It is obvious that in European plants an increase of phosphorus in the seeds is followed by a decrease in the leaves. With the exception of *Aristida congesta*, the formation of haulms at Armoedsvlakte is *not* accompanied by a decrease of phosphorus in the vegetative organs. Some roots have at this time a lower phosphorus content, but this may be accidental and caused by other factors. Apparently in most cases the phosphorus intended for haulm formation is taken up independently of that for the leaves. If, however, the percentage amount of phosphorus in the leaves does not decrease, the number of leaves and therefore the absolute amount of phosphorus in the vegetative organs may be decreased by haulm formation (see next paragraph).

Seasonal change of the phosphorus content in roots and leaves (Theoretical Curve).

It may appear superfluous to return to this subject after discussing the influence of rain, but it seems necessary to emphasise certain points " independently of the moisture." As there are a great number of values with many fluctuations for every species average values must be calculated in order to obtain the theoretical curve for the year.

The construction of such a curve shows the exceedingly peculiar fact that in green leaves *there is no continuous decrease in the phosphorus content from Spring to Autumn.* The fluctuations of the average values are insignificant, but have a pronounced minimum between the end of December and the beginning of February. If green grass is present in winter, as was the case in ⅔ of the species in 1925, this grass is richer in phosphorus than the grass of the summer drought period. The average yearly curve of phosphorus in green grass is therefore a slow decrease from August to January followed by an increase from February to the end of the season. This increase is not quite regular, being more rapid in the first weeks of the second rainy period than later. This does not alter the fact that the phosphorus content of dying leaves decreases, as only the leaves which survive the winter or are developed then have a higher percentage of phosphorus than the leaves of the summer drought period. The winter phosphorus minimum is apparent in all dry organs.

It is possible that the average phosphorus curve varies somewhat in different years in accordance with the distribution of rain (compare, for instance, plate 23 in " Phosphorus in the Livestock Industry.") In previous investigations green and dry leaves were not separated, so that the comparison is difficult. It is permissible, however, to draw some conclusions, as the green material always contains the higher amount of phosphorus. The absolute maximum will necessarily vary.

The values obtained on unburnt veld will first be compared. The maximum in October and November corresponds to the maximum found in this investigation, but the maximum in very young leaves in August and September does not appear in the mixed fresh and dry material, as the absolute amount of fresh material is at this time very small. It is certainly striking that in 1920 the October-November maximum is so pronounced, in spite of the rainfall being much lower than in 1924. After this maximum the percentage of phosphorus falls somewhat in 1920, but in 1924 the decrease during the January drought period is more pronounced. Then only is there a big difference. In 1920 the heavy February rains have scarcely any effect on the percentage of phosphorus, whereas in 1925 the March values may be as high as those of November. As there is in 1925 a minimum of dead material at the same time, this cannot possibly have any influence. At present it seems impossible to explain this discrepancy.

The winter decrease of phosphorus in the total aerial material again corresponds with results obtained in 1925.

It is peculiar that on burnt veld (1919) a second maximum appears after the February rains, corresponding better to the 1925 curve. The order of the actual values of 1919 is nearer those of 1925, for the simple reason that in 1919, after the veld had been burnt no dead material remained, so that it is a curve of green leaves, as in 1924-25. It is true that values obtained in November, 1919, are about 30 per cent. higher than those of 1924, but this is probably due to special treatment, namely the burning of the veld, by which the phosphorus of the dead parts becomes available for the plant. Theoretically the effects of burning may be manifold. Phosphorus which in the dead organs is lost to the tuft enters the soil in the immediate surroundings, and after the first good rain reaches the root. From the first the root is probably able to store more. By burning the top layers of soil may be to some extent altered, but this factor has not yet been experimentally studied, and it is not possible to advance any hypothesis on this subject. The burning itself certainly acts as a stimulus to the plant, just as a branch placed in warm water shoots out more quickly than one in cold water.

The Distribution of the Phosphorus in the Different Parts of the Plant with the Changing Season.

(Charts and tables 14-26).

In the tables 14-26 the phosphorus content of the plant is calculated in two different manners. In the first case the phosphorus content of one part of roots was taken as unity, and the relation of one part of any other organ to this calculated. In the second the total phosphorus content of the plant was taken as 100 per cent., and the position devoted to every organ was calculated.

Sometimes the one and sometimes the other aspect shows to advantage. The charts 14-26 are drawn in accordance with the second scheme, and in spite of heterogeneous material of different sized tufts the charts give on the whole a very good survey of the distribution of the phosphorus.

In early spring most of the phosphorus is in the dead aerial material, but as the spring advances the dead material decreases, and is partially replaced by the new green leaves. At this time the greatest amount of phosphorus is in the young leaves and the phosphorus content of the root usually decreases. This condition holds until about the middle of November, when, after good rains the leaves elongate and the first haulms of *Themeda* and the two species of *Eragrostis* appear. The phosphorus content of the dead material is now very low, but remains so only for a short time. The phosphorus of the root also is almost exhausted.

Most of the other grasses are in this condition a little later, usually in December, 1924, but *Digitaria* and *Pogonarthria* only in

January. Grasses which wilt easily (*Anthephora, Digitaria* and *Fingerhuthia*) have a second phosphorus maximum in the dead material at this time, showing that a large proportion of the newly formed leaves has already died down.

There is never any long-continued period when the phosphorus content of the haulms is greater than that of the leaves. For a fair comparison the values for young and old leaves must be taken together. At this time haulms were so scarce that a separation into spike and stalk, as was done later, could not be carried out.

During the following months there is a typical change in the organs which contain the most phosphorus. In most of the grasses (*Eragrostis Lehmanniana. Themeda, Aristida congesta, Fingerhuthia, Pogonarthria, Eragrostis superba, Sporobolus*) maxima are found in the vegetative organs in January, March and May, in the reproductive organs in February, the end of March and sometimes even in June. In the other grasses the maxima occur at different times, but it is exceptional for maximal values of the vegetative and reproductive organs to fall together. The maximal values of the vegetative organs are absolute maxima, that is to say the leaves at this time contain most of the phosphorus of the grass tuft. This is not always the case for the maximal values of the reproductive organs. The maxima of the haulms are often very low, and are sometimes exceeded by an absolute maximum of phosphorus in the dead organs, so that the greater part of the phosphorus is at that time in the dead material.

In the majority of the grasses most of the total phosphorus during the drought period is in the dead aerial material, which corresponds very well with the fact that at this time the percentage of phosphorus in the green leaves and roots is very low.

Close consideration of the phosphorus curve for spikes and stalks reveals the extraordinary fact that the amount of phosphorus in the stalks is greater than that in the spikes (e.g. *Sporobolus fimbriatus, Digitaria, Eragrostis superba, Chrysopogon, Fingerhuthia, Anthephora*). *Eragrostis Lehmanniana* on one occasion, *Themeda triandra* on two and *Aristida congesta* always behave differently. This fact has doubtless a close relation to the production of seed. *Tragus* occupies a separate position, as the haulms were too small to be separated. At the time that *Eragrostis Lehmanniana* had more phosphorus in the spikes than in the stalks it produced a few hard seeds, and *Themeda* did the same on some occasions. In the case of *Tragus*, as soon as spikes with seeds appear the phosphorus content is exceedingly high.

Towards winter the amount of phosphorus in the dead material rises considerably, and the amount stored in the root increases, but to a much lesser degree. This large percentage of total phosphorus in the dry material is caused by the increase of dead matter, and not by an absolute increase of phosphorus. The high percentage in the root, however, is due to actual translocation of phosphorus from the dying organs. Only a part of the phosphorus is stored in the root. The majority remains in the aerial parts and only acts as a reserve for the tuft to a small degree, as in spring the dry material breaks off without having given up all its phosphorus. It is peculiar that grasses which have such a struggle to obtain sufficient phosphorus waste so much in winter. As a large amount of water is necessary for the translocation, it is possible that the leaves are too dry for the migration of any further phosphorus.

