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GRAZING ON HERBAGE AT DIFFERENT GRAZING STAGES: ITS EFFECT ON A COCKSFOOT DOMINANT LEY AND ON MILK PRODUCTION

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INTRODUCTION

The concept of intensity of defoliation of a pasture has been used in literature in estimating the intensity of defoliation both from the point of view of the grazing animals and of the plants being grazed. Thus Klapp (1954) mentions intensity of defoliation as the number of grazings and their dates, as well as the basic function of grazing. Jäntti (1953) has used the concept of d e g r e e o f d e f o l i a t i o n, which is close to the intensity concept, but deals with the defoliation effect more from the point of view of the plant. In determining this, attention is paid to the amount of herbage both at the beginning and at the end of grazing.

In this study the grazing stage of herbage means the developmental stage of the plant, commercing soon after the start of growth and finishing in the heading stage, i.e., the stage during which grazing usually takes place.

MEASUREMENT OF GRAZING STAGE

It is much more difficult to give an accurate description of the grazing stage than of the later stages in the herbage's development. Thus the silage stage can be described, for example, as the heading stage. When making hay the developmental stage of the sward can be indicated very exactly by the flowering stage of the dominant species of grass. The grazing stage is usually expressed as the height of the herbage, which in practice is a comparatively good method, but it is not sufficiently exact when comparing different kinds of swards and different fertilizations. Leaf area index, which was used by the New Zealander Brougham (1955), is a somewhat better criterion for defining grazing stage than the above. It is a ratio expressing the relation of the leaf area of the plants to the corresponding ground area. Its measurement, however, is a laborious procedure. According to Brougham's investigation the leaf area of the grazing stage herbage increases in somewhat the same proportion as the amount of dry matter. This gives good grounds for using Jäntti's (1953) method, in which the amount of dry matter in the herbage is taken as measurement of the grazing stage. In these grazing experiments, where the yield was determined by cutting samples, the grazing stage was also determined at the same time.

EARLIER INVESTIGATIONS

Investigations to ascertain the effects of grazing stage have been few and, in general, no attention has been drawn to the amount of the herbage yield. Jones (1939) arranged various limited grazing trials on leys where cocksfoot comprised part of the sward, but his tests, too, were concentrated in the main on variations in the botanical composition. Again, the Swede Borg (1955) has ascertained from his wide investigations that the amount of utilizable herbage per areal unit (ymnighet) greatly affects the milk production of the grazing animals. On the other hand, the effects of the intensity of defoliation of the ley have been examined in many cutting trials and it has been shown that different defoliation treatments very greatly affect the persistency of the herbage plants and their ability to produce continuously, as well as their yields.

The purpose of this investigation is to ascertain how repeated grazing at early, normal and late grazing stages respectively, affects a cocksfoot dominant ley and the milk production of the cows grazing on it.

I. Grazing stage trial on pastures at Jokioinen in 1954—56

The main trial in this investigation was carried out at Nummela Farm on the Jokioinen Estate, Jokioinen.

A. Trial conditions

1. Type and fertility of soil in trial area

The 6.5 ha trial area was situated on Nummela Farm, in the middle of a field (14.17 ha) at its most uniform part. Topographically the area was practically level, sloping 0.5—1.0 % to the south-west. Tile drains had been laid down in the field in 1949. The subsoil of the whole area consisted of clay and the topsoil of heavy and silty clay with a small humus content. Results of soil fertility tests carried out on the trial area in 1956 are presented in Table 1.

Table 1. Soil nutrients in the 18 cm deep topsoil on the experimental area at Jokioinen in 1956.

Taulukko 1. Maan ravinnepitoisuus Jokioisten laidunkoealueella 18 cm:n ruokamultakerroksessa v. 1956

Treatments *Koejäsenet* 1				2				3			
pH	$CaCO_3$ tons/ha *tn/ha*	K_{40} kg/ha	Psf kg/ha	pH	$CaCO_3$ tons/ha *tn/ha*	K_{40} kg/ha	Psf kg/ha	pH	$CaCO_3$ tons/ha *tn/ha*	K_{40} kg/ha	Psf kg/ha
5.9	13.6	1 550	260	5.8	12.0	1 575	120	5.8	11.5	1 200	90
5.9	11.0	1 650	100	5.8	14.5	2 050	100	6.1	16.0	1 175	240
5.8	10.2	1 275	130	6.0	11.0	1 100	150	5.8	8.4	1 625	100
5.9	13.2	1 400	160	5.9	13.2	1 475	180	5.9	10.8	1 225	140
Average — *Keskim.*											
5.9	12.0	1 470	160	5.9	12.7	1 550	140	5.9	11.7	1 310	140

The results of analysis indicate that the area was uniform in quality.

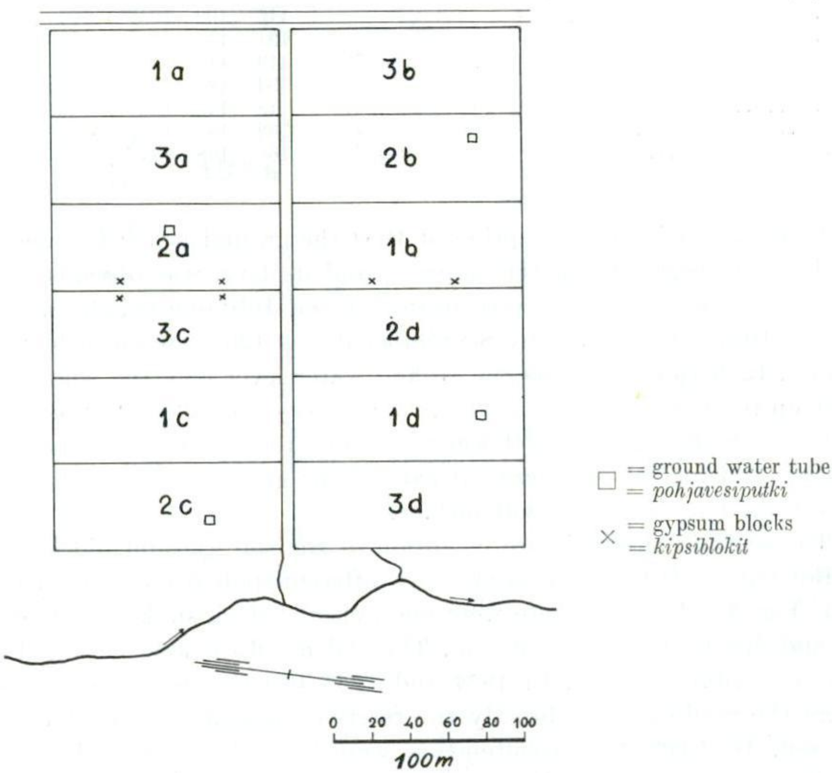

Fig. 1. Grazing trial area at Jokioinen
Kuva 1. Jokioisten laidunkoealue.

2. Ground water level and soil moisture

During the growing season the ground water level was measured at different parts of the trial area at two week intervals, using four wooden tubes (Fig. 1, p). These tubes were 190 cm long. Table 2 presents the average of measurements from three tubes only, as the one in block 2b was empty for the greater part of the time. The average value for the three tubes is probably representative on the approximate depth of ground water over most of the trial area, as these three readings, taken from spots a long way apart, were always on the same level between themselves.

Table 2. Depth in cm. of ground water below soil surface at Jokioinen in 1954—56 (average value and range for three tubes).
Taulukko 2. Pohjaveden etäisyys maan pinnasta Jokioisissa v. 1954—56 (kolmen torven keskiarvo ja vaihtelulaajuus) cm.

Date *Päivämäärä*	1954	1955	1956
1. 6.		85 (77—91)	109 (103—114)
15. 6.		115 (109—124)	121 (117—130)
1. 7.		121 (112—131)	125 (117—135)
15. 7.	170 (153—175)	119 (110—125)	129 (121—141)
1. 8.	147 (137—159)	134 (126—146)	139 (130—150)
15. 8.	134 (128—147)	148 (142—156)	140 (130—151)
1. 9.	130 (117—145)	162 (152—170)	139 (130—151)
15. 9.	122 (110—138)	168 (158—177)	

In the exceedingly dry spring of 1954 the ground water was deep down right at the beginning of the summer, and its level was obviously already rising when measurements were started. From July onward the water level rose continuously, so that by September it was 120—130 cm below the soil surface. In both other years the ground water level sank the whole summer right up to September, though there was heavy rainfall in July and August 1956, for example. The level was very slow to conform with variation in rainfall, and for the most critical part of the growth period the water was more than 1 m below the soil surface.

To ascertain the moisture condition of the soil gypsum blocks, as used by Bouyoucos (1954), were sunk in six different spots (two in each treatment area, Fig. 1), At each, there were one gypsum block sunk to a depth of 10 cm and one to a depth of 30 cm. The soil moisture was measured weekly with a resistance gauge. In 1954 and 1955 Bouyoucos's gauge was used, where the reading gave directly the relative amount of utilizable water in the soil. In 1956 the measurements were carried out with Ruhrstrat's resistance gauge, and the readings were converted to conform with Bouyoucos's scale.

