

# THE INFLUENCE OF TIME OF CUTTING UPON THE YIELD AND COMPOSITION OF HAY.

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THE variation in the chemical composition of fodder plants with advancing maturity has been the subject of numerous investigations on the Continent, but has received little attention in this country<sup>1</sup>, despite its close bearing upon the annually recurring problem as to when the hay crop should be cut in order to obtain the best results.

There is no reason to doubt that the general conclusions drawn from the continental work are broadly applicable to the fodder crops grown in Great Britain but, in view of the great differences in climatic and soil conditions and the great influence which these factors exercise upon the growth of plants, there is obviously room for considerable variation in detail. It may be doubted, for instance, whether the changes in the composition of fodder plants growing under normal climatic conditions here will take place with such rapidity as has frequently been found to be the case on the Continent, where a delay of only a few days in cutting has apparently led to a serious depreciation in the value of the crop<sup>2</sup>. In other respects also there are such possibilities of variation that we have thought it desirable to place on record the results of comparative tests made by us with "seeds" hay grown in 1909 and 1910 at the Manor Farm, Garforth, Yorkshire. The hay was in each case the produce of a seeds mixture of the subjoined composition, sown with a corn crop in the preceding spring at the rate of 18 lb. per acre:

<sup>1</sup> Voelcker, *Journ. Roy. Agr. Soc.* 2nd Ser. III. 41 (1867).

<sup>2</sup> Wolff, *Landw. Jahrb.* (1879) VIII. 1, Suppl. pp. 34, 78.

*Time of cutting of hay*

Perennial Rye Grass	2 parts;	Alsike	3 parts
Italian Rye Grass	2	„	English Single-Cut Cowgrass 1 part
White Clover	4	„	Chilian Red Clover 1 „
Trefoil	4	„	Ribgrass 1 „

The two hay crops were grown in fields similarly situated near each other, and having soils of similar character, as may be seen from the analyses:

*Composition of Soils.*

	Field 114 1909 Crop	Field 112 1910 Crop
<i>Mechanical Analysis</i>		
	per cent.	per cent.
Hygroscopic moisture .....	1.35	1.32
Fine gravel .....	2.3	8.6
Coarse sand .....	41.0	42.1
Fine sand .....	38.9	22.8
Silt .....	8.2	10.4
Fine silt .....	5.1	8.5
Clay .....	2.0	2.3
Matter dissolved by Acid, etc.	0.6	1.1
<i>Chemical Analysis (Air-dried Fine Earth)</i>		
Loss on ignition .....	4.91	4.76
Silica, insoluble .....	86.32	85.27
„ soluble .....	0.20	0.26
Fe <sub>2</sub> O <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> .....	5.76	6.43
CaO, total .....	.39	.53
CaCO <sub>3</sub> .....	.14	.21
MgO .....	.12	.47
P <sub>2</sub> O <sub>5</sub> , total .....	.29	.16
„ available .....	.049	.008
K <sub>2</sub> O, total .....	.39	.28
„ available .....	.013	.012
SO <sub>3</sub> .....	.09	.08
Nitrogen .....	.127	.115

The soil of Field 112 was evidently appreciably richer in lime and magnesia, and poorer in available phosphates than the soil of Field 114, but otherwise there are no significant differences.

*1909 Crop.*

The seeds mixture from which this crop was derived was drilled on April 22, 1908, Tartar King oats having been sown ten days earlier. On May 11, 1909, a manurial dressing was given consisting of nitrate of soda (1 cwt.), superphosphate (2 cwts.), sulphate of potash ( $\frac{1}{2}$  cwt.) and muriate of potash ( $\frac{1}{2}$  cwt. per acre). The whole of the field was cut on June 10, 1909, with the exception of a piece about 11 yards

square, very uniformly covered with crop. From one side of this a portion 10 yds.  $\times$  2 yds. was then cut carefully by hand, the produce collected at once, weighed, and dried under cover, mechanical losses being reduced to a minimum. When air-dry the weight of the hay was ascertained.