The Phosphorus Content of the Dry Harts Grasses.

On comparison with Armoedsvlakte material it appears that the phosphorus content of the Dry Harts grasses, especially of those of the vlei, is very much higher, not only in the leaves, but in the roots. The young leaves, in particular, are not inferior to European grasses. The seasonal fluctuations are on the whole not large, except towards winter, when there is a pronounced decrease in the phosphorus of the leaves. In only a few cases can a corresponding increase in the root be observed. It is characteristic that in autumn green leaves are rare or completely absent in the vlei at a time when they were still present on the kopje. The haulms also die down sooner, probably because a soil rich in phosphorus accelerates the development and maturity of the plants (*Russel*, 1921, page 65). As samples were taken at intervals of several weeks the formation of seeds could not be followed as closely as at Armoedsvlakte, and it could not with certainty be decided whether seeds capable of germination were produced.

The positions of the maxima and minima in the leaves are not nearly as uniform as at Armoedsvlakte. Most of the minima are in March, but of the others six are in December and four in January. The maxima are still more scattered. Most occur in December and January, but a few are in the very young leaves shooting in winter, and some in March. It therefore appears that maxima and minima of different species may occur in the same month, which was never the case at Armoedsvlakte. It must be emphasised, however, that maxima and minima do not as a rule differ much from the average value, and consequently have not the same importance as in Armoedsvlakte material and are more probably accidentally caused.

The minima are easier to explain. They occur at a time when an abundance of young haulms is developed, and part of the phosphorus is probably translocated for haulm formation. This translocation of phosphorus corresponds to processes observed in European material, in which a maximum in percentage of phosphorus in the leaves was found before any flower buds appeared (*André*, 1902, cited after *Czapek*, 1921, page 432; *Hall*, 1919).

The difference between European and South African plants is that European material never has a second maximum, whereas the South African generally does, but it must be remembered that grass haulms in South Africa appear several times in the course of one season.

Although in the preceding paragraphs the differences between minima at Armoedsvlakte and Dry Harts have been emphasised, this does not exclude the possibility of Dry Harts having minima caused by drought as at Armoedsvlakte. Possibly in the infrequent sampling such a minimum was not found.

It has already been emphasised that the values in general are much higher than those of Armoedsvlakte grasses. It follows, therefore, that the minima are much higher than at Armoedsvlakte, and the dead leaves also have a higher phosphorus content. The same cannot be said for the roots. Although the maxima and average values are generally very high, some minima found at Dry Harts are of the same order as those found at Armoedsvlakte.

Wilting has no direct effect on the phosphorus content of the leaves, and the same deductions may be made as on the Armoedsvlakte material.

There are certain peculiarities in the distribution of phosphorus in the stalks and spikes. Whereas at Armoedsvlakte the phosphorus, except in the young haulms, is seldom higher than in the leaves, in Dry Harts this often occurs. During the development it often happens, especially in the flood area, that the stalks have a higher percentage of phosphorus than the spikes, so that it appears that phosphorus is at the time still being translocated. When a remigration of phosphorus takes place from the empty spikes through the stalks of the old haulms, the stalk may again have a high percentage. which soon, however, falls to a very low value. It is peculiar that at death haulms have lost far more of their phosphorus than the vegetative organs, which in winter often contain three or four times the percentage of the stalks, although they have been under the same moisture conditions.

From the tables 27 to 45 it is obvious that in a soil rich in phosphorus different species may also take up quite different amounts of phosphorus. The leaves, however, differ less than the roots, which, contrary to those of Armoedsvlakte, vary more than the leaves.

A comparison of the behaviour of the same species from the vlei and the kopje reveals some interesting differences. In spring and summer the dry matter of the vlei plant is nearly always lower than that of the kopje, but in autumn this relation is often reversed. In spring and summer the kopje plants wilt more quickly than those of the vlei.

As has already been mentioned, the plants from the vlei particularly are characterised by a high phosphorus content. (See tables 27, 28; 39, 40; 31, 32; 29, 30.) This is not surprising, considering the big differences in available phosphorus between the soil of Dry Harts and that of Armoedsvlakte (see "Phosphorus in the Livestock Industry," p. 39, and this paper, p. 1085). Clay soil of Dry Harts, 0.007 per cent. P_2O_5; kopje, Dry Harts, 0.003 per cent. P_2O_5: leached sandy soil of Armoedsvlakte, 0.0005 per cent.; dolomite soil of Armoedsvlakte, 0.001 per cent. *Old* leaves of the vlei have high values compared with those of the kopje, but *young* leaves of the kopje plants sometimes have higher values than those of the vlei (see *Cymbopogon* 33, 34, and *Eragrostis Lehmanniana* 43, 44). No explanation can be found for this phenomenon. The young leaves of the kopje plants in general, not only of *Cymbopogon* and *Eragrostis Lehmanniana*, have a higher percentage of phosphorus than those of Armoedsvlakte, but the old leaves are about the same. It is more the higher root values which constitute the difference between these and Armoedsvlakte grasses. This is probably due to a somewhat higher rainfall.

It is peculiar that brown leaves of both kopje and vlei have a much higher phosphorus content than those of Armoedsvlakte. Values of brown leaves from the kopje reach 0.14 per cent. to 0.16 per cent., whereas in the vlei *Eragrostis superba* dies down with a phosphorus content of 0.21 per cent. The values obtained from brown leaves on the kopje are higher than the absolute minimum of green grass in summer at Armoedsvlakte, and those of the vlei correspond to the average summer values at Armoedsvlakte. *It therefore appears that plants on a phosphorus deficient soil can withdraw more phosphorus from the dying leaves than those on a soil which is richer in phosphorus.*

The difference between the phosphorus contents of the leaves and of the haulms is usally small in both vlei and kopje plants. There are a few exceptions when ripe seeds are produced (table 39). It is possible that in other grasses ripe seeds were missed in the long interval between collections.

In Bechuanaland it is accepted that on a veld on which *Ganna* (*Salsola Zeyheri*) grows, there is no Pica. This suggests that *Salsola* should contain far more phosphorus than the other plants in its association. As the Dry Harts vlei is characterised by an abundance of Ganna, analyses on the plant leaves were carried out (table 58), which proved this supposition to be erroneous. *Ganna* contains no more, and at times rather less phosphorus than the surrounding grasses investigated at the same time.

Ganna is therefore a bush which can grow only on a rather rich soil, and is an indicator of this, but it is not a plant rich in phosphorus. The Pica on such a veld is repressed by the high phosphorus content of the associated grasses.

TABLE L.

Salsola Zeyheri. *Phosphorus content as percentage of phosphoric oxide on plant dry matter. Leaves.*

Date.	P_2O_5 per cent.
24.1.1925...........	0·349
5.3.1925...........	0·259
29.4.1925...........	0·300

THE PHOSPHORUS CONTENT OF THE BIESJESVLAKTE GRASSES.

(Charts and Tables 46-49.)

The phosphorus content of the leaves of the Beisjesvlakte grasses is on an average somewhat higher than that of the Armoedsvlakte leaves, but not nearly as high as of those of the Dry Harts vlei. Only *Anthephora* and *Aristida uniplumis* have low minima, but not as low as those of Armoedsvlakte, although the grasses were gathered at the end of a drought (26.2.25). The influence of a prolonged drought or a continuous rain is in general the same as at Armoedsvlakte, but is quantitatively different, as drought does not repress and rain does not increase the values as much as at Armoedsvlakte. This may be due to the physically different soil which also retards wilting. Long rains increase the root values, but there is not always a corresponding increase in the leaves.