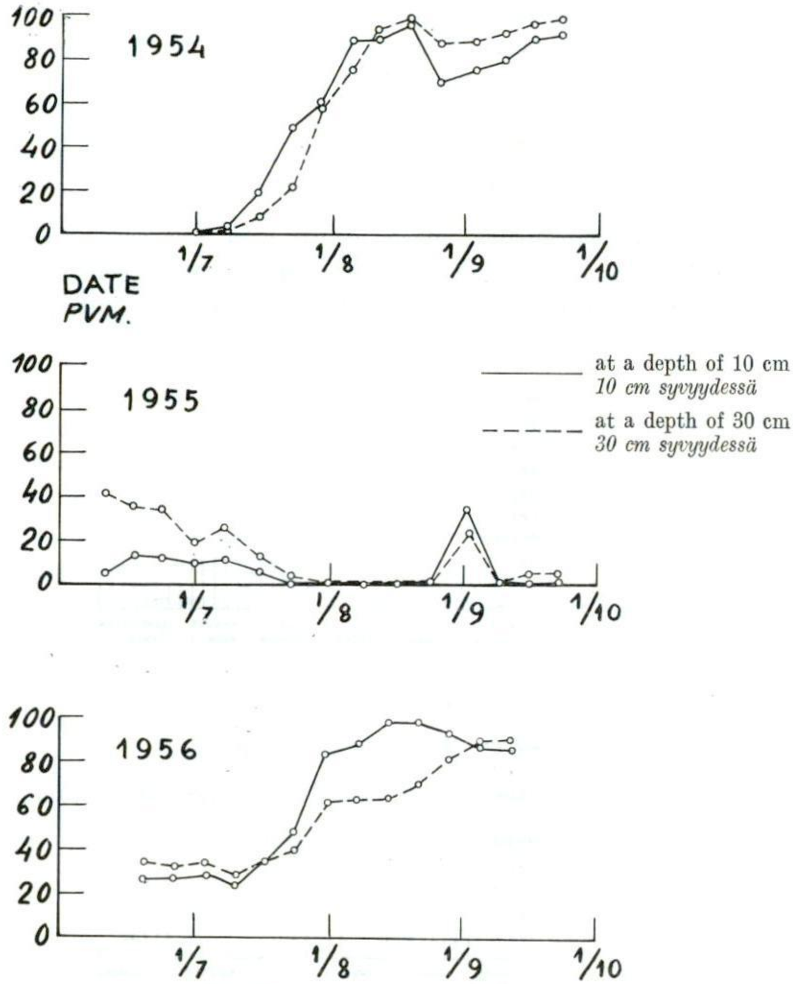

Fig. 2. Soil moisture (percentage of utilizable water-retaining capacity).
Kuva 2. Maan kosteus (% hyödyllisestä vesikapasiteetista)

The gauge readings varied considerably for the different blocks and at times appeared somewhat inaccurate in spite of the fact that in 1956 blocks of an improved model were used. The results presented in Fig. 2 are the average values from measurements carried out at the six spots on the grazing area, for depths of 10 and 30 cm respectively.

There was a surprisingly small variation between the moisture condition of the soil at a depth of 10 cm and that at a depth of 30 cm. It was greatest in the early summer of 1955. The soil surface (10 cm) naturally dried and became moist more quickly than the subsoil at 30 cm depth. The figure confirms that the soil moisture content was quite small during June in all three years. In the rainy late summers of 1954 and 1956 the soil moisture content was almost at field capacity for a long time, but in the dry year of 1955 it was at wilting percentage for part of the late summer (cf HEINONEN 1954).

3. Weather conditions

Regular meteorological observations were not carried out at the trial area at Jokioinen, but the figures given Fig. 3 were recorded at the Department of Plant Breeding of Agricultural Research Centre, situated about 6 km away.

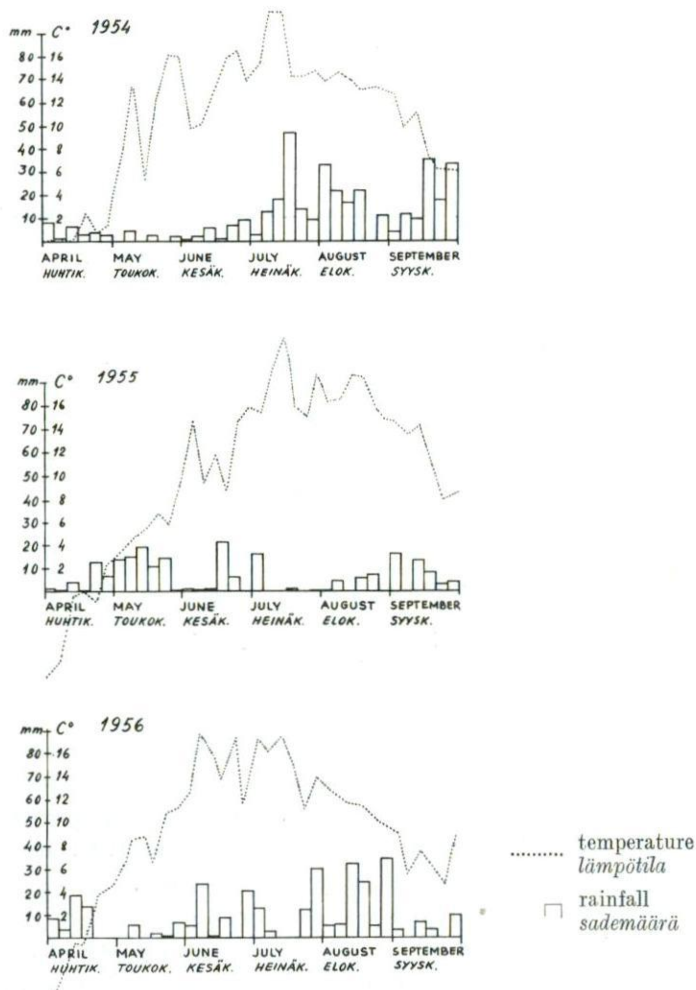

Fig. 3. Rainfall and mean temperature per pentad at Jokioinen in 1954—56.
Kuva 3. Sademäärä ja keskilämpötila pentaadeittain Jokioisissa v. 1954—56.

The summer of 1954 was warm. All the mean temperatures in June were higher than normal. There was very little rain in the spring, the rainfall from April to June having been only $^1/_3$ of the normal. A rainy period eventually started in the early part of July, and lasted the whole autumn.

In 1955 the spring was very cold. In April, May, and even in June the temperatures were below normal. However, by the end of June a period of heat began, which lasted until the end of August. Even in September the temperature was nearly 4 degrees higher than normal. On the other hand, the rainfall was exceptionally slight the whole summer. It rained heavily in May, but very little during the other months. In July—August there was continuous dry weather for seven weeks, while the September rainfall (47 mm) was no more than a good half of the normal.

In 1956 the summer was once again late. During the latter part of May the weather became constantly warmer, and June was almost three degrees warmer than normal. The weather began to grow cooler by the end of July, and the whole of the late summer was cooler than usual, while night frosts were very general. There was little rain in May, and also in September. The rainfall in June and July was fairly normal, but in August it was almost one and a half times heavier than the normal.

B. The field trial and its performance

1. Treatments

The treatments in the experiment were as follows:

Treatment	Dry matter content of herbage in kg/ha			
	At start of grazing	At end of grazing	Amount removed by grazing	
			calculated	actual in 1954—56
1	500	0	500	530
2	1 500	500	1 000	1 000
3	2 250	750	1 500	1 440

There were four replicates. The area of each grazing paddock was 0.54 ha. The paddocks were situated in the field in accordance with the block method, allotting each plot a position in one of the blocks (Mudra 1952). The blockswere placed in two groups, between which there was a 7 m wide pathway for the cattle to pass along (Fig. 1, p.).

In treatment 1 grazing took place when the herbage had grown so that the amount above the cutting level of a Gravely mowing machine (2—3 cm above the soil surface) contained 500 kg/ha dry matter. The height of the herbage was then about 15 cm and the leaf area index (Brougham 1956) was 3—4. Immediately after grazing the remaining herbage was cut by machine, leaving as short a stubble as possible (as compared to Gravely's stubble there remained about 100 kg/ha dry matter). In treatment 2 the herbage was allowed to grow to a height of about 25 cm, when the corresponding dry matter was 1 500 kg/ha and the leaf area index 8—10. This was the so-called normal grazing stage, where the cows left a somewhat longer stubble during the short grazing period than in the previous treatment. After grazing, the herbage was cut level, leaving a stubble of about 7 cm, the amount of dry matter differing from GRAVELY's stubble by 500 kg/ha. Grazing on treatment area 3 was not started until the herbage had grown to the so-called silage stage. At this time the cocksfoot was usually just beginning to head, the height of the herbage was 30—40 cm and the leaf area index 9—12. On this pasture the amount of dry matter was over 2 000 kg/ha. When grazing on herbage which had grown so high, the cows did not graze as closely as in the previous cases. The herbage was cut level to leave a 12 cm stubble and on this occasion there was about 750 kg/ha dry matter remaining.

The treatments were chosen as described here in order to obtain three different grazing stages, deviating as much as possible from each other, and also so that herbage in the trial could be removed by grazing as closely as possible. In each case both the amount of herbage at the start of grazing and also the amount of dry matter in the stubble remaining varied in comparison with the other treatments. The individual effect of each factor was determined by additional experiments.

2. Earlier cultivation of the trial areas and establishment of the pastures

The field in question had been used during recent years under ley farming consisting almost 50 % in grassland, but in no regular rotation. The preceding crop on the ley in 1952 had consisted partly of sugar-beet and partly of barley. The whole area had been limed, using 3 tons/ha ground limestone. 500—1 000 kg/ha superphosphate fertilizer had been applied. In addition, 40 tons/ha farmyard manure had been spread on the part where the beet had been grown. In 1953 the whole field was established as ley. 750 kg/ha fine ground rock phosphate and 100 kg/ha muriate of potash were used for store fertilizing. Further, 16 tons/ha cow manure was applied to the land where the barley had been grown. Apu spring wheat was used as nurse crop. The seed mixture used for the ley was:

	kg/ha
red clover (Jokioinen local strain)	5.0
white clover (Nora)	1.5
timothy (Jokioinen local variety)	15.0
cocksfoot (Daeno II)	15.0

The seeds were sown using an ordinary hayseed sowing-machine, the timothy and clover being sown together and the cocksfoot separately, with the same machine. The sowing was done after the sowing of the nurse crop. The seeds of the herbage plants were dragged with a light spiked harrow and finally the ground was rolled. The summer of 1953 was wet enough for the seeds to germinate and sprout extremely well. The nurse crop remained erect and ripened in time. It was harvested at the end of August and beginning of September and gave a grain yield of 1 940 kg/ha. Sprouting had taken place evenly and well over the entire field and, as the whole of October was very warm, the young sprouts were able to become strongly established before the winter.

3. Yearly fertilization of the pastures

300 kg/ha of Kotka phosphate and 80 kg/ha muriate of potash were spread yearly on the Jokioinen trial pastures. For artificial nitrogen fertilization 800 kg/ha calcium nitrate was selected, and this was spread in three lots of about 270 kg each. Phosphate and potassium fertilizers were applied at the beginning of May, immediately the earth was hard enough to bear the machines, and the first nitrate application was given about the middle of May. The second and third lots of nitrate were applied to treatment 3 after the first two grazings, and at the same time to the rest of the whole trial area. In 1954 and 1955 the fertilizers were applied strictly according to plan, but in 1956 spring fertilization was carried out in the form of normal complete fertilizer (700 kg/ha). The last part of the nitrogen fertilization was applied as two equally large lots of calcium nitrate, as previously.

