ANNALES AGRICULTURAE FENNIAE
Maatalouden tutkimuskeskuksen aikakauskirja
1964 Supplementum 4 Vol. 3
Seria AGRICULTURA N. 17 — Sarja KASVINVILJELY n:o 17

THE EFFECT OF FREQUENCY AND HEIGHT OF CUTTING ON COCKSFOOT SWARDS

ERKKI HUOKUNA
Agricultural Research Centre, South Savo Agricultural Experiment Station
Mikkeli, Finland

Selostus:

Leikkuukertojen lukumäärän ja leikkuukorkeuden vaikutus koiranheinänurmiin

HELSINKI 1964

ANNALES AGRICULTURAE FENNIAE

Maatalouden tutkimuskeskuksen aikakauskirja
Journal of the Agricultural Research Centre

Ilmestyy 4—6 numeroa vuodessa; ajoittain lisänidoksia
Issued as 4—6 numbers yearly and occasional supplements

SARJAT — SERIES

Agrogeologia, -chimica et -physica
— Maaperä, lannoitus ja muokkaus
Agricultura — Kasvinviljely
Horticultura — Puutarhanviljely
Phytopathologia — Kasvitaudit
Animalia domestica — Kotieläimet
Animalia nocentia — Tuhoeläimet

JAKELU JA VAIHTOTILAUKSET
DISTRIBUTION AND EXCHANGE

Maatalouden tutkimuskeskus, kirjasto, Tikkurila
Agricultural Research Centre, Library, Tikkurila, Finland

A N N A L E S A G R I C U L T U R A E F E N N I A E
Maatalouden tutkimuskeskuksen aikakauskirja

1964 Supplementum 4 Vol. 3

Seria AGRICULTURA N. 17 — Sarja KASVINVILJELY n:o 17

THE EFFECT OF FREQUENCY AND HEIGHT OF CUTTING ON COCKSFOOT SWARDS

ERKKI HUOKUNA

Agricultural Research Centre, South Savo Agricultural Experiment Station, Mikkeli, Finland

Selostus: **Leikkuukertojen lukumäärän ja leikkuukorkeuden vaikutus koiranheinänurmiin**

To be presented, with the permission of the Faculty of Agriculture and Forestry of the University of Helsinki, for public criticism in Auditorium XII on December 9, 1964, at 12 o'clock.

HELSINKI 1964

HELSINKI 1964
KIRJAPAINO Oy VERSAL Ab

PREFACE

This study was carried out in the years 1954—62 as a part of the experimental program of the Agricultural Research Centre. The subject of the study was initially given by Mr. August Jäntti, Dr. of Agric. and Forestry, who directed the over-all pasture investigations embracing the present trials up to the year 1958. Also during the final phases of this work, Dr. Jäntti has given me useful advice, for which I wish to express my thanks.

During the various stages of this study, Professor Juhani Paatela, Dr. of Agric. and Forestry, has reviewed the experimental plan as well as the manuscript and has made valuable suggestions, for which I am very appreciative. Professors Onni Pohjakallio, Dr. of Agric. and Forestry, and Lauri Paloheimo, Dr. of Agric. and Forestry, have generously offered their assistance and have also kindly provided the use of equipment and other facilities of their departments. The sugar determinations in this study were performed under the direction of Miss Maija-Liisa Salo, Lic. of Agric. and Forestry. Mr. Erkki Kivi, Ph.Dr., read the manuscript and made noteworthy improvements in it. Mr. Jaakko Köylijärvi, M.Sc., and my wife, Mrs. Kirsti Huokuna, helped me in the statistical analyses of the material. I wish to extend my sincere thanks to all of these persons as well as to the many other employees and trainees of various institutions who have assisted in the performance of the trials.

I am also grateful to Mr. Edvin Risser, M.Sc., who translated the manuscript, and to Mrs. Jean Margaret Perttunen for linguistic revision of the translation.

This study was financed in part by grants from the August Johannes ja Aino Tiuran Maatalouden Tutkimussäätiö (August Johannes and Aino Tiura Agricultural Foundation), the Emil Aaltosen Säätiö (Emil Aaltonen Foundation) and the Suomen Kulttuurirahasto (Finnish Cultural Foundation). To these institutions I express my sincere appreciation.

Mikkeli, September 1, 1964.

Erkki Huokuna

CONTENTS

INTRODUCTION

The cultivation of cocksfoot (*Dactylis glomerata* L.) as the main grass species on leys used for grazing and silage did not start to become common in Finland until after 1950. Cocksfoot occurs as a wild grass species in all parts of Finland, but its cultivation has been rare. In the 1920's, when the first steps were taken to establish and manage pastures, it was recommended that cocksfoot seed be used in the mixture at the rate of 2 kilograms per hectare (JÄÄSKELÄINEN 1930). Such a low rate (the total seed rate being 40—42 kg) proved impracticable. The cocksfoot plants grew more vigorously than the other species, displacing them from the sward. In addition, being a rapidly-growing species, it soon became coarse, and since it is a less palatable grass than the other species, it often remained uneaten on the pasture. For this reason, farmers preferred not to use cocksfoot. JÄNTTI (1953) recommended the cultivation of cocksfoot in accordance with British experience. An extensive experimental programme was therefore set up in order to study the agronomic value of this plant. Field trials were begun at the University of Helsinki Experimental Farm Viik, at the State Agricultural School Farm Jokioinen Estate, and at the Pasture Experiment Station and the Department of Plant Husbandry of the Agricultural Research Centre.

These trials showed that cocksfoot was a valuable pasture plant when its seed rate was so high that it became the dominant species in the sward. Under such conditions the sward could be managed according to the specific requirements of this plant. Cocksfoot was found to thrive well on clay soils, for example in the extensive clay soil districts of South and Southwest Finland, where a drought-resistant grass was especially needed.

The cultivation of cocksfoot spread very rapidly, but in many cases there were difficulties in its utilization. Because it is a rapidly-growing species, cocksfoot readily forms stalks, which decrease its palatability and food value. It was recommended that close grazing should be avoided, since as a result erect grass species, including cocksfoot, often disappeared from the sward.

In order to study these problems, an intensity-of-defoliation trial on pasture was carried out at Jokioinen in the years 1954—56. There were three different grazing intensities tested: 3, 4, and 6 times during the course of the summer. The results of this trial showed that with a decrease in the number of grazing periods there was an increase in the dry matter yield. At the same time, the digestibility and protein content of the crop decreased and the fibre content rose. The highest fodder unit yield was obtained with four grazings. An appreciable decline in milk production occurred in the cattle on the paddock that was grazed six times; here the stand was very short (HUOKUNA 1960 a).

In the above-described grazing trial, it was not possible to include a sufficient number of different treatments to determine the effect of various grazing methods. Therefore a cutting trial was arranged at the same time and on the same pasture in order to establish the effect of two other factors, height of stand and level of cutting, upon the sward and its yield.

Even in the first year the results showed a divergence from the belief accepted at that time that cutting at high level — i.e. retaining a large amount of photosynthesizing leaf area — was the best method for ensuring the largest yields. The literature contained a few reports which agreed with those obtained in the above cutting trial. In view of various results the hypothesis was put forward that the effect of cutting height was possibly dependent upon the frequency of cutting. In order to test this hypothesis, different field trials were established, with the aim of testing all the effects of cutting height and frequency both upon the plant itself and also upon the quantity and quality of the yield. These studies were limited to leys consisting entirely or predominantly of cocksfoot and during its vegetative stage of growth.

EXPERIMENTAL MATERIAL AND METHODS

Trial localities and growing conditions

The field trials made in connexion with the present studies were carried out in three different localities. In the years 1954—56 trials were conducted at the Jokioinen Estate on a cocksfoot-dominated pasture sown in 1953. The sward was cut when the stand had reached a certain height. The purpose of this trial was to investigate the effect of cutting frequency and height of cut. In 1956 there were also two rate-of-growth experiments on the same pasture in order to test the afore-mentioned working hypothesis of these studies.

The second locality was the Viik Experimental Farm at Helsinki, where in 1957 a rate-of-growth trial was carried out and in 1958—59 a trial was conducted on the effect of nitrogen fertilization and height of cut upon the sward.

At the South Savo Agricultural Experiment Station at Mikkeli a trial was carried out in 1959 dealing with the effects of nitrogen fertilization, irrigation, and cutting frequency on pasture. In the years 1961—62 a trial on frequency

Table 1. Level of ground water, measured from soil surface (cm) at Jokioinen.

Date	1954	1955	1956
1.6.		85	109
15.6.		115	121
1.7.		121	125
15.7.	170	119	129
1.8.	147	134	139
15.8.	134	148	140
1.9.	130	162	139
15.9.	122	168	

and height of cutting was conducted, in which part of the pasture was cut at equal growth stages and part at equal time intervals.

The geographical situation of the trial areas was as follows:

Jokioinen	60° 50' N. lat.	23° 25' E. long.
Viik	60° 10' »	25° 00' »
Mikkeli	61° 40' »	27° 10' »

Soil type and condition

At Jokioinen the trials were situated on low-humus heavy or silty clay having a pH of 5.9 in water. The nutrient content of the 20-cm layer of topsoil was as follows: $CaCO_3$ 9 tons, phosphorus as superphosphate 180

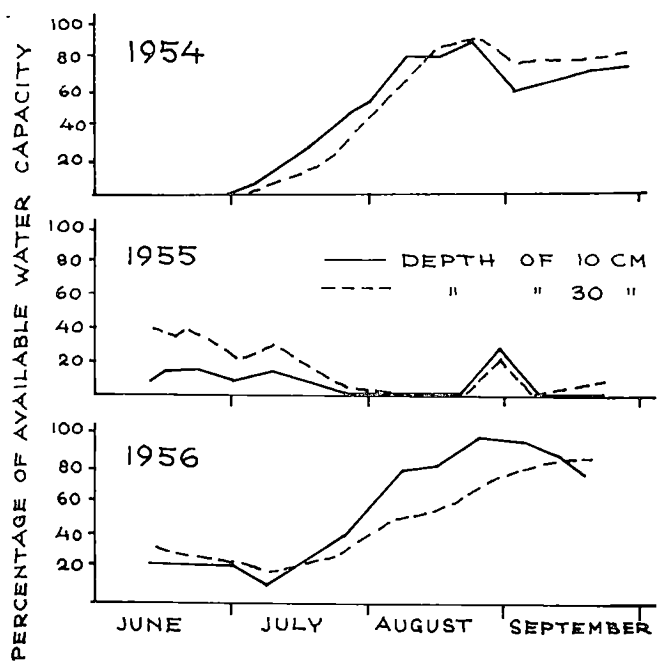

Fig. 1. Moisture content of topsoil on trial area at Jokioinen (percent of available water).

Table 2. Mean monthly temperatures and amounts of precipitation from April to September at Jokioinen 1954—56, Viik 1957—58 and Mikkeli 1959 and 1961—62.

Month	Mean temp. (C°) and dev. from normal		Precipitation (mm) and dev. from normal		Mean temp. (C°) and dev. from normal		Precipitation (mm) and dev. from normal	
	Jokioinen 1954				Jokioinen 1955			
IV	+1.3	—0.9	27	— 5	—1.8	—4.0	24	— 8
V	11.7	+2.7	11	—30	5.8	—3.2	74	+33
VI	12.8	—0.5	26	—20	12.1	—1.2	30	—16
VII	15.9	—0.7	108	+31	17.4	+1.2	17	—60
VIII	14.1	—0.5	108	+29	17.1	+2.5	19	—60
IX	9.7	+0.1	118	+48	12.4	+2.8	47	—23
	Jokioinen 1956				Viik 1957			
IV	—0.1	—2.3	46	+14	+1.1	—1.8	17	—24
V	8.9	—0.1	18	—23	8.9	—0.3	55	+ 8
VI	15.5	+2.2	62	+16	12.8	—1.3	63	+14
VII	15.0	—1.6	60	—17	18.1	+0.3	72	— 5
VIII	11.7	—2.9	112	+33	15.5	—0.8	112	+29
IX	7.7	—1.9	27	—43	9.4	—2.1	102	+29
	Viik 1958				Mikkeli 1959			
IV	+0.3	—2.6	16	—25	+2.5	+0.6	46	+12
V	8.3	—1.0	70	+23	9.6	+0.6	43	—25
VI	14.0	—0.1	13	—36	15.8	+2.2	23	—41
VII	15.6	—2.3	89	+22	18.0	+1.1	52	—12
VIII	14.4	—1.9	58	—25	15.8	+1.2	145	+73
IX	9.7	—1.8	32	—41	6.9	—2.5	45	—17
	Mikkeli 1961				Mikkeli 1962			
IV	+0.5	—1.2	17	—17	+3.9	+2.0	36	+ 2
V	9.3	+0.3	41	— 7	8.2	—0.8	56	+ 8
VI	16.4	+2.8	68	+ 4	11.6	—2.0	51	—13
VII	15.7	—1.2	73	+ 9	13.8	—3.1	83	+19
VIII	13.4	—1.2	153	+81	11.7	—2.9	98	+16
IX	8.1	—1.3	36	—32	8.4	—1.0	108	+40

kg/ha, and potassium as 40 % KCl 950 kg/ha. At Viik the soil type was very fine sand, the pH 5.8, and the topsoil nutrients 10.2, 280 and 1100 respectively. At Mikkeli the soil type was fine sand, the pH 6.0, and the nutrients 7.5, 90 and 970.

At all three locations the trial fields were in good condition. Annual mineral fertilization consisted of 120 kg/ha N, 60 kg/ha P_2O_5 and 50 kg/ha K_2O. Phosphorus and potassium were applied together once in the spring, while nitrogen was given as three equal-sized applications in May, June and July. Although the kind of fertilizer varied somewhat at the different places, the amounts of the elements applied were the same.

Level of ground water at Jokioinen

At Jokioinen the level of the ground water was determined by means of a measuring tube extending 2 metres into the soil. The measurements (Table 1)

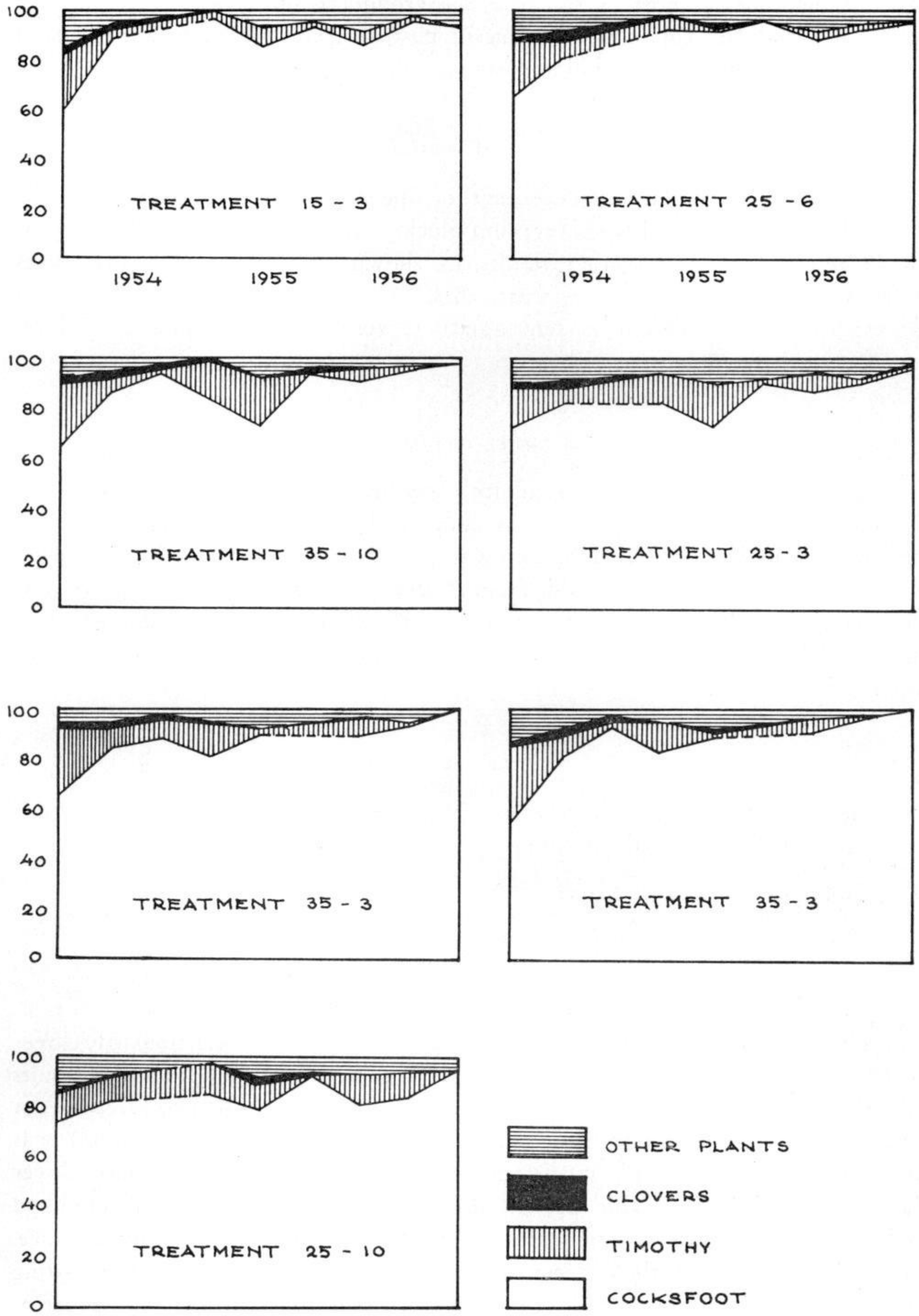

Fig. 2. Botanical composition of trial swards at Jokioinen.

showed that during most of the time the ground water level varied between about 120 and 160 cm. On the adjacent pasture trial area four tubes showed similar fluctuations and a similar mean ground water level.

Moisture content of topsoil at Jokioinen

At Jokioinen the moisture content of the topsoil was measured by the method of BOUYOUCOS (1954). Gypsum blocks were placed in the soil at depths of 10 and 30 cm. The average results are shown in Figure 1. No differences were found between the various treatments.

At Viik and at Mikkeli no determinations were made of ground water level or moisture content of the soil.

Weather conditions

In Table 2 are presented the monthly precipitation and mean temperatures in different years in the three areas concerned. During the trials, both wet and dry periods occurred. Drought was prevalent in 1955 and 1959, during which time the plants suffered from water shortage. The year 1962 was characterized by heavy rainfall and low temperatures during the growing season. The other years were close to normal, short rainy and dry periods occurred.

Trial swards

The trial field at Jokioinen was established as pasture in 1953 by broadcasting the following seed mixture:

red clover (local strain)	5.0	kg/ha
white clover (Nora)	1.5	»
timothy (local strain)	15.0	»
cocksfoot (Daeno II)	15.0	»
total	36.5	»

With the exception of the first spring harvest, the proportions of clover and timothy in the yields were very low (Fig. 2, p. 11), and thus the results of this trial are also included in the present study as representing a cocksfoot trial. At Viik a field consisting only of cocksfoot (variety: Trifolium) was drill-sown with a 15-cm row distance in 1956. However, wild white clover later appeared in it (Table 28, p. 66). At Mikkeli the trial field contained only cocksfoot of the variety Daeno II drill-sown with a 15-cm rov distance. At Jokioinen and Viik the experiments were begun in the first year after sowing and at Mikkeli in the second year. All the fields were sown with a cereal nurse crop. In each case they became well established and produced a dense, closed stand.

The trial plots were situated in the most uniform places in the fields according to the block or split plot methods (Mudra 1952). The plot size was 1×5 metres at Jokioinen and 1×3 at Viik, and the plots were separated by a border strip 30—40 cm wide. At Mikkeli the plots were 0.7×2 m in size, but the actual yield-sampling plots measured 0.5×0.5 m. The number of replicates was 5 at Jokioinen and 4 at Mikkeli and Viik. At Jokioinen and Viik the swards were cut with a mower having a blade 1 m in length and provided with various foot plates for regulating the height of the cut. At Mikkeli cutting was done with scissors.

The fresh yield of each plot was weighed on the field immediately after cutting, and from each treatment a representative sample was taken and chopped. Two 150-gram subsamples were taken from the chopped grass and dried in a drying oven at 100° C. The dried samples were subsequently analysed for crude protein and fibre either at the Department of Animal Husbandry of the University of Helsinki or at the State Agricultural Chemical Laboratory. Crude protein was determined by the Kjeldahl method and fibre by a modification of the Weende method (Puranen and Tomula 1930).

Root investigations were performed at Jokioinen by the method of Salonen (1949). At Viik and Mikkeli root studies were made by digging up at random points along the rows blocks of soil measuring 10×35 cm and extending to a depth of 40 cm. The earth was carefully removed by washing and the root samples dried as rapidly as possible at 60° C in a drying oven provided with a fan. Samples consisting of the basal parts of the shoots were also dried at the same temperature. Sugar analyses were made at the Department of Animal Husbandry of the University of Helsinki. Reducing sugars were determined by the method of Somogyi (1945), and in addition fructose was determined separately by the colorimetric method of Arni and Percival (1951).

The vigour of the plants was investigated by growing pieces of sod (25 cm square, 15 cm thick, 3 replicates arranged by the block method) in the dark at 20—25° C. The plants formed new leaves, but after having exhausted their food reserves, they died. The length of time during which the individual shoots remained alive was taken as the criterion of vigour.

The botanical composition of the harvest was determined on a fresh weight basis from the cut samples.

The leaf area was measured by the method described by Brougham (1956). From plots 25×25 cm in size selected randomly on the sward, the grass was cut with a knife at ground level; two or three such plots were used for each treatment. The foliage was separated into three categories. The first consisted of dead leaves. The second comprised the actual leaves, which were obtained by cutting the mature leaves at the base of their blade; in addition, the upper, fully mature part of the leaves still partly enclosed in the sheaths was cut at the point of the sheath. The remaining part of the plant, consisting of the yellowish or pale greenish basal portions, comprised the third category and will be termed the stem base in this study.

The leaf area was determined by taking 40 mature leaves over 10 cm in length and severing their ends so that a 10-cm central portion remained. The width of the centre part of the blade was measured, and from this the leaf area could be calculated. Only one of the two surfaces of the blade has been taken into consideration. Both the measured 10-cm sections as well as the cut ends were dried and weighed, and the total leaf area was thus determined. The leaf area index (LAI) is a figure expressing the leaf area in comparison to the ground surface area occupied by the plants in question. These same samples were also used for tiller counts.

The lay-out of the trials and the analyses of variance were made according to MUDRA (1952) and the regression calculations according to BONNIER and TEDIN (1940) and QUENOUILLE (1950).

THE EFFECT OF CUTTING ON COCKSFOOT SWARDS

Number of tillers

Very few studies have been made on the density of tillers of cocksfoot. It appears, however, that the response of cocksfoot to various cutting treatments is similar to that of other pasture grasses, such as ryegrass (*Lolium*) and brome grass (*Bromus*).

The formation of new tillers is not dependent upon the time of the year, but occurs continually (LANGER 1957). The process appears to be easily disturbed by defoliation. For example, SCOTT (1957) found that cutting resulted in complete cessation of tillering for some time and that not until five weeks later did it regain the tillering rate of the uncut controls. In his studies certain South African grass species were used. ALBERDA (1957) tested *Lolium perenne* in pot trials and observed that each cutting delayed the formation of tillers for a period of 4 to 5 weeks. In addition, some of the plants died. After five weeks the number of tillers again increased, and in the fifth and sixth weeks tillering was more rapid in the cut than in the uncut plants.

Using spaced plants of English ryegrass, BAKER (1957 a) found that 3 or 4 clippings a year considerably reduced the numbers of tillers as compared with the unclipped controls. ALBERDA (1957) mentioned that those factors which stimulate leaf growth also deplete the food reserves in the plant and thus retard other growth processes such as root development and tillering.

Conflicting results have been obtained from field trials. In studies on the influence of intensity of grazing on sward density, JONES (1939) established that the greatest density of cocksfoot occurred on ungrazed pasture. If this density was taken as 100, that of lightly-grazed pasture was 70 and after heavy grazing only 60. On the other hand, BAKER (1957 b) observed that there were more plants and tillers on fields which had been cut 3—4 times the previous summer than on uncut fields. BARKER *et al.* (1957) mentioned that frequent defoliation stimulated tillering, and that despite close grazing the basal storage organs of cocksfoot remained intact, thus allowing rapid recovery growth and renewal of photosynthetic activity. In studies using several different grass species, CARTER and LAW (1948) found only small differences in number of tillers between fields cut at 15- and at 30-day intervals. According to KYDD (1957), cocksfoot under intense grazing is induced to tiller, especially in the early spring, but in such cases tillering reduces the vigour of the plant.

In 1957, a cutting trial on cocksfoot was performed at Viik with the aim of determining the rapidity of growth of swards cut at different heights. The trial area was cut in the middle of July to 3, 6 and 10 cm. On August 9 the swards were cut again at the same heights. Immediately afterwards calcium nitrate at 200 kg/ha was applied to the swards. Rain fell shortly thereafter, and as a result growth was rapid. Five days after the second cut, observations were made on the numbers of tillers and the extent of their growth (Table 3). In spite of the favourable conditions, the growth of the cocksfoot was rather uneven.

Table 3 shows that in this trial about 60—70 % of the tillers immediately began to form a new leaf which grew at a rate of about 2 cm per day. The leaf growth of 5—9 % of the tillers was somewhat slower, amounting to only 1—2 cm within five days. 6—10 % of the tillers failed to renew growth and they gradually withered and died.