A second portion, 10 yds.  $\times$  2 yds., of the reserved piece was cut on June 28, and the produce dealt with similarly; whilst further similar plots, each 20 sq. yds., were cut on July 15 and Aug. 3 respectively. The weights of air-dry hay obtained at each cutting are given below:

Date of cutting	Yield of hay <sup>1</sup>	
	Per plot	Per acre (to nearest cwt.)
	lbs.	cwts.
June 10.....	15	32
" 28.....	19½	42
July 15.....	22½	48
Aug. 3.....	23½	50

At the first cutting the rye-grass was in full flower whilst there was a good bottom growth of the leguminous plants. Practical opinion was unanimous in condemning the cutting as too early, the second and third cuttings being regarded as more in accord with the normal practice of the district. At the second cutting the rye-grasses were distinctly taller, and seed-formation was actively in progress whilst the clovers were beginning to flower. At the third cutting the grasses were ripening and the clovers were in full bloom, whilst at the last cutting the whole crop was decidedly ripe.

The following table gives an indication of the general meteorological conditions during the active growing period and during the intervals between the respective cuttings:

Period	Rainfall inches	Sunshine hours	Average temp. ° C.	Increase of crop lbs. dry matter per acre
April .....	2.40	199	45°	
May .....	2.13	226	49°	
June 1—14 .....	0.12	81	50°	
" 14—28.....	3.52	42	53°	950
June 28—July 15 .....	1.68	63	56°	620
July 15—Aug. 3 .....	2.63	75	58°	300

<sup>1</sup> The results obtained with duplicate plots in the following year (p. 314) give an indication of the margin of error that should be allowed for in interpreting the results.

It will be observed that a fairly sunny and moist April and May were followed by a cool and—after the middle of June—moist June and July. The average temperature, though somewhat low, rose steadily throughout the whole period. The conditions were thus favourable for steady and prolonged growth, which is evidenced by the substantial increases of crop obtained between the different cuttings.

### *Analysis of Hay.*

For the purposes of analysis the whole crop of hay from each of the four plots was passed separately through a chaff-cutter, with the blades set to give the finest cut. Three separate samples of two or three pounds each were then drawn from the well-mixed chaff, or twelve samples in all. Before analysis each sample was reduced to a finely-divided condition in the laboratory. The portions actually used for the analyses were in every case drawn from the whole sample by a process of quartering.

The estimations commonly included in the analysis of feeding-stuffs were made, together with estimations of true protein (from nitrogen precipitated by cupric hydrate<sup>1</sup>), and pentosans (by distillation with hydrochloric acid and separation as furfural hydrazone), whilst a partial analysis of the ash was also carried out. The results are summarised below. For convenience of comparison they are expressed as percentages of the dry matter in each case. The percentages of dry matter in the air-dried hays are also given so that the composition of the hay can be readily ascertained if desired.

The results tabulated for the first and second cuttings represent in each case the means of duplicate analyses of the three samples drawn from the chaff-cutter. In all subsequent cases the three samples were mixed together and a triplicate analysis made of the combined sample after comminution. The general lowness of the probable errors indicates that these methods were sufficiently reliable for the purpose.

The chief points of interest in the results are briefly:

- (a) The steadily increasing proportion of crude fibre throughout the whole eight weeks.
- (b) The gradual fall in the proportion of "amides" up to the third cutting, after which the reduction was very pronounced.
- (c) The fall in the proportion of true protein during the moist

<sup>1</sup> Barnstein, *Landw. Versuchsst.* 1900, 54, 327.

latter half of June, followed by steady rise up to the period of the fourth cutting.

The true protein formed a steadily increasing proportion of the crude protein, the proportions in the hays obtained at the different cuttings being 70.1, 72.9, 72.8 and 85.3 per cent. respectively.

	1st Cutting (June 10)	2nd Cutting (June 28)	3rd Cutting (July 15)	4th Cutting (Aug. 3)
Percentage in air-dry hay				
Total dry matter.....	88.65 ± .07	88.66 ± .09	89.06 ± .09	89.79 ± .14
Percentage in dry matter				
True protein .....	10.28 ± .11	9.27 ± .06	9.67 ± .04	10.19 ± .01
"Amides" .....	4.36 ± .13	3.45 ± .09	3.62 ± .11	1.76 ± .16
Ether extract .....	2.65 ± .12	1.64 ± .04	1.58 ± .03	1.47 ± .02
<sup>1</sup> Ash .....	8.82 ± .26	7.90 ± .11	8.81 ± .05	9.61 ± .14
Crude fibre .....	27.3 ± .3	30.6 ± .2	31.7 ± .2	34.4 ± .2
Sol. Carbohydrates and other matters not estimated .....	46.6	47.1	44.6	42.6
Pentosans .....	20.7 ± .3	22.2 ± .3	20.5 ± .4	24.0 ± .3
Percentages in ash				
<sup>1</sup> Including SiO <sub>2</sub> .....	15.3	18.6	26.4	25.9
K <sub>2</sub> O .....	14.2	12.7	12.4	11.2
CaO .....	9.4	8.6	9.6	8.0
P <sub>2</sub> O <sub>5</sub> .....	6.7	4.0	3.4	4.1