4. Grazing and trim cuts

The grazing stage trial was grazed by one herd of animals, the Nummela Ayrshire herd, using the method of rotational grazing. The number of cows was 50—60. These were milked in the mornings and evenings in a cowshed about 300 m from the trial area. Immediately after milking they were driven back to pasture. The trial pastures were grazed only when required, while at other times the cattle grazed elsewhere on the farm. When the amount of herbage on each trial paddock appeared suitable according to the treatment, as judged by the eye, the cattle were put on this, and grazing was commenced on the replicate with the most herbage. The whole herd was on the same replicate and the animals had free passage only along the central pathway to the drinking place at the stream. When the cows had grazed the replicate to leave the desired length of stubble, they were moved on to another replicate belonging to the same treament. All four replicates of each treatment were always grazed in unbroken sequence. The grazing of the four replicates took 1—2 days in the case of treatment 1, 2—3 days for treatment 2, and 3—5 days for treatment 3. Immediately all four had been grazed, the uneaten spots and the remaining herbage were cut by machine to the stubble length agreed for the treatment in question. The cut herbage was raked up and taken away.

5. Determination of yield

The yield of the grazing paddocks was measured solely on the basis of sample cuttings. Measurement was carried out by systematically choosing from the map 10 sampling spots in each paddock, for each grazing period. These spots were marked in the plots by stakes. Just before grazing was started, samples 1 × 2 m in size were cut at the marked spots, with a GRAVELY tractor fitted with a 1 m blade. The yields from all ten samples were combined and weighed fresh. From this a representative sample weighing about 1 kg was taken and chopped. Two samples of 150 gm each were taken from the choppings and were dried in a drying oven at a temperature of 100—104° C. After weighing the the samples were combined and were dealt with further at the laboratory of the University Department of Animal Husbandry at Viik.

Immediately after cutting level following grazing, ten new samples running in the same direction as the previous ones, and close by the previous sampling spots, were cut to determine the amount of herbage suitable for grazing in the stubble. Samples taken after cutting were treated in precisely the same way as the samples taken prior to cutting. The dry matter content of the herbage removed by grazing and trimming was determined as the difference between the two samples mentioned. The amount of herbage removed by trim cut, which was always comparatively small, was estimated after being driven away.

6. Determination of botanical composition

The botanical composition of the herbage was determined from the samples cut to ascertain the yield. The determination was carried out three times during the growing season; the first time at the first grazing of the summer, the second usually in July, and the third time with the last grazing in the autumn. Analyses were made only for replicates 1b, 2a and 3c, which were situated in the middle of the trial area, and the plant species composition of which appeared to the eye to be well representative of each treatment area as a whole.

Weight analysis was carried out by taking three samples of 200—400 gm each at random from the samples which had been cut in order to determine the yield. From these samples all the species which had been sown were separated into groups, and the wild species were put in a group of their own, The groups were weighed fresh.

7. Methods of investigating the root systems

A preliminary root system investigation was carried out in the autum of 1955 by selecting three sampling spots at random in the c-block. Samples 25 × 25 × 20 cm in size were dug up from these spots, were washed and separated into individuals, and then dried and weighed. The main root system investigation was carried out in the spring of 1957, using SALONEN's (1949) method. The samples, however, were taken down to a depth of 45 cm only, whereas SALONEN had gone down to 55 cm for his samples.

The food reserves of the root system were determined by analyzing the amount of utilizable carbohydrate from the stubble and roots by the method reported by WEIMANN (1947) in carrying out measurement of final sugar content by SOMOGY's (1945) method. Differences between the food reserves from the different treatments were also measured according to the method indicated from the investigations of POHJANKALLIO, ANTILA and ULVINEN (1958), by allowing samples of turf from the ley to grow under approximately optimal moisture and temperature conditions, but in complete darkness. The samples rapidly grew a foliage in which there was practically no chlorophyll, which consumed the food reserves in respiration, but which was in no way capable of forming new reserves while in the dark. From the length of time which each in the sample was able to survive, the amount of food reserves used was ascertained.

8. Analysis of quality of yield samples

Dried samples of the yield were pulverized and their crude protein content determined by KJELDAHL's method, while the crude fibre was ascertained by the method of WEENDE, as performed by PURANEN and TOMULA (1930). Using herbage from the grazing trial a digestibility test was carried out with rams at the Department of Animal Husbandry, Agricultural Research Centre, in 1956. Samples for the digestibility test were taken in July 1956 and dried in a barn.

9. Statistical treatment of the experimental material

Arrangement of the field trials and analysis of variance calculations were carried out according to Mudra (1952).

II. Effect of grazing stage on individual development of various species and on botanical composition and density of the ley

There is very little mention or description in literature of how various species develop under different grazing stages. On the grazing trial ley at Jokioinen red clover was not worth mentioning as factor at any phase. In the autumn of the sowing year the red clover was luxuriant and strong, but by the first winter clover rot *(Sclerotinia trifoliorum)* had destroyed a great number of the plants. As the following spring (1954) was very dry, the clover suffered more than the cocksfoot, for example, and when the rainy period commenced it was over shadowed by the latter plant, which was growing vigorously. The individual clover plants developed only 1—3 slender stalks and during the second winter these weakened individuals disappeared for the most part.

In this connection no difference was observed between the different treatments. To some extent white clover occurred generally during the wet summer of 1956, but in all places it was very short and its leaves were small. It appeared most in treatment 1 (covering 80 % of the ground): it was also quite plentiful in treatment 2 (50 %), but noticeably less in treatment 3 (20 %).

In the autumn following the summer of sowing there were about 200 cocksfoot individuals per m^2. Most of these were strong and vigorous, and had 2—3 tillers. In the summer of 1954, when the real trial period began, there was plentiful formation of new tillers in each treatment area. A proper inspection was not performed, but according to visual observations and to the photographs presented here the cocksfoot individuals developed fairly similarly in all treatments, even as regards the number of tillers. However, in the summer of 1955 it looked as if treatment 3 was starting to form tussocks. To throw light on this an investigation was made on replicates 1c, 2c and 3d. Sampling spots were chosen at random and from each replicate three samples 25 × 25 cm in size were taken down to the depth of the topsoil (18 cm) and an additional five samples down to a depth of 2 cm. From the last-mentioned samples it could even be verified with reasonable certainty to which individual each tiller belonged. The soil was carefully washed away from the samples and the individuals were separated from each other and divided into the shoot portion above the surface of the soil and the root portion. The total weight of the shoots from treatment 1 was 103 gm, from treatment 2 156 gm, and from treatment 3 250 gm. The material was divided into five classes, so for treatment 2 the class interval of treatment 1 was multiplied by 1.5 and for treatment 3 by 2.5. The results are given in Table 4.

Table 4. Distribution of the number of cocksfoot and timothy individuals (shoot portion) in different weight classes for the different treatments in the autumn of 1955 (Sum total of individuals from eight samples 25 × 25 cm = 0.5 m²)

Taulukko 4. Koiranheinä- ja timoteiyksilöiden (verso-osan) jakaantuminen painoluokkiin eri koejäsenillä syksyllä 1955. (Yksilöiden summa kahdeksasta 25 × 25 cm:n näytteestä = 0.5 m²)

Treatment *Koejäsen*	1		2			3		
Weight class *Painoluokka*	Cocksfoot *Koiranheinä*	Timothy *Timotei*	Weight class *Painoluokka*	Cocksfoot *Koiranheinä*	Timothy *Timotei*	Weight class *Painoluokka*	Cocksfoot *Koiranheinä*	Timothy *Timotei*
a. <0.5 g	42	124	0.75g	52	71	1.25g	38	97
b. 0.5—1.0 g	30	1	0.76—1.5 g	30	4	1.26—2.5 g	17	
c. 1.1—2.0 g	26	1	1.6 —3.0 g	26	1	2.6 —5.0 g	21	1
d. 2.1—3.0 g	9		3.1 —4.5 g	6		5.1 —7.5 g	7	
e. >3.0 g	3		4.6 g	8		7.6 g	6	
Total *Yhteensä*	110	126		122	76		89	98

According to this the number of individuals in treatment area 3 was a little smaller than in the other areas. The relative number of individuals in the various weight classes shows that there were still no fundamental differences between the treatments up to the autumn of the second year, nor were any such differences observed even in the third year of the trial.

As the cocksfoot individuals developed the oldest tillers died and new ones commenced to grow right from the base of the main stalk, curving outside the original centre of the plant, so that by the autumn of 1955, on looking from above, the most vigorous individuals were seen to have formed a circle, the centre of which had already decayed. However, a great number of the individuals had only 1—2 tillers.

Towards the end of the dry period lasting for many weeks in 1955, it was established that the growth of the cocksfoot still continued, even when the growth of other species had already ceased. This growth deviated from the customary growth in that the leaves were narrow, their width being only half that of normal. It occurred in only a few of the tillers. Hardly any of the old tillers showed this growth, but,on the other hand, in the younger tillers curving away from the base the leaves had grown very long, though narrow. These were probably in all respects the strongest tillers, the roots of which had spread to the moist soil layers. A corresponding unevenness in the sward was regularly encountered in the spring at the beginning of growth, which at that time was hindered by low temperatures.

The number of timothy individuals in the autumn following the summer of sowing was visually estimated as a little bigger than the number of cocksfoot individuals. However, the growth of the timothy also suffered extremely from the drought in the spring of 1954. In treatments 1 and 2 the timothy individuals were overshadowed by the cocksfoot immediately after the first grazing. In treatment 3 a few individuals managed to reach the heading stage but most of them were left in the shade on this pasture too. The timothy held on to life very tenaciously even when heavily shaded. Thus in the autumn of 1955 the number of timothy individuals (Table 4) was large. In treatments 1 and 2 no dead timothy individuals were found, but on the other hand 1—3 dead individuals occurred in the 25 × 25 cm samples from treatment 3. In treatments 1 and 2 the timothy plants were slenderer than month-old sprouts. Most of the timothy in treatment 3 was also the same, but here there were taller individuals as well, in which the main shoot was dying, but new shoots were appearing from the lower part of the basal bulb.