Newly-formed tillers which had grown so tall that they were cut by the mower blade, amounted to 16 % in the 3-cm stubble and 22 % in the 6-cm stubble, but were not found at all in the sward cut at 10 cm. Only 5—9 % of the new tillers were so short that their tips did not extend to the cutting level.

The height of cutting had only a slight influence on the elongation growth of the leaves. No difference was found between the 6-cm and 10-cm stubbles, whereas the growth of the sward cut to 3 cm was slightly slower. The height of cutting had no effect on the numbers of tillers continuing growth. However, the numbers of new tillers showed pronounced differences;

Table 3. Tiller number and growth of cocksfoot leaves in cutting trial at Viik 1957.

	Height of stubble cm		
	2–4	5–7	9–10
Number of tillers per m²	1710	2050	1650
Percentage of old tillers, leaf growth 6—12 cm	64	56	76
—»— —»— 1—2 cm	5	5	9
—»— no growth	10	8	6
Percentage of new tillers, leaves severed	16	22	0
—»— —»— intact	5	9	9

Table 4. Numbers of cocksfoot tillers per m² in cutting trial at Mikkeli 1961—62.

	Height of cut cm	No. of cuts	Number of tillers per m²: September 1961, Living	September 1961, Dead	September 1961, Total	June 1962	September 1962 Living
		0	2240± 128	—	2240± 128		
A	20	12	2320± 64	—	2320± 64	2016	1872± 200
	20	5	1584± 280	176± 56	1760± 224		1488± 344
B	10	12	1792± 64	352± 48	2144± 16		
	10	6	1888± 432	272± 8	2160± 424	2208	1488± 56
	10	4	1696± 152	432± 16	2128± 168		1696± 208
C	5	12	1744± 256	480± 48	2224± 304		
	5	5	1648± 224	320± 36	1968± 188	2272	1392± 240
	5	4	1712± 80	544± 40	2256± 120		1360± 152
D	0	7	352± 28	—	352± 28		
	0	4	1632± 48	—	1632± 48		
	0	2	1728± 272	—	1728± 272		
E	5	10	1696± 288	1072± 96	2768± 192		
	5	8	1376± 24	944± 16	2320± 40		1370± 120
	5	4	1808± 168	304± 40	2112± 128		1328± 144
F	0	8	192± 80	—	192± 80		
	0	4	1216± 232	—	1216± 232		
	0	2	1744± 488	48± 16	1792± 520		

C and D were cut when they had reached equal heights,
E and F at equal intervals of time.

they were fewest when the sward was cut to 10 cm (140 per m²), intermediate at the 3-cm level (350) and greatest when cutting was done at 6 cm (620 per m²). For this reason the total number of tillers was highest in the plots cut to 6 cm. Tillers which failed to renew growth were least numerous in the 10-cm stubble, but the differences between the three cuts were only slight.

At Jokioinen the tiller density of the trial swards was counted at the end of the 3-year experimental period. The numbers of tillers ranged from 992 to 1 472 per square metre, with no statistically significant differences between the various treatments (F-value = 1.25°).

In the cutting trial at Mikkeli, tiller counts were made in September 1961, and also in June and September 1962 on those plots where the cutting treatments were continued. In these latter plots the cocksfoot had been subjected to a definite cutting treatment during the entire growing season. The observations were made on two random spots 25×25 cm in area.

Table 4 shows the results of this trial and gives means of two parallel sets of observations. Since the tiller counts were only general approximations, no conclusions can be drawn on the basis of the small differences that appear. At the beginning of the trial period the tiller density was about 2 000 per m². In the swards cut at levels of 5 cm or higher, no appreciable changes in tiller density were visible during the first summer. On the other hand, in the swards cut at ground level 7—8 times during the summer, the number of tillers was reduced to $^1/_6$ — $^1/_{10}$ of the initial density. The decrease in tiller number was less when cutting was less frequent. Large numbers of dead tillers were found in the swards cut at 5 and 10 cm.

During the winter and spring no noteworthy changes occurred in tiller density. However, during the course of the following cool, rainy summer, when cuttings at 5, 10 and 20 cm were made simultaneously, a reduction in tiller density was observed in the sward cut at 5 cm.

The studies made on stands of pure cocksfoot at Viik and Mikkeli showed that the frequency and height of cutting have only a slight effect on tiller density, providing that the cutting is not made closer than 3 cm. In swards cut at ground level, there was a pronounced effect of cutting frequency. The swards cut two and four times during the summer were affected only slightly, but those cut 7—8 times were greatly weakened.

The conflicting reports in the literature concerning the effect of cutting on tiller density are only apparent. Although it is true that cutting weakens tiller formation in the individual grass plants, the actual situation on the sward is different, since there the competition between adjacent plants is a much more powerful factor preventing tiller formation. This is especially true in tall stands, where shading may have a decisive effect. ALBERDA (1956), for example, found that under conditions of weak light, new tillers rapidly died. At Mikkeli it was found that the tiller density in uncut swards increased during the summer, but that in the following spring when new growth was beginning, about 60 % of the young tillers died, evidently as a result of shading caused by the uncut growth from the previous year. In the moderately-cut swards, on the other hand, the corresponding figure was only 10—25 %.

Abundant tillering is not always essential for high yields. ALBERDA (1957) found that although the tillering recovery time of ryegrass was as much as 5 weeks, cutting four times at intervals of 3 weeks resulted in no diminution of yield. With cocksfoot such three-week defoliation could be continued for two years without reduction in yield. In the trial at Mikkeli, the treatment consisting of six cuts corresponded approximately to three-week intervals, and no decrease in numbers of tillers occurred if a stubble of at least 5 cm was left. As the old tillers died, new ones appeared. This result agrees with the observations of CARTER and LAW (1948).

The absence of detrimental effects due to such cutting is demonstrated by the fact that the dry-matter yields in these trials were even slightly greater than those obtained in other trials on cocksfoot-dominant leys (JÄNTTI 1953 b; SAARINEN and JÄNTTI 1955).

The decrease in density of pasture swards in actual grazing practice may be due to excessively close defoliation, but may also be a result of the same plants being severed on several successive days. In this case, even though the stubble remaining is relatively long, more damage to the plant is caused than by the single, close defoliation of mowing. This may also be the reason for the weakening in vigour of the grazed pasture in the trials of JONES (1939).

The results of the present trials, like those of previous investigations (e.g. BAKER 1957a), show that the frequency of cutting (1—12 times during the growing season) and the height of cutting (3—20 cm) have only a relatively small effect on the tiller density of cocksfoot swards. Three or four cuts during the growing season appeared to stimulate tillering and to increase the density of the sward in comparison with a single cut.

Storage organs and vitality of plants

Root system

The functions of the root system in grasses, as in other plants, are to anchor the plant to the soil and to absorb water and water-soluble nutrients from the soil. In addition, the root system also serves as a storage organ for food reserves. In many grass species stolons and rhizomes likewise function as storage organs. Many studies have shown that various cutting treatments have a marked influence on the volume and weight of the roots.

Frequency of defoliation

SCOTT (1957), in his studies on certain South African grass species, found that cutting to a height of $1/2''$ caused a complete cessation of root growth for 24 hours. The roots, which were originally white, became yellow and the root hairs disappeared. The old roots failed to continue their elongation growth, and only after the passage of a certain period of time did new roots begin to grow from the base of the severed stem. The length of time during which there was no root growth varied according to the species and was found to increase when cutting was repeated. ALBERDA (1957) observed that when plants of English ryegrass were clipped, the roots did not grow for four weeks. Since the roots of unclipped grass continue their normal growth, repeated defoliation generally results in a decrease in the size of the root system.

The literature on this subject contains only a few reports where cutting had no effect on the root system of grasses. In his studies on *Lolium perenne*, BAKER (1957b) found that the total root weight was about the same in uncut swards and in swards cut 1—4 times. In cutting trials with *Cynodon dactylon* in South Africa, WEINMANN (1948) established that three cuttings a week during the entire summer caused no appreciable decrease in the size of the root system. When the frequency of cutting was increased still further, the root system was weakened in most cases.

The effect of the cutting interval on the roots is clearly seen from the results of LOVVORN (1945), which are mean values for many grass species:

cut every	10	days, root	weight	0.49	g/pot
»	20	»	»	1.04	»
»	30	»	»	1.68	»
»	60	»	»	4.79	»

Cutting grass plants when they are very young has an especially pronounced effect. GRABER (1931), for instance, found that the root weight of young grass plants cut seven times was only $^1/_8$ to $^1/_{18}$ that of the controls.

The effect of cutting treatment on the roots may be as much as twice as great as its effect on the yield of the aerial parts of the plants (ROBERTSON 1933). GERNERT (1936) found that in certain grass species even one cutting diminished the weight of the roots as compared with the uncut controls. Diverging results were obtained by KLAPP (1942), however, in his studies on cocksfoot. He found that the largest root system in first-year leys occurred when the stand had been cut once, while in second-year leys two cuts resulted in the heaviest root system. In all species, when the number of cuttings increased beyond three, the yields of both the above-ground and the underground parts showed a steady decrease. Within certain limits, a similar effect was caused by the amount of herbage at the time of cutting, the cutting interval, and the cutting frequency. These factors are related in such a manner that as the cutting frequency is decreased and the interval consequently increased, the amount of herbage is greater and there is a resultant increase in the size of the root system and the amount of food reserves. CARTER and LAW (1948) studied awnless brome grass (*Bromus inermis*) when it was cut at intervals of 15 and 30 days and also at the hay stage. The size of root system increased very markedly as the cutting interval increased; the root weights were 8.3, 16.2 and 92.0 grams per pot. The corresponding leaf yields were 20.6, 21.2 and 36.0 g. BAKER (1957 a) investigated the effect of cutting frequency on spaced plants of *Lolium perenne* and obtained the following results (in grams per plant):

No. of cuts	0	1	2	3	4
Weight of herbage	13.1	10.6	8.1	7.3	5.8
» roots	10.2	8.0	6.3	4.6	6.0

The effect of cutting was thus similar on both the above-ground and the underground parts of the plants.

KLAPP (1937) studied the effect of number of cuttings on the weight of cocksfoot roots. The relative weights were as follows:

4	cuts rel. root	weight	100
3	»	»	129
2	»	»	228
1	»	»	294

Table 5. Effect of differential cutting on mean leaf area and roots of cocksfoot. First harvest year, Mikkeli 1961.

	Height of cut cm	No. of cuts	Mean leaf area (LAI)	Root weight g/m² in summer	Root weight g/m² in autumn
Cut at equal stages		0	5.65		497
	20	12	2.50	323	291
	20	5	2.73	235	345
	10	12	1.60	221	277
	10	6	1.89	306	300
	10	4	2.19	262	332
	5	12	1.14	242	230
	5	5	1.76	283	240
	5	4	2.38	186	323
	0	7	0.29	169	57
	0	4	0.83	199	186
	0	2	1.64		332
Cut at equal intervals	5	10	1.28		156
	5	8	1.45		142
	5	4	2.41	325	242
	0	8	0.28	118	81
	0	4	1.54	230	167
	0	2	3.40	510	231
F-value					20.1***
L.S.D. 95 %					92
» 99 %					121
» 99.9 %					156

TORSTENSSON (1938) carried out investigations with *Lolium multiflorum* and *Festuca pratensis* and came to the conclusion that when the plants were cut at 5 cm, there was no difference in root weight between cutting intervals of 10 and 15 days, but that when the cutting level was 2 cm, the longer interval resulted in a greater root weight.

A general rule in the case of all grass species appears to be that the less frequently the cuttings are made, the larger is the amount of both root system and top growth (LOVVORN 1944; KENNEDY and RUSSEL 1948; ALBERTSON *et al.* 1953; KLAPP and SCHULZE 1957).

In the present studies root samples were taken to a depth of 40 cm at Mikkeli in 1961. In the middle of the summer, samples were taken from only some of the treatments but in the middle of September from all of them. The largest root system was found in the plot which had not been cut during the entire summer (Table 5).

With cutting at 5 cm or higher, slightly greater weights of roots were formed when the cutting frequency (ranging from 12 to 4) was low, but this tendency was very distinct when the sward was cut at ground level. The only statistically significant correlation was between mean leaf area and root weight (F-value = 33.40***). The coefficient of correlation was +0.823.

Table 6. Effect of differential cutting on mean leaf area and roots of cocksfoot. Second harvest year, Mikkeli 1962.

Height of cut cm	No. of cuts	Mean leaf area (LAI)	Root weight g/m²
20	4	4.35	527
20	2	4.63	260
10	4	2.58	461
10	2	4.05	267
5	4	2.10	320
5	2	3.33	263
*) 5	4	2.05	212
*) 5	2	3.60	237
F-value			12,5***
L.S.D. 95 %			99
» 99 %			137
» 99.9 %			191

*) cut at equal intervals

An especially detrimental effect on the roots was caused by frequently repeated cuttings at ground level. The root weight of the plots cut at ground level 7—8 times was only about one-fourth that of the plots cut at the highest level.

In 1962, cutting treatments were continued on those plots which had survived statisfactorily over the winter. Cuts were made simultaneously at 5, 10 and 20 cm (each plot to the same height as the previous year). One of the 5-cm series was cut at equal intervals. The figures in Table 6 correspond to the two lower treatments shown in Table 5 of those series which contain three treatments.

Root studies were performed in September at the time of the final cut. It was found (Table 6) that no appreciable differences in root weight had occurred since the previous year. A comparison of the simultaneous cuttings showed that when four cuttings were made, the root weight was directly proportional to the cutting level. On the other hand, when two cuttings were made, the root weights were approximately the same for all cutting heights. In all the plots cut at the same stage of growth, the weight of the roots was greater in plots cut four times than in those cut twice; in the plots cut at equal intervals, however, the results were the reverse.

Inconsistent results on the effect of cutting frequency on cocksfoot roots were likewise obtained in the trial performed at Mikkeli in 1959 (Table 7). It can be seen from these results that the root weight of the ley (in the year of sowing) receiving irrigation and nitrogen was less than that of the unfertilized, unirrigated control, in spite of the much more profuse foliage of the former ley. The difference in number of cuts, whether 2 or 3, had no significant effect on the root weight.

Table 7. Yields of roots and herbage of a cocksfoot ley in nitrogen fertilization and irrigation trial at Mikkeli 1959 (height of cutting 5 cm).

Treatment	No. of cuts	Mean yield at harvest g/m²	Weights (g/m²) of roots	stubble
Untreated	2	134	420	510
Water + nitrogen	3	134	360	560
—»—	2	219	350	630
F-value			0.50°	

In investigations carried out by the writer at Jokioinen, the cutting frequency had only a slight influence on the root weight (Table 8), and there were no statistically significant differences between the various treatments. It is true that one of the treatments (height of sward 15 cm, cutting height 3 cm, number of cuts 6) showed a poorer root growth than the others, a difference which was statistically significant, but this was probably a result of the combined influence of both height and frequency of cutting.

Intensity of defoliation

According to reports in the literature, the cutting level may have a very pronounced effect on the weight of roots of grasses. When cuttings are done at the same time, the closer the cut the smaller the weight of the roots. HARRISON (1931) found that the size of the root system of meadow grass and red fescue decreased parallel with a reduction in cutting height from 3″ to 1/4″. ROBERTS and HUNT (1936) tried various cutting treatments on English ryegrass and timothy, using cutting heights of 1″, 1/2″ and at ground level. In both species the weight of the roots diminished sharply as the cutting level decreased. TORSTENSSON (1938) carried out both pot and field trials with Italian ryegrass, English ryegrass, meadow fescue and meadow grass. He found that in all cases close cutting resulted in a smaller root system than lax cutting. In the trials of HARRISON and HODGSON (1939) the weight of roots of timothy and cocksfoot showed a marked decrease when the cutting height was decreased, whereas the reduction in the root system of couch-grass and meadow grass was not so pronounced. JUSKA *et al.* (1955) found that meadow grass produced a greater amount of roots when cutting was done at 2″ than at 3/4″. As the cutting height was decreased, the weights of both rhizomes and roots declined in the same proportion.

The effect of cutting on the *depth of growth* of the root system has been investigated by TORSTENSSON (1938) and THAINE (1954), among others. Both these workers came to the conclusion that the increase or decrease in root growth occurs in the same proportion both in the topsoil and in the subsoil. On the other hand, ALBERTSON *et al.* (1953) found that in those cases where the size of the root decreased, the reduction was greater in the lower layers of the soil.

Table 8. Weights of roots of cocksfoot-dominated ley at Jokioinen in spring 1957 (g/m²). In parentheses are given the average number of cuts each summer during the 3 years 1954—56.

Height of sward at time of cut cm	Height of cut 3 cm		6 cm		10 cm	
35	670	(2.7)	690	(2.7)	690	(3.0)
25	620	(3.3)	600	(4.0)	760	(4.3)
15	480	(6.0)				

F-value 1.78°. F-value of treatment 15—3 in comparison to the others 6.48*, L.S.D. (95 %) 150 g/m².

Table 9. Numbers of roots per sample (35×10 cm) below a depth of 45 cm at Jokioinen in spring 1957. In parentheses in the percentage of root system in the topsoil.

Height of sward at time of cut cm	Height of cut 3 cm		6 cm		10 cm	
35	10—12	(94.5)	10—30	(98.0)	7—15	(95.5)
25	10—20	(94.0)	5—10	(96.0)	10—30	(95.3)
15	5—10	(97.3)				

The same result was obtained by KLAPP (1951). Severe defoliation causes a diminution not only in the weight of the root system but also in its volume (GERNERT 1936; CARTER and LAW 1948).

The mean figures of the trial performed at Jokioinen (Table 8) tend to indicate that the root weight may be greater when cutting is done at a high level and on a sward which has attained the greatest height. But the differences are so slight that on the basis of the small number of samples (five), they are not statistically significant.

No significant differences were found, either, in the numbers of roots growing below 45 cm in the soil (Table 9). Only rarely did the roots penetrate to a depth of 80—100 cm; the great majority of them, 94—98 %, were in the upper 20-cm layer of topsoil. The differences between cutting treatments were negligible, and no trend was observable in the effect of cutting level, height of sward, or number of cuts.

In the summer of 1957 a trial was carried out at Viik on the effect of cutting height on unfertilized and on nitrogen-fertilized cocksfoot leys. Root investigations made in connexion with this trial showed that nitrogen increased the weight of the root system (Table 10). On the unfertilized ley there was no clear effect of cutting height on the roots. On the fertilized ley, on the other hand, there was a reduction in root growth paralleling an increase in cutting level.

Root investigations made in connexion with a defoliation intensity trial with cocksfoot at Mikkeli in 1961 (Table 5, p. 20) showed that variation in the

Table 10. Weight of roots and sugar contents of roots and basal stems of cocksfoot at Viik, 1958.

Height of cut cm	No. of cuts	Unfertilized g/m²	Unfertilized Roots Reducing sugars % dry wt. 15. 9.	Unfertilized Roots Reducing sugars % dry wt. 29. 10.	Unfertilized Stems Reducing sugars % dry wt.	Nitrogen applied g/m²	Nitrogen applied Roots Reducing sugars % dry wt. 15. 9.	Nitrogen applied Roots Reducing sugars % dry wt. 29. 10.	Nitrogen applied Stems Reducing sugars % dry wt.
3	4	377	6.0	6.5	14.7	646	5.7	7.3	11.5
6	4	283	4.3	9.0	11.6	568	5.9	9.0	9.4
10	5	381	6.2	10.0	13.3	331	4.2	8.2	12.5

F-value 4.99 *
L.S.D. (95 %) 210 g/m²

cutting level from 5 to 20 cm had no noteworthy effect on root weight. In the treatments receiving 12 and 4 (or 5) cuts, however, slight differences were observable, namely that the weight of the roots decreased as the cutting level was decreased. When cutting was done at ground level, the size of the roots was greatly diminished. The same result was obtained by Harrison (1934).

Time of defoliation

The weight of the root system of grasses fluctuates somewhat according to the time of year. Baker, for example, (1957 b), found that the root weight declined during the winter and steadily increased during the summer. Various investigators have established that the rate of root growth fluctuates during different parts of the growing season. In general, it appears to be most active in the spring and early summer but decreases at the flowering stage (Weinmann 1948). A diverging observation was that of Remy (1923), who found that the weight of cocksfoot roots increased between the middle of the summer and the autumn. Sampson and McCarty (1930) also established that root growth was most active in the autumn.

In the trial at Mikkeli in 1961, root investigations were made three times during the growing season. In the spring the weight of the roots was found to be 361 g/m² (Table 5, p. 20). At the beginning of July, when some of the treatments were investigated, most of them showed a decrease in root weight. In the autumn an increase in the amount of roots was found only in the swards which were cut at levels of 5 cm or higher. A marked reduction in root weight occurred when the grass was cut level with the ground.

Among the swards cut at the shortest intervals and at ground level, those cut at equal stages suffered more than those cut at equal intervals. The former treatment had a weakening effect right at the beginning of the summer — during the period of rapid growth — when cuts were made at 8-day intervals. When the frequency of defoliation was less, however, the root system of the swards cut at equal stages was larger than that of the swards cut at equal

Table 11. Root weight (g/m²) of cocksfoot ley when cut equal stages (A) and at equal intervals (B). Analyses made at Mikkeli in autumn 1961 and 1962.

Height of cut Year	0 cm 1961			5 cm 1961	5 cm 1962	
No. of cuts	8	4	2	4	4	2
A	57	186	332	323	320	263
B	81	167	231	242	212	237

intervals (Table 11). This indicates that longer rest periods between cuttings during the latter part of the summer and early autumn — when the growth of the grass is slow — had a beneficial effect in strengthening the root system.

Carbohydrate reserves

In temperate zones the food reserves in grasses are mainly in the form of simple carbohydrates. The most important carbohydrate in the basal parts of the stem is fructose and in the roots sucrose (Sprague and Sullivan 1950; Percival 1952; Sullivan and Sprague 1953; Mackenzie and Wylam 1957; Couchman 1959). In tropical grasses polysaccharides, of which starch is the most important, also occur as food reserves. Proteins may also serve to a slight extent as stored reserves. On the other hand, cellulose and hemicelluloses are structural — and not reserve — carbohydrates (Weinmann 1948).

The storage organs in grasses are the roots, rhizomes, stolons and basal parts of the stem. The most important storage organ in cocksfoot is the base of the stem (Hiepko 1959), although reserves are also stored in the roots. Defoliation treatments which alter the volume of the storage organs often have a marked effect on the total amounts of food reserves.

Frequency of defoliation

After defoliation there is a rapid decrease in the soluble carbohydrates serving as food reserves in the plant, since these are necessary for producing new foliage. According to Sullivan and Sprague (1943), the content of carbohydrates in the roots was at a minimum 11—16 days after cutting and that in the stubble 7—11 days after cutting. Thereafter the amounts of carbohydrate began to rise and reached their initial level about one month after defoliation. Similar results were also obtained by Biswell and Weaver (1933) and Alberda (1957 b).

Consequently it is obvious that frequent defoliation has a detrimental effect on the carbohydrate content of the storage organs. Since an increase in cutting frequency reduces the size of the storage organs, the total amount of reserves is still further diminished. For example, Thaine (1954) found that the carbo-

Table 12. Amounts of roots, stem bases and reserve carbohydrates in cocksfoot at Mikkeli in 1961.

	Height of cut cm	No. of cuts	Roots in summer g/m²	Roots in summer Reducing sugars % dry wt.	Roots in summer Fructosans % dry wt.	Storage organs in autumn: Roots g/m²	Roots Reducing sugars % dry wt.	Roots Fructosans % dry wt.	Stems bases g/m²	Stems bases Reducing sugars % dry wt.	Stems bases Fructosans % dry wt.	Reserve carbohydrates g/m²
		0				497	5.77	3.66	133	20.56	16.98	56.0
	20	12	323	6.51	3.94	291	7.67	5.18	63	31.55	23.97	42.2
	20	5	235	6.63	5.39	345	5.99	4.43	83	25.50	20.27	41.8
Cut at equal stages	10	12	221	4.16	2.79	277	6.91	5.07	38	30.33	24.61	30.7
	10	6	306	4.58	3.36	300	7.22	6.12	82	28.44	24.03	45.0
	10	4	262	6.92	6.04	332	7.24	5.74	77	25.94	21.56	44.0
	5	12	242	2.88	1.63	230	6.83	4.80	21	29.01	23.76	21.8
	5	5	283	3.96	2.02	240	6.31	3.86	57	29.20	23.64	31.7
	5	4	186	3.75	2.03	323	8.64	6.24	74	36.49	28.19	54.9
	0	7	169	1.29	—	57	3.11	1.64	—	—	—	1.8
	0	4	199	2.25	0.29	186	6.48	5.07	39	32.46	23.76	24.8
	0	2				332	5.41	4.11	41	17.72	10.84	25.3
Cut at equal intervals	5	10				156	6.08	3.94	18	26.63	23.20	14.3
	5	8				142	6.22	4.05	13	25.12	17.99	12.1
	5	4	325	5.26	3.57	242	7.18	4.54	58	35.63	29.01	38.1
	0	8	118	2.91	0.10	81	2.89	0.67	—	—	—	2.3
	0	4	230	1.83	—	167	7.64	5.94	18	34.33	23.56	18.7
	0	2	510	3.53	2.21	231	4.91	3.07	128	28.69	20.18	48.0
F-value						20.01 ***						
L.S.D. 95 %						65						
» 99 %						87						
» 99.9 %						112						

Table 13. Roots, stem bases and reserve carbohydrates in cocksfoot at Mikkeli in 1962.

