The Chlorophyll-Content of Grasses in Bechuanaland.

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IN a previous paper on grass wilting, attention was drawn to the fact that, under certain circumstances, the grass-veld of Vryburg is vividly green in the early morning and grey-green at noon. This striking change seemed worthy of further investigation.

Experience of European conditions suggested a superficially simple explanation, and it was at first thought that the change was due to ordinary migration of chloroplasts. Chloroplasts distributed over the whole cell in the early morning should migrate towards the interior walls of the palisades during the heat of the day (Senn, 1908). Actual transverse sections through the leaves seemed to confirm this idea. In the early morning the chlorophyll grains were spread apart, and at noontime were found accumulating in the interior of the cells towards the bundle. It was therefore considered that the diurnal colour change bore no specific relation to "grass wilting," until a peculiar observation suggested closer investigation.

Several grasses, including *Tragus racemosus*, were under investigation in another connexion in pots upon the veranda of a dwelling-house, and being regularly watered showed abundant root and leaf development. During personal absence in March, 1923, however, watering was accidentally neglected, and on coming under observation again after an interval of six days the leaves of the grasses were found to be completely dry and white. Since pot-cultivation of grasses in Bechuanaland is a troublesome matter, an attempt was made to rescue the plants and encourage fresh shooting by abundant watering. Contrary to expectation, new leaves were not developed, but the old leaves revived, turning light-green after forty-eight hours and bright dark-green after seventy-two hours. This accidental observation was repeated experimentally with the same result. Indeed, so beautifully could the phenomenon be demonstrated that it would have made an excellent class-demonstration for students. The change from white leaf to green was so striking that a series of chlorophyll determinations upon the grasses was undertaken.

METHOD.

The method of analysis adopted was essentially that of Willstätter and Stoll (11), copper chlorophyll, kindly supplied by Professor Stoll himself, being used as basis for the colorimetric standard. The data in the appendix tables represent total chlorophyll $(a + b)$, calculated upon unit weight of grass.

Standard.—A stock solution of copper chlorophyll was made up in ethereal solution, and aliquots saponified for use as required, by the method indicated below. The concentration used was 0.038 grm. in 300 c.c. of liquid, sometimes diluted to 600 c.c., for the Hellige colorimeter; or further diluted to 1,000 c.c. or 2,000 c.c. when the Duboscq colorimeter was used. 0.038 grm. of copper chlorophyll corresponds to 0.050 grm. of *natural* chlorophyll.

Extractions.—Since grass leaves are difficult to dry without destruction of chlorophyll, *fresh* leaves were always used. 10 grm. of the fresh grass leaves were cut up as fine as possible and ground in a porcelain mortar with sand, a small quantity of chalk, and 20 c.c. of 40 per cent. acetone. Owing to the high silica-content of the grasses, 15 grm. of sand was usually sufficient. In absence of a suitable pump, extracts were filtered through ordinary Whatman filter-paper, and, although slow, the process gave satisfactory clear solutions. The rate of filtration is in any case less important with grasses than with certain other plants, since grasses contain very little chlorophyllase (Willstätter and Stoll, 1913, p. 178) to attack the chlorophyll when the solution is left too long in contact with the leaves.

In the filter the ground leaves were further extracted and washed with 80 c.c. to 100 c.c. of 35 per cent. to 40 per cent. acetone, and the brown filtrate and washings shaken with ether to recover traces of chlorophyll removed in this " preliminary extraction." The leaves were then extracted with 200 c.c. to 300 c.c. of pure acetone, and finally with a little 90 per cent. acetone and a few c.c. of ether. It may be noted that the quantity of acetone required to effect complete extraction was frequently much higher than that prescribed in the process of Willstätter and Stoll, and in this connexion it may be added that, although fresh leaves of high water-content yielded their chlorophyll-content easily, wilting leaves of lower water-content were found much more difficult to extract. It seems that the chlorophyll in a leaf poor in water is much more intimately bound than in the turgescent leaf, since mere addition of water before extraction did not remove the difficulty. The use of the small quantity of ether at the end of the acetone extraction much facilitated the work, especially the removal of colour from the margins of the filter-paper.