The grazing stage trial ley showed an even density right from the start. To be sure, during the first winter clover rot destroyed about 25 % of the red clover. On the other hand, the grasses conserved their full numbers. The differences between the densities of the three treatments remained small even in the final phases of the trial. During the long dry period prevailing in the autumn of 1955 small open patches appeared to be forming on the ley. According to counts carried out in September (1955) the individual numbers of the different species were as follows:

Treatment	Cocksfoot	Timothy	White clover
1	224	128	16
2	274	80	5
3	240	112	10

The formation of the bare patches evidently arose from the fact that development of the shoots was hindered by the drought. With the coming of rain the sward became even, much as before, so that the following year no essential differences in the densities were observed.

Certain investigators have come to the conclusion that difference in grazing stage leads to differences in the density of the sward. Klapp (1951) mentions that heavy grazing makes the ley denser, while on the other hand a late first grazing increases the struggle for existence between the plant species, thus leading to gaps in the sward. Ahlgren (1938) also confirmed that the later grazing was carried out, the greater the thinning of the ley. Again Jones (1939) came to the conclusion that heavy grazing reduces the number of tillers in the plants which had been sown, but in his trials the gaps were filled up by wild species. In the Jokioinen trial the differences in density caused by different treatments were so slight that statistically they had no significance. This is not in disagreement with the earlier investigations mentioned, as the differences in treatment in the Jokioinen trial were relatively small. The trial lacks such extreme cases in which the above-mentioned differences in density arose.

The plant species composition of the pastures was determined by weight analysis, examining one replicate from each treatment (replicates 1b, 2c and 3c) three times during the summer. As regards the other replicates and other grazing periods the determination was carried out visually in 1954 and 1955. The plant species composition in the other replicates proved to be almost the same as in those for which the weight analysis was performed.

The plant species composition of the grazing trial is made clear in Fig. 4. During the first spring, in 1954, the proportion of timothy was rather great in all treatments, and was greater the higher the herbage was allowed to grow before being grazed. The cocksfoot comprised about half of the plants. There was very little clover and in the group comprising other species there was couch-grass *(Agropyron repens)*, creeping thistle *(Cirsium*

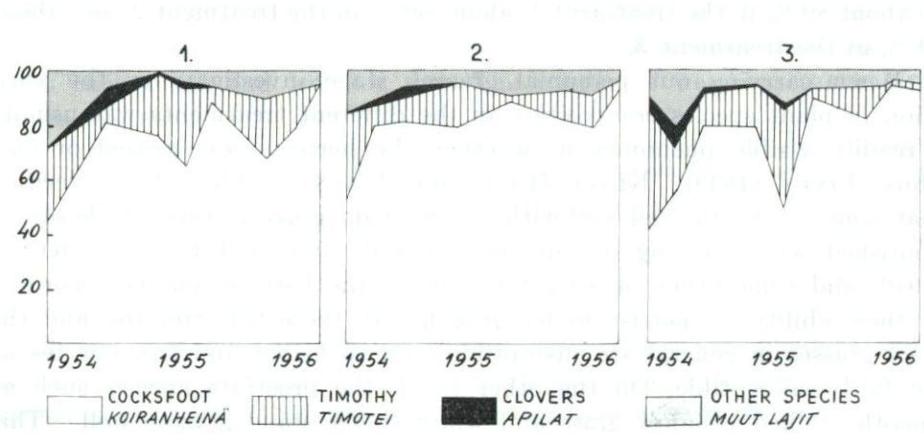

Fig. 4. Botanical composition of the trial pastures.
Kuva 4. Koelaitumien kasvilajikoostumus.

arvense), and some dandelion *(Taraxacum officinale)* and common horsetail *(Equisetum arvense)* as well. In the middle of the summer yellow rocket *(Barbarea vulgaris)* was also noted to some extent. During the first spring the group comprising the other species was mainly made up by the creeping thistle which appeared in the samples from replicate 1b. Towards autumn the proportion of cocksfoot increased greatly, so that it comprised 80 % of the plants in all treatments. The proportion of timothy developed in the opposite direction. Both white and red clover were found to some extent among the plants, but their total quantity was very small. From spring to autumn in the following year development took place in a similar way to that in the first year, but the changes were smaller. In the autumn the cocksfoot comprised about 90 % of the sward, but in the spring there was also 10—20 % timothy among the plants, though in the autumn this plant was found only in very small quantities. The proportion of clover decreased continuously and in the third year there was only a trace of it. Evidently wild white clover was plentiful on the ley in the autumn in 1955 and particularly in 1956, but it had very small leaves and was so short that it did not appear in the samples. The proportion of the group comprising other species also remained fairly unchanged. Its plant species composition changed in so far as dandelion and particularly thistle disappeared, but the quantity of yarrow *(Achillea millefolium)* increased conspicuously.

With the exception of the variation in the amount of timothy during the first spring, no distinctions were observed between the various treatments during the whole period of growth. On the other hand, there were clear differences in the covering of white clover in the autumn of 1956. On evaluating the percentage of white clover covering all the plots, it proved to be about 80 % in the treatment 1, about 50 % in the treatment 2, and about 20 % in the treatment 3.

When carrying out perennial grazing stage investigations, the variation in plant species composition in the different treatments was usually a readily visible phenomenon, whether the herbage was grazed or cut. Thus Jones (1939), Klapp (1951) and Wagner (1952) have verified that some species thrived well with a very slight grazing stage, while others flourished when grazing or cutting occurred often and heavily. Klapp (1942) and some other investigators ranked the herbage plants according to their ability to persist under grazing. In these lists timothy and the erect grasses in general are susceptible, and cocksfoot and meadow fescue are fairly susceptible. On the other hand, the prostrate species such as smooth stalked meadow grass and white clover stand grazing well. This ability does not depend principally on their ability to stand being trampled, but the most important factor is the struggle for light and, in general, living space. Thus erect grasses thrive well if grazing is infrequent. There is time for them to grow tall in between the grazings, leaving the low-growing plants in the shade. On the other hand, with frequent and close grazing the prostrate species are able to commence growing quickly after grazing, because of their leaf area and underground food reserves combined, and they thrive well when there is no shade.

The explanation why the plant species composition in the Jokioinen trial remained almost the same for all treatments, with the exception of the cover of white clover referred to, is probably that cocksfoot is a particularly aggressive species, even on clay soil poor in humus. As the pastures received ample nitrogen fertilization, the cocksfoot was always vigorous, especially on this kind of soil, on which herbage plants with shorter root systems did not thrive well. The differences in composition would obviously have been noticeably greater in trials like this on other types on soil.

III. Effect of grazing stage on root systems and food reserves of herbage plants

Various investigators have confirmed that the grazing stage has a particularly great effect on the roots. This effect may be many times the effect on the parts above the soil (Robertson 1933, Graber 1933). Klapp (1942) confirmed that in all species the weight and volume of the roots decreased as the number of cuttings increased. Torstensson (1938), Thaine (1954), Albertson *et al.* (1953) and Gernert (1936) are among those who have come to the same results.

In the autumn of 1955 preliminary root system investigation was carried out on the c block in the grazing trial at Jokioinen. Three random samples measuring 25 × 25 × 18 cm were taken from each treatment area. The soil was washed away and the cocksfoot and timothy roots were separated from each other and weighed dry. The results of weighing (gm/sample) are as follows:

Treatment	Cocksfoot	Timothy	Total gm/sample	Total tons/ha
1	19.2	8.2	27.4	4.4
2	41.8	2.5	44.3	7.1
3	26.9	3.6	30.5	4.9

There were roots of very few species other than cocksfoot and timothy in the samples, for which reason the combined amount of these two species indicates accurately the weight of the entire root system of the ley.

Variations between the treatments were relatively slight (the figures for treatment 2 may have been larger than the usual by chance). The difference between the roots of cocksfoot and those of timothy was plain. It seems that in the slight grazing stages (treatments 2 and 3) the timothy root system was smaller than in the heaviest grazing stage of the three (treatment).

The main investigation on the roots was performed in the spring of 1957, using SALONEN's method. Samples were taken at the end of May and beginning of June. At that time almost the whole mass of roots was still old, having been formed the previous year at least, for it was only in the last samples taken after June 10 th new white roots appeared. The soil in the sampling spots consisted of uniform heavy clay everywhere. There were very few roots below a depth of 45 cm, down to which the samples were taken.

The amount of organic dry matter in the roots from each treatment is given in Table 5.

Table 5. Amount of organic dry matter in the roots in the trial pastures at Jokioinen in the spring of 1957

Taulukko 5. Juuriston orgaanisen kuiva-aineen määrä Jokioisten koenurmilla keväällä 1957

Treatment *Koejäsen*	Weight of sample gm *Näytteen paino g*	Tons/ha *tn/ha*	Percentage of roots in 18 cm topsoil layer *Juuristosta % 18 cm:n ruokamulta-kerroksessa*
1	16.5	4.7	93.8
2	18.2	5.2	94.7
3	25.3	7.2	95.7

F-value 2.41° L.S.D. 5 % 3.88 gm

The differences were comparatively clear, but the weights of the samples varied so much that these differences were not significant.

Comparison of results from the root experiments in 1955 with the abovementioned amounts of roots in the grazing trial confirms that the amounts of dry matter are on the same level, but because of the small number of samples the order of treatments 2 and 3 in 1955 had evidently turned out by chance to be the exact opposite of that in the 1957 experiments.

A. Vitality (food reserves) of the trial pastures in the spring of 1957

In ascertaining the food reserves in the root samples dug up from the trial pastures at Jokioinen the carbohydrates were not determined, because during soaking the samples were submerged in a stream for a number of days and different samples were under water for different lengths of time. On the other hand, by May 5th, samples of turf had been taken from the various treatments, and these were allowed to grow in the dark until the plants died, having exhausted their energy reserves.