It is peculiar that the maxima occur at two different times, those of *Sporobolus and Anthephora* during the first, and of *Aristida uniplumis* and *Cymbopogon marginalis* after the second rainy period.

An increase in the phosphorus of the root occurs in May, but the value falls in June, when new leaves appear, although the new leaves have a low phosphorus content. The root values are usually higher than those of Armoedsvlakte and very low minima, such as occur at Armoedsvlakte or Dry Harts, are never found.

With the exception of *Sporobolus fimbriatus* the phosphorus content of the haulms is low. Haulm formation does not decrease the phosphorus content of the leaves, except in the case of *Sporobolus*, which in January produced ripe seeds. The phosphorus content of the stalks and spikes is very high, and a depression of the amount of phosphorus in the leaf was noticeable. This fact agrees perfectly with data obtained by *Arendt* (1859, cited after *Swart*, 1914) in which the phosphorus of the leaves of *Avena* decreases after the plant has flowered, when the phosphorus of the leaves and stalks migrates to the seed.

Another point, interesting from the agricultural and ecological point of view, may be mentioned. Ripe seeds of *Aristida uniplumis* were never found (possibly they were missed), and the spike usually had rather a low phosphorus content. In June, however, when the haulms, except at the bottom, were quite dry, the phosphorus content of the stalks and spikes was high, higher even than that of the leaves and roots, the latter having decreased considerably after the rains at the end of May. There was certainly a movement of water from the roots to the haulms, as the stalks had a longer green portion at the bottom than before, and the phosphorus apparently rose with the water. In winter cattle are known to be particularly fond of *Aristida* haulms, which is not surprising, as at this time of the year no other grass contains so high a percentage of phosphorus. Winter grazing on an *Aristida* veld is therefore very good in spite of the lack of green or dry leaves.

Comparison of the Values obtained at Armoedsvlakte with European Values.

It is difficult or even impossible at my present residence for me to consult the scattered literature on the phosphorus content of European plants, and I am restricted to figures given in *Czapek's* Biochemie (1921, II) or other handbooks. Most European figures are given in percentages of the pure ash, whereas the figures in this investigation are given in percentages of the dry matter. A recalculation is possible, as in total analyses done for another purpose the ash was determined. In leaves it varies from 7-9 per cent. (average 8 per cent.) of the dry matter, in roots special determinations gave an average of 3.1 per cent. of ash. These numbers are good enough for a general orientation. Leaf values found in the present investigation must be multiplied by 12.5, root values by 32.2 to compare them with European figures.

The dry matter of the South African grasses is usually considerably higher than that of any European material (see *Czapek*, 1921, II, p. 424, ff). The ash content, however, does not differ very much, i.e. higher or lower values are found in Europe (*Czapek*, 1921, II, p. 423, or *Johnston*, Appendix, Meadow Grass varies from 5.9 to 10 per cent.). According to *Wolff's* table (cited after *Johnson*, 1908, appendix) the phosphorus content of European meadow and pasture grass varies from 1.3 to 2.4 per cent. of the fresh matter, or 0.43 to 0.8 per cent. of the dry matter. For comparison the highest, the lowest and one frequently occurring average value of Armoedsvlakte may be taken, e.g. 0.11 per cent., 0.2 per cent., and 0.42 per cent. Green grass from Armoedsvlakte therefore contains only a half to a fourth the amount of phosphorus of a European grass. As *Czapek* gives the P_2O_5 in percentage of ash the Armoedsvlakte values must be multiplied by 12.5 in order to compare with European material. For the extreme cases of Armoedsvlakte 1.37-5.25 per cent. P_2O_5 of ash are got as compared to European material of 4.2 to 12.2 per cent. (*Czapek,* 1921, II, p. 432). The relation is of the same order as those of *Wolff's*, 2.3-3.0 times as great. *Wolff's* values being limited to *Gramineae* naturally give a better comparison, so these figures are sufficient to illustrate the phosphorus deficiency of Armoedsvlakte grasses. The percentage values of ash in roots given by *Czapek* (1921, II, p. 468 ff) are few, but an average of 3.1 per cent. of ash is, nevertheless, very small in comparison to that of European material. Unfortunately no figures for pasture grass are available, and the comparison can only be made with corn in water cultures, the ash content of which varies between 6.2 and 24.5, with the most frequent value about 13 per cent. The roots of Armoedsvlakte grasses therefore contain only a half to a quarter of the ash of European *Gramineae*. Summer values of the phosphorus content of the roots must be used for comparison. Summer values at Armoedsvlakte vary from 0.03 per cent. to 0.12 per cent. P_2O_5 of the dry matter, or, calculated on the ash 0.9 to 3.7 per cent. The European values of 5.0 to 23.5 per cent. P_2O_5 with a most frequent value of about 6.0 per cent. must be compared with these. The European material has at least twice, and up to six times as much phosphorus as the Armoedsvlakte material.

Unfortunately it is not possible to separate the husks and seeds of Armoedsvlakte grasses, as the seeds are too few and too small even for a micro-analysis, and direct comparison with European seeds is not possible. The comparison must be restricted to those European values which include the husks and the glumes (*Czapek,* 1921, p. 379). Contrary to what occurs in Europe, the husks are not low in phosphorus in comparison with the seeds. The loss of the seeds, shrivelled or mature, whether they are capable of germination or not, often does not depress the phosphorus content of the spike at all (table 5) or only to $\frac{3}{4}$ or $\frac{2}{3}$ of the original value. These values were obtained before any translocation of phosphorus towards the root took place, as after that the values are much lower.

From these figures it is evident that seeds and husks differ very little in their phosphorus content, or that the seeds contain $\frac{1}{3}$ more than the glumes. In comparison with European material, where the seed sometimes contains more than twenty times as much phosphorus as the husks, these differences are insignificant. From the special case where the husks and the seeds contain practically the same amount of P_2O_5 some conclusions may be arrived at. According to *Wolff's* table for cereal seeds (*Johnson*, 1908, appendix) recalculated on dry matter, the values vary from about 0.7 to 1.1 per cent., so that the seeds of Armoedsvlakte with 0.3 per cent. P_2O_5 contain 2.3 to 3.6 times less phosphorus.

In conclusion it may be said that all the organs of the Armoedsvlakte perennial grasses contain far less phosphorus than those of European plants. This difference is the greatest for roots and smaller for leaves and for seeds.

Swart (1914) criticises the method of calculation of the analyses on the percentage of ash, on the grounds that this does not give absolute numbers. As the percentage composition of the ash of the leaves varies in the course of the development, on account of the increase of lime and silica, the percentage alone does not give the correct relations and better results would be obtained from absolute figures either of the number of leaves or their surface. Most of the analyses were made on woody plants. The calculation on the dry matter is also criticised (p. 41), although in this case the increase in single ash constituents has no effect. The variation lies more in the changing content of organic substances, especially carbohydrates, as these substances constitute the greater part of the dry matter.

In answer to these objections the following facts may be mentioned. A calculation of the results on the numbers of grass-leaves would probably be valueless, as the leaves vary considerably in size at different times of the year.

Calculation of results on equal surfaces certainly has its advantages. It was not done in this case as another manner was adopted to show the distribution of the phosphorus (see below) and the use of a leaf cutter on the small and often rolled grass-leaves of Bechuanaland would be impossible. From another investigation figures are available to allow of a calculation of the relation between fresh matter and surface. The values are fairly constant (table 51). For those who prefer the other form of representation it is an easy matter to calculate from these figures, the phosphorus content on the surface, at least of some of the grasses. It will not alter the result of this work at all.