The green acetone solution was then transferred to a separating funnel with twice its volume of ether, and the acetone carefully removed by washing with eight times its volume of water. For the final aqueous washings a small quantity of methyl alcohol was added to inhibit emulsification. If any chlorophyll passed off in the washing water it was recovered by shaking out with ether and sodium chloride.

The ethereal solution was then shaken with 4 c.c. to 8 c.c. of caustic potash solution in methyl alcohol. When the resulting " brown phase " had passed over to the typical green, the saponified alkaline layer was again shaken out with water and the chlorophyll solution run into a measuring cylinder. A second more prolonged treatment with alcoholic potash was sometimes necessary to recover all the chlorophyll from the ethereal solution.

The chlorophyll solution was then brought to approximately the same concentration as the standard and colorimeter readings taken. When the Hellige colorimeter was used the average value of ten readings was accepted. In the case of the less frequently used

Duboscq, check-readings were taken by reversing the cups. All determinations were then calculated on the basis of 10 grm. fresh matter and of 1 grm. dry matter, and are expressed in this form in the appendix tables.

Plant Material Used.

Regular determinations of the chlorophyll-content of *Digitaria eriantha*, *Themeda triandra*, *Eragrostis superba*, and *Tragus racemosus* were made. A few determinations were also carried out on *Tragus koelerioides* at a time when *Tragus racemosus* was not available.

In order to obtain a curve showing seasonal variation of chlorophyll-content, material was at first gathered at noontime. Later on, when it became obvious that diurnal variation was also important, collection of material was made at about 6 a.m., again at 12 a.m., and again in the early morning of the following day.

Results.

Changes in chlorophyll-content throughout the year.—Tables 1, 2, 3, and 4 of the Appendix, showing determinations on *Eragrostis superba*, *Digitaria eriantha*, *Tragus racemosus*, and *Themeda triandra*, demonstrate that the chlorophyll-content of these grasses is subject to great changes. For this demonstration it does not matter whether the chlorophyll is reckoned on the basis of fresh leaf or of dry matter (100° C.). The table for Digitaria shows that for comparatively young leaves the chlorophyll-content is exceptionally high, but that it decreases rapidly under arid conditions and reaches a minimum value in the period of drought. The same rate of decrease of pigment holds for Eragrostis, but apparently not for Themeda.

A good rain considerably increases the chlorophyll-content *after twenty-four hours*. So long as the soil retains sufficient moisture the high chlorophyll remains, but the content decreases suddenly as soon as the grass wilts under drought. This behaviour is repeated throughout the year as occasion arises. In autumn, when the temperature diminishes and the transpiration of the grasses is low, the rise in chlorophyll-content after rain is retained longer than in the hot summer. Whenever rain causes growth of young leaves, even in autumn, the chlorophyll rises unexpectedly high, as may be noted from the figures for Themeda in March and April, 1924.

Before dying down of the leaves the chlorophyll-content decreases, the actual amount depending upon the circumstances attending the decline. For Tragus and Eragrostis, determinations were made in the autumn of both 1923 and 1924, and the results show considerable variation. April and May, 1923, were dry months, and, owing to slow drying out, the autumn leaves showed a relatively low chlorophyll-content. In 1924 the leaves (except Themeda) were killed by frost following a good rain, and the chlorophyll-content was correspondingly high.

A comparison of fresh leaves with wilted or withered leaves of the same species, analysed at the same time, shows striking differences, especially when compared upon the basis of dry matter (Digitaria in February, 1924). The withered plant has much less chlorophyll.

The influence of rain is brought out very clearly when the chlorophyll values are plotted on the same chart as the rainfall, or when one chart is read alongside the other (Plate I, page 271).