Height of cut cm	No. of cuts	Roots g/m²	Roots Red. sugars % dry wt.	Roots Fructosans % dry wt.	Stem bases g/m²	Stem bases Red. sugars % dry wt.	Stem bases Fructosans % dry wt.	Reserve carbohydrates g/m²
20	4	527	8.67	6.49	165	16.07	9.55	72.2
20	2	260	3.96	3.66	162	15.43	9.54	35.4
10	4	461	5.63	4.89	74	15.88	9.75	37.8
10	2	267	3.67	2.92	129	17.57	10.51	32.4
5	4	320	4.91	4.24	72	14.20	8.61	25.9
5	2	263	2.41	1.97	93	11.87	7.47	17.3
*) 5	4	212	3.66	2.72	78	11.24	5.58	16.6
*) 5	2	237	4.07	2.35	110	16.41	11.93	27.6
F-values		12.5 ***						
L.S.D. 95 %		98						
» 99 %		135						
» 99.9 %		187						

*) cut at equal intervals

hydrate content of the roots of *Elymus junceus* decreased markedly when the number of cuts rose from one to five. This has been confirmed by other investigators (ALDOUS 1930; KLAPP 1937; AHLGREN 1938). Frequent defoliation close to the ground may lead to the death of the plants. WEINMANN (1948) mentioned that clipping at fortnightly intervals (or 16 times per season) for two years led to an almost complete exhaustion of carbohydrate reserves and to the death of many plants.

In the current studies analyses of total reducing sugars and particularly of fructosans were made on root and stem samples of cocksfoot. At Mikkeli in 1961 the sugar content of the roots was clearly higher in the autumn than in July. The amounts of fructosans were somewhat greater in the autumn than in the summer (Table 12). The sugar content of the stem bases was about four times that of the roots, and the proportion of fructosans among the sugars was approximately equal in both roots and stem bases. The effect of defoliation frequency on the total reserve supply (total reducing sugars in roots and stem bases) was very distinct: as the frequency increased, the reserves declined.

When the cutting height was moderate (10 or 20 cm), there was only a small influence due to frequency of cutting. On the other hand, when the sward was cut at 5 cm, the root system and reserves were substantially weakened by cutting frequencies of 8 or more per season. The most marked effect of cutting frequency was seen in the swards cut at ground level. When 7—8 cuts were made, the amount of reserves in the autumn was only one-tenth of the average amount in the other treatments, whereas when only two cuts were made, amount of reserves was quite considerable.

A diverging result was obtained in 1962 (Table 13) when comparisons are made between the 2- and the 4-cut treatments. Four cuts stimulated the root growth of cocksfoot so much that the carbohydrate reserves in all the swards cut at equal stages were greater after four than after two cuts.

Intensity of defoliation

Repeated defoliation close to the ground reduces the size of both the underground and the aerial parts of grasses. On the other hand, according to WEINMANN (1952), it does not always diminish the carbohydrate content. In the investigations performed by the writer at Viik in 1958, no consistent variations were found in the sugar content of roots and stubble which were related to the height of defoliation (Table 10, p. 24). In many cases the sugar content was least in the swards cut at 6 cm.

In the trials carried out at Mikkeli in 1961 (Table 12) the sugar content of the roots in the middle of the summer was directly related to the cutting height. In the autumn, however, there were no differences, with the exception that the plots cut at ground level showed exceptionally low values.

Neither were there any significant differences in the sugar contents of the stem bases. In the following summer, 1962, it was found that on the same trial sward the sugar content of both roots and stems was slightly higher in the plots cut at a greater height. But since close cutting reduced the size of the root system and the stem bases, it consequently caused a decrease in the amounts of stored reserves. Similar results were also obtained by WEINMANN (1948; 1952).

Time of defoliation

McILVANIE (1942) investigated the variations in the content of soluble carbohydrates of *Agropyron spicatum* at different times during the growing season. The concentration of carbohydrates in both the roots and tops was found to decrease during the beginning of growth in the spring, but rose during the time of flower stalk formation. In the herbage the maximum content occurred at heading and in the roots at the time of seed-ripening. According to WEINMANN (1952), the fluctuations in carbohydrate levels during the course of the growing season are similar in different species of perennial grasses, even though the minimum concentration in the storage organs may occur at flowering in certain species, whereas in others it may be during stalk formation or even earlier (RUELKE and SMITH 1956; COUCHMAN 1959).

In connexion with the effect of cutting time on the reserves of grasses, it can be mentioned that SAMPSON and McCARTY (ref. WEINMANN 1948) found that in *Stipa pulchra* maximum accumulation of carbohydrates was not prevented by grazing or cutting once or twice early in the growth cycle of the plant, but removal of the herbage between the time of flower stalk formation and seed maturity was harmful in this respect. In a further paper the authors reported that both clipping and grazing lowered the percentages of reserve carbohydrates in the stem bases and roots of *Bromus carinatus* and *Agropyron trachycaulum;* the degree of reduction depended on the time, frequency and closeness of cutting. Plants clipped early and at or near the close of the season maintained greater carbohydrate reserves than plants cut during the middle of the season when reproduction was still in progress.

A diverging result was obtained by ALBERDA (1956). Working with English ryegrass, he found that the content of soluble carbohydrates did not decrease during the time of rapid stalk formation, nor did defoliation at this stage cause any greater reduction in reserves than cuttings made later.

In 1961—62, the influence of time of cutting on cocksfoot was studied in a trial at Mikkeli. In this trial some of the cuttings were performed when the sward had attained a certain height, i.e. so that the yield of herbage was the same at each cutting. Consequently the cuttings were made at more frequent intervals in the period of rapid growth in the early summer, and less often during the phase of slow growth in the late summer and autumn. In contrast

Table 14. Weight of roots and amounts of reserves in cocksfoot swards cut at equal stages (A) and at equal intervals (B) at Mikkeli in 1961—62.

Height of cut cm	No. of cuts		Weight of roots in autumn g/m²	Sugars in roots % dry wt.	Reserve carbohydrates in roots and stem bases g/m²
	1961				
0	A	7	57	3.11	1.8
0	B	8	81	2.89	2.3
0	A	4	186	6.48	24.8
0	B	4	167	7.64	18.7
0	A	2	332	5.41	25.3
0	B	2	231	4.91	48.0
5	A	4	323	8.64	54.9
5	B	4	242	7.18	38.1
	1962				
5	A	4	320	4.91	25.9
5	B	4	212	3.66	16.6
5	A	2	263	2.41	17.3
5	B	2	237	4.07	27.6

to this system of clipping, other plots were cut at equal time intervals ($^1/_2$, 1 and 2 months). Attempts were made to make the same number of cuts in both of these treatments. Table 14 presents certain data on this trial. The growing season began around the middle of May and maximum growth took place during the first half of June (compare Fig. 7, p. 49).

The weight of the root system, determined in the autumn at the time of the final cutting, was generally greater in the swards cut at equal stages than in those cut at equal intervals. The only exception to this was the treatment consisting of 7—8 cuts level with the ground. The opposite results of this treatment were probably due to the fact that the large number of consecutive cuts made at the beginning of the summer in the former treatment weakened the plant so severely that part of its root system died and decayed by autumn. With two exceptions, the sugar content of the roots was greater in the equal-stage cutting treatment than in the equal-interval treatment. When four cuts were made, the total content of reducing sugars in the roots and stem bases was invariably greater in the former (equal-stage) treatment, whereas when only two cuts were made the reverse was the case.

In the swards cut twice at equal intervals during the growing season, the stem bases of the cocksfoot plants developed very vigorously. The weights of the stem bases in 1961 were: equal-stage cutting 41 g/m² and equal-interval 128 g/m²; in 1962 the corresponding figures were 93 and 110 g/m² (compare Table 12, p. 26). This may appear surprising, since at the time of measurement the former swards had grown for a longer time since their last defoliation than the latter. It is probable that the time of cutting (at the beginning of July, when the normal flowering of cocksfoot has just ended) was favourable for the regrowth of the plant. This is supported by the report of HIEPKO (1959) that delaying the first cut promotes the development of the stem-bases of cocksfoot. On the other hand, the long intervals between cuttings in the latter part of the summer caused increases in the amount of roots, their sugar content, and the content of reducing sugars in the storage organs of the plant.

The other observations made in this trial supported the claims of PARKER and SAMPSON (1930) and JONES (1933) that defoliation during the period of most rapid growth caused a decrease in the total yield of the whole summer (compare Table 19, p. 43) and that cocksfoot became more vigorous when the rest intervals during the latter part of the summer were long. The influence of time of cutting was distinctly less pronounced when the cutting height was 5 cm or greater.

Vitality of plants

Frequency and intensity of defoliation

The reduction in size of the root system and carbohydrate reserves in grasses as a result of severe defoliation causes a decrease in the vitality of the plant. This is manifested in the following year by poor growth, and thus the effects of defoliation are cumulative (WEINMANN 1948). According to JULANDER (1945), a certain supply of food reserves is necessary to enable the plant to withstand drought, heat and cold.

The results of all investigations show that cutting weakens grass plants. For instance, the capacity of the plant for water uptake is greatly diminished. Whereas an intact plant is able to absorb water against a pressure of 15 atmospheres, a closely-defoliated plant can perform this only against 1—2 atmospheres (cf. JÄNTTI 1953 a). GRABER (1931) established that the interruption of photosynthesis caused by complete defoliation resulted in susceptibility to drought and weakened water uptake, as well as increased susceptibility to winter and insect damage. According to POHJAKALLIO and ANTILA (1955), defoliation reduced the drought resistance of red clover and timothy. HUOKUNA *et al.* (1962) observed that severing the tip of cocksfoot leaves at the time of stalk formation diminished the formation of stalks by 50 %. WEAVER (1930) as well as CARTER and LAW (1948) held the belief that the decrease in the size of the root system caused by defoliation results in a weakening of the plant's drought and disease tolerance as well as of its ability to compete with other plant species.

The effect of cutting depends greatly on the closeness of the defoliation. Working with couch grass (*Agropyron repens*), JOHNSON and DEXTER (1939) found that cutting at ground level resulted in the death of some plants after as little as 2 weeks. When cutting was made at 1″, the plants began to die after

5 weeks, and at a cutting height of 3″ the plants lived much longer. These investigators came to the conclusion that the size of the root system remained the same when the stubble of the heavily nitrogen fertilized sward was 3—6″ and that of the unfertilized sward 1—3″. SPRAGUE *et al.* (1952) found that in the case of certain grasses with reserves in their stem bases, close cutting could completely prevent regrowth.

In trials performed by the writer at Mikkeli in 1961, cocksfoot was cut at ground level so that only 2—3 mm of the tops remained. The consequence of this first cutting was that about 50 % of the tillers died, whereas when the first cut was made at 5 cm or higher, all the plants survived.

At Jokioinen turf samples (three replicates) were taken from the trial swards on May 5, 1957, and allowed to grow in the dark. At a temperature of 20—23° C the grass grew rapidly. Three days later the leaves had grown 2—3 cm and were green in colour. Five days later the plants were 7—10 cm in height; at this time only 1—2 cm of the tips of the leaves were green, while the lower parts of the leaves were pale yellow. After May 22 no further elongation growth occurred, and at this date all the tillers were still alive. The average height of the grass was as follows:

Treatment 1954-56			
Height of sward at time of cut cm	Height of cut cm	Av. height of grass cm	Range cm
35	10	33	31 — 35
35	6	27	25 — 28
35	3	24	20 — 30
25	10	30	25 — 30
25	6	30	30 — 30
25	3	30	30 — 30
15	3	25	22 — 28

The numbers of living tillers were counted at intervals of 3—4 days. The first tillers died 17—20 days after the turf samples were put in the dark. The cause of death was depletion of sugar, since only 1.4 — 1.7 % soluble sugar was found in the dead stem bases as compared with 39.4 — 41.1 % before they were transferred to the dark. The sugar content of the roots was 0.4 — 0.5 % as compared with 5.6 — 5.9 % before the experiment. Most of the tillers died 20—25 days after being put in the dark (Fig. 3). Those still surviving at this date remained alive for a long time.

The curves in Fig. 2 a representing the death of cocksfoot are seen to occur in a compact group. The largest differences between different treatments were found 25 days after transference to the dark, after which the differences lessened. When the various curves are examined, it can be seen that the curves representing the treatments 35—6 (height of grass 35 cm and height of stubble 6 cm), 35—10 and 25—3 are generally above the others, while the curves 15—3 and 25—6 are clearly below the main group. From this, it can be concluded that infrequent cuttings (tall height of stand) and a high level of cutting

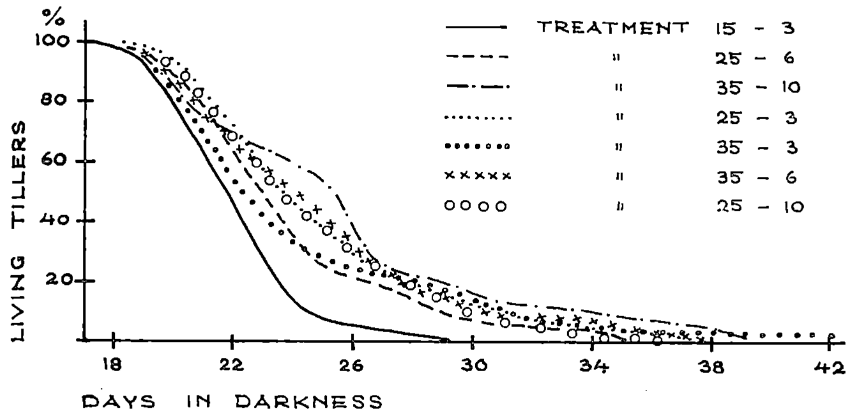

Fig. 3. Death rate of cocksfoot tillers, grown in darkness. Swards from Jokioinen trial fields in 1957.

generally increased the vitality of the cocksfoot in comparison to the other treatments. An exception was the treatment 25—3, which resulted in a very vigorous turf sample in spite of the closeness of the cut.

When the percentages of tillers surviving at each of the five counts were summed, a value was obtained which showed the vitality after each treatment. The rank order of the different treatments was found to be as follows:

Treatment		
Height of sward at time of cut cm	Height of cut cm	Vitality value
25	3	192
35	6	190
25	10	179
35	10	174
35	3	169
25	6	150
15	3	96

This series of values supports the conclusions previously drawn concerning the vitality of the grass after different cutting treatments. The differences between treatments were quite small; only the treatment 15—3 was distinctly weaker than the others.

In the trial at Jokioinen observations on the height of the sward in the spring were made on May 28, 1955 (the begin of the second year) and on May 20, 1957 (the spring after three years treatment). These determinations (Table 15) showed that the vigour of spring growth of cocksfoot was directly proportional to the level to which it was cut the previous summer. The height of the sward at the time of cutting had a smaller, but nevertheless appreciable effect. All the plots cut frequently (6 times) and close to the ground proved to have weaker growth than the others. The differences between

Table 15. Height of grass in spring 1955 and 1957 and numbers of stalks at Jokioinen.

Treatment in 1954			Height of grass cm		No. of stalks/m²
Height of sward cm	Height of cut cm	No. of cuts (in brackets 1956)	28. 5. 1955	20. 5. 1957	15. 6. 1957
35	10	3	15	12	112
35	6	3	14	9	16
35	3	3	12	6	0
25	10	5 (4)	15	11	96
25	6	4	13	9	64
25	3	4 (3)	11	9	48
15	3	6	10	8	80

treatments were approximately the same in both after the first and third year's cutting treatment.

On June 15, 1957, counts were made of the number of tillers. The swards had been allowed to grow undisturbed up to this time. The results (Table 15) showed that as the cuts became closer, the number of tillers decreased; the differences between treatments were statistically significant. The effect of cutting height was most pronounced when the height of the sward was greatest (35 cm) and three cuts were made.

The effect of nitrogen fertilization and cutting height was studied at Viik in 1958 by measuring the height of the grass and estimating its density in the spring following cutting treatment. The results (Table 16) showed that higher cuts resulted in a more vigorous spring growth. No differences were found between the fertilized and control swards. Distinct differences were observed in the density of cocksfoot: increasing the cutting height resulted in a corresponding increase in density. Such differences in density were more pronounced in the fertilized than in the unfertilized plots.

At Mikkeli the vigour of spring growth of cocksfoot as well as the mortality of its tillers was determined on May 18, 1962, one year after the cutting treatment (Table 17). In this trial also it was found that the vigour of the sward was directly related to the cutting height: the higher the level, the more vigorous the spring growth. The plots cut at ground level had very poor growth, but distinct differences were also evident between plots cut at 5, 10 and 20 cm. In general the plots cut frequently grew slightly less well than those cut at longer intervals.

Marked differences were also observed in the mortality of tillers between the different cutting treatments. An unexpectedly high mortality was found in the uncut sward, amounting to 62 %. Evidently the dead herbage, which was not removed until May 15, killed the young shoots by shading and smothering them. No appreciable occurrence of plant diseases was observed in this sward. There was practically no difference in the numbers of dead shoots between the plots cut to 10 and 20 cm, but between the plots cut to 5 and 10

Table 16. Height and density of cocksfoot at Viik May 5, 1959.

Treatment in 1958		Unfertilized		N-fertilized	
Height of cut cm	No. of cuts	Height cm	Density (0-10)	Height cm	Density (0-10)
10	5	17.2	8.5	17.0	9.0
6	4	12.0	8.0	12.0	7.0
3	4	10.5	7.0	10.0	4.8

Table 17. Height of grass and mortality of tillers at Mikkeli, May 18, and herbage yields of the first cut in 1962.

	Treatment in 1961		Height of grass cm	Mortality of tillers %	Dry matter yield 1962 g/m^2		
	Height of cut cm	No. of cuts			7. 6.	19. 6.	11. 7.
Cut at equal stages		0	24	62			385
	20	12	24	10	97		
	20	5	27	10		167	
	10	12	19	10			439
	10	6	22	10	138		
	10	4	21	15		245	
	5	12	14	19			378
	5	5	17	18	142		
	5	4	19	12		277	
	0	7	6	85			
	0	4	9	54			
	0	2	9	78			
Cut at equal intervals	5	10	13	20			391
	5	8	12	24	67		
	5	4	16	19			
	0	8	6	88			
	0	4	8	78			
	0	2	8	68			
F-values			69.8***	25.3***	0.4°	5.1°	23.4**
L.S.D. 95 %			2.3	16.8			41
» 99 %			3.1	22.4			62
» 99.9 %			4.0	29.2			

cm there was a clear difference. The cutting treatment at ground level resulted in the death of most of the plants.

The four treatments in this trial which were not included in the regular experimental treatments in 1962, were harvested for hay on July 11 in order to determine the after-effect of the cuttings performed the previous year. These four yield figures, shown in Table 17, indicate that the differences in spring-time vigour had been smoothed out. The variations observed in the spring in the vigour and mortality of the stands appeared much greater than the corresponding differences in hay yield (all four plots were mown at a height of 5 cm). The recovery in vitality of those swards which had appeared weak in the spring is also revealed by the dry matter yields of the harvests made on June 7 and 19; the yields from the closer-cut plots were found to be higher. These figures as such cannot be compared directly with those representing the vigour of the stands, but they nevertheless indicate that even the plots cut in the previous summer to a short stubble underwent very vigorous growth during the following spring and early summer.

Time of defoliation

PARKER and SAMPSON (1930) found that defoliation was most damaging, i.e. that the smallest yields were obtained, when it took place during the time of most active growth. The same result was obtained by BLAISDELL and PECHANEC (1949) in their studies on *Agropyron spicatum* and *Balsamorhiza sagittata*. Clipping done in the early spring was not so harmful as that made somewhat later, in May or June, during a period of drought. Clipping done later than this had only a slight influence on the yield the following year. JONES (1933) found that cocksfoot benefited by a rest period in the early autumn and English ryegrass by a similar period even later. WAGNER (1952) emphasized that the time of cutting mixed grass leys, especially in the spring, has a distinct influence on the subsequent botanical composition of the ley. The time of cutting determines the species which are better able to outgrow the others after the cut and thus dominate the stand. The time of defoliation, however, does not always have a distinct effect. For instance, ALDOUS (1930) found that after the first of June the rest period had no appreciable effect on the size of the yield.

In the trials carried out by the writer at Mikkeli, the swards cut when they had reached equal heights proved to have a more vigorous spring growth than those cut at equal intervals (Table 17). The result was the same both in the plots cut at ground level and in those cut at 5 cm.

The vigour of cocksfoot as compared with other species

In practical grassland farming, adjacent plants — often of different species — are generally cut at the same height. As a result, the various plant species — which differ in their growth characteristics — are subject to what is apparently the same cutting treatment, but in actual fact is different in the case of each species. Close cutting is best withstood by those species with a prostrate growth habit, which consequently have a considerable photosynthesizing leaf area remaining even after close defoliation. Examples of this kind of plant are white clover (*Trifolium repens*) and meadow grass (*Poa pratensis*) (LOVVORN 1944; JONES 1933). Plant species whose carbohydrate reserves are located mainly in their roots, rhizomes or stolons are also resistant to close defoliation (KLAPP 1942; 1951). Herbage species which are resistant to close cutting, because of either their prostrate growth or their abundant reserves, are thus able to recover rapidly after being cut, and in a mixed sward they soon outgrow and overshadow the species with a poorer regrowth ability (KLAPP 1942; ROBINSON *et al.* 1952; HARRISON and HODGSON 1939). Species with an erect growth habit generally can not tolerate close defoliation. Their reserves are usually located in the bases of their shoots, and thus close cutting greatly retards — or can even completely check — their regrowth (SPRAGUE *et al.* 1952). Considerable differences in vigour can also be observed between similar species, and even different strains of the same species may respond in different ways to the same cutting treatment (BIRD 1943).

Various investigators have arranged grass species in the order of their regrowth vigour. In general, erect species are found to have a poor regrowth ability, while prostrate species are vigorous; the exact order of the species, however, varies according to the investigator. KLAPP (1942) places them in the following order (from most vigorous to weakest): *Poa pratensis, Festuca rubra, Dactylis glomerata, Lolium perenne, Phalaris arundinacea, Bromus inermis, Festuca pratensis* and *Avena elatior.* In a later publication KLAPP (1951) mentions that the most resistant species were *Poa pratensis* and *Lolium perenne* while the weakest were *Avena elatior, Dactylis glomerata* and *Festuca pratensis.* According to JONES (1939), *Dactylis* was even less tolerant of defoliation than *Lolium*, and *Phleum pratense* was similar to *Dactylis* in vigour. HARRISON and HODGSON (1939) established that both *Phleum* and *Dactylis* were susceptible, while *Agropyron repens* and *Poa pratensis* were resistant to defoliation. According to WAGNER (1952), *Dactylis* had a definitely better regrowth ability than *Bromus,* and HIEPKO (1959) found *Dactylis* to be more resistant than *Arrhenatherum.*

The regrowth ability of timothy after defoliation is known to be poorer than that of meadow fescue or cocksfoot (JÄNTTI 1953 b). Especially during periods of low rainfall, timothy growing in mixed leys becomes shaded by cocksfoot, since its regrowth after cutting is slower than that of the latter species (HUOKUNA 1960). On the other hand, when the spring yield of the sward was grazed, timothy formed many more stalks than cocksfoot (HUOKUNA *et al.* 1962).

In the present investigations no comparisons of the regrowth vigour were made between the different grass species, but in all the treatments cocksfoot was one of the most vigorous of the erect grasses. Even in the plots cut level with the ground 8 times during the summer, 10 % of the shoots were still alive in the autumn. When cut rather close (3—5 cm), some of the cocksfoot shoots died, but only when cut at ground level was the sward thinned to a serious degree.

The results of most of the present experiments agree with those obtained by other workers on cocksfoot and other grasses. The actual wound damage to the plant as a result of cutting was slight. When a blade of cocksfoot was severed, its elongation growth continued even during the following 24-hour period. The cut end gradually became yellow and withered over a length of several millimeters. Otherwise no damage to the plant was visible. Increasing the cutting frequency from 2 to 12 times generally weakened the vigour of the roots, but this effect was definitely smaller at both Jokioinen and Mikkeli than that mentioned by KLAPP (1937), LOVVORN (1945) or BAKER (1957 a). Only in those cases where the sward was cut at ground level were the differences in effect of cutting frequency pronounced.

The cutting height (3, 6, 10 cm) had only a slight effect at Jokioinen; at the lower levels of cutting, there was a tendency for the root system to become weaker. At Viik there was no clear effect on the unfertilized ley, and on the fertilized ley (125 kg/ha N) the tendency was the reverse of that at Jokioinen.

At Mikkeli the general tendency was the same as at Jokioinen, but variation of the cutting height from 5 to 20 cm had only a negligible effect. Only when the cut was made at ground level did the root system show a weakening in vigour proportional to the frequency of cutting. Generally other investigators, such as HARRISON (1931), ROBERTS and HUNT (1936) and TORSTENSSON (1938) found a more pronounced effect of cutting height on the roots than was found in the present study.

Only a few observations at Jokioinen were made on how the cutting treatments affected the downward vertical growth of the roots. These agreed with the view of THAINE (1954) and TORSTENSSON (1938) that different methods of cutting had the same effect on the vertical growth as on the weight of the roots.