At a temperature of 20—23° C the herbage grew quickly in the dark. By May 8th the leaves had grown 2—3 cm, and at that time they were still green. On May 10th the plants had already reached a height of 7—10 cm and the leaves were green only for about 1—2 cm from their tips, while the whole basal part was pale yellow. The plants did not grow any taller after May 22, at which time they were all still alive. The average height of the herbage for each treatment was then:

Treatment	Average height cm	Variation in different samples
1	22	19—28
2	25	20—30
3	27	25—30

To some extent the height of the herbage varied similarly to the height of stubble from the treatment in guestion. Except for this difference in height the samples all seemed practically similar. As cocksfoot was the supreme dominant species among the plants, its death rate in the various treatments is presented in Fig. 5.

The timothy shoots were observed to die at somewhat the same time as the cocksfoot, but in some of the samples several of the timothy plants survived for a long time. In following the withering of the cocksfoot it was confirmed that the first tillers died during the 17—20 day interval following transference of the turf samples into the dark. Many of the tillers died 20—25 days after transference. At this stage a good deal of the individual plants remaining survived for a very long time. The curves (Fig. 5) for the death rate of cocksfoot from the different treatments run quite close to each other.

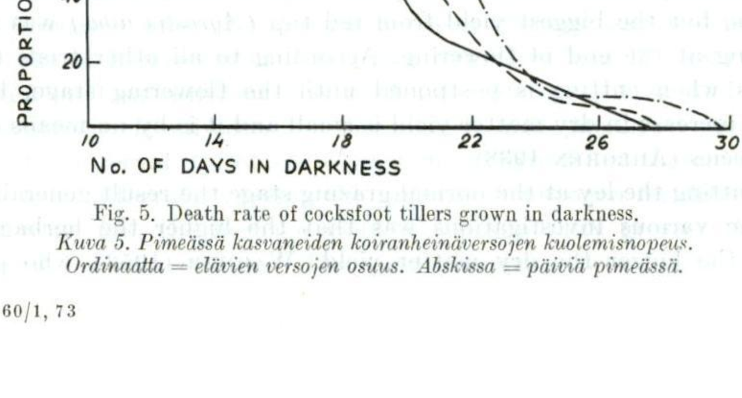

Fig. 5. Death rate of cocksfoot tillers grown in darkness.
Kuva 5. Pimeässä kasvaneiden koiranheinäversojen kuolemisnopeus.
Ordinaatta = elävien versojen osuus. Abskissa = päiviä pimeässä.

The cocksfoot in treatment 1 succumbed most easily, and that in treatment 3 survived best. Treatment 2 fell in between the other two, though in the final stage it proved worse than treatment 1. The differences were not great, except for the twentieth day, when they were considerable.

If the figures for the percentage of living plants are calculated from these observations, as was done during the wilting period, so a single figure, describes, (vitality points), the ability to survive of each treatment, the treatments can be arranged in the following order of hardiness:

Treatment	Vitality points
3	103
2	65
1	49

The results of this trial corroborate the results of the root system experiments. The later the grazing stage of the herbage when grazing began, the more extensive the root system and the greater the food reserves. In general, the same results have been arrived at in all investigations.

IV. Effect of grazing stage on dry matter yield

Actual grazing stage trials in which the yield of the ley is measured have been carried out very seldom. However, the phenomenon has been studied quite considerably by arranging cutting trials. The dry matter yield of herbage plants is generally larger the later the stage of development at which cutting is carried out. Thus Jones (1939) verified in trials carried out in Wales that the largest yield from cocksfoot, meadow fescue and red fescue, among other plants, is obtained when they are cut only once during the summer. Bird (1943) studied the reaction of a number of species to different grazing intensities. His results were, in general, similar to those from other corresponding experiments. The average dry matter yield of various species increases with postponement of cutting (or grazing) right up to the seed formation stage, and the differences in the yields from the aftermath were very small. This tendency was clear in brome grass and Kentucky bluegrass, but the biggest yield from red top *(Agrostis alba)* was obtained on cutting at the end of flowering. According to all other trials the yield increases when cutting is postponed until the flowering stage, but after that the increase in dry matter yield is small and it is by no means observed in all species (Ahlgren 1938).

On cutting the ley at the normal grazing stage the result generally reached in the various investigations was that the higher the herbage before cutting, the bigger the dry matter yield. Wagner (1952), who presented grazing stage in terms of height of herbage, came to the result that in nearly all cases a larger yield was obtained by cutting when the herbage had reached a height of 12 in. than by cutting when it was 6 in. high. Taking part in his trial were cocksfoot, brome grass, Ladino clover and lucerne mixtures. The average yields were as follows:

	Dry matter	tons/acre	
Date of last cutting	15.9.	15.10.	11.11.
Cut when 6 in. high	2.13	2.20	2.27
» » 12 » »	2.46	2.67	2.71

Nelson and Robinson (1956) also used the same treatments, and in all cases the 12 in. high cocksfoot ley gave a bigger yield on cutting than the 6 in. ley. One particular trial carried out with Kentucky blue grass (Mortimer and Ahlgren 1936) proved an exception, however, for in it dry matter yields obtained from plants cut when 8—10 in high proved to be same size as those from plants cut when 4—5 in. high.

In these trials, where the intervals between cuttings are presented as corresponding to the amount of height of herbage at the grazing stage, the trend is for the dry matter yield of the herbage to become bigger the longer the interval between cuttings. Thus Woodman *et al.* (1929), as much as three decades ago, examined the effect of the interval between cuttings on the yield of a sward dominant in perennial ryegrass. According to these experiments the dry matter yields were as follows:

	lb/acre
Cut weekly	1982
» after 2-week intervals	2562
» after 3- —»—	3216

Torstensson (1938) verified that Italian ryegrass and meadow fescue both gave a bigger yield when there was a 15-day interval between cuttings than when the interval was 10 days. In the trials of Kennedy and Russel (1948) the dry matter yield increased as the interval between cuttings was prolonged from 1 to 8 weeks. This investigation was carried out in the U.S.A. on a Kentucky blue grass — white clover sward. The yield from permanent pastures increased when the interval between cuttings was prolonged from 1 to 3 weeks in Klapp's trial (1951) too. Peterson and Hagan (1953) experimented on four different leys with intervals of 2, 3, 4, and 5 weeks between cuttings. In all cases the dry matter yields increased with prolongation of the interval. Crowder *et al.* (1955) Carried out the cutting at 2, 4, and 8 week intervals, varying the amount of nitrogen fertilizer applied. In these trials tco, the herbage yield was consistently greater the longer the interval between cuttings. The yield differences were quite big in all the trials. From weekly cutting PRINE and BURTON (1956) obtained a yield which was 34.6—50.1 % of that obtained when cutting was performed every 8 weeks. The variation was smallest in rainy years and greatest in dry ones.

Many workers have reported the grazing stage only as the number of cuttings. GRABER (1931) verified that a grassland cut 6 times gave a yield of only 38—43 % of that from a grassland cut once. GERNERT (1936) carried out experiments with prairie plants, obtaining the largest yield with two cuttings and the smallest with 8—10 cuttings. KLAPP (1942) obtained the maximum yield with 2—3 cuttings in his trials, and with more cuttings than this the yield decreased.

THAINE (1954) performed cutting treatment experiments with *Elymus junceus*, obtaining a bigger yield with five cuttings than with two. This one of the exceptional cases rarely encountered in the literature. On the other hand, when cutting a herbage in the grazing or silage stage the rule seems to hold that the more seldom the cutting occurs, i.e., the higher the herbage is allowed to grow, the bigger the yield of dry matter, and this is independent of species, as well as of soil type, amount of nutrients, and moisture, etc. (COMSTOCK and LAW 1948, CROWDER *et al.* 1955).

The results of the Jokioinen trial conform rather exactly with a number of other investigations. The dry matter yields obtained from this trial are presented in Table 6.

Table 6. Dry matter yields in the Jokioinen grazing trial in 1954—56
Taulukko 6. Jokioisten laidunkokeen kuiva-ainesadot v. 1954—1956

Treatment *Koejäsen* / Year *Vuosi*	Dry matter kg/ha *Kuiva-ainetta kg/ha* 1	2	3	Average *Keskimäärin*
1954	3 880	4 270	4 410	4 190
1955	2 810	3 860	4 160	3 610
1956	2 850	3 850	4 360	3 690
Average — *Keskimäärin*	3 180	3 990	4 310	3 830

Table of variances

Factor	Sum of squares	Degrees of freedom	Variance	F-value
Total	137 716	35	1 718	3.80*
Blocks	5 155	3	40 724	90.10***
Treatments	81 449	2	11 500	25.44***
Years	23 000	2	1 307	2.89
Blocks × treatments	7 841	6	528	1.17
Blocks × years	3 168	6	2 920	6.46**
Treatments × years	11 679	4	452	
Error	5 424	12		

The differences in yields from the various treatments were clear. Statistically they were highly significant. The yield level showed a highly significant variation for each year and the relation of the dry matter yields of the different treatments (the relative difference in yield increased) varied so much from one year to another that the interaction treatment x years was highly significant.

The yield from treatment 1 showed a relatively greater decrease in the dry summer of 1955 than the yields from the other treatments, and it did not manage to reach its earlier level again in the wet summer of 1956.

L. S. D. (5 %) in dry matter yield was 189 kg/ha; L. S. D. (1 %) 265 kg/ha and L. S. D. (0.1 %) 374 kg/ha. For all the years the yield from treatment 1 was highly significantly smaller than the yields from the other treatments. The difference between treatments 2 and 3 was always significant, too, but it did not become highly significant until the third year.

A. Distribution of the yield

The distribution of dry matter yield during the season is presented in Fig. 6. In this the curves have been plotted in accordance with the method described by Rappe (1946). The year 1954 is typified by the lowness of the usual early summer peak. The curve then sloped gently downwards until the end of June/beginning of July. It was not until the end of July, with the beginning of a rainy period, when a growth commenced, which lasted right up until September, and when the daily increase in dry matter was over 50 kg/ha. For the rest of the summer the grazing trial curves ran in almost the same direction (the small deviations result from the drawing technique), but during the dry period in the middle of the summer the growth of the herbage was clearly heavier in the case of treatment 3 than in the case of the other treatments.