The fact that the data show bigger differences when reckoned on dry matter than when reckoned on the fresh plant is particularly striking. As already pointed out in a previous paper (*l.c.* 4) when describing the veld, the percentage of dry matter in the fresh-cut grass varied enormously with the weather, increasing even up to 70 per cent. at a time of severe drought and decreasing to 20 per cent. after rain. At noon, except on rainy days, the leaves are always in a state of incipient or actual wilting; the term "incipient wilting" being used in the American sense, and in this case denoting a marked fall of water-content between early morning and midday, causing a sudden fall in transpiration with a subsequent rise.

The chlorophyll-content therefore not only decreases with decreasing moisture in the soil and atmosphere, but also with decreasing water-content in the leaf itself. This is still more clearly shown when the daily variations of chlorophyll and water are considered. The greater the loss of water in the leaf the lower is the chlorophyll-content at a given period of the season. Apparently chlorophyll is first anabolized after rain, and only later is the normal fresh weight of the leaf again established. This is illustrated by the figures for Eragrostis of 31st October, in which the chlorophyll-content is much higher when expressed on the dry matter, and lower when calculated on the fresh matter, than it is in the preceding determination.

The annual curves for chlorophyll-content of all four grasses show interesting points of similarity and difference when considered in the light of the behaviour of European plants. Common points are the decrease of chlorophyll in autumn, and the lower content in the youngest leaves as compared with leaves a few weeks old. The main point of difference is the big seasonal and diurnal variation of chlorophyll in the Bechuanaland grasses, as a result of climatic and edaphic factors. In Europe the drought factor does not play any important rôle, and strong insolation is not alone sufficient to change the chlorophyll-content of sun-plants in a few weeks' time (Henrici, 1918, page 61). Some plants ordinarily growing in the shade in Europe do lose much chlorophyll when brought into sunlight, but the whole plant generally then dies down.

Diurnal Changes of Chlorophyll-content.—From the recorded changes in chlorophyll throughout the year it is apparent that the content in the grasses steadily diminishes under the influence of drought. Compared with its original high figure, Eragrostis, for instance, dropped in chlorophyll-content to one-fifth at the period of severest drought, and even to one-third on days still relatively moist after preceding rain. These differences were so great that it was considered desirable to ascertain whether even a diurnal variation could be detected. Between 11th and 23rd December Eragrostis lost over 50 per cent. of its pigment, and the question arose as to whether the chlorophyll-content decreased uniformly from day to day or whether the decrease was irregular.

Sampling of the same species of grass was therefore undertaken three times within twenty-four hours; the first sample between 5 a.m. and 6.30 a.m., the second at noon, and the third again next morning. The first determination was carried out with Digitaria at the end of a drought period on 28th February, 1924. The result was surprising. Calculated on the fresh matter, the plant lost about 3 per cent. of its chlorophyll between morning and noon; calculated on the dry matter, about 30 per cent. The actual figures (Table 5) were 0.637 per cent. on the fresh plant at 6 a.m. and 0.616 per cent. at noon; or 2.31 per cent. on the dry matter (27.6 per cent.) in the morning, and 1.43 per cent. on the dry matter (43.1 per cent.) at noon. Even allowing for experimental error, this showed quite clearly that the decrease could not proceed uniformly, since if it did the total chlorophyll would disappear in a few days; whereas, in point of fact, the veld is consistently bright green in the early morning, except at the time of permanent wilting.

The third determination early next morning (Table 5) showed 0.648 per cent. on the fresh plant, or 1.86 per cent. on the dry matter, i.e. a compensating increase over the noon values and an approach to the morning values of the previous day.

It must, of course, be emphasized that this experiment represents an extreme case, since Digitaria at this time was on the verge of permanent wilting, and would have perished entirely but for the timely rain next day. But the issue is clear: the plant loses chlorophyll during the sun-scorched day and builds it up again during the night period of darkness and higher relative humidity.

The determinations of 10th March on Eragrostis and of 13th March on Themeda (Table 5) show the behaviour of the grasses at a time when the water in the soil was sufficiently abundant to allow of carbon assimilation by the plant. The result is the same in principle: destruction of chlorophyll during the day, synthesis during the night. The significant difference between these determinations and the preceding determination on Digitaria shows that, when sufficient water is present in the soil, chlorophyll is less extensively destroyed by day and practically wholly restored by night.