In this investigation it was considered preferable to calculate the percentage phosphorus content on the amounts of the different organs. This appears to give a good idea of the absolute amount of phosphorus in each organ, as in the tables 14-26 the relation between the organs is also given. It was not considered advisable to give the absolute weights of the organs, but to refer them to the root as unity, firstly on account of the changing material, and secondly because it is tiresome for the eye and brain to have to compare numbers in long tables and at the same time to have to think of the exact relation between them, if no unity is given.

TABLE LI.

RELATION OF FRESH MATTER TO SURFACE.

(Simple Surface.)

Average Values.

1	gr.	*Eragrostis superba* is	34.6 $cm.^2$
1	,,	*Cymbopogon plurinodis* is	36.9 ,,
1	,,	*Aristida uniplumis* is	42.0 ,,
1	,,	*Digitaria eriantha* is	43.0 ,,
1	,,	*Sporobolus fimbriatus* is	53.8 ,,
1	,,	*Themeda triandra* is	60.0 ,,
1	,,	*Tragus racemosus* is	100.0 ,,

PHOSPHORUS CONTENT OF THE PLANTS IN RELATION TO SOIL ANALYSES.

With reference to the soil analyses on page 14 it appears that low phosphorus content of grasses occurs in the same area on acid and on alkaline soil. On the other hand the available (citric acid soluble) phosphorus *alone* does not determine the percentage of the plant phosphorus. Should it be so, then Biesjesvlakte and the leached soil of Armoedsvlakte should have grasses with the same percentage of phosphorus which is not the case. Moreover the kopje area of Dry

Harts should have grasses with a much higher phosphorus content. As a matter of fact the plants of the two acid soils (Biesjesvlakte and kopje area of Dry Harts) have nearly the same phosphorus content and agree much better than the two soils with the same phosphorus content (Biesjesvlakte and leached soil of Armoedsvlakte). The highest phosphorus percentage of the grasses is found on the soil with the most available phosphorus.

It may once more be emphasized that on one and the same soil the different plants take up different amounts of phosphorus and even for one and the same species the amount of phosphorus drawn in the different seasons from the soil is not constant.

The Influence of a Phosphorus Deficiency on Plant Life.

In this investigation the phosphorus content is given in terms of P_2O_5. No attempt was made to determine the compounds in which the phosphorus occurs. It would be interesting to determine which compounds are most reduced in amount in a phosphorus deficient veld. In artificial experiments (*Koch* and *Reeds*, 1907) it was found that during phosphorus starvation *Aspergillus* lost first organic and inorganic water soluble phosphorus and then lecithin, but there was no decrease of nucleo-protein phosphorus. In artificial experiments phosphorus deficiency leads to an accumulation of fatty substances, as there is no phosphate present to bring about the synthesis of glycero-phosphoric acids, e.g. lecithin from the glyceryl esters (*Reeds*, 1907). These direct phosphorus compounds are altered, but a lack of phosphorus also brings about vital changes in the metabolism of bodies of which it is not a constituent. *Reeds* (1907) found that phosphorus deficiency increases the formation of cellulose and erythodextrin, both carbohydrates occurring as assimilation products instead of starch. Little data is available for higher plants.

Micro-analyses made in 1923 with Magnesia mixture and Ammonium molybdate showed that the leaves of Armoedsvlakte grasses contained no inorganic phosphates, whereas *Salsola zeyheri* did. As only water soluble phosphorus, chiefly inorganic, is translocated, it is easy to understand that haulm formation has no influence on the percentage of phosphorus in the green leaves. Investigations should be carried out to determine whether, under South African veld conditions in an area where haulm formation causes a decrease in the phosphorus of the leaves, water soluble phosphorus is present.

Although the only available literature concerning the relation between the carbohydrates and the phosphorus deals with low plants, certain conclusions may be drawn. The minima of starch and phosphorus of the Armoedsvlakte plants do not occur by accident at the same time (*Henrici*, 1927). Generally speaking the maxima of the direct assimilates also correspond to the phosphorus maxima. Complete accordance cannot be expected, considering that the photosynthesis is influenced by so many factors. The ash of the starch also contains phosphorus (*Thomas*, 1904, cited after *Czapek*, 1921, II, p. 429), so it is not surprising that a minimum of starch and a minimum of phosphorus occur together.

In one case of *Digitaria* the minimum of starch in January corresponds to a maximum of reducing bodies soluble in dilute acid, whereas in other grasses the minima of these two substances usually occur together. It does not appear, therefore, as though a body between starch and cellulose, a hemicellulose, is formed in place of starch at a time of a phosphorus minimum except in the case of *Digitaria*. The other grasses contain a carbohydrate soluble in a stronger acid. No tests for Erythrodextrin have yet been made.

There is no doubt that phosphorus deficiency has a more far reaching effect in the case of the higher plant than in the low. Wilfarth, Römer and Wimmer (1906) found that a migration of phosphorus took place, from the stalk to the ripening seed of barley, the nuclei-proteids of the seed increasing in proportion to the decrease of water soluble phosphorus in the stem. Although the different compounds of phosphorus in the Armoedsvlakte grasses were not separated, it is certain that, with a few exceptions, nothing of the kind occurs.

Growth may be stunted by phosphorus deficiency. Although the elongation of the haulms and leaves is not hindered at all at Armoedsvlakte, except when there is a deficiency of water at the same time, different species which occur in other parts of the Union (*Themeda triandra*, *Eragrostis superba*, *Cymbopogon plurinodis* and *Digitaria eriantha*) never grow as luxuriantly as, for instance, in the surroundings of Pretoria. It is moreover characteristic that the time of slowest growth, as observed from actual experiments on growth, occurs at a time of phosphorus deficiency. This is naturally during a period of drought, so that the influence of the water deficiency is combined with that of the phosphorus deficiency, and it suggests that water deficiency alone may be responsible for the retarded growth. But in spring, on the other hand, when there is no water but the stored phosphorus is available, growth does take place.

In a previous investigation (*Henrici*, 1926, II) it has been pointed out the grasses have an excessive transpiration power which is dangerous in a drought area. This intense transpiration has one advantage, in that the nutrition salts are carried to the leaves more rapidly than would be the case with a feeble transpiration, especially as the amount of phosphorus available in the soil and therefore in the water is so limited.

The Remigration of the Phosphorus in Armoedsvlakte Grass as Compared with European Material.

The translocation of phosphorus in Armoedsvlakte grasses may be compared briefly with the process under European conditions. It has already been stated in the introduction that even in Europe the problem has not been altogether solved, but it is generally accepted that in autumn phosphorus, potassium and nitrogenous substances migrate from the leaves of trees (*Swart*, 1914) and perennials (*Hall*, 1918, p. 72, ff.; *Czapek*, 1921, p. 447, where more literature is cited) back to the axis and roots. The roots and axes were not analysed, but it was concluded from the differences in the ash substances of leaves which grew old on the tree to those which were picked earlier that large amounts of valuable substances were translocated, and it was thought that the amount lost from the leaves would be found in the roots.

In this investigation the fact that the theory of remigration was first based on percentage values of ash and not on absolute values has been ignored, as later *Swart* (1914), who in accordance with the views of *Wehmer*, criticised the method, obtained the same result with absolute figures.