During the dry summer of 1955 the curve clearly formed a single peak, as the short-period spurt of growth in September is not shown in the figure. From Fig. 6 it can be seen that the growth in treatment 1 was obviously slower during the whole of the dry period in July and August than that of the more slightly treated pastures. Even here the curves for the other treatments were practically similar in direction, so that almost without exception their order shows directly the order of the treatments as regards their ability to produce a good yield. In the third year the curves exhibited much greater discrepancy than in either of the previous years. The peak belonging to treatment 1 in the grazing trial was surprisingly high, but it was narrow and for the greater part of the summer the curve unmistakably ran below the others.

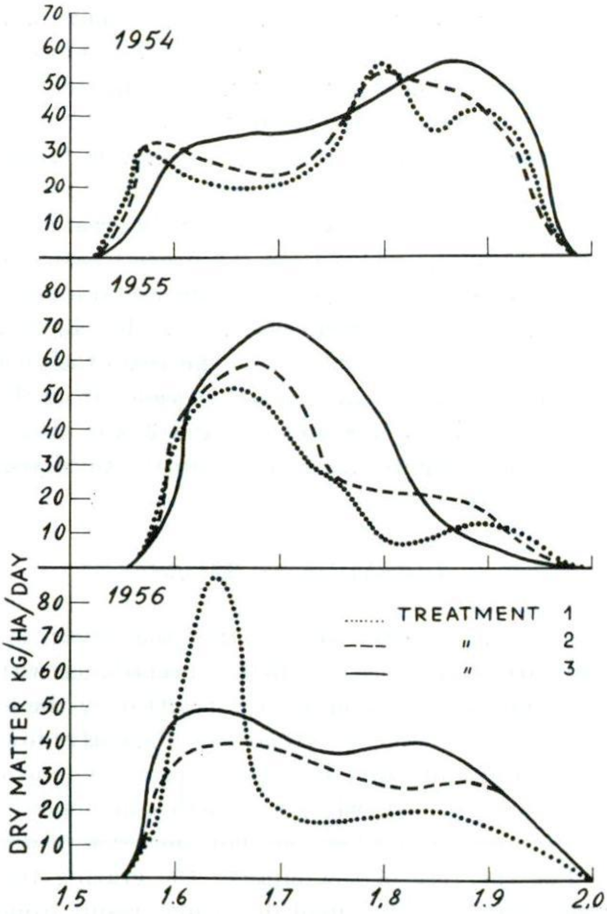

Fig. 6. Distribution of dry matter yield during the summer.
Kuva 6. Kuiva-ainesadon jakaantuminen (kg/vrk:ssa) kasvukauden aikana.

The differences between the dry matter yields of the various treatments were clear, and of the same magnitude as had been obtained in other corresponding trials. In general no essential differences were observed in the distribution of the yield. The most noteworthy observation at Jokioinen was the considerable weakening of the aftermath in treatment 1 during the dry period.

B. Effect of grazing stage on quality of yield

The grazing stage has a greater effect on the quality of herbage, which is best characterized by the protein and fibre contents, than on the dry matter yield. All experimental results point in a similar direction. As the herbage becomes older its protein content and the digestibility of the nutrients become less and the fibre content increases (WOODMAN *et al.* 1929, KLAPP 1951, GEERING 1941, PRINE and BURTON 1956). GEERING (1941) verified that the age of herbage and its crude protein content are in simple logarithmic correlation: crude protein content = 28.6 × 17.2 log t, where t = age of herbage in weeks. In the investigations of WOODMAN *et al.* (1929) the crude protein content of the herbage remained more or less the same whether the ley was cut weekly or every two weeks, but with three weeks' interval between cuttings the protein content of the herbage was about 2 %-units less. In the same way KLAPP (1951) confirmed that the protein and fibre contents were the same with intervals of one and two weeks between cuttings, but with a 3-week interval the protein content dropped by almost 3 %-units and the fibre content rose to 19.5—20.8 %. As the herbage grew still older the protein content decreased and the fibre content rose quite sharply. The rate of the development depends on the botanical composition of the herbage. Thus on a lucerne — brome grass ley the changes in protein content were always slight towards the latter part of the flowering stage (DOTZENKO and AHLGREN 1951). In BIRD's experiments (1943) the protein and fibre contents of the various species of herbage changed rather sharply as the stage of growth progressed. There were no substantial differences between brome grass, creeping bent, timothy and meadow fescue. Even though the protein content of the herbage becomes less the yield of protein remains somewhat the same, within certain limits, because the dry matter yield increases with prolongation of the interval between cuttings (PRINE and BURTON 1956). The digestibility of the nutrients becomes less as the herbage becomes older. However, WOODMAN *et al.* (1929) confirmed that the digestibility of the protein did not change when the interval between cuttings was prolonged from 1 to 3 weeks and the digestibility of the fibre was only a little less with 3-week interval than with an interval of 1—2 weeks. GEERING (1941) came to the conclusion that the digestibility coefficient of pure protein decreased most (1.5 % per week) when the corresponding figure for crude fibre was 1.2 %.

The crude protein yields and average crude protein contents of the herbage in the Jokioinen grazing trial are presented in Table 7.

On an average treatment 2 (normal grazing stage) gave the best yield of crude protein. Although the dry matter yield from treatment 3 was noticeably larger than the yield from treatment 2, the crude protein content of the herbage was so much smaller that the crude protein yield of treatment 3 remained, on the average, less than the corresponding yield from treatment 2 for all years.

The protein yield from treatment 1 was larger than the others in the first year, but in the following year it became so much smaller on account

Table 7. Crude protein yields and crude protein content of the dry matter in the Jokioinen grazing trial in the years 1954—56.

Taulukko 7. Jokioisten laidunkokeen raakavalkuaissadot ja kuiva-aineen raakavalkuaispitoisuus v. 1954—56

Year *Vuosi*	Treatment 1 *Koejäsen 1*		Treatment 2 *Koejäsen 2*		Treatment 3 *Koejäsen 3*	
	Yield kg/ha *Sato kg/ha*	Grude protein percentage in dry matter *Raakavalkuaisprosentti*	Yield kg/ha *Sato kg/ha*	Crude protein percentage in dry matter *Raakavalkuaisprosentti*	Yield kg/ha *Sato kg/ha*	Crude protein percentage in dry matter *Raakavalkuaisprosentti*
1954	756	19.5	738	17.3	696	15.8
1955	608	21.7	738	19.1	703	16.9
1956	623	21.8	821	21.3	774	17.8
Average — *Keskim.*	662	20.8	766	19.2	724	16.8

of decrease in the dry matter yield that during the third year its average yield was clearly the smallest of all the treaments. In the other treaments the protein yield increased during the second and third years, although the corresponding dry matter yields were largest in the first year.

The differences between the crude protein contents of the herbage from the different treatments were very clear; the more lenient the grazing stage the smaller the protein content. These differences are statistically reliable too. The F-value was 28.98 and the L. S. D. (5 %) 1.2; (1.0 %) 1.6 and (0.1 %) 2.2 percentage units. On the average the difference between treatments 1 and 2 was highly significant for all years and also for the individual years 1954 and 1955. On the other hand, in 1956 this difference was so small that it had no statistical significance. The crude protein content from treatment 3 was always so much smaller than the corresponding figures for treatments 1 and 2 that the differences on the average and for all years separately were very highly significant.

On the basis of this test material, the correlation between the crude protein content of the dry matter and the amount of herbage removed at each grazing was calculated. The regression line equation was $y = 24.3 — 0.528x$, $r = —0.628$. The variations confirmed by the line were very highly significant, the F-value being 100.17.

On examining the differences between the different years it was noted that the protein content of the herbage was less in 1954 than in either of the following years. This probably arose from a somewhat more lenient grazing stage, from the inclusion of stubble from the nurse-crop in the samples, and from the shortage of nitrogenous nutrients in the soil.

Figures for the fibre content of the yield are given in Table 8.
F-value between the treatments was 30.61; and between the years 15.36. L. S. D. (5 %) 0.96; (1 %) 1.35; (0.1 %) 1.90 percentage units.

Table 8. Crude fibre content of dry matter yield in the Jokioinen grazing trial in the years 1954—56

Taulukko 8. Kuiva-aineen raakakuitupitoisuus Jokioisten laidunkokeen sadossa v. 1954—1956

Treatment *Koejäsen* / Year *Vuosi*	1	2	3
1954	22.8	24.4	27.0
1955	20.5	22.6	24.1
1956	21.8	23.3	24.2
Average — *Keskimäärin*	21.8	23.6	25.1

According to the variance analysis the differences between treatments 1 and 3 were very highly significant for all years and on the average. The differences between all three treatments were very highly significant on the average, and it was only between treatments 2 and 3 in 1956 that there was no significance. From the figures in the table it can be seen directly that the fibre content of the herbage increased as the grazing stage became lenient. Taking into account all the grazing periods and repetitions, the fibre content of the herbage depends on the amount removed during the grazing period, according to the equation $y = 21.3 + 0.215x$. Thus the fibre content was increased by 0.215 percentage units in the growing of 100 kg herbage. The differences confirmed by the line were highly significant (F-value 13.35). The correlation coefficient was + 0.283. The figures for fibre content were obviously larger during the first year than during the following years. This may have arisen but also from the fact that during the first year a certain amount of stubble was present in the samples. However, the actual grazing stage was also at that time somewhat more lenient than in either of the later years.

Using samples of herbage from the Jokioinen grazing trial a digestibility test was performed at the Department of Animal Husbandry, Agricultural Research Centre, at Tikkurila, in 1956. For this test samples were cut as follows: from treatment 3 on July 20 th, from treatment 1 on August 1 st and from treatment 2 on August 10 th. The cutting was done at the beginning of the normal grazing period for each treatment. The amount of herbage collected was 200 kg and this was dried in a shed. The dried herbage was sent to the Department of Animal Husbandry, where a digestibility test was arranged with rams. Two rams were used in testing the herbage from treatment 1, and one ram for each of the treatments 2 and 3.

According to the digestibility test the digestibility of the most important nutrients was somewhat the same in treatments 1 and 2, except that the digestibility of the nitrogen-free extract was a little less in treatment 2 than in treatment 1. On the other hand, in the herbage from treatment 3 the digestibility of the nutrients was clearly less than in the other treatments. This is seen from Fig. 7.