The other recorded determinations of chlorophyll were carried out about eight months later. in the less extreme season of the following year. It is surprising to note (Tables 5, 1, 2, 3) that the investigated grasses showed less chlorophyll than under similar conditions the year before, and it is difficult to explain the fact from the standpoint of available moisture alone. In both cases middle-aged leaves were studied. In 1924 the total rain was less than in 1923, the temperature lower, the insolation about the same, and the wind stronger. The reason for the observed difference in chlorophyll therefore probably lies in nocturnal rather than diurnal factors. In 1923 the temperature was high during the night (15° to 20°), and in the corresponding period of 1924 much lower (10°). Indeed, in November, 1924, the minimum thermometer fell even to freezing point, so that in a period of maximum day-temperature of 35° C. plants were actually being killed by nocturnal frost. These low temperatures would directly decrease the synthesis of chlorophyll (Elfving, 1880, Ivanoff, 1922) by night and also restrict water absorption from the cold soil. In day-time, when the shallow soil was warmer, taking up of water would be easier, but owing to the destructive strong sunlight chlorophyll formation would be reduced. It is therefore of interest to note that in November, 1924, the grass leaves were open in day-time, but grey-green in the morning and distinctly grey at noon.

The data for *Eragrostis superba* from 5th November are interesting. The plant was analysed after a long drought period, and although some rain fell a few hours before the first sampling, the moist period was too short to exercise any significant influence. The rest of the day was clear until the afternoon, and at night it rained heavily. The figures (Table 5) show that the chlorophyll, although diminishing during the day, was more than doubled in amount by the following morning as a result of the warm shower. During the same night the relative proportion of dry matter in the leaves fell from 45 per cent. to 33 per cent.

Tragus racemosus (Table 5), sampled on a relatively dull day, showed a nearly constant chlorophyll-content on 11th November (1924), owing to lower insolation. The interesting point is that the following night was very cold, and no chlorophyll was built up in spite of the fact that it rained.

The important conclusion may therefore be once more emphasized:—*Under the influence of the drought and strong insolation of the Bechuanaland veld the grasses lose a considerable part of their chlorophyll during the day. During the night the chlorophyll is resynthesized completely if soil moisture is adequate, and even partially resynthesized in times of drought.* This conclusion is not to be regarded as contradicting the general conception that chlorophyll is only built up in the light, since this refers to the "preliminary formation" of chlorophyll. In the case of the Bechuanaland grasses there is still enough chlorophyll, even after partial destruction by excessive insolation, to act autocatalytically for new chlorophyll formation (Schmidt, 1914). The general results recorded here do, nevertheless, contradict the general experience elsewhere, as discussed by Willstätter and Stoll (1918, pp. 1–40; 1915, p. 336). It is true that these two authors draw attention to the fact that excessive illumination may effect destruction of chlorophyll by a process independent of photosynthesis, but they regard the phenomenon as having no significance in relation to the rôle of chlorophyll in assimilation (1918, p. 40). Concerning the type of resynthesis now under discussion, there appears to be no mention in the literature.

Constancy of chlorophyll-content does not, of course, exclude the probability that anabolic and katabolic changes are in equilibrium, so that, in any given unit of time, under ordinary European conditions, the same number of chlorophyll molecules are built up as are broken down. Indeed, there is good reason to believe that this is the general case, and that in the Bechuanaland grasses it is the synthetic process which is unfavourably affected by the drought. The *nature* of the process of destruction of chlorophyll during the day, however, is a point which is still obscure. The fact that the plant can rebuild the pigment so quickly would suggest that the chemical change which the chlorophyll undergoes is not a far-reaching one.

