26	19	33
Orchardgrass, Akaroa	59	50	57	46	43	45	31	22	44
Orchardgrass, common	56	53	55	43	43	41	29	21	43
Orchardgrass, Oregon 233	44	52	60	50	45	47	32	25	44
Orchardgrass, S-143	42	50	57	44	40	43	32	21	41
Perennial ryegrass, Oregon	55	41	31	22	26	28	25	22	31
Perennial ryegrass, S-23	30	41	36	23	22	24	23	20	27
Reed canarygrass, ordinary	46	44	43	30	34	31	24	15	33
Smooth bromegrass, Achenbach	49	42	44	30	31	34	28	19	35
Timothy, ordinary	38	49	39	25	29	30	24	16	31
Tall oatgrass, Tualatin	63	43	67	44	49	42	28	23	45

1/ Height based on the average distance from ground surface to longest blade tip.

Appendix Table 3. Average height in centimeters of twelve grass species and strains for each clipping number when harvested on a growth stage basis at a two-inch mower bar height. 1/

Species and strains	Clipping number 1	2	3	4	5	Average height, all clippings
Tall fescue, Alta	65	54	55	56	19	50
Meadow foxtail, ordinary	28	45	39	32	14	32
Orchardgrass, Akaroa	59	52	53	54	20	48
Orchardgrass, common	56	52	52	53	18	46
Orchardgrass, Oregon 233	44	54	57	55	23	47
Orchardgrass, S-143	58	60	54	48	17	47
Perennial ryegrass, Oregon	55	49	28	17		37
Perennial ryegrass, S-23	42	37	27			35
Reed canarygrass, ordinary	56	60	42			53
Smooth bromegrass, Achenbach	61	59	40			53
Timothy, ordinary	55	56	36	14		40
Tall oatgrass, Tualatin	63	63	60	60	19	53

1/ Height based on the average distance from ground surface to longest blade tip.

Appendix Table 4. Average height in centimeters of twelve grass species and strains for each clipping number when harvested on a growth stage basis at a four-inch mower bar height. 1/

Species and strains	Clipping number 1	2	3	4	5	6	Average height, all clippings
Tall fescue, Alta	65	58	61	60	42		57
Meadow foxtail, ordinary	28	47	50	40	33		40
Orchardgrass, Akaroa	59	56	62	56	54	29	53
Orchardgrass, common	56	53	56	55	45		53
Orchardgrass, Oregon 233	44	56	57	59	60	34	52
Orchardgrass, S-143	58	56	58	58	48	27	51
Perennial ryegrass, Oregon	55	51	29	31			42
Perennial ryegrass, S-23	42	45	25	30			36
Reed canarygrass, ordinary	56	58	42				52
Smooth bromegrass Achenbach	61	59	41				54
Timothy, ordinary	55	56	35	21			42
Tall oatgrass, Tualatin	63	65	69	63	26		57

1/ Height based on the average distance from ground surface to longest blade tip.

Appendix Table 5. Average dry matter yields in pounds per acre according to clipping dates for twelve grass species and strains harvested on a calendar date basis at two mower bar heights.

	Average yield in pounds per acre for each clipping date							
Species and strains	April 25	May 21	June 19	July 15	Aug. 13	Sept. 8	Oct. 3	Oct. 25
Tall fescue, Alta	2226	797	1129	507	682	737	300	152
Meadow foxtail, ordinary	802	1272	1295	364	585	484	92	32
Orchardgrass, Akaroa	1899	691	1203	466	899	797	166	51
Orchardgrass, common	1858	728	1272	438	830	687	194	64
Orchardgrass, Oregon 233	1415	926	1360	521	871	913	198	92
Orchardgrass, S-143	1443	973	1351	447	922	816	207	69
Perennial ryegrass, Oregon	1696	714	631	143	313	309	74	51
Perennial ryegrass, S-23	747	982	830	120	313	346	106	51
Reed canarygrass, ordinary	1037	779	1111	364	959	581	166	55
Smooth bromegrass, Achenbach	1692	687	1162	346	668	512	129	46
Timothy, ordinary	1097	1000	830	184	562	461	97	37
Tall oatgrass, Tualatin	1761	369	1770	304	1194	567	254	115