Wilfarth, Römer and *Wimmer* (1906), who also analysed the roots of these cereals noticed a peculiar phenomenon. These authors determined the absolute as well as the percentage amounts of ash in the plants and found that the absolute maximum of potassium, nitrogen and phosphorus of the whole plant does not occur at the end of the vegetation period, but much earlier, although all loss of the brown leaves was carefully avoided. In barley, for example, the loss of potassium is 35 per cent., of nitrogen 25.5 per cent., and of phosphorus 7 per cent. (p. 11). The loss of phosphorus is therefore much less than that of the other valuable substances. The authors have agreed that the disappearing substances were used when the plant was in a condition of rapid growth, and that later, after having fulfilled their special function without having taken an actual part in the formation of new substances, they were unnecessary, and migrated back through the root to the soil (p. 27, ff.). This conception and the analyses are noteworthy, especially as there are almost no data concerning roots.

In the present investigation an attempt was made to calculate the absolute phosphorus content of the grasses, but the analysed tufts varied in size to too great an extent so that no yearly graph could be drawn from the data. For August, 1925, a new series of determinations was therefore begun and continued until August, 1926. *Digitaria eriantha* and *Chrysopogon serrulatus* were gathered in an unmanured unwatered camp in which some years previous to this work all other grasses and bushes had been removed. It was thought that under these conditions the tufts would be more uniformily developed. This was true only to a certain extent and very big fluctuations in size could still be detected. It was, however, possible to calculate from the average monthly values the value for an ideal plant corresponding to 100 gr. roots. The results are given in the tables 52 and 53.

The tables are calculated as follows. The relation of the weight of all the plant organs with the root as unity is given. In the next column the amount of P_2O_5 in 100 gr. root is given. It varies, especially for *Digitaria*, but little. In the folowing columns the absolute P_2O_5 content of the corresponding amount of leaves, haulms, spikes, dry leaves, dry haulms and root neck is given, calculated from the percentage amount of P_2O_5 and the figures of relation. All these absolute amounts of P_2O_5 were added up to the total amount of P_2O_5 in the tuft corresponding to 100 gr. root. Finally a monthly average is calculated as well for the single organs (except spikes) as for the whole plant. These figures will be discussed in the following pages. If in the column " dry leaves " two figures are given, it means that two kinds of dry leaves could be distinguished, very leached ones and brown ones, which had but recently dried out. Strange to say in most cases the leached leaves contained more phosphorus than the leaves recently died.

More uniform results would have been got, if instead of calculating to 100 gr. root substance, a correcting figure for the alteration in the amount of root would have been introduced; that is to say if as basis for the calculation an average value of the amount of roots would have been chosen. This reduction was purposely omitted because in free nature the amount of roots also changes with the season.

Before discussing the obtained data in detail, some general features may be mentioned. It must be borne in mind that such a table depends very much on the distribution of the rainfall and the periods of drought of the season, and therefore minima and maxima may lie in different years in different months. According to European experience for the aerial parts, especially for the leaves, a graph may be expected rising from a minimal value in winter to a maximal value in autumn before the leaf-fall and the remigration of P_2O_5. The amounts of P_2O_5 in the whole plant should show the same curve. In the moment of leaf-fall a rapid decrease would occur, but if the total of fallen leaves and their P_2O_5 content is known, the phosphorus in the axis and roots plus the amount in the fallen organs should add up to the maximum unless such a phenomenon as remigration to the soil occurs. For the present investigation it may be said that the breaking off of old haulms and leaves especially takes place towards the end of the winter, for *Digitaria* earlier than for *Chrysopogon*.

The percentage values for phosphorus are not indicated in tables 52 and 53; as a rule they are slightly lower than in 1924-25 probably due to the drier season. All points explained for the data 1924-25 hold good for 1925-26.

The absolute amount of phosphorus in *Digitaria* is in a yearly average higher than in *Chrysopogon* if calculated on 100 gr. root substance, but not by tuft as will be explained below. From the data of 1924-25 it is known that *Digitaria* and *Chrysopogon* are of the best Armoedsvlakte grasses from the point of view of phosphorus. It appears from tables 52 and 53 that the total phosphorus varies considerably during the year and does not at all correspond to the theoretical curve. As the phosphorus contained in the root scarcely varies and is but little, the changes occur in the aerial parts. From the minimum in winter the total amount of P_2O_5 rises quickly to a maximum in October which is much higher for *Digitaria* than for *Chrysopogon*. For both grasses a big decrease follows, partly caused by the lack of green leaves, partly by a general percentage fall of phosphorus. The minimum is reached in February, *Chrysopogon* showing a little rise in January, after some rain. The drought in February is pernicious for both grasses, the total amount of P_2O_5 in *Chrysopogon* being even smaller than in winter, for *Digitaria* being about the same in February and winter. From March the total amount of phosphorus rises after rain and increases towards winter. In the discussion of the results 1924-25 it was mentioned that the percentage of phosphorus of grass leaves in winter is higher than in the drought period of summer (p. 1101) the same phenomenon holds good for the total absolute phosphorus of the two grasses.

If from the total phosphorus the amount for root and root crown is deducted, the available phosphorus for the cattle pro tuft of 100 gr. grass roots is found. To get a rough idea how many tufts produce together 100 gr. roots, it may be mentioned that a middle sized tuft of *Digitaria* has on an average 2 gr., of *Chrysopogon* 5 gr. of roots. This would mean that 50 tufts of *Digitaria*, 20 of *Chrysopogon* contain the absolute total amount of phosphorus.

It says also that the tuft of *Chrysopogon* contains about twice as much phosphorus as the *Digitaria* tuft considering that the yearly average value of total of phosphorus is somewhat lower for *Chrysopogon* than for *Digitaria*.

The curve of the absolute phosphorus of the plant organs eaten by cattle is very similar to the curve of absolute phosphorus of the whole plant, at least for *Chrysopogon*. The maximum is in October, the minimum in February; for both grasses the February minimum is considerably lower than the winter value from June to August.

Absolute amount of phosphorus in organs available to cattle—

pro 100 gr. root in gr. P_2O_5.

	Digitaria.	*Chrysopogon.*
August, 1925	2.0	3.0
September	1.3	2.7
October	7.2	4.0
November	2.0	3.2
December	1.6	3.7
January	2.2	3.5
February	1.7	1.7
March	2.0	2.8
April	2.7	1.8
May	2.2	2.7
June	2.5	3.0
July	2.5	2.9
August, 1926	2.8	1.2

Digitaria shows some variations with very low values in September and December; it is peculiar that these exceptions are both combined by a higher value in the root neck, so that apparently the phosphorus has gone back towards the root neck, in September from old material, in December from newly dried out material. The process is doubtless caused by the fact that *Digitaria* is much more affected by drought and high temperature than *Chrysopogon*.

After discussing the total phosphorus of the whole plant, the absolute phosphorus of the single organ may be considered. The root values especially of *Digitaria* change but little and are decidedly lower for this grass than for *Chrysopogon*. The minimum value is reached in February for *Chrysopogon*, in March for *Digitaria*. The hibernal accumulation is not strongly pronounced, however, detectable.

The green leaves have their maximum in October, a minimum in February and in the winter months. Correspondingly the dry leaves show a maximum in winter and a minimum in September, in the time when the old leaves have been broken off and no withering has yet taken place.

For the root neck no concordant results for both grasses can be given. There is certainly a minimum in August and again a relative minimum in February. But the maxima are scattered, even partly in time of drought when other organs are in a decreasing state. This suggests that at certain times of the year the root crown acts as storage organ of phosphorus, that phosphorus is accumulated here and not in the root. So for both grasses in October when the root is better developed and phosphorus comes from the soil, and for *Chrysopogon* again in January when haulms come up. But curiously enough, neither of the grasses show a considerable increase in winter time, so that the root crown is certainly not a storage organ for phosphorus in winter but may be so at other times of the year. For both grasses it is the organ containing the most phosphorus right from September to December, for *Digitaria* even through the whole year with the exception of the winter months.