It is also interesting to record the fact that the regeneration of chlorophyll in Bechuanaland grasses is not confined only to the blades, but can also be observed in the stalks of various species. In describing the veld in the previous paper (*l.c.* 4), the fact that apparently dead stems can become green again was mentioned. *Aristida uniplumis* and *stipoides*, *Eragrostis superba* and *lehmanniana*, *Fingerhuthia africana*, and *Digitaria* all showed absolutely yellow haulms, free from chlorophyll, in the winter of 1924. *Before* the first rain, about 10th September, the old haulms of the two *Aristida* species, of *Fingerhuthia*, and *Eragrostis lehmanniana* became green. After the first rain on 24th September the other grasses showed the same phenomenon. With the ensuing drought the chlorophyll again disappeared. The amount of chlorophyll shown during the period of regeneration was by no means normal, since sections through the stem showed a quantity of destroyed granules, but the proportion of active chlorophyll was sufficient to form starch.

The question as to whether plants other than grasses show the same phenomenon of destruction and resynthesis of chlorophyll has not yet been investigated.

Absolute Amount of Chlorophyll.

Compared with the chlorophyll-content of plants investigated by Willstätter and Stoll (1918), the grasses of Bechuanaland are relatively rich when they are young and fresh. Even when they are withered their pigment-content is still moderately high, and it is only after prolonged drought that the figure falls to a really low level.

The variations in different years have already been noted in comparing the data for 1923 and 1924. The available data for European grasses (Willstätter and Stoll, 1913, pp. 109-110) are scanty, and opportunity for comparison therefore limited. One of the European records, however, shows 6.71 grm. chlorophyll per kg. of dry grass leaves, and 1.26 grm. per kg. of fresh material. Compared with these figures, the amounts found in South Africa are exceedingly high, especially when it is considered that only sun-plants were investigated. It must, however, be borne in mind that the relationship between fresh material and " dry matter " of European gramineae is quite different from South African, and that individual Bechuanaland grasses are very light and their surface area therefore relatively great. This means that the South African grasses have rather less chlorophyll per unit *surface* than European grasses, though more per unit *weight*.

The values of Willstätter and Stoll (1918, pp. 134 and 137) for *Zëa mais* are 0.0117 grm. per 10 grm. fresh matter, 0.0086 grm. per 1 grm. dry matter; grown in solution with iron salts, 0.0155 grm. per 10 grm. fresh matter and 0.0163 grm. per grm. of dry matter. It will be noted these figures resemble the grass values recorded here. Taking the chlorophyll figures as a whole, it may be considered that the Bechuanaland data for fresh green grass in a hot season are higher than those of Europe; for grass in a state of wilting or incipient wilting, in a hot period, or even for turgescent grass in a summer with cold clear nights, they are of the same magnitude as those of European gramineae. Nevertheless the grass never gives the " colour impression " of fresh green European meadow except, perhaps, after heavy rains. The causes for this may be various; primarily the position of the chlorophypll grains (Senn, 1908) and the whole arrangement of the green tissue. In the grasses at Armoedsvlakte only the coronoid palisade cells (Kranzpalisaden) have chlorophyll grains; all other leaf tissue, mostly sclerenchyma and "Gelenkzellen" (Goebel, 1924, pp. 129-139), or "motor cells," is colourless. The tremendous loss of water during the hot part of the day may also contribute to the "grey-green" colour, by "total reflection," due to replacement of water in the tissues by air, as in the case of *Lichens* in Europe.

Drought and excessive light have been discussed as responsible for destruction of chlorophyll, but there may be compensating factors favourable to its formation. The prevailing high temperature, and probably also the high iron-content of the soil, may be regarded as such. The low night temperatures of September and November, 1924, are exceptional, and in general the average temperature over the summer months in Bechuanaland is high and conducive to the synthetic phase of the "chlorophyll balance."

Consequences of Loss of Chlorophyll.