The experiments carried out show that when cocksfoot is the dominant plant the food value and crude protein and fibre contents of the herbage, as well as the digestibility of the nutrients, change in the same way as the progress of the developmental stage of the herbage, as has been confirmed in other studies regarding pasturage. It is noteworthy that the digestibility of the nutrients was of somewhat the same magnitude in the yields from treatments 1 and 2, and only the yield of treatment 3 showed a poorer digestibility. This indicates that the quality of the herbage as cattle fodder did not deteriorate except perhaps in the fact that the protein content of the herbage dropped. Woodman *et al.* (1929) also obtained corresponding results. It appears that the nutritional value of herbage plants only begins to deteriorate rapidly when the heading stage commences.

Grazing stage has a small effect on the composition of the mineral constituents in the herbage. According to Peterson and Hagan (1953) the ash

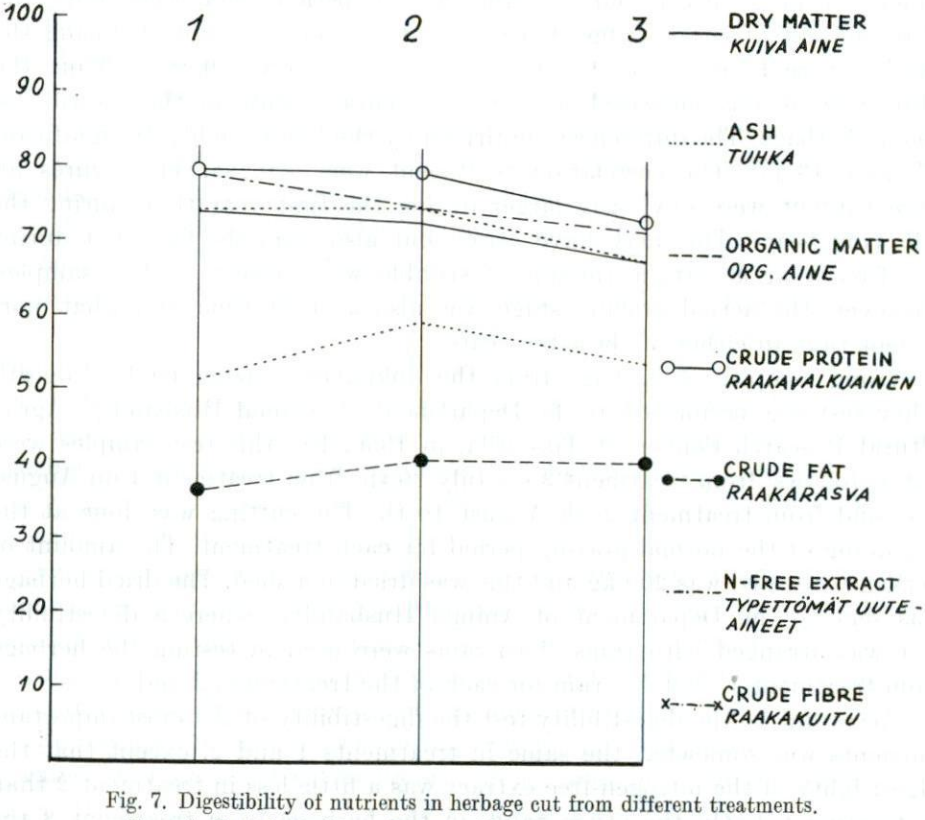

Fig. 7. Digestibility of nutrients in herbage cut from different treatments.
Kuva 7. Ravintoaineiden sulavuus eri koejäseniltä korjatussa ruohossa.

content decreases very slowly with prolongation of the interval between cuttings. The CaO content remains rather the same, regardless of grazing stage (WOODMAN *et al.* 1929), or increases very slightly with progress of the developmental stage (DOTZENKO and AHLGREN 1951). On the other hand, according to GEERING (1941) it decreases. The P_2O_5 content drops slightly (DOTZENKO and AHLGREN 1951 and GEERING 1941). The K_2O content decreases (GEERING 1941), or remains fairly unchanged with progress of the stage of growth (DOTZENKO and AHLGREN 1951). Changes in the composition of the mineral constituents were so small that they probably have no significance worth mentioning in estimating the quality of the herbage. On account of this, determination of mineral constituents in the yields from the Jokioinen trial was not carried out at all.

C. Effect of grazing stage on yield of food units from the pasture

From the yield in the Jokioinen trial the average yield of food units in the grazed herbage from the different treatments was calculated, using values from the digestibility test and LARSSON's (1945) table. The food unit values for the dry matter in the herbage and the yield of food units calculated from these figures were as follows:

Treatment	Scandinavian fodder units/kg dry matter	Yield/ha Scandinavian fodder units
1	0.78	2 480
2	0.74	2 960
3	0.68	2 930

The biggest yield of food units was thus obtained in the case of the so-called normal grazing stage (4 grazings during the grazing season). Continuously grazing at too early a stage caused an 10 % reduction in yield. Even in the case of grazing at the silage stage the yield of food units was slightly less than in normal grazing, although the dry matter yield was obviously larger. GEERING (1941) also obtained an entirely corresponding result, according to which the largest dry matter yield was obtained by cutting three times, and the largest yield as starch equivalent by cutting four times during the summer.

V. Animal behaviour on trial pastures

A. Observations oo grazing

The paddocks in the Jokioinen trial were relatively small (54 ares) for the Nummela herd of 50 dairy cows. As the cows were accustomed to grazing on fields of some hectares, to begin with they could not settle down quietly on the trial plots. Particularly in the case of treatment 1 the first grazing in the spring lasted longer than usual. However, the cows became accustomed to the small plots fairly soon, when they noticed that they were moved to a new plot as soon as the herbage was finished on the plot on which they were grazing. In the middle of the summer, when the other pastures belonging to the farm were poor, the grazing on the trial plots progressed well and rapidly.

On an average, grazing of the four replicates of treatment 1 lasted 2.1 days, grazing of those of treatment 2 took 3.3 days, and of treatment 3 3.7 days. Only very rarely did the cows graze so evenly and closely that it was unnecessary to level the sward with a mowing machine. The amount of herbage removed by cutting level was, on an average, as follows, in the different treatments:

Treatment 1	....	39 kg/ha dry matter
» 2	....	50 »
» 3	....	55 »

From these figures it can be seen that the amount left ungrazed was fairly constant, for only comparatively seldom did the cows graze even treatments 1 and 2 to leave the shorter stubble desired. In cutting level the combined amounts of herbage remained relatively small, and the slight differences between the treatments are insignificant.

In treatment 1, where the amount of herbage at the beginning of grazing was 500 kg/ha, as measured from the level of a Gravely tractor blade (1—2 cm from the surface of the soil), there was too little for this herd, although it was moved from one replicate to another in the middle of the milking interval. It was noteworthy that when the cows were moved from other plots where the herbage was plentiful, they were not ready to graze immediately, although the herbage looked excellent.

The grazing progressed the best in treatment 2, which corresponded to the normal grazing stage, and the cows were always placid.

In treatment 3 the amount of herbage at the beginning of grazing was 2 250 kg/ha and at the end it was 750 kg/ha, which latter figure corresponds to a 10—12 cm stubble. The amount of herbage in this treatment corresponded to the silage stage and it was the outside case in which the plants could be considered as suitable for grazing. In general, at the beginning and in the middle of the summer, and particularly during dry periods, the grazing of this treatment progressed well, but in rainy weather its herbage was less palatable. However, the grazing progressed satisfactorily, because the paddocks were so small that a change from one to another took place every day. Consumption of dry matter in the herbage was, on the average, 10.0 kg per cow per day for treatment 1, 12.4 kg per cow per day for treatment 2, and 16.1 kg per cow per day for treatment 3, during the whole of the summer. The differences are great and they indicate the importance of the amount of herbage available to the cow for grazing. Borg (1955) is among those who have come to the conclusion that the amount of utilizable herbage offered has a much more decisive effect on the amount eaten by the cows than is believed in general. This is also confirmed by the results of the present investigation.

B. Milk production

The milk yield from the entire Nummela herd was weighed per milking (twice per day). However, on an average 20 % of the cows were in the cowshed when the trial pastures were grazed. Their milk yield is included in the total yield, but this former remained somewhat uniform from one day to another, as it was unaffected by changes in nutrients or in weather conditions. Thus it can be presumed, with reservations, that changes in the total milk yield arose for the most part from grazing conditions.

On this basis milk yield was calculated for the first day, the second day and so on as an average of all grazings for each treatment. Curves for these milk yields are presented in Fig. 8.

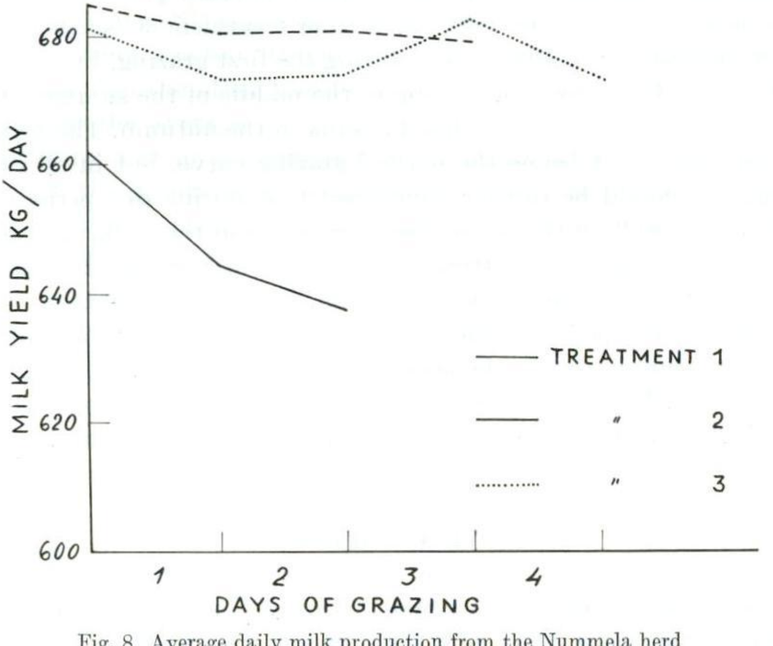

Fig. 8. Average daily milk production from the Nummela herd for the different treatments in 1954—56.