As can be seen from table 52, *Digitaria* scarcely produced any haulms during the season 1925-26, less even than the previous year. On the whole it appears that for *Digitaria* and *Chrysopogon* rather small tufts produce haulms, which would mean younger plants. For reasons which have been explained previously (p. 1087) it is not possible to calculate average values for young haulms and spikes. But in spite of this it can be seen that haulm formation is not accompanied by a decrease in the absolute amount of phosphorus in the leaves, a fact which was already pointed out for the percentage phosphorus. The relative high value of the total phosphorus of *Chrysopogon* in January is due to the phosphorus in the haulms. In February less green haulms are available, and in March all the haulms are yellow and from this time their absolute amount of phosphorus decreases towards June, in the winter months it is rather higher than at the end of October, this is doubtless due to the process that already in July phosphorus migrates from the roots to new formed green leaves. Dry haulms during winter may be a storage organ for phosphorus which is withdrawn in spring.

As has been pointed out the yearly curve of the total amount of phosphorus may change with the year. In spite of the varying material in 1924-25, it can be said that the minimum of total phosphorus was in January and beginning of February, and again in May, this time being the drought period of the season and early winter, the maximum was found between October and November corresponding with good rains. The lowest value in May was followed by a rapid rise corresponding to plenty of new leaves which were shooting after heavy rains in May.

Up to now it was stated that a phosphorus minimum occurred during summer. Naturally the question arises where the disappearing phosphorus goes to.

No satisfactory explanation can be found at the present moment, but with reference to the results of Römer, Wilfarth and Wimmer (1906) a hypothesis may be suggested. In time of extreme drought the phosphorus goes back to the soil through the roots, because it is unlikely that in February considerable amounts of aerial plant parts are broken off. It is thought to test this hypothesis in pot experiments where every loss of dry leaves is prevented. No other explanation can be thought of. Armoedsvlakte grass certainly differs considerably from the cereals investigated by the German authors, so that the quantitative remigration may be different, although qualitatively the same phenomenon may occur. The occurrence of two relative maxima in the absolute phosphorus content of the Armoedsvlakte leaves is due to the entirely different climate. The fact that in the following years the same results were obtained only temporarily postponed on account of the rains, rather supports the hypothesis.

Resuming it may be said: During the drying out of the leaves and haulms of Armoedsvlakte grass a portion of the phosphorus is withdrawn, the haulms especially losing nearly all they contain. Part of the migrating phosphorus is stored in the root, but the fate of the remainder has up to the present not been experimentally determined. The absolute amount of phosphorus stored in the root is very small and much less than that remaining in the dead aerial parts.

Résumé.

The phosphorus content of a number of Bechuanaland grasses was determined during a year. The investigation was carried out in

Armoedsvlakte, the Government farm west of Vryburg, on a soil very poor in available phosphorus. Leaves, roots, haulms, spikes and dry material were separately analysed.

The plants were taken from the veld. In summer they were collected every 8th day, in winter every fortnight. The sampling in the veld involved big individual fluctuations; nevertheless it was possible to construct a yearly phosphorus curve for every organ except the haulms.

It appeared that the phosphorus content of the organs was considerably lower than of any European grass, the Armoedsvlakte grasses having only from one-half to one-sixth as much phosphorus. The older the grass the less favourable is the comparison with the European grasses.

Temporary wilting after the rains does not decrease the phosphorus content of the leaves, nor does a single shower of rain increase it. But a long drought decreases, and a rainy period increases, the phosphorus of any organ.

In spite of the leaf phosphorus decreasing during drought, no accumulation of phosphorus in the root can be detected. Up to now the missing phosphorus, which is also missing if calculated in absolute figures, could not be found in any plant organ and no satisfactory explanation can be given. An hypothesis is offered based on observations of German authors that part of the phosphorus migrates back to the soil.

In winter part of the phosphorus migrates back to the root. Expressed in percentage figures the root may double its average phosphorus content. In absolute figures, however, it is but very little.

Half of the phosphorus of the dying leaves is not translocated; with few exceptions, however, the old haulms are better emptied. In spring time when new leaves are produced and phosphorus migrates with the water from the roots to the aerial parts, often the old haulms are supplied with phosphorus, a sheer waste from the point of view of the plant. Later in the season, however, this phosphorus may be leached or translocated.

Haulm formation does not decrease the phosphorus in the leaves nor does an accumulation of phosphorus take place in the seeds. As a matter of fact, only few ripe seeds of perennials were found and it is thought that the lack of phosphorus is either the primary cause or a secondary effect of the bad seeding.

Only annual weeds like *Tragus* and *Aristida congesta* showed plenty of vital seeds and during seeding a three times as high phosphorus content than the other grasses.

It was further observed that on one and the same soil the different grasses contain different amounts of phosphorus and that even one species contains more phosphorus at certain times of the year than at others.

For comparison grasses of two other farms of Vryburg District were analysed. Dry Harts, south of Vryburg, was chosen as a farm which was rich in available phosphorus due to a yearly flooding and to natural manuring in spring time. Biesjesvlakte, west of Armoedsvlakte, was selected as a pure sandveld farm with the same rainfall and available phosphorus as Armoedsvlakte.

As expected the grasses of the flooded area of Dry Harts showed a considerably higher phosphorus content and matured earlier than

Armoedsvlakte grasses. But also the grasses of the sandveld farm contained more phosphorus than the Armoedsvlakte grasses, and some seed formation was noticed.

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TABLE I.

Themeda triandra, Armoedsvlakte. Phosphorus content as percentage phosphoric oxide on plant dry matter throughout the year.

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	Roots. P_2O_5.	Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
		Dry Matter. %	P_2O_5. %	Dry Matter. %	P_2O_5. %		%			
6.5.1924	Green leaves...............				0·217					
27.7.1924	No green leaves. Brown leaves			92·0	0·063					
7.8.1924	New green leaves...........	48·6	0·200			No removable tissue........	0·182			
25.8.1924	Green leaves, 2 cm. long....	47·0	0·244			No removable tissue........	0·120			
3.9.1924	Folded, 6 cm...............	45·0	0·203			(28.8) No removable tissue..	0·121			
10.9.1924	Partly folded...............	32·0	0·390			No removable tissue........	0·107			
19.9.1924	Mostly folded, somewhat red-purp., 5–7 cm. long	34·0	0·246			Secondary roots and a few root hairs	0·128			
25.9.1924	Open, 12 and more cm. long	32·0	0·277			Secondary roots and a few root hairs	0·150			
2.10.1924	Open, many leaves very long	35·0	0·373			Dry, very few root hairs....	0·125	First young haulms, too little material to separate the spikes	0·300	
14.10.1924	Fresh, 20–30 cm. long......	43·0	0·250			Secondary roots, no root hairs	0·115	Very young haulms with flowering spikes	0·189	0·242
21.10.1924	Folded and drooping, tips of leaves brown. ca. 24 cm. long	50·0	0·242			Few secondary roots, no root hairs	0·117			
28.10.1924	Folded, tips brown, 26–28 cm. long	57·0	0·242			Few secondary roots, no root hairs	0·132	Flowering spikes...........		0·197
31.10.1924	Open, to 30 cm. long, some brown at tip	52·0	0·250			Secondary roots............	0·110			
11.11.1924	Open, 30 cm. long..........	35·0	0·330	50·0	0·214	Root hairs and secondary roots	0·107	Very young spikes..........		0·462
18.11.1924	Young leaves rolled or folded. Older leaves half folded, 45 cm. long	45·0	0·250	45·0	0·273	Some roots with root-hairs, others dry, secondary roots	0·117			
26.11.1924	Old leaves brown at tip....	48·0	0·300	52·0	0·205	No root hairs, secondary roots	0·115	Stalks from flowering haulms:	0·312	
								Young haulms, spikes not separated; flowering spikes and haulms	0·150	0·357
								Young haulms.............	0·306	
8.12.1924	Old leaves folded, but fresh.	37·0	0·242	50·0	0·277	Root hairs and secondary roots	0·095	Half-grown haulms.........	0·300	
17.12.1924	Open......................	40·0	0·271	50·0	0·207	New roots, secondary roots and root hairs	0·156			

TABLE I—(*continued*).