The annual curves for chlorophyll-content (Plate I) show that in times of drought the mechanism for assimilation is seriously impaired. Iljin (1923) found that flaccid plants assimilate less than turgescent plants, and it is more than possible that his results are partly explainable as due to loss of chlorophyll. At any rate, low chlorophyll-content in the Bechuanaland grasses is definitely associated with low carbohydrate-content. During the time of severest drought at Armoedsvlakte the carbohydrate-content of the grasses sank to one-quarter or one-sixth of the value reached on a sunny day after rain. In this case the deficiency of *water* is the limiting factor, which in turn influences the chlorophyll-content and carbon assimilation. It was also found that the low chlorophyll-content of the grasses in November, 1924, due to low nocturnal temperature, affected the carbohydrate-content in the same direction, the figures being considerably lower than in the previous rainy season of 1923, in spite of sufficient soil moisture. In this case the low chlorophyll-content may be regarded as the direct "limiting factor."

With variations in carbohydrate metabolism the nitrogenous metabolism may of course also be affected.

Summary.

1. The chlorophyll-content of Bechuanaland grasses is not constant throughout the year, but varies from a very high initial value on young leaves, decreases according to the duration and intensity of drought periods, and increases again after rains.

2. Even during periods of twenty-four hours the chlorophyll-content varies greatly, decreasing from early morning to midday, and increasing again during the ensuing night. Decrease and increase depend upon meteorological factors of the moment, so that on rainy days the variation lies within a few per cent., but on extremely dry and sunny days may extend to 30 per cent.

3. High nocturnal temperature favours a higher general chlorophyll-content throughout the day. Low nocturnal temperature is associated with low chlorophyll, even although the soil moisture is adequate. In both cases, however, chlorophyll destruction and chlorophyll synthesis are regarded as occurring concurrently, the actual content at any time representing the equilibrium between the two processes.

4. The values found in 1923–24 were higher than those found in 1924–25 owing to differences in nocturnal temperature in the two seasons. In the 1923 growing season the chlorophyll-content of the grasses of the Vryburg District was higher than that of European grasses; in the 1924 season about the same, or rather lower.

Since the average chlorophyll-content is different in the two seasons, the data cannot be directly compared. What is termed a low value for 1923 would be high for 1924. Apart from nocturnal temperature, other factors, as yet uninvestigated, may play a rôle.

1.—CHLOROPHYLL. *Eragrostis superba.* Midday values.

Date.	Reading.	Absolute amount pro 10 grm. fresh matter in grm.	Absolute amount pro 1 grm. dry matter in grm.	Remarks.
14/5/1923......	0·85	0·0409	0·0200	—
3/9/1923......	3·62	0·1771	0·0377	—
19/9/1923......	1·68	0·0844	0·0210	—
6/10/1923.....	1·30	0·0650	0·0138	—
18/10/1923.....	1·26	0·0630	0·0130	—
31/10/1923.....	1·11	0·0557	0·0145	Gathered during first rain.
13/11/1923.....	2·01	0·1007	0·0245	After 2·1 in. of rain.
28/11/1923.....	1·96	0·0984	0·0268	After rain.
11/12/1923.....	1·47	0·0735	0·0168	The first wilting since 5/12.
23/12/1923.....	0·675	0·0337	0·0075	—
8/1/1924......	1·376	0·0688	0·0193	After rain.
5/2/1924......	1·05	0·0527	0·0133	—
27/2/1924......	1·18	0·0592	0·0124	Gathered on a dull day.
10/3/1924......	2·01	0·1007	0·0283	After rain.
2/4/1924......	1·44	0·0724	0·0213	After rain.
16/4/1924......	1·72	0·0864	0·0204	—
7/5/1924......	2·12	0·1063	0·0262	Rain between this determination and the last.
20/5/1924......	1·43	0·0716	0·0195	During rain.

2.—CHLOROPHYLL. *Tragus racemosus* and *koelerioides.* Midday values.