(d) The gradual reduction in the proportion of "carbohydrates" after the second cutting.

(e) The relatively high proportion of pentosans throughout the whole period.

(f) The increasing richness of the ash in silica, whilst the proportions of K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> tended to fall.

In many ways a clearer indication of the history of the crop is given by the absolute weights of each ingredient produced upon a given area, as tabulated below for the crops per acre.

It will be noted that there was a steady increase throughout in the weights of total dry matter, true protein, crude fibre, pentosans, total ash, silica, lime and potash; that the weight of "amides" fell after the third cutting, and of "soluble carbohydrates" after the second cutting. Attention may be specially directed to the rapid rate of increase in crude fibre and silica.

	Pounds per acre				Increase [or decrease (-)] over 1st Cutting		
	1st Cutting	2nd Cutting	3rd Cutting	4th Cutting	2nd Cutting	3rd Cutting	4th Cutting
Total dry matter.....	3220	4180	4800	5100	per cent. 80	per cent. 49	per cent. 59
Crude protein .....	470	535	635	610	14	35	30
True protein .....	380	390	465	520	18	41	57
"Amides" .....	140	145	170	90	3	21	-36
Ether extract .....	85	70	75	75	-18	-12	-12
Crude fibre <sup>1</sup> .....	880	1280	1520	1760	45	73	100
Pentosans <sup>1</sup> .....	670	930	1160	1230	39	78	84
Sol. Carbohydrates excluding pentosans...	830	1040	980	940	25	18	18
Ash .....	285	330	425	490	16	49	70
SiO <sub>2</sub> .....	43	61	112	127	42	160	195
CaO .....	27	28	40	39	4	48	44
P <sub>2</sub> O <sub>5</sub> .....	18	13	15	20	-28	-17	11
K <sub>2</sub> O .....	41	42	42	55	2	2	34

No attempt was made to estimate the amount of loss of dry matter that took place during the drying of the hay, but this was probably quite inappreciable.

#### *Digestibility of Hay.*

In the absence of facilities for conducting digestion trials it was not possible to obtain more than an approximate estimate of the digestibility of the hay obtained at the different cuttings.

The digestible protein can, however, be estimated in the laboratory by means of an acid solution of pepsin, and such estimations were made on the lines of the Wedemeyer method<sup>2</sup>.

No such laboratory method is available for the estimation of digestible carbohydrates and fibre, but in the case of coarse fodders their sum may be arrived at with fair accuracy by Henneberg and Stohmann's rule applying to digestion by ruminants<sup>3</sup>, viz. that the total "soluble carbohydrates, etc." of a coarse fodder as estimated by chemical analysis are equal in amount to the sum of the digested "carbohydrates" and fibre. Kellner<sup>4</sup> quotes numerous data which lend strong support to this rule.

The ether extract is so trifling in amount that there is no appreciable

<sup>1</sup> Some of the pentosan matter would be included in the crude fibre so that these two sets of figures overlap to some extent.

<sup>2</sup> *Landw. Versuchsstationen*, 1899, **51**, 383.

<sup>3</sup> Henneberg and Stohmann, *Neue Beiträge zur Begründung einer rat. Fütterung der Wiederkäuer*, 340 (1870).

<sup>4</sup> Kellner, *Die Ernährung der landw. Nutztiere*. 4te Aufl. S. 40.

error in assuming it to have been equally digestible in each sample, say 50 per cent.<sup>1</sup>

The "amides" may be regarded as completely digestible.