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	Roots. P_2O_5.	Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
		Dry Matter. %	P_2O_5. %	Dry Matter. %	P_2O_5. %		%			
29.12.1924	Old leaves half folded, dry at tip, 22 cm. long, young leaves folded	50·0	0·158	57·0	0·230	Thin absorptive tissue, no root hairs, secondary roots	0·089	Spikes beginning to flower, stalk yellow	0·106	0·273
5.1.1925	Old leaves folded, 18 cm. long	47·0	0·200	58·0	0·185	Dry, secondary roots, no root hairs	0·090	Pollen shed, stalks yellow.	0·072	0·208
12.1.1925	Old leaves open, 26 cm. long	45·0	0·241	69·0	0·144	Dry secondary roots, no root hairs	0·125	Spike seeding, but seeds unable to germinate, stalks yellow	0·048	0·157
19.1.1925	Old leaves folded...........	50·0	0·233	50·0	0·184	Very dry, no absorptive tissue nor root hairs	0·100	Spikes dry with dough seeds, stalks yellow	0·068	0·143
26.1.1925	Folded, but not withered, old and young leaves mixed			55·0	0·157	Dry, practically without absorptive tissue, no root hairs, few secondary roots.	0·093	Spikes dry, no seeds, stalks yellow	0·026	0·115
3.2.1925	Open, to 18 cm. long, not separated			57·0	0·250	Dry, practically without absorptive tissue, no root hairs	0·088	Spikes dry, all seeds gone, stalks yellow	0·058	0·079
10.2.1925	Old leaves 37 cm. long.....	53·0	0·189	58·0	0·187	Dry, no root hairs..........	0·085	Spikes dry, seeds lost, some shrivelled, stalks yellow	0·042.	0·156
17.2.1925	Old leaves nearly open, young leaves rolled, old leaves' apex dry	33·0	0·263	47·0	0·150	Secondary roots, thin removable tissue	0·079	Spikes dry, empty, stalks yellow	0·050	0·122
25.2.1925	Old leaves open, apex dry..	47·0	0·259	50·0	0·205	Dry, thin skin, no root hairs	0·090	Stalks yellow, spikes dry and empty	0·034	0·104
10.3.1925	Old leaves open, grey green.	31·0	0·288	46·0	0·300	New roots, root hairs, absorptive tissue	0·084	Spikes just after flowering...	0·068	0·167
20.3.1925	Old leaves open............	35·0	0·230	38·0	0·211	New roots, thin absorptive tissue	0·064	Spikes finished flowering....	0·052	0·319
30.3.1925	Old leaves open............	40·0	0·250	45·0	0·211	Absorptive tissue, new roots, root hairs	0·100	Spikes have just flowered...	0·094	0·300
9.4.1925	Old leaves open............	37·0	0·250	43·0	0·208	Absorptive tissue, root hairs	0·085	Spikes flowering............	0·073	0·246
20.4.1925	Half folded................	37·0	0·250	48·0	0·200	Absorptive tissue, no root hairs	0·109	Spikes have flowered........	0·056	0·230
4.5.1925	Old leaves half open........	35·0	0·261	42·0	0·153	Absorptive tissue, root hairs	0·150	Spikes flowering............	0·058	0·240
15.5.1925	Old leaves half or three-quarters open, young leaves folded, scarce	46·0	0·193	50·0	0·166	Absorptive tissue, root hairs	0·143	Green haulms with spikes which have just flowered	0·054	0·254
								Grey dry haulms with dry spikes, empty	0·044	0·129

TABLE I—(*continued*).

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	Roots. P_2O_5.	Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
		Dry Matter. %	P_2O_5. %	Dry Matter. %	P_2O_5. %					
29.5.1925	Green leaves still abundant, open old dry leaves......			44·0	0·158 0·067	No absorptive tissue, secondary roots	0·119	Stalks grey at top, bottom still yellow, spikes empty	0·039	0·129
12 6.1925	New leaves coming up after rain, old leaves brown	50·0	0·176		0·057	No absorptive tissue, secondary roots	0·107	(15.6) Spikes and stalks dry	0·026	0·030
29.6.1925	Green leaves folded......... Brown leaves..............			50·0	0·162 0·030	No absorptive tissue, secondary roots	0·115	Spikes and stalks dry.......	0·027	0·062
13.7.1925	Few green leaves, folded.... Brown leaves..............			50·0	0·156 0·077	Dry, almost no absorptive tissue	0·144	Spikes dry.................	0·033	0·078
27.7.1925	Green leaves folded......... Brown leaves..............			50·0	0·180 0·046	Some new roots, absorptive tissue with root hairs	0·127	Haulms dry................	0·040	
4.8.1925	New young green leaves, old leaves brown	32·0	0·163		0·094	Thin absorptive tissue with fine root hairs	0·167			

Table II.

Digitaria eriantha, Armoedsvlakte. Phosphorus content as percentage phosphoric oxide on plant dry matter throughout the year.

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	P_2O_5.	Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
		Dry Matter. %	P_2O_5. %	Dry Matter. %	P_2O_5. %		%			
16.8.24	Green....................	30·0	0·303			No removable tissue........	0·159			
4.9.24	Withered, but open, 1½–2½ cm. long	33·0	0·220			No removable tissue........	0·136			
10.9.24	Fresh, half closed, 5 cm. long	32·0	0·235			No removable tissue........	0·114			
19.9.24	Very short, most in good condition, some withered	30·0	0·300			No root hairs..............	0·115			
29.9.24	Open, after rain...........	27·0	0·240			After rain secondary roots	0·111			
2.10.24	Open, about 10 cm. long, hairy	25·0	0·278			Root hairs and secondary roots	0·093			
14.10.24	Somewhat withered, 12–15 cm. long	35·0	0·233			Very few secondary roots...	0·110			
21.10.24	Withered, tips of leaves red, 12–23 cm. long	51·0	0·233			No root hairs, secondary roots	0·094			
28.10.24	Withered, 15–20 cm. long, red at tips	51·0	0·250			No root hairs nor secondary roots	0·107			
31.10.24	Open, brown at tip, ca. 17 cm. long	33·0	0·250			No root hairs, but secondary roots, fairly fresh	0·123			
11.11.24	Open, reddish brown at tip, ca. 15 cm. long, young leaves very short	30·0	0·306	43·0	0·277	Many root hairs and secondary roots	0·084			
18.11.24	Fresh, 27 cm. long, dry at tip, young leaves fresh	33·0	0·312	40·0	0·254	Secondary roots, a few new roots	0·110			
26.11.24	Old leaves open, tip dry, young leaves fresh	42·0	0·319	39·0	0·240	Few root hairs at top, secondary roots	0·108			
8.12.24	Old leaves open, tip dry, 30 cm. long, young leaves fresh	30·0	0·306	36·0	0·193	Dry, secondary roots.......	0·094			
17.12.24	Old leaves open, 40 cm. long, young leaves fresh	30·0	0·435	39·0	0·323	Rather dry, secondary roots	0·104	Very young haulms, spikes before flowering } haulms } spikes	0·300	0·250
29.12.24	Old leaves partly folded, 32 cm. long, young leaves folded	39.0	0·306	32·0	0·165	Very dry, no root hairs, secondary roots	0·094	Spikes before flowering......	0·224	0·375
5.1.25	Withered, 12 cm. long......	40·0	0·214	42·0	0·250	Very dry, no root hairs, secondary roots	0·100	Spikes before flowering......	0·192	0·375
12.1.25	Rather withered, old leaves 30 cm. long	42·0	0·312	46·0	0·227	Dry, open absorptive tissue, no root hairs	0·069	Very young spikes and haulms, not separated	0·326	
19.1.25	Fairly fresh................	35·0	0·235	47·0	0·146	Dry, absorptive tissue dead	0·087	Spikes seeding, but seeds dough	0·200	0·250
26.1.25	Folded, but not withered, 32 cm. long			47·0	0·141	Dry, no absorptive tissue nor root hairs	0·063	Spikes have just finished flowering	0·263	0·268

TABLE II—(*continued*).