Date.	Reading.	Absolute amount pro 10 grm. fresh matter in grm.	Absolute amount pro 1 grm. dry matter in grm.	Remarks.
22/5/1923......	1·07	0·0538	0·0070	—
24/9/1923......	2·47	0·1237	0·0297	—
2/1/1924......	1·95	0·0975	0·0147	In the interval, grass could not be found.
5/2/1924......	1·08	0·0543	0·0151	—
12/2/1924......	1·03	0·0518	0·0081	Withered.
18/3/1924......	0·96	0·0480	(?)	*Tragus koelerioides.*
22/4/1924......	1·701	0·0700	0·0206	*Tragus koelerioides* after rain.

3.—CHLOROPHYLL. *Digitaria eriantha.* Midday values.

Date.	Reading.	Absolute amount pro 10 grm. fresh matter in grm.	Absolute amount pro 1 grm. dry matter in grm.	Remarks.
31/8/1923......	1·051	0·0527	0·0139	—
21/9/1923......	2·373	0·1189	0·0304	—
10/10/1923.....	1·603	0·0801	0·0181	—
7/11/1923.....	1·04	0·0522	0·0125	—
27/11/1923.....	1·39	0·0693	0·0289	After rain.
15/2/1924......	1·21	0·0606	0·0209	In the meantime no grass could be found. Plant looking very well; from a part of the farm which got rain in February.
18/2/1924......	0·78	0·0377	0·0074	Withered; from another place.
28/2/1924.......	1·23	0·0616	0·0143	After rain.
24/3/1924......	1·15	0·0580	0·0210	After rain.
9/4/1924......	1·07	0·0539	0·0178	—
12/5/1924......	3·11	0·1623	0·0633	After rain; plenty of young leaves, which were killed soon afterwards by frost.

4.—CHLOROPHYLL. *Themeda triandra.* Midday values.

Date.	Reading.	Absolute value pro 10 grm. fresh matter in grm.	Absolute value pro 1 grm. dry matter in grm.	Remarks.
27/8/1923......	1·67	0·0835	0·0180	—
26/9/1923......	1·60	0·0799	0·0135	—
23/10/1923.....	1·57	0·0786	0·0126	—
20/11/1923.....	2·88	0·1444	0·0323	After rain.
5/12/1923.....	2·55	0·1275	0·0194	First wilting observed.
18/12/1923.....	1·0	0·0500	0·0091	Wilted.
15/1/1924......	1·0	0·0500	0·0100	Rain between the two determinations.
5/2/1924......	1·25	0·0624	0·0116	Rain between the two determinations.
3/3/1924......	1·33	0·0668	0·0162	—
13/3/1924......	1·57	0·0789	0·0183	Rain before sampling; new leaves coming.
29/4/1924......	3·04	0·1520	0·0481	After rain.
27/5/1924......	1·20	0·0604	0·0121	—
17/6/1924......	1·05	0·0513	0·0104	—

5.—Changes in Chlorophyll-Content during 24 Hours Time.

Date.	Plant.	Amount of Chlorophyll pro 10 grm. fresh matter in the early morning, first day. In grm.	Amount of Chlorophyll pro 10 grm. fresh matter at noon. In grm.	Amount of Chlorophyll pro 10 grm. fresh matter in the early morning, following day. In grm.	Amount of Chlorophyll pro 1 grm. dry matter in the early morning, first day. In grm.	Amount of Chlorophyll pro 1 grm. dry matter at noon. In grm.	Amount of Chlorophyll pro 1 grm. dry matter in the early morning, following day. In grm.
28/2/1924......	*Digitaria eriantha*............	0·0637	0·0616	0·0648	0·0231	0·0143	0·0186
27/11/1924.....	*Digitaria eriantha*............	0·0350	0·0228	0·0360	0·0140	0·0069	0·0124
13/3/1924......	*Themeda triandra*............	0·0839	0·0789	0·0839	0·0254	0·0183	0·0253
11/11/1924.....	*Tragus racemosus*............	0·0257	0·0277	0·0277	0·0069	0·0066	0·0069
10/3/1924......	*Eragrostis superba*...........	0·1144	0·1007	0·1129	0·0363	0·0283	0·0371
5/11/1924.....	*Eragrostis superba*...........	0·0212	0·0173	0·0432	0·0053	0·0038	0·0131