Proceeding upon these lines the following data were arrived at for the digestibility of the hays, and the weights of digestible matter per acre obtained at each cutting:

	Per cent. in dry matter				Weight per acre			
	1st Cutting %	2nd Cutting %	3rd Cutting %	4th Cutting %	1st Cutting lbs.	2nd Cutting lbs.	3rd Cutting lbs.	4th Cutting lbs.
Crude protein .....	12.84	10.65	10.86	8.27	415	445	515	422
True protein .....	8.48	7.20	7.24	6.51	275	300	345	332
"Amides" .....	4.36	3.45	3.62	1.76	140	145	170	90
Sol. Carbohydrates and fibre .....	46.6	47.1	44.6	42.6	1500	1970	2140	2180
Ether extract .....	1.3	0.8	0.8	0.7	43	35	38	88

It will be noted that the crop became steadily less digestible as growth advanced, the maximum yield of valuable nutritive matters being attained at the third cutting.

From the proportions of digestible nutrients the relative nutritive values of the different hays either for maintenance or for productive purposes can be estimated. The "starch equivalent" for maintenance purposes is arrived at from the expression:

$$(\text{Digest. Protein} \times 1.25) + (\text{Digest. "Oil"} \times 1.9) \\ + \text{Dig. Carbohyd}^2 + \text{Dig. Fibre} + (\text{Amides} \times 0.6),$$

the expression being based upon the relative physiological heat-values of the different nutrients<sup>3</sup>.

The "starch-equivalents" for productive purposes are arrived at by Kellner's rules<sup>3</sup>, summarised in the expression:

$$[(\text{Dig. Protein} \times 0.9) + (\text{Dig. "Oil"} \times 1.9) \\ + \text{Dig. Carboh.} + \text{Dig. Fibre}] - [\text{Total Fibre} \times 0.6].$$

The values arrived at in these ways are given below:

<sup>1</sup> Kellner's averages for meadow hay and red clover hay of medium quality are 51 % and 53 % respectively.

<sup>2</sup> Kellner, *loc. cit.* 84, 86, 88, 93.

<sup>3</sup> *loc. cit.* 580, 581.

*Time of cutting of hay**Starch-Equivalents of Hays.*

	Per 100 lbs. dry matter		Total crop per acre	
	For maintenance lbs.	For production lbs.	For maintenance lbs.	For production lbs.
1st Cutting	62	40	2000	1300
2nd "	60	36	2500	1580
3rd "	57	33	2740	1610
4th "	53	29	2700	1490

It will be noted that as growth progressed the crop became steadily less "concentrated," notably when appraised as food to be used for productive purposes. Thus, whereas 100 lbs. dry matter of the first cutting was equivalent for productive purposes to 40 lbs. starch, the same weight from the fourth cutting was equivalent to but 29 lbs. starch; or, in other words, 100 lbs. of the earliest cut hay was equivalent to 138 lbs. of the latest cut.

As regards the value of the total crop per acre, it will be seen that this reached its maximum at the third cutting, and although after this there was little depreciation in the maintenance value, there was a marked falling-off in the value for productive purposes. This deterioration is mainly due to the lowering of digestibility with advancing maturity, but there would also be mechanical losses of seeds in the latest stages owing to the ripeness of the plants. It should moreover be borne in mind that in the above estimates the pentosans have been classed as of equal value with the other carbohydrates. There is little doubt, however, that they are appreciably inferior in feeding value to starch and cellulose, and in view of the increase in the amount of pentosans recorded at the later cuttings the actual decrease in nutritive value of the crop must have been more marked than the above figures indicate.

*1910 Crop.*

The experiment was continued upon the same lines in 1910, except that at the third cutting duplicate plots were cut, in order to test the uniformity of the plots and the reliability of the methods of sampling, etc. As before, each plot was 20 sq. yds. in extent; and the whole of the produce was removed, dried under cover and weighed. After



reducing to fine chaff three samples were taken in each case, mixed together and this larger sample then analysed in triplicate.

The seeds were drilled on May 12, 1909, Standwell barley having been sown about a month earlier. No manurial dressing was given.

The cuttings of hay were taken on June 9, June 23, July 7, and July 21, 1910.