In regard to the carbohydrate reserves and the vitality of the plant, it was found that as the frequency of cutting increased and the height of cutting decreased, the reserves generally diminished. This was a result of a reduction in the weight of the roots and stem base of the plant. The sugar content of the roots was highest in the plots cut four times and fell when cuts were made at intervals more or less frequent than this. The total amounts of reserve sugars in the present trials did not decrease as sharply as was found by THAINE (1954), AHLGREN (1938) and KLAPP (1937), but the observation was made, in agreement with WEINMANN (1948), that frequent cutting at ground level resulted in exhaustion of the reserves and death of the plant. Small differences in amounts of reserves caused distinct differences in the growth of the plants the following spring, but it appeared that these variations were smoothed out as growth continued. Similar differences were also produced when turf samples were grown in the dark. The differences between cutting treatments in such reserve exhaustion tests were just as insignificant as those in the weights of the roots. At Mikkeli winter mortality was observed only in the uncut plot and in that cut at ground level, whereas no differences were found in the swards cut at height of 5 cm and above. The report of WEINMANN (1948) that the effect of cutting is cumulative was not confirmed in regard to cocksfoot in the present trials (similar differences were found at Jokioinen in 1954 and 1957). Varying the frequency of cutting from 2 to 12 and the cutting height from 5 to 20 cm caused relatively small differences in the vigour of the plants. Nitrogen fertilization was found to strengthen the roots, a result also obtained by REMY (1923).

The time of defoliation had an appreciable effect on the roots, top growth and reserve supply. The swards cut at equal growth stages, i.e. more frequently during the period of rapid growth and less frequently in the latter part of the growing season, generally had a more vigorous root system and a larger supply of reserves than the swards cut at equal intervals during the entire growing season. This confirms the reports of SAMPSON and MCCARTY (1930) as well as MCCARTY and PRICE (1942) that defoliation is not so detrimental to root growth in the early part of the summer as later in the season. Evidently long rest periods in the latter part of the summer are advantageous for root development, even though the top growth at this time is rather slow.

Herbage yield

Quantity of yield

Frequency of defoliation

The dry matter yield of grasses is generally larger when the harvest is made at later stages of growth. For example, JONES (1939), in his trials in Wales, found that various grasses such as cocksfoot, meadow fescue and red fescue gave the largest yields when they were cut only once during the summer. BIRD (1943) investigated the same problem in the USA on many different grass species. He established that the dry matter yields rose as the time of harvest was delayed up to the stage of seed formation and that the differences in aftermath yield were very small. *Agrostis alba* gave the highest yield when the main cut was made at the beginning of flowering, while timothy yielded most when cut after flowering had ended. The highest yields of brome grass and meadow grass were obtained when they were cut at the stage of seed formation. According to AHLGREN (1938), the yields of all herbage grasses increase as the harvest time is delayed up to the flowering stage, but after this time there is only a small increase in dry matter yield, and none at all in some species.

When leys are harvested at the grazing stage, it has generally been found that the taller the grass at harvest, the larger is the dry matter yield. WAGNER (1952) investigated different mixtures of cocksfoot, brome grass, Ladino white clover and alfalfa. The average yields at different times and heights of cut were as follows:

Height of cut	Dry matter tons/acre when last cut was on		
	15. 9.	15. 10.	15. 11.
6″	2.13	2.20	2.27
12″	2.46	2.37	2.71

NELSON and ROBINS (1956) carried out cutting trials on a cocksfoot-Ladino sward. In all cases cutting at a height of 12″ resulted in greater yields than at 6″. BRYANT and BLASER (1961) also studied the effect of time and frequency of cutting on cocksfoot. When the cutting height was 2 $^{1}/_{2}$″, the yields were as follows:

Stage at cutting	No. of cuts	Yield, lbs/acre
Flowering	4 — 5	8463
Stalk formation	5 — 6	6882
11″ high	7 — 9	5252
5″ »	10 — 12	4303

In the case of nearly all grass species, it has generally been found that the higher the stand at the time of cutting, the greater the dry matter yield (CHESTNUTT 1960; GERVAIS 1960; BURGER *et al.* 1962). An exceptional case was one trial with meadow grass (MORTIMER and AHLGREN 1936) in which equally large yields were obtained at cutting heights of both 8—10″ and 4—5″.

Certain workers have carried out cutting trials at definite time intervals. WOODMAN *et al.* (1929) studied the effect of cutting interval on the yield of an English ryegrass-dominated sward. His results were as follows:

Cutting interval	Dry matter yield lbs/acre
1 week	1982
2 weeks	2562
3 »	3216

TORSTENSSON (1938) obtained larger yields with Italian ryegrass and meadow fescue when cut at 15-day intervals than at 10-day intervals. KENNEDY and RUSSEL (1948) conducted trials in the USA with swards of meadow grass and white clover. They found that the dry matter yield rose steadily at the cutting interval increased from 1 to 8 weeks. Similarly in the trials made by KLAPP (1951), increasing the interval between cuttings from 1 to 3 weeks resulted in an increase in the yield of permanent grassland. PETERSON and HAGAN (1953) tested cutting intervals of 2, 3, 4 and 5 weeks on four different kinds of leys. In all cases the longer intervals gave larger yields than the shorter. The same result was obtained by LANGILLE and WARREN (1961) using intervals of 3, 4 and 8 weeks on a cocksfoot ley. CROWDER *et al.* (1955) used intervals of 2, 4 and 8 weeks on leys given different nitrogen fertilization treatments; as the interval lengthened, the herbage yield consistently increased. In all these trials the differences in yield were quite large. PRINE and BURTON (1956), cutting at weekly intervals, obtained total yields which were only 34.6—50.1 % of those at 8-week intervals. The differences were smallest in a dry summer and largest in a wet summer.

Certain investigators have reported intensity of cutting only in terms of number of cuts. GRABER (1931) found that a sward cut 6 times yielded only 38—43 % that of a sward cut once. GERNERT (1936) carried out trials with prairie grasses and obtained the highest yields with two cuts. KLAPP (1942) obtained maximum yields with 2—3 cuts per season; the yields declined with an increase in number of cuts.

THAINE (1954) conducted cutting trials with *Elymus junceus* and obtained higher total yields with five cuts than with only two. This is one of the few exceptional cases reported in the literature. As a general rule, it has been found that when harvesting is carried out at the grazing or silage stage, larger dry matter yields are obtained when the cuts are made infrequently. This relationship is true regardless of the species, soil type, and other environmental conditions such as nutrition or moisture (COMSTOCK and LAW 1948; CROWDER *et al.* 1955; ELOFSON and HOFMAN-BANG 1922; RAPPE and OLOFSSON 1945).

At Jokioinen the writer conducted a cutting trial on a cocksfoot-dominated ley, in which the cocksfoot grew rapidly and became practically the only species in the sward (Fig. 2, p. 11). The results of this trial are shown in Table 18.

This table shows that the average differences between both the treatments and the years were highly significant. In the first year of the trial the average

Table 18. Number of cuttings and herbage yields (D. M.) of cocksfoot cutting trial at Jokioinen, 1954—56.

Treatment: Height of stand cm	Treatment: Height of cut cm	1954 No. of cuts	1954 Yield g/m²	1955 No. of cuts	1955 Yield g/m²	1956 No. of cuts	1956 Yield g/m²	Average No. of cuts	Average Yield g/m²
35	10	3	490	3	316	3	375	3.0	394
35	6	3	595	2	477	3	510	2.7	527
35	3	3	651	2	498	3	536	2.7	562
25	10	5	423	4	252	4	358	4.3	344
25	6	4	532	4	374	4	316	4.0	407
25	3	4	723	3	434	3	401	3.3	519
15	3	6	458	6	279	6	265	6.0	327
Average		4.0	550	3.4	376	3.7	394	3.7	440

F-values: all treatments 60.6***, between years 145.5***, treatments × years 5.4***. L.S.D. (95 %) 35, (99 %) 46 and (99.9 %) 91 g/m².

yield was quite high, but in the following dry summer it dropped sharply and did not rise appreciably in the subsequent year. At the same time the ratios between the yields changed so that also the combined effect for treatments × years in the variance analysis became highly significant.

The smallest dry matter yield was obtained from the treatment 15—3 (height of grass 15 cm, height of cut 3 cm), which was cut 6 times each summer. Its yield was significantly less than that of all the other treatments except 25—10 and it remained at a low level each year. The difference was also significant in comparison with the average yields of all the other treatments. An analysis of variance was performed on the dry matter yields of these latter treatments in such a way that they were divided into two groups according to the height of the stand at the time of harvest. The average yields were as follows:

Height of stand cm	Yield g/m^2
35	494
25	428

The F-value of the effect of height of stand was found to be 62.55***, or highly significant.

The annual fluctuations in dry matter yield were quite large. The highest yields were obtained in the first year of the trial, when rainfall was sufficient in the latter part of the summer. In the following year, 1955, drought caused a decrease in average yield of about 200 g/m^2. In 1956 rains were abundant, but the yield was only slightly greater than in the previous year. The annual variations in yield between the different treatments are shown in Fig. 3, in which the yield of each treatment in 1954 is taken as 100.

All the treatments showed a considerable decrease in yield between 1954 and 1955. The decrease was relatively least in treatment 35—6, which was cut 3 times in 1954 and twice in 1955. Likewise, in treatment 35—3 the drop in yield was small. The greatest reduction occurred with treatment 25—3, which in 1954 had given the highest yield. Similarly treatment 25—10 produced less in 1955 than was expected. It appears that the diminution in yield in the second summer was least in those swards which had not been cut until they had grown tall, whereas those swards which were cut when they had reached heights of 15 and 25 cm showed the greatest decreases in yield.

The sward which gave the greatest yield in 1954 was weakened relatively the most in the following year, but those yielding next highest in 1954 were weakened only slightly. On the other hand, the lowest-yielding treatments in 1954 showed the greatest reduction in 1955.

In 1956, the relative yields generally increased. The swards which were tall at the time of cutting and which gave the highest yields in the first and second summers, were also the best in the third summer. Their yields in the third year were slightly above those of the previous summer. The greatest relative increase, however, occurred with treatment 25—10, and a moderate

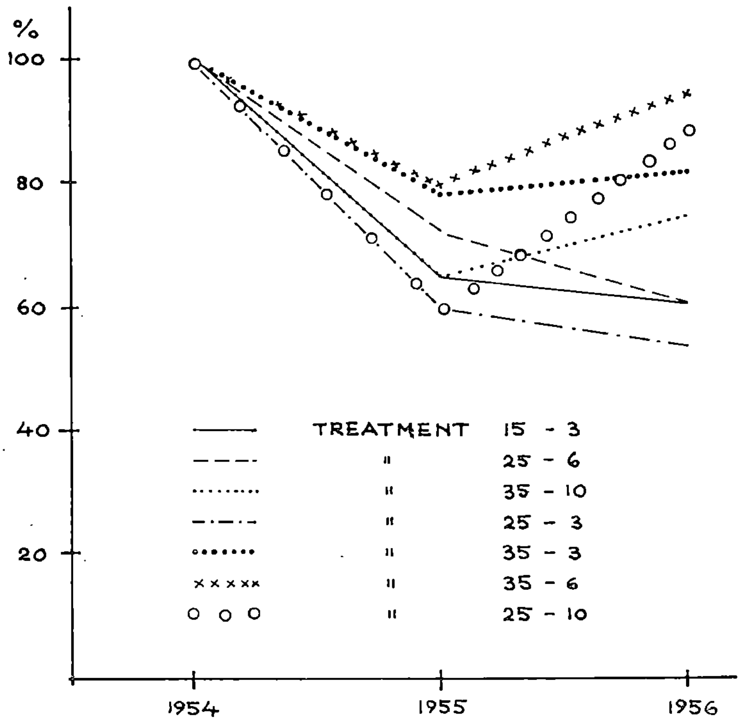

Fig. 4. Annual variations in dry matter yield at Jokioinen; 1954 yield = 100.

rise was also noted with 35—10. On the other hand, those swards given the most radical treatment (cut close when the stand was still low) yielded even less in 1956 than in the previous year. Of these, the yield of one was above the 1955 average, the yield of another was below this average, while that of the third was the same as the average. The number of cuts in the previous year was not especially important in these comparisons, although the sward that had been cut most frequently (6 times) was weakened and that cut twice showed an increase. However, the greatest increase was shown by one of the swards cut four times, although the other showed a decrease in yield. The difference between these was that the former had been cut to a height of 10 cm and the latter to 6 cm. When the years 1955 and 1956 are both taken into consideration, it can be concluded that the main cause for the decrease in yield was too frequent harvesting.

In 1961 a defoliation trial was begun at the South Savo Experiment Station at Mikkeli on a second-yeard ley of cocksfoot (Daeno II). The cutting heights were 0, 5, 10 and 20 cm and the frequency of cuts 0—12. In this trial the cutting frequency had a very strong effect, as can be seen from the figures in Table 19.

Table 19. Number of cuttings and dry matter yields in trial at Mikkeli, 1961.

Cut at equal stages								Cut at equal intervals			
Height of cut cm											
20		10		5		0		5		0	
No. of cuts	Yield g/m²	No. of cuts	Yield g/m²	No. of cuts	Yield g/m²	No. of cuts	Yield g/m²	No. of cuts	Yield g/m²	No. of cuts	Yield g/m²
12	452	12	425	12	283	7	203	10	388	8	210
5	459	6	524	5	481	4	363	8	496	4	514
*)	983	4	527	4	558	2	597	4	616	2	1010
Average											
8.5	456	7.3	492	7.0	441	4.3	388	7.3	500	4.7	578

F-values 27.6***
Influence of frequency 76.05***
*) Cut at ground level in the autumn.

The yield of the plots cut frequently (7—12 times) was, on the average, only half that of those cut infrequently (2—4 times). When part of this trial was continued in 1962, the effect of cutting frequency was very pronounced (Table 20, p. 46). In general, plots cut twice gave distinctly higher yields than those cut four times. The only exception was the plot cut at a height of 20 cm, in which the four-cut treatment resulted in larger yields than the two-cut.

Intensity of defoliation

The intensity of defoliation (cutting height) has a rather important effect on the quantity of the herbage yield. Conflicting results have been obtained by different workers, however. DRAKE *et al.* (1963) performed cutting trials on cocksfoot swards. The yield was greater when cuts were made at 3″ than at 1.5″. The latter sward suffered especially during the hot part of the summer. WATKINS and LEWY - VAN SEVEREN (1951) as well as JOHNSON (1953) did not find any consistent influence of cutting height in their studies on certain tropical grasses. With some species a close cut gave the best results, while with others a lax cut was most advantageous; the cutting heights ranged from 2″ to 24″. In his trials with prairie grasses, ALDOUS (1930) also obtained diverging results. When the interval between defoliation was 2 weeks, the yield was smallest at a cutting height of 2″, intermediate at $1^1/_2$″, and largest at 4″. On the other hand, when the interval was 3 weeks, the yield was distinctly greater when the stand was cut to $1^1/_2$″ than to 3″. In the trials made by POHJAKALLIO and ESKOLA (1941), the cutting height (ground level and 10 cm) likewise had no appreciable effect on the regrowth of timothy.

Repeated defoliation at ground level eventually results in the death of all herbage species. STAPLEDON (1924) found that when seven cuts were made, larger yields were obtained with a cutting height of 2″ than at ground level. In the trials of ROBERTS and HUNT (1936) with English ryegrass and timothy, the yields steadily decreased as the closeness of cut increased (1″, $^1/_2$″ and ground level). The result was the same with both 10- and 30-day cutting intervals. GRABER and REAM (1931) obtained smaller harvests with meadow grass at $^1/_2$″ cuts than at 1$^1/_2$″ cuts. The ratio between the yields was about the same whether the number of cuts was one or eight. TORSTENSSON (1938) tested Italian ryegrass and meadow fescue and found that with 10-day intervals, higher yields were harvested when the cutting height was 5 cm than when it was 2 cm. On the other hand, with 15-day intervals, no noteworthy differences were observed.

HARRISON and HODGSON (1939) conducted pot trials in which timothy, cocksfoot and couch grass were clipped weekly at heights of 1″, 3″ and 6″ and meadow grass at heights of $^1/_2$″, 2″ and 3″. The yields (g/pot) of the first two species were as follows:

	Height of cut		
	1″	3″	6″
Cocksfoot	22.21	74.25	90.09
Timothy	2.61	8.83	15.33

Couch grass survived the 1″cutting treatment better than cocksfoot. The cutting height had no effect on the yields of meadow grass. In outdoor trials with meadow grass receiving nitrogen fertilizer, JUSKA *et al.* (1955) obtained a larger yield in the plot cut at 2″ than in that cut at $^3/_4$″. JAQUES and EDMOND (1952) established that the yields of cocksfoot and English ryegrass diminished as the cutting height was decreased from 2″ to 1″ to $^1/_2$″. One-week and two-week cutting intervals were used.

In very many trials it has been found that the shorter the stubble (however, at least $^1/_2$″) the greater the dry matter yield. GRABER (1933) cut meadow grass at heights of 1$^1/_2$″ and $^1/_2$″ and found that in the first year the close cut gave higher yields than the lax cut. The close-cut stand subsequently became weakened, however, and grew poorly in the following year. MORTIMER and AHLGREN (1936) carried out a similar trial with meadow grass and during a four-year period, obtained larger yields by cutting at a height of $^1/_2$″ than at a height of 1$^1/_2$″. The grass was allowed to grow to 4—5″ before each cut. Similar results were also obtained by ROBINSON and SPRAGUE (1947) and KENNEDY (1950): conditions of nutrition of moisture had no effect on their results.

In the long term trials of REID (1962) in Scotland the dry matter yields were as follows (100 cwt/acre):

Height of cut	Ryegrass-clover mixture					Timothy-clover mixture		
	1957	1958	1959	1960	1961	1957	1958	1959
1″	79.0	74.5	72.1	61.9	67.0	83.3	76.8	66.0
2$^1/_2$″	59.1	60.6	54.5	43.1	46.4	62.8	64.6	57.2

Similarly in these trials, neither the weather conditions nor application of nitrogen fertilizer had any effect on the relative results. SPRAGUE and GARBER (1950) conducted defoliation trials on leys of cocksfoot-Ladino and of brome grass-Ladino. When the stand had reached a height of 8″, it was cut at levels of either 1″, 2″ or 3″. As the cutting level decreased, the dry matter yield consistently increased. Both BROWN and MUNSELL (1956) and LANGILLE and WARREN (1961) studied cocksfoot dominated leys. The former workers used cutting heights of 2″ and 4″, the latter 1 3/4″ and 3″. In both cases the closer cut always gave the higher yield. Analogous results were also obtained by CHESTNUTT (1960), GERVAIS (1960), WILSON and McGUIRE (1961) and BURGER *et al.* (1962).

In the trials at Jokioinen (Table 18, p. 40), with only one exception, higher yields were obtained with closer cuts. This is revealed by the following results:

Height of cut cm	Yield g/m^2
10	369
6	467
3	541

The F-value of effect of cutting height was found to be 124.5***, which was more significant than the effect of frequency. The F-value of the combined effect was 5.1**, which shows that these two factors were dependent upon one another within the conditions of this trial (the differences between cutting heights were quite small).

The highest average dry matter yield was harvested from the sward which was tallest at the time of cutting and which was cut closest to the ground. In the first trial year, treatment 25—3 gave the highest yield, but in the two following years 35—3 was the highest-yielding. Maximum yields were thus obtained with the closest cuts in the second and third seasons also. The cutting height had no effect on the extent of yield reduction, since among the poorest yielders there were swards that had been cut at both the maximum and the minimum heights. The swards which persisted best were those which had been cut close or at an intermediate height.

In the trial at Mikkeli in 1961 (Table 19, p. 43) the effect of height of cut was quite small. The following tabulation gives the analysis of variance among the 8 treatments which were mutually comparable.

Factor	Sum of squares	Deg. of freedom	Variance	F
Total	37 352	31		
Replicates	120	3	40	
Treatments	31 977	7	4 568	18.27***
Frequencies	19 013	1	19 013	76.05***
Heights of cut	1 779	3	593	2.37
Freq. x Height	11 185	3	3 728	14.91***

The cutting height was not found to be statistically significant, but the combined effect of frequency and level of cutting was highly significant.

Table 20. Dry matter yields g/m² in cocksfoot cutting trial at Mikkeli, 1962.

No. of cuts	Cut at equal stages Height of cut cm			Cut at equal intervals	Average
	20	10	5	5	
4	663	613	595	597	617
2	590	696	639	770	674
Average	626	654	617	683	645

Total	F-value	1.4°
Effect of height of cut	»	0.5°
» » frequency	»	0.1°
» » height × freq.	»	1.4°

This shows that with a high frequency of cuts, the yield declines with a decrease in cutting height, but with a low frequency the relationship is the opposite.

In 1962 the trial at Mikkeli was continued with those plots which had remained in statisfactory condition. The frequencies of cutting were 4 and 2. The comparison between equal-stage and equal-interval harvests was made only on the plots cut at a height of 5 cm. The equal-stage plots were always cut on the same day, so that this trial was mainly a cutting level trial. The results are shown in Table 20.

In this trial neither the frequency nor the level of cutting had any statistically significant effect. From swards cut four times, higher yields were obtained with higher cutting levels. On the other hand, when cut only twice, the order was reversed. The differences were too small, however, to be statistically significant. This result was evidently due to the fact that in this very cool and rainy summer the slightly weakened close-cut swards were not able to produce so much dry matter as the vigorous swards which had been lax-cut.

Time of defoliation

In trials on time of harvesting, it has generally been found that when the first harvest in made relatively late, the yield is large and there is no great difference in the aftermath yield (Poijärvi 1931; Valle and Virtanen 1932). In the trials with cocksfoot leys at Mikkeli, comparisons were made between harvesting at equal growth stages (equal heights of stand) and harvesting at equal time intervals. In 1961 the cutting heights were 5 cm and ground level, while in 1962 only the 5-cm cut was used. The differences in yield were found to be unexpectedly large (Table 19, p. 43, and Table 20). The plots cut at equal intervals, in which greater amounts of grass were removed in the early part of the summer than in the later part, gave consistently higher yields than the plots cut when they had reached equal heights. In 1961 the differences were highly significant. The values of F were: harvest time 314.0***, time x frequency 137.2***, and time x cutting height 38.37***. Especially great differences in yield were found when the swards were cut twice at ground

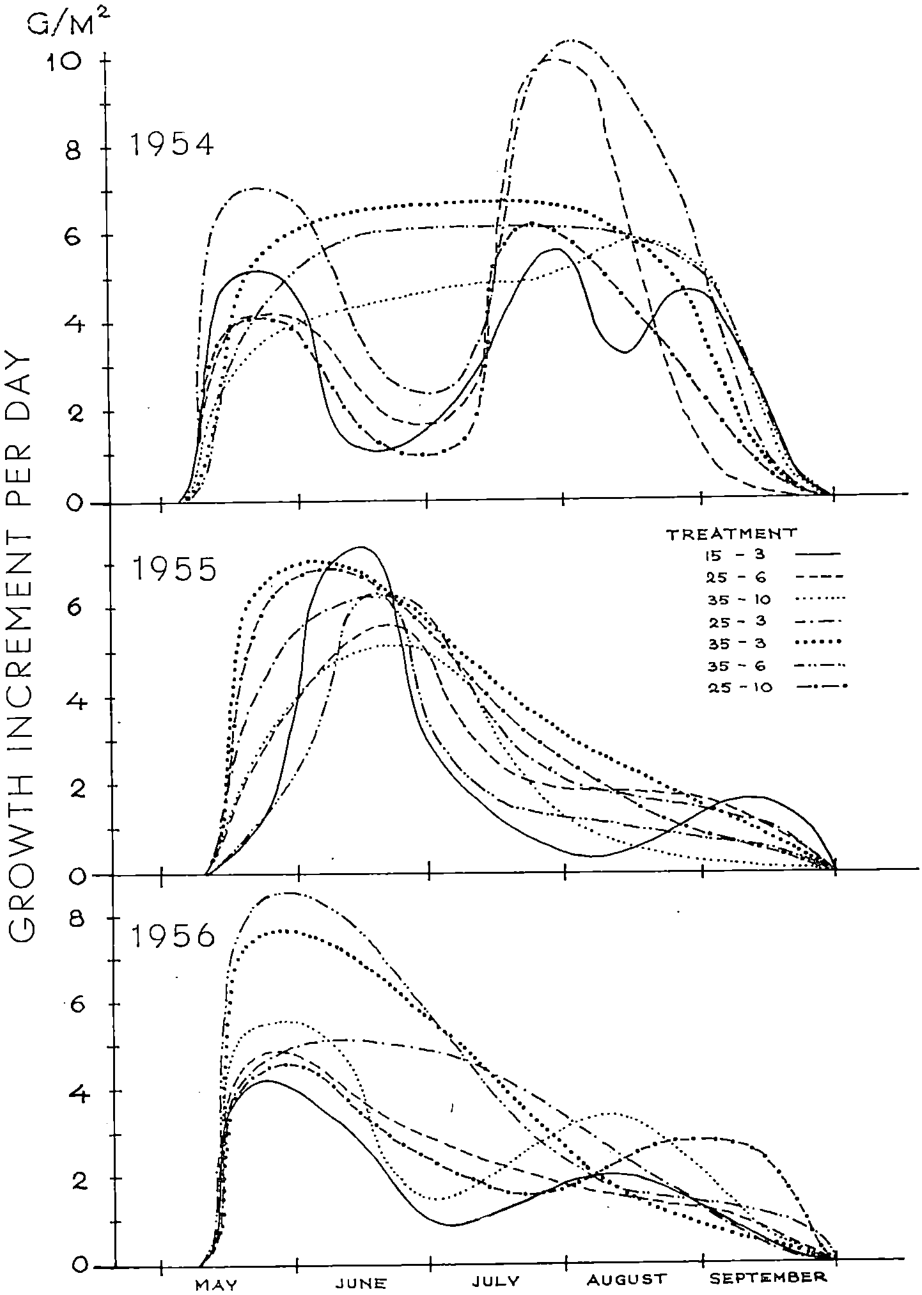

Fig. 5. Seasonal growth curves in the trial at Jokioinen, 1954—56.

level. The equal-stage plot was cut on June 5 at the time of rapid growth and gave a yield of 188 g/m^2. The corresponding equal-interval plot was cut on July 4 and yielded as much as 599 g/m^2. The amount of regrowth occurring by the middle of September was the same for both plots. Cutting cocksfoot leys after the time of flowering (the stalks were removed from this ley) proved to be very advantageous from the standpoint of dry matter yield. In the following year there were no appreciable yield differences among the plots cut four times, but among those cut twice the equal-interval treatment gave distinctly higher yields than the equal-stage. Similar results have also been obtained by SCHOLL *et al.* (1960) and CHESTNUTT (1960).