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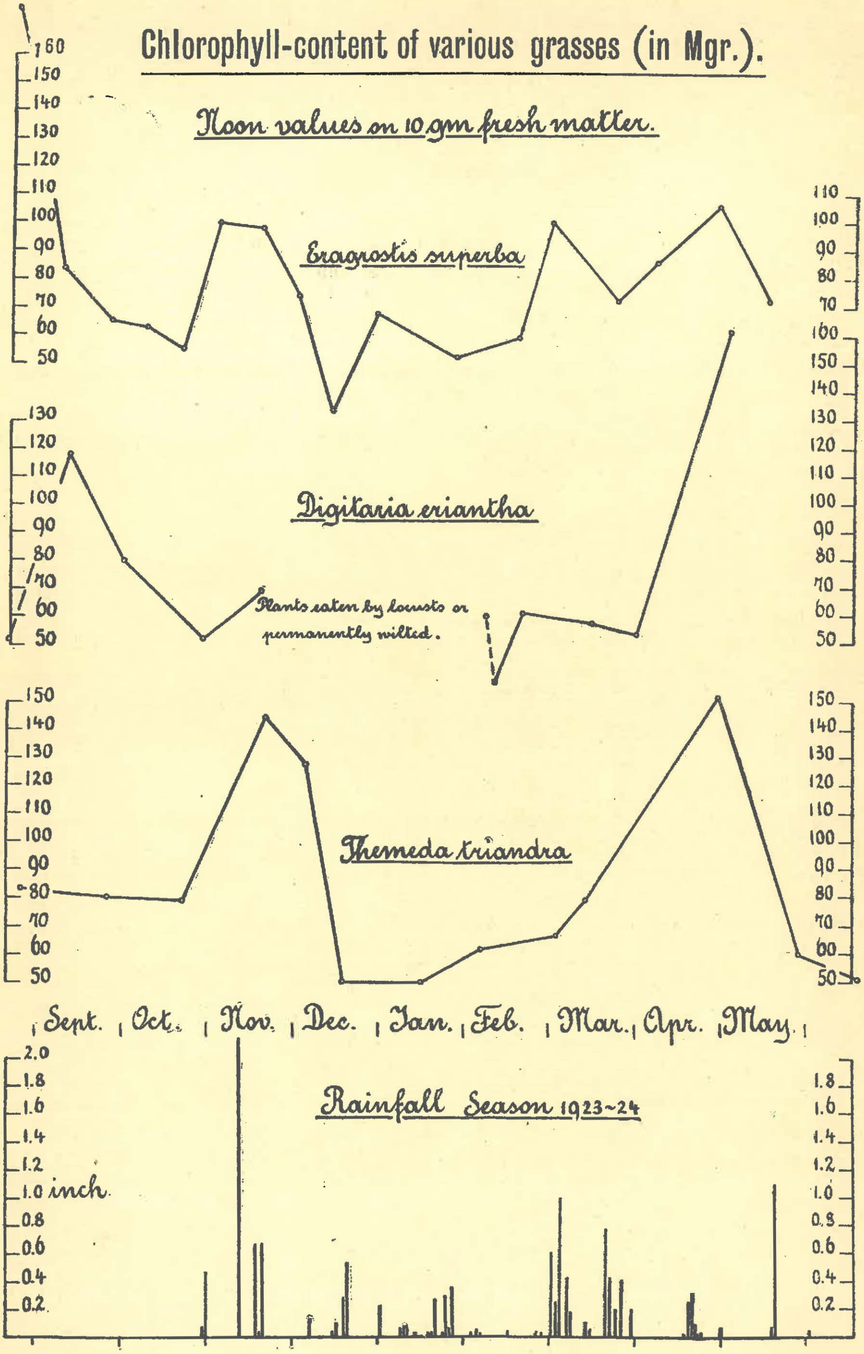

Plate I.] [Henrici.

CHLOROPHYLL-CONTENT.