The character of the season is indicated by the appended meteorological data:

Period	Rainfall inches	Sunshine hours	Average temp. ° C.	Increase of crop lbs. dry matter per acre
April .....	2.02	129	43°	
May .....	2.09	177	51°	
June 1—9 .....	0.26	48	55°	
"   9—23 .....	0.52	112	59°	1260
June 23—July 7 ...	3.89	49	50°	120
July 7—21 .....	0.51	84	56°	360

The outstanding feature of the weather was the dull, cold and almost continuously wet fortnight between June 23 and July 7, when under more genial conditions, as seen in the previous season, considerable growth would have taken place. It will be noted that up to this period the crop had been growing rapidly under genial conditions, but that during the spell of bad weather there was an almost entire cessation of growth, and this was not compensated in the succeeding fortnight, which was dry and sunny, with cool winds.

The weights of air-dried hay obtained at each cutting are given below:

Date of cutting	Yield of Hay	
	Per plot	Per acre (to nearest cwt.)
	lbs.	cwts.
June 9 .....	15½	34
"   23 .....	21½	46
July 7 (Plot A) .....	22½	47
"   7 (Plot B) .....	21½	47
"   21 .....	23½	50

The condition of the crop at the times of cutting was roughly similar to that of the previous year's crop save for the little headway

made between the second and third cuttings. Furthermore in this season the leguminous plants were far less successfully established so that the hay was to a much greater extent a rye-grass hay.

It will be noted that two plots were cut on July 7 (third cutting), and practically identical weights of hay were obtained from each, the recorded difference being well within the limits of error of experiments of this character.

The composition of the crops is given in the appended table :

	1st Cutting (June 9)	2nd Cutting (June 23)	3rd Cutting		4th Cutting (July 21)
			Plot A (July 7)	Plot B (July 7)	
Percentage in air-dry hay					
Total dry matter.....	89.4	90.8	90.8	90.1	91.5
Percentage in dry matter					
True protein .....	6.82	5.04	6.34	6.06	5.88
"Amides" .....	1.76	1.99	1.15	1.33	0.69
Ether extract .....	1.86	1.76	1.59	1.57	1.18
Ash .....	8.06	7.35	7.27	7.17	7.81
Crude fibre .....	27.5	31.3	31.5	31.7	32.7
Sol. Carbohydrates, etc....	54.0	52.6	52.2	52.2	51.7
Pentosans .....	25.8	24.2	23.3	23.7	24.0
Percentages in ash					
Including SiO <sub>2</sub> .....	21.9	26.0	36.5	36.1	37.3
K <sub>2</sub> O .....	28.3	23.2	21.2	19.7	21.8
CaO .....	17.6	19.7	14.9	15.2	15.0
P <sub>2</sub> O <sub>5</sub> .....	8.2	5.8	5.5	4.9	5.9

The most striking feature of the composition of the hays throughout is the extraordinary poverty in protein, the dry matter containing but 5—6 per cent. as compared with 9—10 per cent. in the previous year's crop. This is only partly accounted for by the greater preponderance of rye-grass in the 1910 hay, the principal cause being undoubtedly the dull cool weather throughout the greater part of the period of growth. There is indeed abundant evidence from the earlier investigations of Wolff and others<sup>1</sup> that poverty in protein is a characteristic of fodder grown in such seasons.

The changes with advancing age were broadly similar to those observed in the preceding year, being the most clearly marked in the

<sup>1</sup> *vide* Pott, *Handbuch der tierischen Ernährung*, i. 149.

case of "amides" and fibre, whilst the proportions of true protein and of pentosans showed but little change. The ash, though rather more constant in proportion than in 1909, again showed a steady enrichment in silica, especially up to the time of the third cutting, and was notably richer in this ingredient, in potash and in lime than the hay of the preceding year.

The following table gives the weights per acre of the various ingredients of the crop obtained at each cutting:

	Pounds per acre				
	1st Cutting	2nd Cutting	3rd Cutting		4th Cutting
			Plot A	Plot B	
Total dry matter .....	3410	4670	4830	4740	5150
True protein .....	235	235	305	290	305
" Amides " .....	60	95	55	65	35
Ether extract .....	65	80	75	75	60
Crude fibre <sup>1</sup> .....	940	1460	1520	1520	1680
Pentosans <sup>1</sup> .....	880	1130	1130	1130	1240
Sol. Carbohydrates exclu- ding pentosans .....	960	1320	1390	1320	1430
Ash .....	275	345	350	350	400
SiO <sub>2</sub> .....	60	89	128	121	150
CaO .....	46	66	52	52	60
P <sub>2</sub> O <sub>5</sub> .....	22	20	19	17	24
K <sub>2</sub> O .....	78	80	75	67	88

The practical suspension of protein-formation by the plants during the period investigated is brought out very strikingly. Such little gain of nitrogenous substance as occurred between the first and second cuttings was wholly non-protein in character, and the subsequent changes amounted to little more than the conversion of this "amide" material into true protein.