Seasonal growth pattern

In order to determine the amount of growth throughout the season, curves were constructed according to the method of RAPPE (1946). Figure 5 shows the growth curves for three seasons at Jokioinen. In 1954 the usual early summer peak was low. A pronounced depression occurred during June and July for four of the treatments. Not until the end of July, when a rainy period began, did the growth show a marked increase, which lasted until the end of September. In view of the lateness of the season, this final growth was extremely vigorous and for most of the treatments the peak at this time was higher than in the spring. Treatments 25—6 (height of grass 25 cm and height of stubble 6 cm) and 25—3 showed especially vigorous growth. The more or less level shape of the curves 35—3, 35—6 and 35—10 was due to the fact that they were cut infrequently and thus small variations in their speed of growth do not appear in the curves. Another feature worthy of mention is that treatments 25—10 and 15—3 had much lower late summer peaks than the above-mentioned treatments 25—6 and 25—3, even though all these curves were quite close to one another in the early part of the summer.

In the dry summer of 1955 the curves characteristically show only one peak, since the short period of rapid growth in September does not appear in the curves. The most radical cutting treatment (15—3) displayed slower growth in the middle of the dry summer than the others. In both years the growth of the lax-cut plots declined at the end of the summer.

In the third year the curves show greater divergences than in the first two. The plots cut when they had attained a great height (35 cm) had distinctly higher peaks in the early summer than the others. The most frequently cut plot (15—3) was so weakened that its growth curve was below the others throughout almost the whole season. On the other hand, the lax-cut plots showed a more vigorous growth at the end of the summer than the others.

The seasonal growth patterns for the 1961 trial at Mikkeli are shown in Figures 6 and 7. In Figure 6 it can be seen that the plots cut level with the

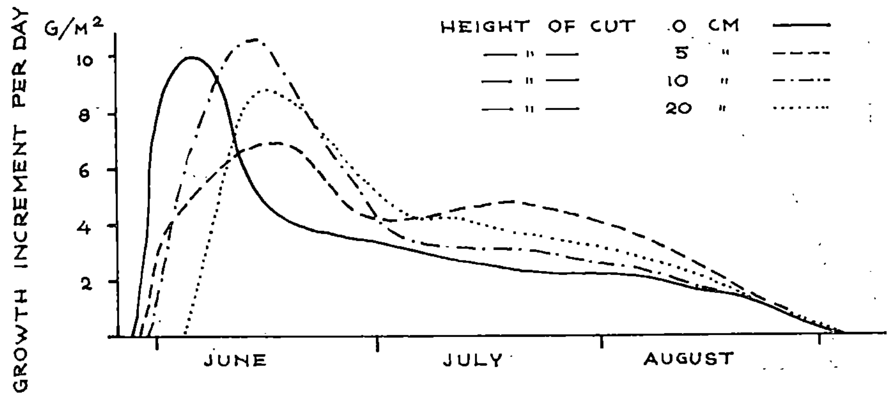

Fig. 6. Seasonal growth curves according to cutting height at Mikkeli in 1961.

ground grew rapidly in the early part of the summer but very slowly during July and August. The early summer peak of the plots cut at 5 cm was lower and broader than that of the others. In addition, a depression occurred in the middle of the summer (cf. RAPPE 1951), but in July and August the growth was more rapid than that of the other treatments. In the summer in question moisture always appeared to be sufficient, and three equally large applications of nitrogen fertilizer were given in May, June and August. The largest total yield was obtained from the plots cut at a height of 10 cm. These plots also showed the highest early summer peak, but their growth rate subsequently dropped, rapidly at first, but then more slowly, so that the curve during the last part of the season remained between those of the 5 and 20 cm treatments.

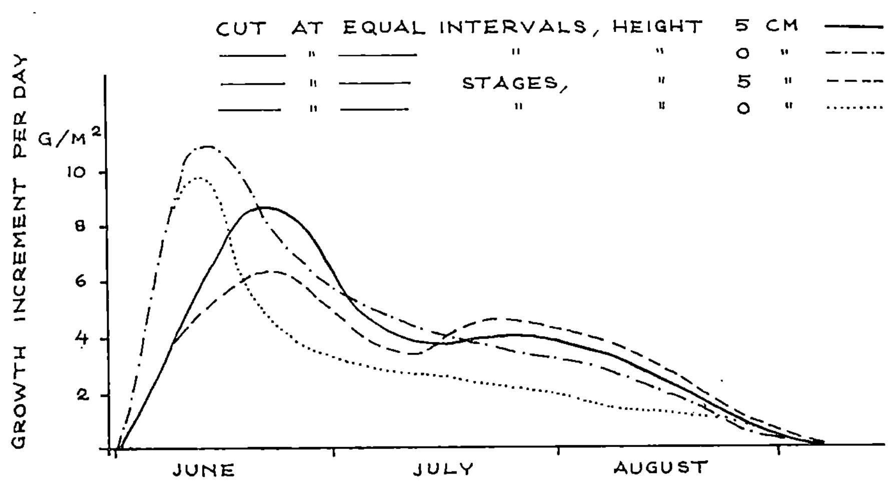

Fig. 7. Seasonal growth curves cut at equal intervals and at equal heights of stand, Mikkeli 1961.

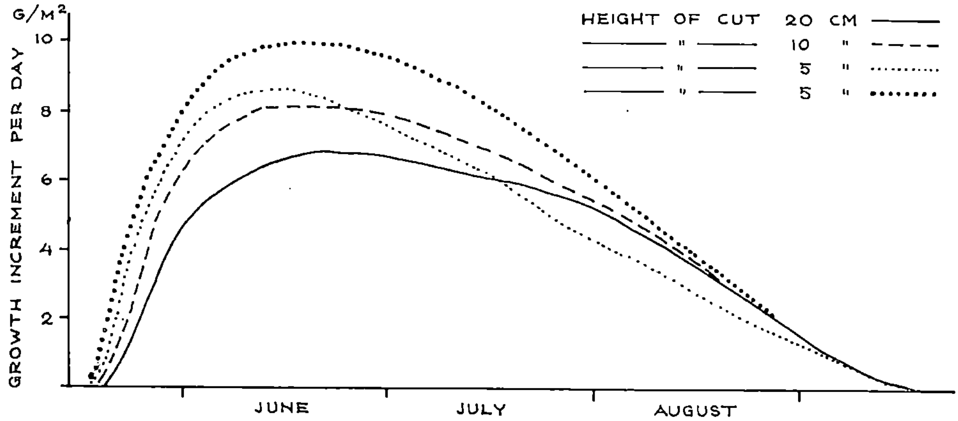

Fig. 8. Seasonal growth curves for plots cut twice during the season, Mikkeli 1962. Stronger dotted curve represents cutting at equal intervals.

The curve for the most lax-cut plots (20 cm) showed a relatively sharp peak in June and a subsequent drop which was more uniform and gradual than that of the others.

Figure 7 shows the growth curves of the plots cut when the stands had attained equal heights in comparison with those cut at equal intervals. In the case of the plots cut to a stubble height of 5 cm, those cut at equal intervals had a definitely higher and broader peak than those cut at equal stand heights. Toward the end of the summer, however, the latter showed slightly more vigorous growth than the former. In the case of the plots cut at ground level, those cut at equal intervals grew more rapidly throughout nearly the whole

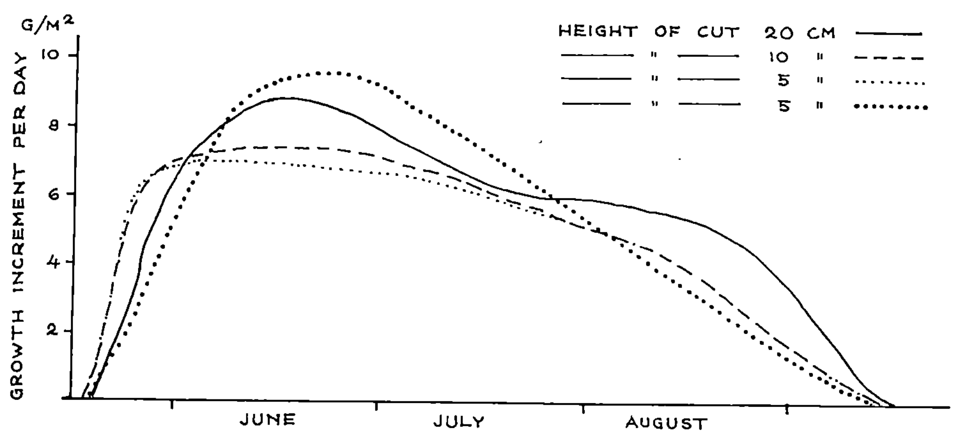

Fig. 9. Seasonal growth curves for plots cut four times during the season, Mikkeli 1962. Stronger dotted curve represents cutting at equal intervals.

summer (with the exception of the end of August) than the plots cut at equal heights of stand.

In 1962 the plots cut twice during the summer to a stubble height of 20 cm had a low early summer peak (Fig. 8), but their growth continued uniformly during the latter part of season. On the other hand, when the cutting treatments were made four times, the growth of the plots cut to 20 cm was more vigorous during the entire summer than that of the other plots cut at equal stand heights (Fig. 9). Especially in the early part of the summer, the plots cut to 5 cm at equal intervals grew more rapidly than those cut at equal stand heights.

The curves showing the seasonal growth patterns are characterized by a peak in the early part of the summer. This has been found in most investigations on the growth cycles of grasses (Rappe 1951; Laine 1953; Jäntti and Huokuna 1955). Weather conditions, in particular the rainfall, affect the shape of the curves. For example, frequent dry periods during the summer result in a narrow peak and a depression in the middle of the summer. If there is then abundant rainfall, the growth of the grasses is stimulated and a second, late-summer peak arises, as has been found in the studies of Rappe (1946).

In general, under Finnish conditions the late summer growth is only about half as great as that occurring in early summer, even though the moisture conditions toward the end of the season may be very advantageous. For example, at Jokioinen in 1956 the early part of the summer was very dry (cf. Table 2 and Fig. 1), but nevertheless the growth at this time was much more vigorous than in the latter part of the season, when rainfall was abundant and the temperature averaged 10—13° C (Fig. 5). Most of the growth curves in these studies resemble the mean curves constructed from results of different ley trials (Jäntti and Huokuna 1955). One exceptional case was that of the 1954 trial at Jokioinen (Fig. 5), when the spring and early part of the summer were extremely dry. First-year leys, in particular, grew very poorly. Growth did not become profuse until the middle of July, when ample rain fell. At Viik in 1958 and at Mikkeli in 1961—62 there was sufficient moisture during the entire growing season. However, as a result of the normal rhythm of the plants, the growth in every case was characterized by a peak in the early summer and a gradual decline toward the autumn, even though in certain trials applications of nitrogen fertilizer were given uniformly throughout the growing season.

Differences caused by different cutting treatments generally appeared most clearly during the time of rapid early summer growth. The curves seldom intercepted one another so distinctly that definite conclusions could be drawn from them. The only noteworthy feature to be observed was the vigorous growth of lax-cut swards in the cool autumn of 1956 (Figs. 5, 8 and 9), even though they had given relatively low yields earlier in the summer.

Discussion

In most of the trials conducted by the writer, the effect of cutting frequency on the dry matter herbage yield was similar and distinct: the less frequently the cuts were made, i.e. the taller the stand at the time of cutting and the longer the intervals between cutting, the larger were the herbage yields. At Jokioinen 2—3 cuts consistently resulted in higher yields than greater numbers of cuts. At Mikkeli the largest yield was obtained when the sward was cut twice and the next largest yield from that which was allowed to grow undisturbed during the entire season (with the exception that flowering stalks were removed as they appeared). When this trial was continued in the second year, the twice-cut swards gave average yields distinctly greater than the swards cut four times. There were only a few exceptional cases at Jokioinen. Another exception concerned the plots in the 1962 Mikkeli trial, which were cut to a stubble height of 20 cm. In general, the results of the present trials agree with those obtained in other investigations on this subject (Wagner 1952; Bryant and Blaser 1961). Such an effect of cutting frequency appears to apply to all herbage grasses (Woodman *et al.* 1929; Torstensson 1938; Klapp 1951; Reid 1959).

The effect of cutting height on the dry matter herbage yields apparently gave contradictory results. In the trial at Jokioinen, the tendency was very clear (Table 18, p. 40): as the cutting height decreased from 10 to 3 cm, the yield increased. A similar relationship occurred at Viik (Table 28, p. 66) both in the unfertilized leys and in those receiving nitrogen dressings. Likewise, in most treatments of the Mikkeli trials the same general results were obtained. The exceptions were some of those cases in which cutting was carried out at ground level (Table 19, p. 43). If such close cutting was performed four or more times, the yields were smaller than those at higher cutting levels. But even though the swards were cut at ground level, a large yield was obtained if only two cuts were made. On the other hand, when the sward was defoliated very frequently, 10—12 times during the summer, the order of yields was reversed (in the range of cutting heights 5—20 cm), the lax-cut swards yielding more than the closer-cut swards. An exception to this was the second-year continuation trial in 1962. In this case, four cuts to a height of 20 cm resulted in the largest yield, and no differences appeared between the other treatments. This result can be explained by reference to Fig. 9 (p. 50), which shows that the growth of this particular sward continued vigorously at the end of the summer. The same phenomenon was also observed in certain cases in the cool and rainy autumn of 1956 (Fig. 5, p. 47), in which some of the lax-cut swards (10 cm) displayed unusually abundant growth even to the very end of the season. These two exceptional cases were probably due to the fact that such lax-cut swards had a well-developed root system and abundant carbohydrate reserves, and thus were able to continue their growth while the other closer-cut swards ceased growing because of the cool weather.

The results obtained in the present investigations explain the conflicting data appearing in the literature on the effect of cutting height. As early as 1930, ALDOUS (1930) observed that the interval between clippings had a pronounced effect on whether lax or close cuts gave the largest yields. This fact was ignored by most subsequent workers (with the exception of REID 1959), who simply reported in their trials — which were either very close or frequently cut — that the lower the cutting level, the smaller the yield (TORSTENSSON 1938; HARRISON and HODGSON 1939; JAQUES and EDMOND 1952). But if the cuttings were infrequent, the yield of, for example, meadow grass was greater when cut to a height of $^1/_2''$ than when cut at higher levels. In the case of erect grasses, such as cocksfoot, relatively infrequent defoliation at 1—2″ results in more herbage growth than when the cuts are made at a higher level (SPRAGUE and GARBER 1950; BROWN and MUNSELL 1956; LANGILLE and WARREN 1961; LAINE 1962).

In theory, the opposite results would be expected, since the leaf area is the site of photosynthesis. It would be expected that the largest yields would be obtained when the leaf area is continually so great that it can utilize all the light energy reaching it (BROUGHAM 1956; JÄNTTI and HEINONEN 1957). The contrary results obtained in many field trials have been a source of concern to investigators. MORTIMER and AHLGREN (1936) believed that the reason for the larger yields of close-cut leys was the fact that the basal parts of young shoots always remained in the stubble and their amounts were subsequently not harvested and weighed when the ley was lax-cut. In the present trials, it is true that at the end of each trial there was more herbage in the lax-cut than in the close-cut swards. In the trials at Jokioinen, however, the differences in total yield were so great that the amount of herbage remaining in the stubble can not completely explain the phenomenon. The difference in yield between the 3-cm and 6-cm cutting heights was 740 kg and between the 3-cm and 10-cm as much as 1 720 kg. The amount of herbage remaining in the stubble was weighed and found to be 300—400 kg in the former case and 800 — 1 000 kg in the latter. The differences in yield were therefore clearly greater than the growth remaining in the stubble. It can thus be concluded that lax cutting had a direct effect in weakening the growth of the sward.

Growth at different cutting heights

These field trials showed that when the interval between defoliations was long, lax cutting gave higher dry matter yields of cocksfoot than close cutting. In the 1961 trial at Mikkeli (Table 19, p. 43) the treatment, consisting of 12 cuts during the season, had an average interval of 10 days (ranging from 2 to 22). The following frequency was 6, which had an average cutting interval of 20 days. This

Table 21. Dry matter yields of cocksfoot-dominated leys when cut to stubble heights of 3, 6 and 10 cm. The Jokioinen trials were carried out in 1956, the Viik trial in 1957. The stubble yields were determined by cutting at a level of 3 cm.

Stubble height cm		Initial cut	Dry matter yield g/m² Days after initial cut									
Jokioinen Stage A		18. 6.	10	14	18	22	26	30	34	38	42	46
3		293	6	17	29	51	40	73	88	117	132	137
6	Tops	205	7	17	26	43	43	55	65	114	134	116
	Stubble		13	9	11	16	16	16	14	25	22	21
	Total		20	26	37	59	59	71	79	131	156	137
10	Tops	172	4	12	22	25	30	30	34	67	63	69
	Stubble		66	45	92	93	73	89	100	111	131	100
	Total		70	57	114	118	103	119	134	178	194	169
Jokioinen Stage B		20. 7.	12	18	24	30	36	42				
3		244	17	59	58	115	147	129				
6	Tops	200	21	57	60	117	116	168				
	Stubble		13	18	17	24	21	36				
	Total		34	75	77	141	137	204				
10	Tops	143	17	37	39	56	94	67				
10	Stubble		88	114	105	122	99	133				
	Total		105	151	144	178	193	200				
Viik		10. 7.	10	15	20	25	30	35	40			
3		125	25	87	72	124	126	129	154			
6	Tops	102	30	88	85	133	148	159	164			
	Stubble		17	17	19	28	18	15	22			
	Total		47	105	104	161	166	174	185			
10	Tops	52	24	94	78	117	113	134	116			
	Stubble		128	127	84	83	75	72	73			
	Total		152	221	162	200	188	206	189			

increased interval was sufficient to reverse the order of yields, so that both the 10-cm and 5-cm cut resulted in larger yields than the 20-cm cut. With only four cuts per season, in which the average interval was 30 days, the plots cut at 5 cm gave higher yields than those cut at 10 cm. These results agree with the so-called rate of growth experiments, which are described below.

Three rate of growth experiments were carried out, two at Jokioinen and one at Viik. The Jokioinen trials were performed in 1956 on the same cocksfoot-dominated ley as the previously mentioned cutting trial; one of these (Stage A) took place in the middle of the summer and the other (Stage B) at the end of the summer; five replicates were used in each trial. The Viik trial was carried out at the end of the summer of 1957, with three replicates.

Table 21 gives the results of these three trials and shows the rate of growth of the leys when cut at different levels. At Jokioinen the stubble also made steady growth, but at Viik, where the sward consisted almost entirely of cocksfoot, the amount of stubble began to decrease about three weeks after the initial cut.

Figure 10 shows graphically the growth of the leys, presented as averages of the three trials. The beginning part of the curves has been drawn in the shape of a gently sigmoid curve (Brougham 1955). The top growth of the sward cut to a stubble height of 6 cm was greater than that of the others, and it continued uninterrupted for 40 days. The growth curve of the 3-cm sward was parallel to the former, but slightly lower. On the other hand, the growth of the sward cut to 10 cm was initially as rapid as that of the others, but after 25 days it began to decline.

Since the points depicting the total yields (stubble + harvested tops) from the Jokioinen trials appeared to be linearly correlated, the regression lines were calculated in each instance. The results were as follows:

	Stubble height cm	Regression function	F-value	Correlation coefficient
Stage A	10	$y = 33.4\ x + 328$	103.77***	+ 0.827
	6	$y = 38.7\ x - 309$	106.20***	+ 0.830
	3	$y = 40.6\ x - 451$	313.01***	+ 0.931
Stage B	10	$y = 30.4\ x + 796$	27.25***	+ 0.702
	6	$y = 49.2\ x - 239$	50.41***	+ 0.802
	3	$y = 41.9\ x - 258$	61.39***	+ 0.829

The coefficient x in the function shows the daily increase in dry matter yield (kg/ha). All the functions are seen to agree highly significantly with the variations in the results observed. In every case the daily growth increment was less in the 10-cm swards than in the 6- or 3-cm swards. Because of the non-uniformity of the ley, there were no statistically significant differences in the direction of the lines, with the exception of the comparison between the 10- and 6-cm swards in Stage B. In this comparison the growth increment in the 6-cm sward was significantly greater ($F = 14.11^{*}$) than in the 10-cm sward.

In these rate of growth experiments, it was not observed that the lax-cut plots grew more rapidly immediately after cutting than the close-cut plots. This was due to the fact that the first harvest cuts were not made until 10 days after the initial cut. In other trials conducted by the writer it was observed, however, that immediately after cutting, the lax-cut stands had the most vigorous regrowth, as has been mentioned by Brougham (1956). The stands cut at 3—5 cm, however, soon attained the same rate of growth as those cut at 10—20 cm and rapidly exceeded it, too.

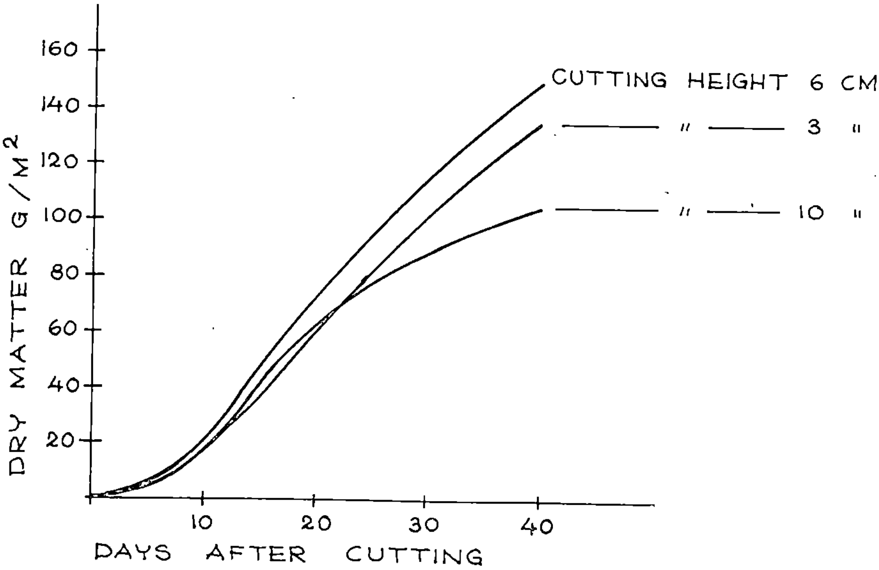

Fig. 10. Growth of cocksfoot-dominated ley when cut to different stubble heights (averages of 3 trials).

When growth curves are drawn for two swards cut at different heights, the curves intersect at a certain point as a consequence of a slowing in growth rate of the lax-cut sward. In the present trials, the point of intersection occurred about 20—25 days after the initial cut. It can also be concluded from the results of Brougham (1956) that 24 days after cutting, the stand having a cutting height of 1″ grew more rapidly than those with cutting heights of 3″ or 5″. The differences were so small, however, that Brougham did not arrive at the same conclusion as the present writer.

On the basis of all the rate of growth experiments mentioned above, it can be concluded that in general immediately after cutting, the growth of lax-cut swards is more vigorous than that of close-cut swards, but that after a certain period of time the rates become equal and still later the relationship is reversed. At a certain point after cutting both swards give equal yields. This point, where the growth curves intersect, can be termed the compensation point, and the interval of time between cutting and this point can be termed the equilibration period. In the trials conducted by the writer this latter period had a duration of 20—25 days.

The equilibration period in the 1961 trial at Mikkeli was calculated on the basis of the yield results by determining when the ratio of the yields changed in favour of the shorter stubble. Comparing the 20-cm and 10-cm treatments, this period lasted 10—20 days. Between the 20-cm and 5-cm treatments is was about 20 days and between the 10-cm and 5-cm treatments 25—30 days. These figures agree well with the lengths of the equilibration period found in the rate of growth trials. The length of this period appears to depend upon the two cutting treatments under comparison; it is relatively short in comparisons of the 20-cm and 10-cm treatments but much longer when, for example, the 12-cm and 2-cm treatments are compared.

The duration of the equilibration period probably varies according to the grass species, although external factors, such as moisture, temperature and phase of growth, may affect it. A thorough explanation of this phenomenon requires extensive investigation.

The occurrence of an equilibration period explains many of the trial results in which no differences in yield were observed. In such cases the cutting interval was close to the duration of the equilibration period, and consequently the yields of the different cutting treatments were almost the same (ALDOUS 1930; HARRISON and HODGSON 1939; JÄNTTI and HEINONEN 1957). The experimental period in the latter trial was three weeks, which — as in the writer's own studies — was too short a period for reaching the compensation point when one of the cutting heights under comparison was as short as 1 cm.