Kuva 8. Nummelan karjan päivittäinen maitotuotos keskimäärin v. 1954—56 laidunnettaessa syöttöastekokeen eri koejäseniä.

The milk curve for treatment 1 is the mean value curve for a total of 15 grazings, that for treatment 2 the mean value curve for a total of 12 grazings, and that for treatment 3 the mean value curve for a total of 9 grazings. In treatment 1 (early grazing stage) the milk production during grazing remained on the same level only once, and at all other times it decreased from one milking to the next. This was in spite of the fact that the quality of the herbage was especially high, the average crude protein content in the dry matter being 20.8 %, and the fibre content 21.8 %. The good quality was not able to compensate for the amount of herbage being too small for dairy cows giving large milk yields. The amount eaten was much smaller than in grazing on the other treatment areas and this is already a sufficient explanation of the drop in milk production. For treatment 2 (normal grazing stage) the milk yield during grazing sometimes rose slightly and sometimes fell, so that the mean value curve runs on somewhat the same level above the others. As regards seasonal variations it should be mentioned that in 1954 and 1955 the curve trended downward in the first spring grazing, but in 1956 it rose again quite steeply. At all other times it remained at the same level, sometimes varying a little from one day to the other. The quality of the herbage was satisfactory, the percentage of crude protein being 19.2 % and that of fibre 23.6 %, and amount available was obviously sufficient, although only 12.4 kg D. M. was consumed per cow per day.

The development of the milk yield from treatment 3 (silage stage) was the most interesting. In 1955 it rose during the first grazing, but in the other years it dropped slightly. For grazing in the middle of the summer the curve rose regularly, but on the other hand it sank in the autumn. The mean value curve runs somewhat below the normal grazing curve, but in all cases it is very high. It should be further mentioned that during dry periods grazing also progressed well on the silage stage herbage and the milk yield remained level, but in the autumn, particularly during wet periods, the palatability decreased and with it the milk production. The milk production remained high in spite of the fact that the quality of herbage was by then quite poor, valued as pasturage, its crude protein content being 16.8 % and its fibre content 25.1 %. The plentiful amount eaten probably made up for the poorer quality. Presumably the protein content was also just sufficient.

VI. Conclusions

A grazing stage trial was carried out on a cocksfoot dominant ley at Jokioinen in the years 1954—56. Comparison was made of the following: 1) an early grazing stage (6 grazings during the summer); 2) a normal grazing stage (4 grazings); and 3) a late grazing stage (3 grazings) where the herbage was practically at the silage stage. The experiment (area 6.5 ha). was on heavy clay soil and it was grazed by dairy cattle.

The largest yield of dry matter, which was obtained from the late grazing stage, was 4 310 kg/ha, the yield from the normal grazing stage was somewhat smaller, being 3 990 kg/ha, and the smallest yield, which came from the early grazing stage, was 3 180 kg/ha.

The crude protein contents of the dry matter in the herbage were in the corresponding order: 16.8 %, 19.2 % and 20.8 %, and the fibre contents of the dry matter were 25.1 %, 23.6 % and 21.8 %.

The digestibility of the nutrients was of the same magnitude in the herbage from the early and normal grazing stages, but it was somewhat less in the silage stage grazing.

The biggest yield as Scandinavian fodder units was obtained from the pasture grazed at the normal grazing stage, being 2 960 f.u./ha. The yield from treatment 3 was 2 930 f.u./ha and that from treatment 1, 2 480 f.u./ha.

There was a rather small difference in the way the different grazing stages affected the density of the sward and its plant species composition.

Consumption of the dry matter in the herbage from the point of view of the cows differed greatly in the various grazing stages. It treatment 1 it was 10.0 kg/day, in treatment 2 12.4 kg/day, and in treatment 3 16.1 kg/day.

The milk production decreased regularly during the days when treatment 1 (height of herbage about 15 cm) was being grazed. This arose from the fact that there was too little herbage, although its quality was excellent. During grazing on the other treatments areas the milk production remained unchanged on the average.

The grazing also progressed well on the silage stage pasture during dry periods, but the palatability deteriorated during rainy periods. However, the grazing progressed fairly satisfactorily, here, too, considering the grazing plots were very small, only about 1 are per cow.

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SELOSTUS

Laidunnurmen syöttöasteen vaikutus koiranheinävaltaiseen nurmeen ja maidontuotantoon

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Jokioisten kartanoitten Nummelan tilalla suoritettiin v. 1954—56 koiranheinävaltaisen laidunnurmen syöttöastekoe. Koenurmi oli v. 1953 perustettu tasalaatuiselle aitosavimaalle. Perustettaessa annettiin runsas PK-lannoitus. Nurmen siemenseos oli seuraava: puna-apilaa 5, valkoapilaa 1.5, timoteita 15 ja koiranheinää 15 kg/ha. Nurmi oli koko koealueella tiheä ja tasalaatuinen. Koejäsenet olivat: 1 varhainen syöttöaste (6 syöttöä kesän kuluessa), 2 normaali syöttöaste (4 syöttöä) ja 3 myöhäinen syöttöaste (3 syöttöä), jolloin ruoho oli laidunnettaessa jo melkein säilörehuasteella. Kokeessa oli neljä kerrannetta. Kunkin lohkon suuruus oli 0.54 ha, koko koealueen ala siis n. 6.5 ha.

Koe laidunnettiin yhdellä eläinryhmällä (n. 50 ay-lehmää) siten, että karja otettiin koelaitumille silloin, kun ruoho oli kasvanut ko. koejäsenelle sovitulle asteelle. Kaikki neljä kerrannelohkoa syötettiin perättäin ja syötön jälkeen niitettiin sänki tasaiseksi. Sadonmääritys suoritettiin niittämällä koealat ennen ja jälkeen syötön. Sato laskettiin kuiva-aineena ja ruohon syöttöasteen mittana pidettiin ruohomäärää kg:ina ha:a kohti.

Koealueella suoritettu viljavuustutkimus (taulukko 1) osoitti, että alue oli maan ravinteisuuden kannalta tasalaatuinen. Pohjaveden korkeus mitattiin neljästä pohjavesiputkesta (putkien sijainti kuvassa 1) ja maan pintaosien kosteutta seurattiin kuuteen paikkaan 10 ja 30 cm:n syvyyteen upotetuista Bouyoucosin kipsiblokeista. Kosteuden mittaus tällä menetelmällä perustuu siihen, että kipsin sisään valettujen elementtien välinen sähkövastus vaihtelee kosteuden mukaan. Mittaustulokset esitetään kuvassa 2. Kuva osoittaa, että alkukesän parhaana kasvukautena maa oli kaikkina kolmena koevuotena liian kuivaa.

Nurmelle levitettiin vuosittain hehtaarille 300 kg kotkafosfaattia ja 80 kg kalisuolaa sekä kalkkisalpietaria 800 kg kolmena yhtä suurena eränä.

Kasvustot kehittyivät nopeasti jo ensimmäisenä kesänä täystiheiksi ja erittäin heinävaltaiksiksi (kuva 5). Puna-apila, jota kylvökesän lopulla oli runsaasti, hävisi nopeasti osaksi apilamädän tuhoamana ja jäi myöhemmin rehevästi kasvaneen koiranheinän varjoon. Koejäsenten väliset kasvilajikoostumuksen erot jäivät vähäisiksi, paljon pienemmiksi kuin mitä tämäntapaisissa tutkimuksissa on muualla todettu. Tämä johtui todennäköisesti siitä, että koiranheinä on runsaasti lannoitetulla savimaalla erittäin kilpailukykyinen ja kestävä laji.

Juuristotutkimus osoitti, että nurmen juuristo oli sitä vahvempi, mitä myöhäisemmässä vaiheessa laiduntaminen suoritettiin (taulukko 0). Erot eivät kuitenkaan muodostuneet niin suuriksi kuin monissa muissa tutkimuksissa, joissa tosin käsittelyerotkin ovat olleet suuremmat. Suhteellisen pieniksi jäivät myös koejäsenten väliset erot ns. kasvuston tyhjiinammennuskokeessa (kuva 5).

Huolimatta siitä, että itse kasvit ja koko nurmet säilyivät koeajan keskenään lähes samanlaisina, muodostuivat satoerot melkoisiksi. Suurin kuiva-ainesato, 4 310 kg/ha, saatiin myöhäisellä syötöllä, normaalisyötöllä jonkin verran pienempi, 3 990 kg/ha, ja pienin, 3 180 kg/ha, varhaisella syötöllä.

Ruohon kuiva-aineen raakavalkuaispitoisuudet olivat vastaavassa järjestyksessä 16.8, 19.2 ja 20.8 %, ja kuiva-aineen kuitupitoisuudet 25.1, 23.6 ja 21.8 %.

Ravintoaineiden sulavuus oli varhaisella ja normaalilla syöttöasteella laidunnetussa ruohossa samaa suuruutta, mutta säilörehuasteella syötetyssä jonkin verran heikompi (kuva 7).

Suurin rehuyksikkösato, 2 960 ry/ha, saatiin normaalilla laiduntamisasteella korjatusta nurmesta. Koejäsenen 3 sato oli 2 930 ry/ha ja koejäsenen 1 2 480 ry/ha.

Ruohon kuiva-aineen kulutus lehmää kohti vaihteli suuresti eri syöttöasteilla. Koejäsenellä 1 se oli 10.0, koejäsenellä 2 12.4 ja koejäsenellä 3 16.1 kg vuorokaudessa.

Maidontuotanto väheni säännöllisesti niinä päivinä, jolloin koejäsen 1 (ruohon korkeus n. 15 cm) oli laidunnettavana. Tämä johtui siitä, että ruohoa oli liian vähän korkeatuottoisille eläimille, vaikka sen laatu oli erinomaista. Muita koejäseniä laidunnettaessa maidontuotanto pysyi keskimäärin muuttumattomana (kuva 8).

Säilörehuasteellakin olevan nurmen syöttö onnistui hyvin kuivina aikoina, mutta sadekausina nurmen maittavuus heikkeni. Tällöinkin sen laiduntaminen onnistui jotenkin tyydyttävästi, koska syöttölohkot olivat hyvin pieniä, vain noin 1 aari lehmää kohti.