In accordance with the character of the season the amount of crude fibre increased but slowly, especially after the second cutting, whilst the amount of carbohydrates increased at a rather slower rate.

In general the changes were similar in character to those recorded in the previous season, but were less pronounced after the second cutting, the only appreciable increases then being in crude fibre and silica.

<sup>1</sup> See footnote to table, p. 310.

*Time of cutting of hay**Digestibility and Nutritive Value of Hay.*

The following table gives the data for the digestibility and relative nutritive values of the hays obtained at the different cuttings, these data having been arrived at on the lines explained in connection with the 1909 crop (p. 310).

*Digestible ingredients per cent. of dry matter.*

	1st Cutting	2nd Cutting	3rd Cutting		4th Cutting
			Plot A	Plot B	
	per cent.	per cent.	per cent.	per cent.	per cent.
True protein .....	5.42	4.08	4.38	4.12	3.86
"Amides" .....	1.76	1.99	1.15	1.33	0.69
Sol. Carbohydrates					
+ Fibre .....	54.0	52.6	52.2	52.2	51.7
Ether extract .....	0.9	0.9	0.8	0.8	0.6
Starch equivalent of 100 lbs. dry matter:	lbs.	lbs.	lbs.	lbs.	lbs.
For maintenance ...	63½	60½	60	59½	57½
For production .....	44	39	38½	38½	36½

*Digestible ingredients per acre.*

	1st Cutting	2nd Cutting	3rd Cutting		4th Cutting
			Plot A	Plot B	
	lbs.	lbs.	lbs.	lbs.	lbs.
True protein .....	174	173	195	176	158
"Amides" .....	60	95	55	65	35
Sol. Carbohydrates					
+ Fibre .....	1840	2460	2520	2470	2660
Ether extract .....	32	41	39	38	30
Starch equivalent:					
For maintenance .....	2160	2820	2900	2820	2960
For production .....	1500	1820	1860	1830	1880

The results in the main are similar to those obtained with the 1909 crop, the percentage of digestible protein diminishing appreciably as growth was prolonged, and the whole fodder becoming less "concentrated," as shown by the steadily falling percentage starch value. There is no evidence, however, of any diminution in the nutritive value of the total produce per acre. Still it must be remembered that the produce from the experimental plots was so dealt with as to avoid any mechanical

losses. The plants were, however, so ripe at the time of the fourth cutting that there would inevitably have been considerable mechanical losses of seeds, etc., in winning the crop by ordinary methods, and consequently an appreciable diminution in the value of the crop. It is probable, moreover, that the greater quantity and coarser texture of the fibre in the hay obtained at the last cutting have not been sufficiently allowed for in calculating the starch-values. We are, therefore, of opinion that the third cutting, early in July, as in the previous year represented the most valuable crop. The crop certainly did not appreciate in value after this date.

#### SUMMARY.

The study of two years' hay crops indicates that the composition of the hay steadily changes throughout the period commonly covered by the hay-making season.

The nature of the change depends to some extent upon the character of the season. In the summer of 1909 when the climatic conditions favoured steady growth there was a steady production of protein and fibre and a considerable assimilation of ash ingredients, notably silica. In the following summer the effects of a severe climatic set-back in the later part of June was seen in an almost complete suspension of growth, and notably in the production of protein.

In both seasons there was a steady fall all round in the digestibility of the hay, which in the end more than counterbalanced the increase in weight of the crop.

In both seasons the best results were obtained by cutting about the beginning of July. A fair amount of latitude in the time of cutting—say, a week or 10 days—may be allowed, however, without very seriously impairing the nutritive value of the crop. There was evidence, nevertheless, in each year of appreciable deterioration after the middle of July.