Quality of yield

Leafiness

The leaf/stem ratio of grass growth varies rapidly at the time of stem formation (STAPLEDON 1924). As a result, the cutting frequency has a considerable effect on the leafiness of the harvest (WAITE 1957; MACKENZIE and WYLAM 1957). The cutting height, too, is important, since it determines how much stem is included at each harvest (REID 1959).

In the trials performed by the author at Mikkeli (Table 22, p. 58) each harvest was analysed for its relative content of leaves, stems and dead leaves. It was found that the plot which was allowed to grow undisturbed for the entire summer had only 23 % green leaves and about the same amount of stems (the amount of stalks removed was 0.5 %), while over half of the aboveground growth consisted of dead foliage.

In the other plots, the proportion of leaves was generally higher as the frequency of cutting increased. The cutting height in the range 5—20 cm had only a slight effect on the leaf/stem ratio, but in the swards cut at ground level growth produced a distinctly smaller proportion of leaves than at the other cutting heights. When cuttings were infrequent, dead foliage was most abundant in the autumn harvest. There was also much dead foliage in the spring harvest of the plot cut at ground level. In general, dead leaves were more abundant when cuts were made high. An exception was the case of cutting at ground level, in which there was much dead foliage in the autumn harvest also. It seems that after close cutting, the first leaves were weak, and as a result of subsequent shading they died.

Table 22. The proportions of leaf, stem and dead herbage in the dry matter yield. Mikkeli 1961.

Treatment No. of cuts	Treatment Height of cut cm	Dry matter yield g/m²	Percentage distribution leaf	Percentage distribution stem	Percentage distribution dead
*) 1	0	983	23	22	55
12	20	452	100	—	—
5	20	459	83	—	17
12	10	425	95	1	4
6	10	524	88	2	10
4	10	527	81	4	15
12	5	283	100	—	—
5	5	481	86	2	12
4	5	558	85	5	10
7	0	203	69	6	25
4	0	363	63	17	20
2	0	597	35	42	43
10	5	388	100	—	—
8	5	496	89	5	6
4	5	616	91	3	6
8	0	210	62	6	32
4	0	514	72	16	12
**) 2	0	1010	45	34	21

*) from the plots were removed 10 stalks/m² = 4.4 g/m²
**) —»— 6 —»— = 2.0 »

Crude protein content and yield

The contents of certain compounds affecting the nutritional value of fodder vary considerably as the plant develops. As a consequence, the cutting frequency has an important effect on the crude protein and fibre contents of the herbage. Geering (1941) showed that the age of the grass bore a simple logarithmic correlation to its content of crude protein: cr.pr. content $= 28.6 - 17.2 \times \log t$ when t is the age of the grass in weeks. Woodman *et al.* (1929) found that the crude protein content of the herbage was about the same whether the grass was cut every week or every second week, but when the cutting interval was 3 weeks the protein content was about 2 percentage units lower. Similar results were obtained by Klapp (1951); in his studies both the protein and fibre contents were about the same at either weekly or fortnightly intervals, but when cut at intervals of three weeks, the crude protein content decreased by nearly 3 percentage units and the fibre content increased by more than 1 percentage unit. According to the investigations of Bird (1943), the amounts of protein and fibre changed quite rapidly as the grasses developed. These changes were nearly the same in brome grass, bent-grass, timothy and meadow fescue. In many cases the crude protein content decreased as the dry matter yield increased, with the result that the total protein yield remained approximately the same. Kennedy

(1950) carried out defoliation trials on a ley of meadow grass and white clover and obtained the following average results:

Treatment: Height of sward cm	Treatment: Cutting height cm	Dry matter yield lbs/acre	Total nitrogen %/DM	Crude protein %
8	4	2360	1.75	25.4
8	2	3660	1.88	27.0
6	4	2300	1.98	27.3
6	2	3370	1.84	26.4
4	2	3170	2.28	25.9
4	0.5	4290	2.75	20.6

In the trial conducted by the writer at Jokioinen the crude protein content decreased in direct proportion to the amount of herbage removed at each cutting. From the whole experimental data, an expression of the dependence of the protein content upon the amount of herbage harvested was derived, $y = 21.1 — 0.359\ x$ (F-value = 100.17***), which means that an increase in dry matter of 100 kg/ha resulted in a decrease in crude protein content of 0.359 %. The coefficient of correlation was — 0.625.

In Table 23, showing the results of the Jokioinen trial, it can be seen that there were large variations between the different treatments and years. These variations, however, were smaller — both numerically and relatively — than those in the dry matter herbage yields (Table 18, p. 40). The largest average crude protein yield was obtained from treatment 25—3 (height of grass 25 cm and height of stubble 3 cm), which also gave the highest single yield for one year, 1 215 kg/ha. It is of interest that the protein yield of treatment 15—3 was higher than that of 35—10, even though the latter gave a considerably greater dry matter yield.

All the treatments gave higher crude protein yields in the first trial year; in the following two years these were distinctly lower. The largest relative decrease occurred in the case of treatment 25—3, but the protein yields of 15—3, 25—6 and 35—3 also declined in the second and third years. In the three

Table 23. Contents of crude protein and fibre as well as total protein yields in defoliation trial at Jokioinen, 1954—56.

Treatment		Crude protein yield							
Height of sward cm	Cutting height cm	1954 kg/ha	1954 % of dry wt.	1955 kg/ha	1955 % of dry wt.	1956 kg/ha	1956 % of dry wt.	Average kg/ha	Average % of dry wt.
35	10	785	15.9	541	17.2	640	17.1	655	16.6
35	6	918	15.4	738	15.5	799	14.0	818	15.0
35	3	980	14.9	689	13.8	654	12.2	774	13.7
25	10	760	18.0	498	19.8	661	18.5	640	18.6
25	6	912	17.3	699	18.7	583	18.4	731	18.7
25	3	1215	16.6	791	18.2	621	15.6	877	16.9
15	3	905	20.7	576	20.6	570	21.5	684	20.9

treatments 35—10, 35—6 and 25—6 the third-year protein yields were somewhat larger than those of the second year; in the case of all the other treatments, however, the yields decreased from year to year.

The content of crude protein did not change much during the three-year experimental period. Differences were noted, however, between the different treatments. The highest average crude protein content, 20.9 % of the dry matter, was found in treatment 15—3 and the lowest (13.7 %) in treatment 35—3.

When the results in Table 23 are combined according to the height of the sward at the time of cutting, it is seen, as shown in the following tabulation, that the height of the grass had no effect on the protein yield but did have a distinct effect on its content in the herbage:

Height of sward cm	Crude protein kg/ha	Crude protein %	Fibre %
35	749	15.1	26.1
25	749	17.9	23.9

If the same results are combined according to cutting height, the following average results are obtained:

Cutting height cm	Crude protein kg/ha	Crude protein %	Fibre %
10	647	17.6	24.9
6	775	16.6	25.0
3	826	15.3	25.0

It is seen that as the cutting height was decreased, the crude protein content also fell, but since the herbage yields from the close-cut swards were much greater than those from the lax-cut swards, the total protein yields were clearly greater with a low cutting height.

In the nitrogen fertilization trial at Viik (Table 24) the application of 125 kg/ha N caused an increase in crude protein yield of about 400 kg. In this trial the cutting height had no appreciable effect on either the protein or the fibre content.

Table 24. Contents of crude protein and fibre as well as total protein yields in nitrogen fertilization trial with cocksfoot at Viik, 1958.

Cutting height cm	Not fertilized Crude protein kg/ha	%	Fibre %	125 kg/ha N Crude protein kg/ha	%	Fibre %	Average Crude protein kg/ha	%	Fibre %
10	682	16.4	25.5	1133	18.0	26.2	908	17.2	25.9
6	863	16.3	25.7	1223	17.6	27.1	1043	17.0	26.4
3	942	17.6	25.8	1347	17.1	26.6	1145	17.4	26.2
Average	829	16.8	25.7	1234	17.6	26.6	1032	17.2	26.2

Table 25. Contents of crude protein and fibre as well as total protein yields in defoliation trial with cocksfoot at Mikkeli, 1961.

	Treatment		Crude protein		Fibre
	Cutting height cm	No. of cuts	kg/ha	%	%
	*)		924	9.4	36.7
Cut at equal growth stages	20	12	857	19.0	27.6
	20	5	683	14.9	29.5
	Average		770	16.9	28.6
	10	12	895	21.1	23.9
	10	6	846	16.2	26.6
	10	4	814	15.4	28.9
	Average		852	17.1	26.6
	5	12	629	22.1	23.1
	5	5	810	16.8	27.5
	5	4	833	14.9	27.2
	Average		756	17.1	26.4
	0	7	393	19.4	20.6
	0	4	591	16.3	23.9
	0	2	733	12.3	30.0
	Average		572	14.7	26.4
Cut at equal intervals	5	10	777	20.1	22.5
	5	7	948	19.1	24.5
	5	4	833	13.5	29.4
	Average		853	17.1	26.0
	0	8	350	16.7	22.2
	0	4	847	16.5	24.7
	0	2	910	9.0	30.1
	Average		702	12.1	27.5

*) Cut at ground level in the autumn

In the trial at Mikkeli (Table 25) the crude protein percentages varied more widely than in the two previously-mentioned trials; this was because of the more radical differences in cutting treatment. On the other hand, with the exception of certain of the plots cut at ground level, the yields of crude protein were approximately the same. The highest yield 924 kg/ha was obtained from the treatment cut only once at ground level in the autumn (the stalks had been removed during the course of the summer). Nearly as large a yield (910 kg/ha) came from the plot cut twice at ground level, the first cut taking place as late as July 4. On the average, the cutting height had no distinct influence on the crude protein yields. Instead, these yields quite closely followed the corresponding dry matter yields (Table 19, p. 43). In certain individual cases with cutting heights of 10 and 20 cm, higher protein yields were obtained with more frequent cuts, whereas with low cutting heights (0 and 5 cm) the relationship was the reverse (with one exception).

Table 26. Contents of crude protein and fibre as well as total protein yields in defoliation trial with cocksfoot at Mikkeli, 1962.

Treatment Cutting height cm	No. of cuts	Crude protein kg/ha	Crude protein %	Fibre %
20	4	1195	18.1	26.6
20	2	903	15.3	31.3
10	4	1026	16.7	26.0
10	2	1049	15.1	29.0
5	4	1101	18.5	25.2
5	2	1035	17.4	27.2
5 *)	4	927	15.5	24.5
5 *)	2	1032	13.4	29.1

*) equal intervals

Frequent cuts at ground level resulted in yields only about half the size of those obtained from the other treatments.

The average crude protein content was the same for cutting heights of 5, 10 and 20 cm. Only in the plots cut at ground level was it lower than at the other heights. In certain cases there was a tendency towards a higher crude protein content the more often the grass was cut, i.e. the younger it was, and further, when certain individual cases are compared with regard to the cutting heights, it can be observed that the herbage had a higher protein content when cut closer to the ground. This held true for cutting heights of 20, 10 and 5 cm and for cutting frequencies of 12 and 5—6 times. In the 5-cm treatments, the average protein percentages were the same for both equal-interval and equal growth stage harvesting.

In the yields in the following year (Table 26), there were only small variations in crude protein yields between the different treatments. With a cutting height of 20 cm, four cuts resulted in definitely higher yields than two cuts, but otherwise the differences were very slight. On the other hand, the crude protein content showed a consistent trend: in all cases four cuts gave a protein content which was at least $1^1/_2$ percentage units higher than two cuts. The cutting height had no effect on the protein percentage. Comparison between harvests at equal heights of stand and equal intervals (the 5-cm treatments) showed that the former cutting method gave distinctly higher crude protein contents than the latter.

Fibre content

In the trial at Jokioinen (Table 27) the highest fibre content of the herbage was found in the stand cut when it was 35 cm tall, or at the silage stage. The effect of height of stand on the fibre content is especially clearly

Table 27. Crude fibre content of herbage in the Jokioinen trial, 1954—56.

Year	Cutting treatment						
	35–10	35–6	35–3	25–10	25–6	25–3	15–3
1954	26.5	27.9	27.6	24.7	25.0	25.8	23.8
1955	24.4	24.3	25.2	24.4	23.2	22.6	21.8
1956	25.6	26.5	25.3	23.2	21.2	21.7	19.9
Average	25.7	26.4	26.2	24.1	23.7	23.2	22.1

seen in the tabulation showing the average figures. In this trial the cutting height did not influence the fibre content. An unexpectedly high fibre content was found in treatment 25—10, even though the harvested herbage always consisted of grass growing above the level of 10 cm and thus never contained the basal parts of the stems. The dependence of fibre content on the amount of herbage removed at each cutting is shown by the function $y = 21.9 + 0.180\ x$, which is highly significant ($F = 14.06^{***}$), and explains the variations in results. The coefficient of correlation was + 0.400.

In the trial at Viik the fibre content was nearly the same in all the treatments (Table 24, p. 60). In the Mikkeli trial in 1961 there were also only slight variations in fibre content (Table 25, p. 61). There was a tendency, however, for the content to rise as the cutting height was increased from 5 to 20 cm. The effect of cutting height is also seen in comparing individual cases. A cutting height of 20 cm, for example, led to higher fibre contents than lower heights. The highest content in the whole trial occurred when only one cut was made in the autumn, and the lowest content was found in the treatment cut frequently at ground level.

In the second year of the trial at Mikkeli (Table 26) more consistent results were obtained. When four cuts were made during the season, the fibre content was always greater than when only two cuts were made. There was also a slight tendency for the fibre content to increase with the cutting height. The differences between cutting at equal intervals and at equal sward heights were very small, but the former resulted in slightly higher fibre percentages than the latter.

Other factors affecting quality of herbage

The digestibility of herbage is a very important factor affecting the quality of the fodder. As the grass becomes older, its digestibility decreases, but at the grazing and silage stages this decrease is relatively slow (Woodman *et al.* 1929; Huokuna 1960 a). No results on the effect of cutting height upon the digestibility of herbage have been published in the literature.

The mineral composition of grasses is very little affected by different defoliation treatments, as has been previously mentioned by the writer (Huo-

KUNA 1960 a). The cutting frequency was found to have the largest influence. MOTT (1961) found that the amounts of ash, K_2O, P_2O_5, MgO, CaO, Na_2O and SO_3 increased as the cutting frequency increased.

Discussion

In summarizing the results of the present trials, it can be stated that the *cutting frequency* (height of sward at time of defoliation) had practically no effect on the total crude protein yield. The only exception was the cutting treatment at ground level, since in this case an increase in frequency caused a reduction in protein yield. On the other hand, the protein content of the herbage was distinctly influenced by the cutting frequency, and the results were always similar: the more frequent the cuts, the higher the protein content. In the case of the fibre content, the relationship was the opposite. The results of KENNEDY (1950) also show the same tendency, although his data include one apparent exception (cf. p. 59). The above observations are confirmed by all investigations made on the effect of age of herbage on its crude protein and fibre contents (GEERING 1941; KLAPP 1951; BIRD 1943).

The effect of *cutting height* on the crude protein yield was not consistent in all the present trials. At Jokioinen and Viik the relationship was distinct: the lower the cut the greater the protein yield. At Mikkeli, on the other hand, the highest yield was obtained from the sward cut at a height of 10 cm. Lower yields were harvested from the 20-cm treatment and also from the 5-cm treatment cut at equal growth stages (Table 25, p. 61). The average value from the latter treatment was unduely low because of the exceptionally weakened plot cut 12 times. Excluding this one exceptional plot, the Mikkeli trials show the same general tendency as the others, although the relationship is not so clear.

When cutting was performed at ground level, the protein yield varied widely. Frequent cuttings resulted in a small yield, whereas four cuts or fewer led to a moderate yield.

The results on the effect of cutting height on the crude protein content appear to be contradictory. At Jokioinen higher protein contents were obtained from higher cuts (Table 23). At Viik (Table 24) no distinct effect at all was observed. At Mikkeli, on the other hand, in both years the protein content was slightly higher in the close-cut than in the lax-cut swards (Tables 25 and 26). It is true that this difference was quite small and not statistically significant, since the chemical analyses were made on combined samples from all the replicates. Such a tendency is understandable, however, since close defoliation removes all the old leaves, which contain less protein than the young ones. In lax cutting, by contrast, the coarse, basal parts of the leaves remain and are harvested in the following cut, thus reducing the protein content of the latter sample. Similar results were also obtained by CHESTNUTT (1960), who found that the crude protein content of rye grass was higher with a cutting height of $^3/_4''$ than $1\ ^1/_2''$.

The opposite results obtained in the trial at Jokioinen can be explained by the fact that during close cutting the frequency was, on the average, less than during lax cutting (Table 18). In addition, the cutting at Jokioinen was done at different times, and as is shown in Table 25 the time of cutting has an appreciable influence on the protein content. Another factor may have been the fact that cutting at Jokioinen was done by machine; in this case, at a high cutting level some of the old leaves (with their low protein content) remain below the cutting blades and are not included in the harvested herbage. At Mikkeli, on the other hand, where scissors were used, each leaf was placed in a vertical position and cut at precisely the same level.

In neither the Jokioinen nor the Viik trials did the cutting height have any effect on the fibre content of the herbage. At Mikkeli, a slight influence was noted in both years, an increase in cutting height resulting in a small rise in fibre percentage. The results of KENNEDY (1950) do not show any distinct relationships between cutting treatment and the contents of protein and fibre. Evidently the abundance of white clover and its variations led to his conflicting results.

The influence of external factors

The results of defoliation trials carried out in different parts of the world can be explained on the basis of the frequency of defoliation, as described on p. 73. High temperatures during the growing season, however, may cause exceptions to this general theory (DRAKE *et al.* 1963). On the other hand it is evident, that the influence of other external factors, such as soil type, nutrition, light and daylength, is not sufficiently profound to alter the results greatly. In certain border line cases, i.e. where the interval between defoliation is just so long that the cutting height is not important, they may cause variations in one direction or the other. Certain external factors, however, such as nitrogen supply and moisture, do have a more important effect, and they will be discussed below.

Nitrogen fertilization

The effect of nitrogen fertilization has been studied by many workers, including ROBINSON and SPRAGUE (1947), SPRAGUE and GARBER (1950), ROBINSON *et al.* (1952), CROWDER *et al.* (1955), PRINE and BURTON (1956) and REID (1959). The results of these studies, in agreement with those obtained by the writer in the trial at Viik (Table 28, p. 66), indicate that the differences in yield caused by different cutting treatments are about the same irrespective of the amount of nitrogen fertilizer applied. CHESTNUTT (1960), on the contrary, found that the relative yield difference between ryegrass swards cut at $^3/_4''$ and $1\ ^1/_2''$ was greater in the lightly-fertilized plots than in those heavily fertilized.

Table 28. Results of nitrogen fertilization and cutting height trial on cocksfoot ley at Viik, 1958.

No. of cuts	Cutting height cm	Unfertilized					125 kg/ha N				
		Dry matter		Bot. comp. weight %			Dry matter		Bot. comp. weight %		
		g/m²	%	Cf.	Wc.	Others	g/m²	%	Cf.	Wc.	Others
4	3	535	20.8	80	15	5	787	19.0	93	6	1
4	6	530	21.5	70	22	8	693	20.5	88	5	7
5	10	417	22.1	77	17	6	630	21.8	92	4	4

Abbreviations: Cf.= Cocksfoot, Wc.= White clover.

The effect of complete fertilization, containing all the common mineral nutrients, is similar to that of nitrogen dressings alone. (Graber 1931; Ahlgren 1938). Exceptional results were obtained by Lovvorn (1944), who found that various herbage species responded differently to cutting treatments according to the intensity of fertilizer application. In general, however, fertilization has only a negligible influence in modifying the results. Only where nutrients are in short supply is there an appreciable effect, the swards with the highest yields suffering most in the following years.

Large nitrogen applications may have a detrimental effect in cases where frequent and close defoliation is carried out (Johnson and Dexter 1939).

In 1958 a trial was conducted at Viik on a cocksfoot ley (variety Trifolium) in which three different cutting heights were used, 3, 6 and 10 cm. One part of the trial ley was unfertilized, while the other received 125 kg/ha N given in three equal applications in the form of ammonium nitrate (25 % N). The dry matter yields were found to increase as the cutting height decreased (Table 28).

In contrast to the dry matter yields, the dry matter percentage of the herbage increased in relation to the increase in cutting height. These figures are not strictly comparable, since the swards were not all cut at the same time. They do, however, indicate the tendency correctly, since similar differences were also noted when all cuts were made at the same time. The fertilized and unfertilized plots are truly comparable, and this comparison shows that the plots receiving nitrogen had a lower dry matter content than the untreated control plots (cf. Jäntti and Köylijärvi 1964). This difference was most evident in the early part of the summer, while in the latter part of the season the fertilized herbage sometimes contained more dry matter than the harvest from the unfertilized plots. This was probably due to the larger proportion of white clover, with its high moisture content, in the unfertilized plots.

This trial field was sown with cocksfoot only, but during the course of the summer wild white clover and other plant species, such as *Taraxacum*, appeared in it and spread considerably. The botanical composition fresh weight percentages given in Table 28 are averages of the two last harvests in the season. In the unfertilized swards white clover spread rapidly, while in those receiving nitrogen it made up only a small proportion of the herbage. The

Table 29. Residual effect of nitrogen fertilization on cutting trial sward. Fresh yields tn/ha. Viik 1959.

Cutting height cm	Unfertilized in 1958 tn/ha		Fertilized in 1958 tn/ha	
	Spring yield	Total yield	Spring yield	Total yield
3	9.5	19.5	9.2	19.8
6	9.4	18.9	10.2	22.0
10	9.8	14.6	11.4	18.4

cutting height had practically no effect on the botanical composition in either kind of sward.

In the following year, 1959, three harvests were taken from this trial field (Table 29). At the first harvest, higher yields were obtained from the plots cut at higher levels in the previous year. This relationship was especially evident in the fertilized plots, while in the control plots all the yields were similar. At the later harvests the plots cut close in the previous year grew so vigorously that the total yield from three harvests showed the opposite relationship, i.e. the close-cut treatment gave the highest yields, just as it had done in the year of treatment.

The effect of nitrogen fertilization on the seasonal growth pattern is shown in Fig. 11. In all cases the treated plots grew more vigorously than the untreated ones, and this effect persisted throughout the entire season. The largest relative differences between the fertilized and unfertilized plots were observed in the latter half of June, when the growth peak had been passed. The growth peak was shorter in the unfertilized than in the fertilized grass. Already in the early part of the summer the close-cut swards underwent more rapid growth than the lax-cut swards. In the latter part of the summer the differences in growth were mainly caused by the fertilizer. In general, the curves are seen to follow parallel courses with little intersecting.

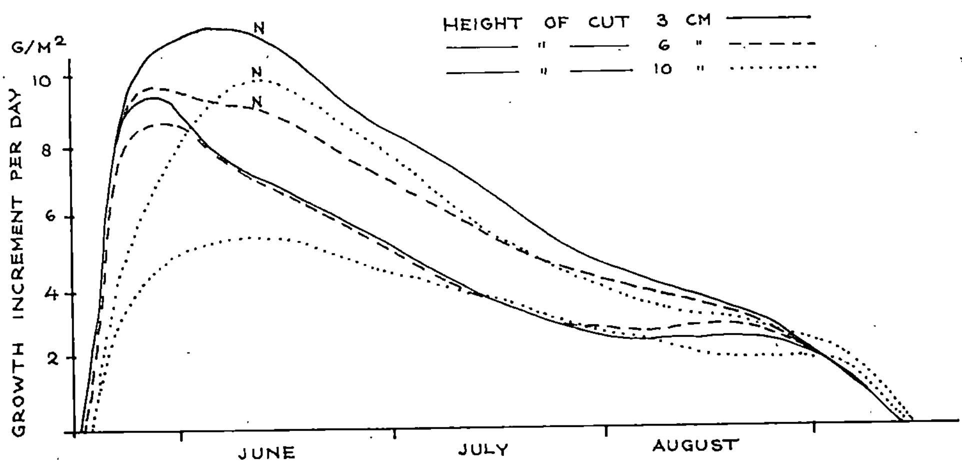

Fig. 11. Seasonal growth curves in the trial at Viik 1958. N = Nitrogen fertilized.

Water

Water is the most important of the growth factors which may modify the yield differences caused by defoliation treatments. Close cutting greatly reduces the water uptake capacity of plants (cf. JÄNTTI 1953 a; KRAMER 1959), and thus it might be thought that the moisture supply would considerably modify the effect of cutting height. Very few data, however, have confirmed this. On the other hand, many results have been obtained on the influence of water supply on the effect of cutting frequency. For instance, STAPLEDON (1924) and WOODMAN *et al.* (1929) found that the yield difference between leys cut often and those cut infrequently increased under dry conditions. In the trials of PRINE and BURTON (1956), *Cynodon dactylon* cut at weekly intervals in a wet summer gave a yield 50.1 % of a corresponding sward cut at 8-week intervals, but in a dry year the figure was only 34.6 %. AHLGREN (1938) carried out a defoliation trial with meadow grass, harvesting at three different stages: 4—5″ in height, beginning of heading, and completely headed. On the non-irrigated plots the yield was greater when the cutting frequency was reduced, but on the irrigated plots (given 1 1/2″ water weekly) the results were the reverse. In both instances the yield differences were very small. Divergent results were obtained by NELSON and ROBINS (1956), who found that the differences caused by different cutting treatments (6″ — 2″ and 12″ — 2″) on a cocksfoot-Ladino ley were greater on moist than on dry soil.

JÄNTTI and HEINONEN (1957) investigated the effect of cutting height on the regrowth of grass on dry and wet soil. When close cut, the sward on dry soil had relatively poorer regrowth after three weeks than that on wet soil. Likewise, in the trials of ALBERTSON *et. al.* (1953) dry conditions hindered the growth of close-cut swards.

On the other hand, in experiments where the sward was cut throughout the growing season, the moisture conditions had no observable influence on the effect of cutting frequency. ROBINSON and SPRAGUE (1947) used cutting heights of 1/2″, 1″ and 2″ on a meadow grass ley when it had attained a height of 4—5″. They found that the closest cutting treatment resulted in the highest yields and that the yield ratios were the same on both the irrigated and non-irrigated plots. Similarly in the trials made by REID (1962) the moisture conditions had no effect on the results.

During the trials carried out by the writer at Jokioinen, the summer of 1955 was very dry. In this year the highest cutting level (10 cm) gave relatively poorer yields than in 1954 and 1956, when rainfall was abundant (Fig. 1, p. 9, Table 2, p. 10). The trials at Mikkeli showed different results. In both 1961 and 1962 there was high rainfall, and according to visual observations there was adequate moisture in the soil during the entire season. However, in these two summers the higher cutting level gave relatively better yields than in the other trials performed by the writer. Many observations indicate that when the entire herbage production of the season is harvested, close-cut leys give satisfactory yields both in wet and in dry summers. In dry years close-cut leys evidently need a longer rest period between cuttings. Although close defoliation markedly reduces the water uptake capacity of the grass, it is probable that this capacity is recovered as new leaves are formed. If the rest period is sufficiently long, about three weeks or more, the roots reach the lower, moist layers of the soil and begin to grow vigorously. It can be assumed that the water uptake capacity of close-cut swards is more efficient that that of lax-cut swards, which have a relatively slower growth but a great transpiring leaf area. If the rest period is too short as a consequence of frequent defoliation, the size of the root system is constantly reduced with the result that the plant suffers in dry conditions.

Other factors

There are few reports in the literature on the influence of light, temperature and daylength upon the variations in yield caused by differential cutting treatments. According to ALBERDA (1957), decreased light retarded the growth recovery of plants after defoliation. LOVVORN (1945) found that an increase in temperature enhanced the growth of those treatments which, owing to cutting treatment or to fertilization, gave higher yields than the other treatments.

Recent studies in the U.S.A. have shown that the temperature may have a pronounced influence on the cutting height of cocksfoot. DRAKE *et al.* (1963) obtained a greater yield with 3″ cuts than with 1 $^{1}/_{2}$″ cuts. This effect can be attributed to the very high temperatures during mid-summer which retarded the growth of the plants so much that their carbohydrate reserves were rapidly depleted. The regrowth of the stand after the hot period had ended was thus dependent upon the size of the reserve carbohydrates remaining in the plant. Consequently it may occur that a close-cut sward looses so much of its reserves during hot weather that its regrowth is considerably poorer than that of a sward cut at a higher level.

The pronounced effect of temperature on the results obtained in this study was also confirmed by the observation of the author that results deviating from the general rule were obtained when the temperature was lower than usual. In the cool autumns of 1956 and 1962 certain of the lax-cut swards — which normally gave lower yields — grew more vigorously than the closer-cut swards (cf. p. 51). The very small number of yield results which deviate from those excepted on the basis of the frequency theory would seem to indicate that the effect of the above-mentioned factors in modifying the yield results is generally quite small.

Discussion of entire results

Mortimer and Ahlgren (1936) attributed the larger yields obtained by close cutting treatment to the greater amounts of young tillers harvested as compared with lax cutting. This may be a valid explanation when the yield differences are small, since at least in cocksfoot leys the formation of young tillers is quite slight (cf. p. 15). The yield differences in the 1961 trial at Mikkeli were small and were approximately the same as the differences in the amounts of stubble (Fig. 12).

In contrast to the Mikkeli trial, at Jokioinen the yield differences between the cutting treatments were considerably larger than the corresponding differences in the stubble (cf. p. 53). This can apparently be explained by the working hypothesis of the present study, namely concerning the effect of plant growth regulators on the growth of the leys under treatment. When the foliage system of the plant reaches a certain size characteristic of the species and the conditions prevailing, the auxins regulate the growth processes of the plant in such a way that an ever increasing share of the products formed by the leaves are directed to the storage organs instead of toward the formation of more new leaves. This fact was demostrated in studying the relationship between roots and tops in the rate of growth trial at Viik (Huokuna 1960 b). Since a lax-cut sward reaches such a maximum foliage size earlier than a close-cut sward, it is understandable that with infrequent defoliation the close-cut sward will give greater total herbage yields.

This phenomenon was confirmed in the Mikkeli trial in 1961, the results of which are depicted graphically in Fig. 12. The vertical columns represent the total weight (both above-ground and underground parts) of each treatment. The horizontal line separates the total weight into the herbage yield (above the line) and the stubble + roots (below). The line of diagonal segments joining the columns indicates the ground level. It can be seen that within a certain range of cutting frequencies (4—6) there were no appreciable differences in the total weight, even though the cutting height varied from 5 to 20 cm. But the herbage yield generally made up a greater proportion of the total weight at the lower cutting heights. Lax cutting resulted in a vigorous root system and a large reserve supply, with the result that the early spring growth the following year was more abundant than in the case of the close-cut swards (Table 17). However, this superiority of the lax-cut treatment was only of short duration, as the results of the trials at Viik and Jokioinen show. Evidently the stimulating effect of light upon the stem bases promotes vigorous growth.

The size of the photosynthesizing leaf area did not have so profound an influence on the yields as has been assumed (Brougham 1956). It is true that as the average leaf area increased, the weight of roots was greater (cf. p. 20), but within certain limits there were no differences in herbage yield or in total weight. Consequently the above-ground growth of the swards having a large leaf area was less than that of swards with a smaller average leaf area.

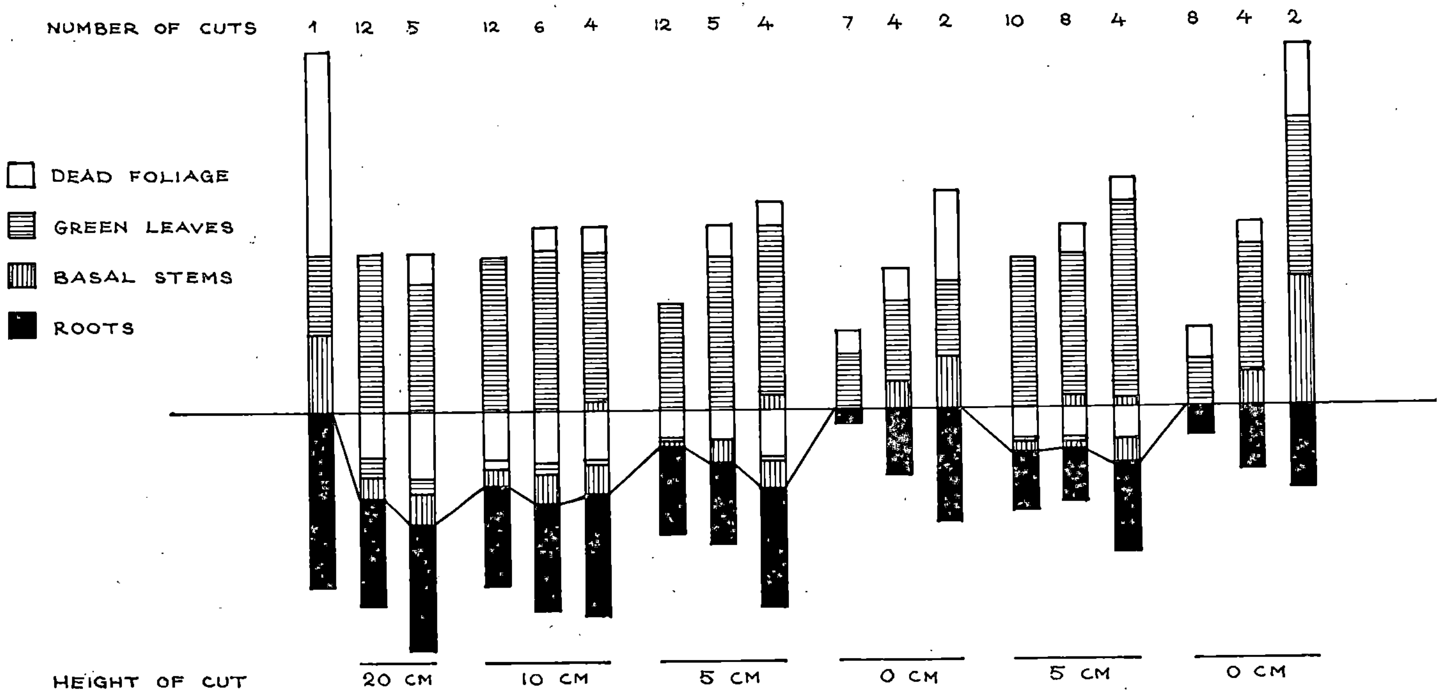

Fig. 12. Total weight (both aerial and underground parts) of cocksfoot swards given different cutting treatments at Mikkeli, 1961.

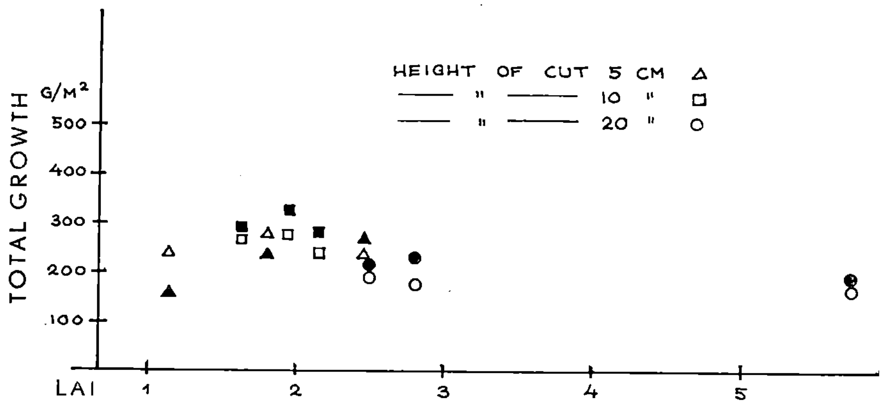

Fig. 13. Total weight (solid figures) and herbage yield (open figures) in relation to leaf area in the trial at Mikkeli, 1961.

In the Mikkeli trial in 1961 the dry matter increment during the season was calculated by subtracting the stubble + root weight in the spring from the sum of the herbage yield and the stubble + root weight in the autumn. This value was then divided by the leaf area index (LAI) to give the total increment per unit leaf area. In a corresponding manner the herbage yield was divided by the same index figure to give the herbage yield per unit area of leaf. It was found that in the close-cut sward (5 cm) the herbage yield per unit leaf area was greater than the total weight (the root system having decreased during the summer), but in the lax-cut swards (10 and 20 cm) the relationship was the opposite (Fig. 13).

In the following year, 1962, it was found that the total growth in relation to the leaf area was always greater than the corresponding herbage yield (Fig. 14). The difference between these was much larger in the lax-cut than in the close-cut swards. Both the figures also show that the total growth per unit leaf area was less in the treatments with a cutting height of over 10 cm than in those with lower cutting levels. This is due to the fact that as a leaf ages, its photosynthetic efficiency declines (Brougham 1956; Langer 1957). Since under the experimental conditions the stems of cocksfoot are about 5—10 cm tall, cutting at a height of 20 cm, for example, results in a stubble with 10—15 cm leaves. Since the rapidly-growing part of a grass plant is located in its stem base, the greater part of a tall stubble consists of old leaves having a reduced photosynthetic efficiency. This fact was also confirmed by the slightly greater fibre contents and correspondingly lower crude protein contents in lax-cut than in close-cut swards.

The statement made by Brougham (1956) that maximum herbage yields are obtained when the leaf area is large enough to intercept all the incident light available, did not find confirmation in the current investigations. The highest yields

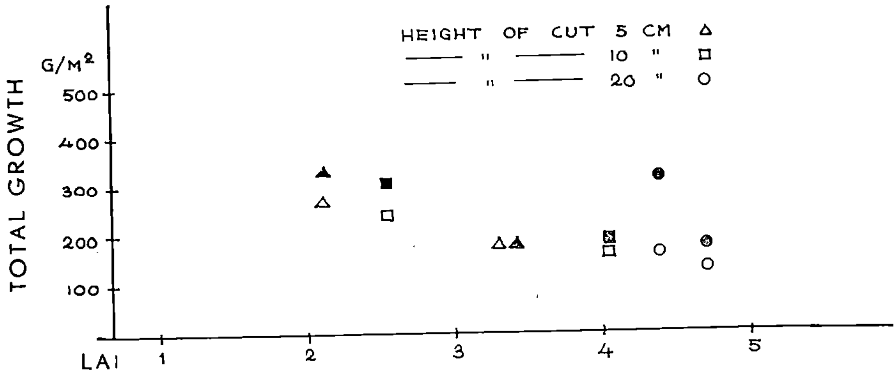

Fig. 14. Total weight (solid figures) and herbage yield (open figures) in relation to leaf area in the trial at Mikkeli, 1962.

were obtained when the leaf area index (LAI) was 2—3, in contrast to the report of Brougham (1956) that the LAI must be 4—5 before all the light is intercepted. The present writer came to the same conclusion as Reid (1962) that at least at the latitudes in Finland (lat. 60—65° N.), where light rays reach the ground at a much lower angle than in New Zealand, where Brougham performed his experiments, a large leaf area is not the only prerequisite for maximum yields of cocksfoot. On the contrary, the dry matter yield on higher latitudes appears generally to be determined according to the frequency theory: with frequent cutting larger yields are obtained with higher cutting levels, while with infrequent cutting the relationship — providing the cutting height is greater than 3 cm — is the opposite. Another feature is that the effect of frequency is more pronounced with close than with lax cutting (Fig. 12).

From the standpoint of forage production, it is desirable that the herbage yield should not only be as large as possible but also meet certain quality requirements. At the same time the plants must be left in such good condition that they persist over the winter and give a good yield the following year as well. Since under Finnish conditions cocksfoot is very hardy, the grower need not be greatly concerned about maximum persistence in his grassland management, but instead he should arrange the harvest treatments to yield the kind of fodder desired (assuming, of course, that sufficient hardiness is present). Figure 15 shows various characteristics of cocksfoot herbage which were obtained by different cutting treatments. The figure has been constructed from the average 3-year results at Jokioinen in 1954—56 and those from Mikkeli in 1961. Below the straight diagonal line are cases in which the plants were weakened. Two cuts at ground level resulted in a large root system, but nevertheless the sward was judged to be weakened, since its sugar content was low and it suffered serious damage in the winter (Table 17).

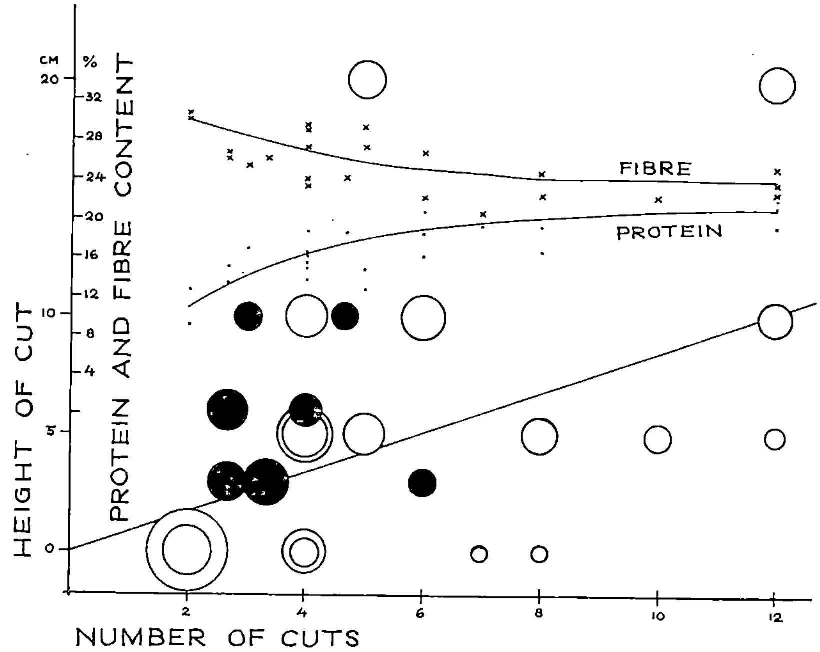

Fig. 15. Herbage yield of cocksfoot swards, crude protein and fibre content. Solid figures Jokioinen 1954—56, open figures Mikkeli 1961. 1 mm in diameter of figures represents 100 g/m^2 D. M.

The two upper curves in Fig. 15 denote the crude protein and fibre contents calculated on the basis of the results of these trials. They were, in general, independent of the cutting height. On the other hand, the cutting frequency in the range from 2 to 4 had a marked effect on the contents of protein and fibre, while above 5 cuts the effect remained practically the same. Since application of fertilizer has been found to have virtually no effect on the fibre content (Saarinen and Jäntti 1955; present work, Table 24, p. 60), the cutting frequency it thus the only factor influencing the fibre content of cocksfoot as shown in the figure.

The position of the curve denoting crude protein content is affected by the nitrogen fertilization, however. In the present instance, the rate was 125 kg N/ha. If no fertilizer had been applied, the curve would have been about 1—2 percentage units lower, and if the nitrogen rate had been doubled, it would have been 2—3 percentage units higher (Jäntti and Köylijärvi 1964). On the basis of various cutting experiments (e.g. Prine and Burton 1956) it can reasonably be concluded that the shape of the curve remains the same irrespective of the nitrogen rate, only its position varying.

In regard to the practical applications of the results of the present study, it can be stated that harvesting cocksfoot leys can be carried out in different ways according to the kind of fodder desired. If a relatively coarse forage is adequate, then 2—3 harvests during the season will give large yields. On the other hand, if the fodder is intended as the only or principal feed for dairy cattle, then large nitrogen applications should be given and at least four cuts made. More than six cuts, however, can not be recommended, since the yield will be small and the quality of the herbage (in terms of its protein and fibre content) is no longer improved. The more frequent the harvests, the higher the cuts should be made in order to preserve the vigour of the sward for future years. If, on the other hand, only 3—5 cuts are made during the season, they should be close (about 5 cm). In this case, a large yield will be obtained, but the sward will still remain vigorous and will persist for many years.

Summary

In the years 1954—62 defoliation trials on cocksfoot leys were carried out at Jokioinen, Viik and Mikkeli. The seed rate in all the trials was 15 kg/ha. The cocksfoot variety at Jokioinen and Mikkeli was Daeno II, at Viik it was Trifolium. At Jokioinen the seed was sown broadcast, at the other locations drill-sown with a 15-cm row distance. The soil type at Jokioinen was heavy clay, at Viik very fine sand, and at Mikkeli fine sand. The soil was in good condition and received annual dressings of 60 kg P_2O_5, 50 kg K_2O and 125 kg N per hectare.

The cutting frequencies varied from 0 to 12, the cutting heights from 0 to 20 cm. The tiller density of cocksfoot was found to be 1600—2300 per m^2. The only treatments which reduced the tiller density were 4 or more cuts at ground level. When 7—8 such cuts were made, 80—90 % of the tillers died.

Defoliation treatment affected the weight of roots more strongly than the tiller density. When the cutting height was 5 cm or more, the effect of frequency was quite slight, the result generally being that the greater the number of cuts, the smaller the root system. When defoliation was made at ground level, the effect of frequency 2—8 was very pronounced. Variations in the cutting height from 3 to 20 cm had no effect on the weight of the roots except with very frequent defoliation, and even then the effect was negligible. The correlation between average leaf area index during the growing season and the weight of the roots was determined at Mikkeli in 1961 to be $r = +0.823$. Nitrogen fertilization increased the weight of roots, but irrigation decreased it (Table 7, p. 22).

In the 1961 trial the cutting frequency had no effect on the sugar content, in roots and stem bases but in 1962 the sugar content was higher in the four-cut than in the two-cut treatment. No effect on the sugar percentage was caused by the cutting height, provided that it was at least 5 cm (Table 12, p. 26). When cut often, the amount of stem bases was generally small, but with infrequent cuts there were no essential differences. The amount of stem bases was greater at higher cutting levels, but the differences were quite small.

With frequent defoliation at ground level, there were very small amounts of reserve carbohydrates in the roots and stem bases. When cut frequently, the volume of these storage organs decreased with closer cuts, but when cut infrequently there was no difference. The early spring growth was vigorous when the amount of food reserves was great in the previous autumn, although in some cases (cut at ground level) the cocksfoot swards overwintered poorly in spite of a large reserve supply. In the 5-cm treatment about 20 % of the tillers died during the winter, while in the 10 and 20-cm treatments the figure was 10—15 %. These differences were soon equalized, however, since on July 11 equally large harvests were obtained from all the plots (Table 14, p. 29).

The dry matter herbage yield was inversely related to the cutting frequency. When the frequency was 10—12, the yield was larger at higher cutting heights. On the contrary, when the frequency was 1—5, the closer-cut swards gave the higher yields. An exception to this rule was defoliation at ground level, since even 3 cuts weakened the sward, with a consequent decrease in yield. The time of cutting was also found to have an effect on the herbage yield. Swards cut at equal intervals, i.e. relatively infrequently during the period of rapid growth in the early summer, gave distinctly higher yields than those cut when they had reached equal heights of stand (Table 18, p. 40).

The reason for the greater herbage yields of the close-cut treatment was that regrowth of lax-cut swards slowed down sooner than that of close-cut swards. This is due to the fact that lax-cut stands soon reach the stage when their photosynthetic products are transported to the roots and other storage organs, whereas close-cut stands continue to produce new foliage. Furthermore, it was established that because of the relatively large proportion of old leaves in the lax-cut sward, its photosynthetic efficiency is reduced, and consequently its total growth is less than that of close-cut swards.

The proportion of green leaves in the herbage yield was generally larger with frequent cuts. The cutting height (5—20 cm) had only a slight influence on the leaf content of the yield. The amount of dead foliage was greatest (55 %) in the sward which had grown undisturbed during the entire summer. In the other treatments, the amount of dead foliage generally rose with an increase in cutting height. The plots cut at ground level formed an exception to this rule, since they contained abundant dead foliage.

The crude protein content of the herbage increased in relation to an increase in cutting frequency. The cutting height (at least 3 cm) had only a slight effect; there was a tendency towards an increased protein content in the close-cut swards. When cut at ground level, however, the herbage contained the least protein.

The crude fibre content of the herbage increased as the length of the cutting interval increased. The cutting height had no effect on the fibre content.

Cutting height of cocksfoot, more than 5 cm, had no advantage from agricultural point of view.

REFERENCES

AHLGREN, H. L. 1938. Effect of fertilization, cutting treatments, and irrigation on yield of forage and chemical composition of the rhizomes of kentucky bluegrass (*Poa pratensis* L.). J. Amer. Soc. Agron. 30: 683—691.

ALBERDA, TH. 1956. De verandering in de koolhydratreserve bij engelsk raaigras (*Lolium perenne* L.) van november 1954 tot november 1955. Rep. Centr. Inst. Landbouwk. Onderz. 1955: 48—56.

—»— 1957. The effects of cutting, light intensity and night temperature on growth and soluble carbohydrate content of *Lolium perenne*. Plant and Soil 8: 199—230.

ALBERTSON, F. W. & RIEGEL, A. & LAUNCHBAUGH, J. L. 1953. Effects of different intensities of clipping on short grasses in West-Central Kansas. Ecology 34: 1—20.

ALDOUS, A. E. 1930. Effect of different clipping treatment on the yield and vigour of prairie grass vegetation. Ibid. 11: 752—759.

ARNI, P. C. & PERCIVAL, E. G. V. 1951. Studies of fructosans. Part III. Triticin from the rhizomes of couch grass (*Triticum repens* L.). J. Chem. Soc. 1951: 1822—1830.

BAKER, H. K. 1957 a. Studies on the root development of herbage plants. II. The effect of cutting on the root and stubble development, and herbage production, of spaced perennial ryegrass plants. J. Brit. Grassl. Soc. 12: 116—126.

—»— 1957 b. Studies on the root development of herbage plants. III. The influence of cutting treatments on the root, stubble and herbage production of a perennial ryegrass sward. Ibid. 12: 197—208.

BARKER, M. G. & HANLEY, F. & RIDGMAN, W. J. 1957. Studies on lucerne and lucerne-grass leys. 4. The effect of systems of grazing management on the persistence of a lucerne-cocksfoot ley. J. Agric. Sci. 48: 361—365.

BIRD, J. N. 1943. Stage of cutting studies: I Grasses. J. Amer. Soc. Agron. 35: 845—861.

BISWELL, H. H. & WEAVER, J. E. 1933. Effect of frequent clipping on the development of roots and tops of grasses in prairie sod. Ecology 14: 368—390.

BLAISDELL, J. P. & PECHANEC, J. F. 1949. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ibid. 30: 298—305.

BONNIER, G. & TEDIN, O. 1940. Biologisk variationsanalys. 325 p. Stockholm.

BOUYOUCOS, G. J. 1954. New type electrode for plaster of paris moisture blocks. Soil Sci. 78: 339—342.

BROUGHAM, R. W. 1955. A study in rate of pasture growth. Aust. J. Agric. Res. 6: 804—812.

—»— 1956. Effect of intensity of defoliation on regrowth of pasture. Ibid. 7: 377—387.

BROWN, B. A. & MUNSELL, R. I. 1956. Effects of cutting systems on Ladino clover. Bull. 313 Connecticut Agric. Exp. Sta. 1956. 42 p. (Ref. Herbage Abstracts 27: 180.)

BRYANT, H. T. & BLASER, R. E. 1961. Yields and stands of orchardgrass compared under clipping and grazing intensities. Agron. J. 53: 9—11.

BURGER, A. W. & JACKOBS, J. A. & HITTLE, C. N. 1962. The effect of height and frequency of cutting on the yield and botanical composition of smooth bromegrass and orchardgrass mixtures. Ibid. 54: 22—26.

CARTER, J. F. & LAW, A. G. 1948. The effect of clipping on the vegetative development of some perennial grasses. J. Amer. Soc. Agron. 40: 1084—1091.

CHESTNUTT, D. M. B. 1960. The effect of cutting treatment on the yield of dry matter and crude protein of eight perennial ryegrass varieties. Res. Exp. Rew. Min. Agric. N. I. 10: 35—52.

COMSTOCK, V. E. & LAW, A. G. 1948. The effect of clipping on the yield, botanical composition and protein content of alfalfa-grass mixtures. J. Amer. Soc. Agron. 40, 1074—1083.

COUCHMAN, J. S. 1959. Changes in the soluble sugar contents of short rotation ryegrass during growth. J. Aust. Inst. Agric. Sci. 25: 315—319.

CROWDER, L. V. & SELL, O. E. & PARKER, E. M. 1955. The effect of clipping, nitrogen application, and weather on the productivity of fall sown oats, ryegrass and crimson clover. Agron. J. 47: 51—54.

DRAKE, M. & COLBY, W. G. & BREDAKIS, E. 1963. Yield of orchard grass as influenced by rates of nitrogen and harvest management. Ibid. 55: 361—362.

ELOFSON, A. & HOFMAN-BANG, O. 1922. Skördetidens inflytande på avkastningsförmågan hos några grässlag. Sv. Betes- och Vallför. Årsskr. 1922: 41—51.

GEERING, J. 1941. Ueber den Einfluss der Häufigkeit des Wiesenschnittes auf Pflanzenbestand, Nährstoffgehalt und Nährstoffertrag. Landw. Jbuch. Schw. 55: 579—597.

GERNERT, W. B. 1936. Native grass behavior as affected by periodic clipping. J. Amer. Soc. Agron. 28: 447—456.

GERVAIS, P. 1960. Effects of cutting treatments on Ladino clover grown alone and in mixture with grasses. I. Productivity and botanical composition of forage. Canad. J. Pl. Sci. 40: 317—327.

GRABER, L. F. 1931. Food reserves in relation to other factors limiting the growth of grasses. Plant Physiol. 6: 43—71.

—»— 1933. Competitive effiency and productivity of bluegrass (*Poa pratensis* L.) with partial defoliations at two levels of cutting. J. Amer. Soc. Agron. 25: 328—333.

—»— & REAM, H. V. 1931. Growth of bluegrass with various defoliations and abundant nitrogen supply. Ibid. 23: 938—944.

HARRISON, C. M. 1931. Effect of cutting and fertilizer applications on grass development. Plant Physiol. 6: 669—684.

—»— 1934. Responses of kentucky bluegrass to variations in temperature, light, cutting and fertilizing. Ibid. 9: 83—106.

—»— & HODGSON, C. W. 1939. Response of certain perennial grasses to cutting treatments. J. Amer. Soc. Agron. 31: 418—430.

HIEPKO, G. 1959. Untersuchungen zum Reservestoffwechsel mehrjähriger und jährlich mehrfach genutzter Futterpflanzen. Z. Acker- und Pflanzenbau 108: 339—364.

HUOKUNA, E. 1960 a. Grazing on herbage at different grazing stages: its effect on a cocksfoot dominant ley and on milk production. Valt. maatal.koetoim. julk. 177: 1—44.

—»— 1960 b. The effect of differential cutting on the growth of cocksfoot (*Dactylis glomerata* L.). Proc. Eight Int. Grassl. Congr. 429—432.

—»— & JATILA, T. & RUUTTUNEN, E. 1962. Koiranheinän korrenmuodostuksesta laidunnurmessa ja sen ehkäisemisestä. S. Laiduntalous 34: 43—50.

JAQUES, W. A. & EDMOND, D. B. 1952. Root development in some common New Zealand pasture plants. V. The effect of defoliation and root pruning on cocksfoot (*Dactylis glomerata*) and perennial ryegrass (*Lolium perenne*). N.Z. J. Sci. Tech. 34: 231—248.

JOHNSON, W. M. 1953. Effect of grazing intensity upon vegetation and cattle gains on ponderosa pine — bunchgrass ranges of the Front Range of Colorado. Circular Nr. 929, 36 p.

JOHNSON, A. A. & DEXTER, S. T. 1939. The response of quack grass to variations in height of cutting and rates of application of nitrogen. J. Amer. Soc. Agron. 31: 67—76.

JONES, M. G. 1933. Grassland management and its influence on the sward. Pt. III. The management of a "grassy" sward and its effects. Emp. J. Exp. Agric. III. 1: 222—234.

JONES, I. 1939. Pasture management and its effects on the sward. Welsh Plant Breed. Sta. Bull. 11: 40—129.

JULANDER, O. 1945. Drought resistance in range and pasture grasses. Plant Physiol. 20: 573—599.

JUSKA, F. V. & TYSON, J. & HARRISON, C. M. 1955. The competitive relationship of merion bluegrass as influenced by various mixtures, cutting heights and levels of nitrogen. Agron. J. 47: 513—518.

JÄNTTI, A. 1953 a. Grassland practices in relation to soil water in Central, West and North European countries. Acta agr. fenn. 81, 2: 1—39.
—»— 1953 b. Koiranheinä ja nurminata lyhytikäisten laidun- ja säilörehunurmien valtakasveina. Ibid. 81, 3: 1—64.
—»— & HEINONEN, R. 1957. Effect of defoliation and soil moisture on grassland re-growth. J. Brit. Grassl. Soc. 12: 56—61.
—»— & HUOKUNA, E. 1955. AIV-rehun korjaaminen lyhytikäisiltä laidunnurmilta. Maatal. ja koetoim. 9: 212—222.
—»— & KÖYLIJÄRVI, J. 1964. Laidunnurmien typpiväkilannoituskokeiden tuloksia. Viikin ja Malminkartanon kokeet 1951—56. Ann. Agric. Fenn. 3: 165—214.
JÄÄSKELÄINEN, O. 1930. Viljelyslaidun. 360 p. Porvoo.
KENNEDY, W. K. 1950. Simulated grazing treatments. Effect on yield, botanical composition and chemical composition of a permanent pasture. Cornell Univ. Agric. Exp. Sta. 295: 1—47.
—»— & RUSSEL, M. B. 1948. Relationship of top growth, root growth, and apparent specific gravity of the soil under different clipping treatments of a kentucky bluegrass- wild white clover pasture. J. Amer. Soc. Agron. 40: 535—540.
KLAPP, E. 1937. Über einige Wachstumsregeln mehrjähriger Pflanzen unter die Nachwirkung verschiedener Nutzungsweise. Pflanzenbau 14: 209—224.
—»— 1942. Entwicklung, Wurzelbildung und Stoffspeicherung von Futterpflanzen. Ibid. 18: 347—352 and 367—387.
—»— 1951. Leistung, Bewurzelung und Nachwuchs einer Grasnarbe unter verschiedener häufiger Mahd und Beweidung. Z. Acker- und Pflanzenbau 93: 269—286.
—»— & SCHULZE, E. 1957. Versuche über Stoffbildung und Stoffspreicherung bei mehrjährigen und mehrschnittigen Futterpflanzen. 2. Mitteilung. Ibid. 103: 361—379.
KRAMER, P. J. 1963. Water stress and plant growth. Agron. J. 55: 31—35.
KYDD, D. D. 1957. Grazing intensity — its effect on botanical composition. Agric. Rev. II 8: 25—30.
LAINE, T. 1953. Menetelmä laidunnurmen keskimääräistä kasvua kuvaavan käyrän laatimiseksi. J. Sci. Agric. Soc. Finl. 25: 185—192.
—»— 1962. Laidunkoeasema vuonna 1961. S. Laiduntalous 34: 71—77.
LANGER, R. H. M. 1957. Growth and nutrition of timothy (*Phleum pratense*). 2. Growth of the plant in relation to tiller development. Ann. Appl. Biol. 45: 528—541.
LANGILLE, J. E. & WARREN, F. S. 1961. Response of certain forage species on dikeland and upland to various clipping intensities. Canad. J. Pl. Sci. 41: 693—702.
LOVVORN, R. L. 1944. The effects of fertilization, species competition, and cutting treatments on the behavior of dallis grass, *Paspalum dilatatum* Poir., and carpet grass, *Axonopus affinis* Chase. J. Amer. Soc. Agron. 36: 590—600.
—»— 1945. The effect of defoliation, soil fertility, temperature, and length of day on the growth of some perennial grasses. Ibid. 37: 570—582.
MACKENZIE, D. J. & WYLAM, C. B. 1957. Analytical studies on the carbohydrates of grasses and clovers. VIII. Changes in carbohydrate composition during the growth of perennial ryegrass. J. Sci. Food Agric. 8: 38—45.
MCCARTY, E. C. & PRICE, R. 1942. Growth and carbohydrate content of important mountain forage plants in Central Utah as affected by clipping and grazing. U.S. Dept. Agric. Tech. Bull. 818: 1—51.
MCILVANIE, S. K. 1942. Carbohydrate and nitrogen trends in bluebunch wheatgrass, *Agropyron spicatum* with special reference to grazing influences. Plant Physiol. 17: 540—557.
MORTIMER, G. B. & AHLGREN, H. L. 1936. Influence of fertilization, irrigation, and stage and height of cutting on yield and composition of kentucky bluegrass (*Poa pratensis* L.). J. Amer. Soc. Agron. 28: 515—533.

MOTT, N. 1961. Der Einfluss der Schnitthäufigkeit auf den Eiweiss- und Mineralstoffgehalt der Wiesenfuchsschwanzwiese. Neue Ergebnisse futterbaulicher Forschung. p. 82—87. Frankfurt.

MUDRA, A. 1952. Einführung in die Methodik der Feldversuche. 178 p. Leipzig.

NELSON, C. E. & ROBINS, J. S. 1956. Some effects of moisture, nitrogen fertilizer, and clipping on yield and botanical composition of Ladino clover- orchardgrass pasture under irrigation. Agron. J. 48: 99—102.

PARKER, K. W. & SAMPSON, A. W. 1930. Growth and yield of certain gramineae as influenced by reduction of photosynthetic tissue. Hilgardia 5: 361—381.

PERCIVAL, E. G. V. 1952. The carbohydrate constituents of herbage. Brit. J. Nutr. 6: 104—109.

PETERSON, M. L. & HAGAN, R. M. 1953. Production and quality of irrigated pasture mixtures as influenced by clipping frequency. Agron. J. 45: 283—287.

POHJAKALLIO, O. & ANTILA, S. 1955. On the effect of removal of shoots on the drought resistance of red clover and timothy. Acta agr. scand. V, 2—3: 239—244.

—»— & ESKOLA, H. 1941. Timotein jälkikasvua selvittäviä tutkimuksia. Valt. maatal.koetoim. julk. 112: 1—8.

POIJÄRVI, I. 1931. Korjuuajan vaikutus heinäsadon määrään ja laatuun. Ibid. 35: 1—87.

PRINE, G. M. & BURTON, G. W. 1956. Effect of nitrogen rate and clipping frequency upon the yield, protein content and certain morphologigal characteristics of coastal bermudagrass (*Cynodon dactylon,* (L.) Pers.). Agron. J. 48: 296—301.

PURANEN, U. H. & TOMULA, E. S. 1930. Nopea ja käytännöllinen menetelmä raakakuidun määräämiseksi. S. Kemistilehti 8—9: 85—89.

QUENOUILLE, M. H. 1950. Introductory statistics. 248 p. London.

RAPPE, G. 1946. Grafisk framställning av betestillväxt och väderlek. Sv. Vall och Mosskulturför. Medd. 13: 558—584.

—»— 1951. Seasonal variations in the rate of pasture regrowth after grazing. Plant and Soil 3: 309—338.

—»— & OLOFSSON, S. 1945. Något om utvecklingstidens inverkan på vallbeståndets avkastning och kemiska sammansättning. Sv. Vall och Mosskulturför. Medd. 11: 455—490.

REID, D. 1959. Studies on the cutting management of grass-clover swards. I. The effect of varying the closeness of cutting on the yields from an established grass-clover sward. J. Agric. Sci. 53: 299—312.

—»— 1962. Studies on the cutting management of grass-clover swards. III. The effect of prolonged close and lax cutting on herbage yields and quality. Ibid. 56: 359—368.

REMY, T. 1923. Beiträge zu den Grundlagen des Gras- und Kleebaues. Landw. J.buch. 58: 655—690.

ROBERTS, R. A. & HUNT, I. V. 1936. The effect of shoot cutting on the growth of root and shoot of perennial ryegrass (*Lolium perenne* L.) and of timothy (*Phleum pratense* L.). Welsh. J. Agric. 12: 158—174.

ROBERTSON, J. H. 1933. Effect of frequent clipping on the development of certain grass seedlings. Plant Physiol. 8: 425—447.

ROBINSON, R. R. & SPRAGUE, V. G. 1947. The clover population and yields of a kentucky bluegrass sod as affected by nitrogen fertilization, clipping treatments, and irrigation. J. Amer. Soc. Agron. 39: 107—116.

—»— & —»— & LUECK, A. G. 1952. The effect of irrigation, nitrogen fertilization, and clipping treatments on persistence of clover and on total and seasonal distribution of yields in a kentucky bluegrass sod. Agron. J. 44: 239—244.

RUELKE, O. C. & SMITH, D. 1956. Overwintering trends of cold resistance and carbohydrates in medium red, Ladino and common white clover. Plant Physiol. 31: 364—368.

SAARINEN, P. & JÄNTTI, A. 1955. Laidunnurmien typpiväkilannoituksesta. Maatal. ja koetoim. 9: 67—79.

SALONEN, M. 1949. Tutkimuksia viljelyskasvien juurten sijainnista Suomen maalajeissa. Acta agr. fenn. 70, 1: 1—91.

SAMPSON, A. W. & MCCARTY, E. E. 1930. The carbohydrate metabolism of *Stipa pulchra.* Hilgardia 5: 61—100.

SCHOLL, J. M. & MCINTOSH, T. H. & FREDERIK, L. R. 1960. Response of orchardgrass (*Dactylis glomerata* L.), to nitrogen fertilization and time of cutting. Agron. J. 52: 587—589.

SCOTT, J. D. 1957. The study of primordial buds and the reaction of roots to defoliation as the basis of grassland management. Proc. Seventh Int. Grassl. Congr. p. 479—487.

SOMOGYI, M. 1945. A new reagent for the determination of sugars. J. Biol. Chem. 160: 61—68.

SPRAGUE, V. G. & GARBER, R. J. 1950. Effect of time and height of cutting and nitrogen fertilization on the persistence of the legume and production of orchardgrass-Ladino and bromegrass-Ladino associations. Agron. J. 42: 586—593.

—»— & SULLIVAN, J. T. 1950. Reserve carbohydrates in orchardgrass clipped periodically. Plant Physiol. 25: 92—102.

—»— & ROBINSON, R. R. & GABRER, R. J. 1952. Management of grasslands in the Northeastern States. Pa. Agr. Exp. Sta. Bull. 554: 1—30.

STAPLEDON, R. G. 1924. The seasonal productivity of herbage grasses with particular reference to the influence of different systems of cutting on indigenous and non-indigenous strains respectively. Welsh Plant Breed. Sta. Bull. H. 3: 5—84.

SULLIVAN, J. T. & SPRAGUE, V. G. 1943. Composition of the roots and stubble of perennial ryegrass following partial defoliation. Plant Physiol. 18: 656—670.

—»— & —»— 1953. Reserve carbohydrates in orchardgrass cut for hay. Ibid. 28: 304—313.

THAINE, R. 1954. The effect of clipping frequency on the productivity and root development of russian wild ryegrass in the field. Canad. J. Agric. Sci. 34: 299—304.

TORSTENSSON, G. 1938. Skördeintervallens och stubbhöjdens inverkan på avkastning och rotutveckling hos gräs. Sv. Betes- och Vallför. Medd. 15: 1—37.

TROUGHTON, A. 1960. Further studies on the relationship between shoot and root systems of grasses. J. Brit. Grassl. Soc. 15: 41—47.

WAGNER, R. E. 1952. Yields and botanical composition of four grass-legume mixtures under differential cutting. U.S. Dept. Agric. Techn. Bull. 1063: 1—53.

WAITE, R. 1957. The water soluble carbohydrates of grasses. III. First and second year growth. J. Sci. Fd. Agric. 8: 422—428.

VALLE, O. & VIRTANEN, A. I. 1932. Tutkimuksia niittoajan vaikutuksesta sadon suuruuteen ja sen laatuun. Valion lab. julk. 1932, p. 1—24.

WARD, C. Y. & BLASER, R. E. 1961. Carbohydrate food reserves and leaf area in regrowth of orchardgrass. Crop Sci. 1: 366—370.

WATKINS, J. M. & LEWY-VAN SEVEREN, M. 1951. Effect of frequency and height of cutting on the yield, stand and protein content of some forages in El Salvador. Agron. J. 43: 291—296.

WEAVER, J. E. 1930. Underground plant development in its relation to grazing. Ecology 11: 543—557.

WEINMANN, H. 1948. Underground development and reserves of grasses. J. Brit. Grassl. Soc. 3: 115—140.

—»— 1952. Carbohydrate reserves in grasses. Proc. Sixth Int. Grassl. Congr. p. 655—660.

WILSON, D. B. & MCGUIRE, W. S. 1961. Effects of clipping and nitrogen on competition between three pasture species. Canad. J. Pl. Sci. 41: 631—642.

WOODMAN, H. E. & NORMAN, D. E. & BEE, J. W. 1929. Nutritive value of pasture. IV. The influence of the intensity of grazing on the yield, composition and nutritive value of pasture herbage. II. J. Agr. Sci. 19: 236—265.

SELOSTUS

Leikkuukertojen lukumäärän ja leikkuukorkeuden vaikutus koiranheinänurmiin

ERKKI HUOKUNA

Maatalouden tutkimuskeskus, Etelä-Savon koeasema, Mikkeli

Vuosina 1954—62 suoritettiin Jokioisissa, Viikissä ja Mikkelissä leikkuukokeita koiranheinänurmilla. Kaikissa nurmissa oli koiranheinän siemenmäärä 15 kg/ha. Lajike oli Jokioisissa ja Mikkelissä Daeno II, Viikissä Trifolium. Kylvötapa oli Jokioisissa hajakylvö, muissa rivikylvö 15 cm:n rivivälein. Maalaji oli Jokioisissa aitosavi, Viikissä ja Mikkelissä hieno hieta. Koealueiden kasvukunto oli hyvä, lannoitus vuosittain 60 kg P_2O_5, 50 kg K_2O ja 125 kg N/ha.

Leikkuukertojen lukumäärä oli 0—12, sängen korkeus 0—20 cm. Koiranheinän versotiheys oli 1 600—2 300 kpl/m^2. Versotiheyttä vähensivät vain maata myöten vähintään neljä kertaa suoritetut leikkuut. Versoista kuoli tällöin 80—90 %, kun leikkuita oli 7—8 (taul. 4, s. 16 ja 17, s. 34).

Leikkuukäsittelyjen vaikutus oli voimakkaampi juuriston määrään kuin versotiheyteen. 5 cm:n korkeudelta tai korkeammalta leikattaessa leikkuukertojen lukumäärän vaikutus oli melko pieni, yleensä niin, että mitä useammin leikattiin, sitä pienempi oli juuristo (taul. 5, s. 20). Maata myöten leikattaessa leikkuiden lukumäärän 2—8 vaikutus oli hyvin voimakas. Leikkuukorkeudella 3—20 cm ei ollut vaikutusta juuriston määrään muulloin kuin hyvin usein leikattaessa, ja silloinkin vaikutus oli vähäinen. Kasvukauden aikaisen keskimääräisen lehtialan ja juuriston painon välillä todettiin positiivinen vuorosuhde. korrelaatiokerroin $r = +0.823$. Typpilannoitus lisäsi juuristoa, mutta kastelu heikensi sitä (taul. 7, s. 22).

Juuriston sokeripitoisuuteen ei leikkuiden lukumäärä vaikuttanut mitään v:n 1961 kokeessa, mutta v. 1962 neljä kertaa korjatuissa koejäsenissä sokeripitoisuus oli suurempi kuin kahdesti korjatuissa. Leikkuukorkeus, vähintään 5 cm, ei myöskään vaikuttanut juuriston sokeripitoisuuteen (taul. 12, s. 26). Versojen tyvien määrä oli usein leikatuissa koejäsenissä keskimäärää pienempi, mutta harvoin (1—5 kertaa) leikattaessa ei syntynyt eri käsittelyjen välisiä oleellisia eroja. Tyvien määrä oli yleensä sitä suurempi, mitä korkeammalta leikattiin, mutta koejäsenten väliset erot olivat melko pienet.

Juuristoissa ja tyvissä oleva vararavinnon määrä oli maata myöten usein leikattaessa hyvin pieni. Usein leikattaessa tämä kasvin vararavintovarasto oli sitä pienempi, mitä tarkempaan leikattiin, mutta harvoin korjattaessa eroja ei ollut. Heinän kevätkasvu oli sitä rehevämpää, mitä suurempi oli vararavintovarasto edellisenä syksynä, mutta eräissä tapauksissa (maata myöten leikatut) koiranheinä talvehtii heikosti runsaasta vararavintovarastosta huolimatta. Talven aikana kuolleita versoja oli 5 cm:n sänkeen leikatuissa koejäsenissä noin 20 %, kun niitä 10 ja 20 cm:n koejäsenissä oli 10—15 %. Tiheyserot tasoittuivat kuitenkin melko nopeasti; 11. 7. korjattiin kaikilta ruuduilta sama heinäsato (taul. 17, s. 34).

Kuiva-ainesato oli sitä suurempi, mitä harvemmin leikattiin. Kun leikkuukertoja oli 10—12, oli sato sitä suurempi, mitä suurempi oli leikkuukorkeus. Mutta kun leikkuukertoja oli 1—5, oli sato sitä suurempi, mitä lyhyempään sänkeen leikattiin (taul. 19, s. 43). Poikkeuksena oli leikkuu maata myöten, siinä jo 3 leikkuuta heikensi kasvustoa niin paljon, että sato jäi pieneksi. Leikkuun ajankohta vaikutti myös kuiva-ainesatoon. Ne koejäsenet, jotka leikattiin harvoin kevätkesän runsaan kasvun aikana (tasavälein korjatut), antoivat selvästi suuremman kuiva-ainesadon kuin tasasadoin korjatut (taul. 18, s. 40).

Syynä lyhyen sängen käsittelyjen suureen ruohosatoon oli se, että korkealta niitettäessä lehdistön lisäkasvu heikkeni nopeammin kuin tarkkaan niitetyssä kasvustossa. Todettiin, että korkealta leikattu kasvusto rupesi melko varhaisessa vaiheessa keräämään yhteyttämistuloksia kasvin varastopaikkoihin, tyviin ja juuristoon, kun tarkempaan niitetty kasvusto kasvatti vielä uutta lehdistöä. Mutta todettiin myös, että korkealta leikatussa kasvustossa oleva vanhan lehdistön suhteellisen suuri osuus heikensi yhteyttämistehoa. Siitä syystä kuiva-aineen kokonaistuotos jäi pienemmäksi kuin tarkkaan leikattaessa.

S a d o n l e h t i p i t o i s u u s oli yleensä sitä suurempi, mitä useammin leikattiin. Leikkuukorkeudella 5—20 cm oli hyvin pieni vaikutus sadon lehtevyyteen. Kuihtunutta lehteä, kuloa, oli eniten (55 %) siinä kasvustossa, joka sai rauhassa kasvaa syksyyn saakka. Muissa koejäsenissä oli kuloa yleensä sitä runsaammin, mitä korkeammalta leikattiin. Poikkeuksena olivat kuitenkin kaikki maata myöten leikatut koejäsenet, joissa kuloa oli runsaasti.

Ruohon r a a k a v a l k u a i s p i t o i s u u s oli sitä suurempi, mitä useammin leikattiin. Leikkuukorkeudella (vähintään 3 cm) oli hyvin pieni vaikutus, sato oli tarkkaan leikatuissa koejäsenissä vain vähän valkuaispitoisempaa kuin korkealta leikatuissa. Maata myöten leikattaessa valkuaispitoisuus oli aina alempi kuin muissa (taul. 23, s. 59, 24, s. 60, 25, s. 61 ja 26, s. 62).

Ruohon k u i t u p i t o i s u u s oli sitä suurempi, mitä pitemmät olivat leikkuuvälit. Leikkuukorkeus ei vaikuttanut sadon kuitupitoisuuteen (taul. 24, s. 60, 25, s. 61 ja 27, s. 63).

Koiraheinänurmen leikkuulla yli 5 cm:n sänkeen ei todettu olevan mitään maataloudellista hyötyä.

MS. received September 1, 1964
Printed November 16, 1964