Date.	Leaves. Remarks.	Leaves. Young. Dry Matter. %	Leaves. Young. P_2O_5. %	Leaves. Full-grown. Dry Matter. %	Leaves. Full-grown. P_2O_5. %	Roots. Remarks.	Roots. P_2O_5. %	Stalks and Spikes. Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
3.2.25	Open, 35 cm. long	45·0	0·273	43·0	0·150	Dry, no absorptive tissue nor root hairs, secondary roots	0·077	Spikes seeding, seeds dough.	0·133	0·273
10.2.25	Old leaves open, tip dry	41·0	0·195	35·0	0·200	Very dry, no absorptive tissue nor root hairs	0·078	Seeds shrivelled, stalks green	0·159	0·261
17.2.25	Old leaves fresh, open young leaves rolled	23·0	0·353	30·0	0·275	Partly removable skin, secondary roots	0·102	Very young stalks and spikes	0·125	0·277
								Older, but still green stalks and spikes	0·116	0·233
25.2.25	Folded and wilting, no young leaves found			58·0	0·150	Dry absorptive tissue, thin and dead	0·075	Spikes with shrivelled seeds	0·150	0·172
10.3.25	Open	22·0	0·355	30·0	0·300	New roots with an absorptive tissue	0·079	Spikes just after flowering	0·183	0·257
20.3.25	Open	25·0	0·399	28·0	0·288	Absorptive tissue, new roots, root hairs	0·070	Spikes with shrivelled seeds.	0·132	0·306
30.3.25	Open	28·0	0·300	32·0	0·250	New roots, removable skin, root hairs	0·105	Spikes with shrivelled seeds.	0·150	0·219
9.4.25	Open	30·0	0·273	30·0	0·250	Absorptive tissue, new roots, root hairs	0·077	Spikes just after flowering	0·095	0·200
20.4.25	Half open	32·0	0·266	32·0	0·292	Removable skin, no root hairs	0·078	Spikes with shrivelled seeds.	0·072	0·136
4.5.25	Open	30·0	0·236	33·0	0·277	No absorptive tissue, but good roots	0·100	Spikes dry	0·150	0·193
15.5.25	Leaves red, half folded, no young leaves found			37·0	0·214	Secondary roots, no absorptive tissue	0·078	Haulms dry, yellow, spikes empty	0·064	0·066
29.5.25	Few green leaves, opén			32·0	0·144	No absorptive tissues	0·075	Haulms and spikes dry, spikes empty, not separated	0·063	
	Old brown leaves				0·063					
15.6.25	Few green leaves, rolled, came up after rain	45·0	0·179			Secondary roots, no absorptive tissue	0·102	No haulms found.		
	Brown leaves				0·057					
29.6.25	Few green leaves, rolled			40·0	0·197	Roots dry and smooth, no absorptive tissue	0·086	No haulms found.		
	Brown leaves				0·065					
13.7.25	Few green leaves, folded			42·0	0·159	No absorptive tissue, secondary roots	0·114	Haulms found, but scarce	0·052	
	Brown leaves				0·060					
27.7.25	Old green leaves, rolled			40.0	0·174	No absorptive tissue or secondary roots	0·125	No haulms found.		
	Brown leaves				0·063					
4.8.25	New green leaves, small, open, very hairy	30·0	0·300			Secondary roots, no absorptive tissue nor root hairs	0·083	No haulms found.		
	Brown leaves				0·060					

Table III.

Eragrostis superba, Armoedsvlakte. Phosphorus content as percentage phosphoric oxide on plant dry matter throughout the year.

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	P_2O_5. %	Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
		Dry Matter. %	P_2O_5. %	Dry Matter %	P_2O_5. %					
13.8.1924	Green, 2 cms. long.........	38·0	0·303			Special absorptive hairy tissue	0·150			
4.9.1924	Rolled, especially at apex, 5 cm. long.	41·0	0·250			Special absorptive hairy tissue	0·113			
10.9.1924	Open, reddish..............	37·0	0·405			Abundant root hairs, root much better developed	0·160			
19.9.1924	Open leaves, red, 12–15 cm. long	30·0	0·273			Less root hairs than last week	0·100			
25.9.1924	Open, after rain, long......	34·0	0·273			Root hairs on the absorptive tissue	0·100	Young green haulms with spikes	0·263	0·300
2.10.1924	Open, 7.5–11 cm. long......	35·0	0·197			Root hairs on the absorptive tissue, some secondary roots	0·106	Young green haulms with spikes	0·214	0·393
14.10.1924	Rolled, drooping, 17–22 cms. long	43·0	0·263			Removable tissue, root hairs plentiful	0·117	Young green haulms with spikes	0·200	0·312
21.10.1924	Rolled and dry, brown at tips, 42 cm. long	42·0	0·246			Root hairs covered with soil, thick absorptive tissue	0·086			
28.10.1924	Rolled, 30–40 cm. long.....	47·0	0·178			Root hairs and secondary roots, thick absorpt. tissue	0·072	Flowering spikes from green haulms		0·203
31.10.1924	Open, 30 cm. long, tips brown	43·0	0·250			Root hairs and secondary roots, thick absorpt. tissue	0·075			
11.11.1924	Old leaves reddish, 30 cm. long, young leaves	40·0	0·323	44·0	0·259	Abundant root hairs covered with soil, thick absorptive tissue	0·072	Very young haulms with spikes	0·333	
18.11.1924	Open, dry at tip, 40 cm. long, young leaves fresh	42·0	0·268	40·0	0·224	Root hairs covered with soil, thick absorptive tissue	0·075			
26.11.1924	Old leaves reddish, tip brown, 24 cm. long, young leaves fresh	47·0	0·319	50·0	0·214	Absorptive tissue with root hairs, secondary roots	0·095	Flowering spikes from green haulms	0·185	0·273
8.12.1924	Old leaves open, reddish at tip, 30 cm. long	40·0	0·210	44·0	0·135	Absorptive tissue with abundant root hairs	0·089			
17.12.1924	Open, 25 cm. long.........	40·0	0·283	52·0	0·244	Root hairs and secondary roots	0·089			
29.12.1924	Open, old leaves dry at tip..	43·0	0·300	45·0	0·250	Thick absorpt. tissue, covered with soil, abundant root hairs and secondary roots	0·069	Spikes coming into flower...	0·176	0·392
5.1.1925	Rolled and withered, ca. 18 cm. long			50·0	0·197	Roots with dry woolly absorptive tissue	0·058	Spikes at the end of flowering	0·159	0·259
12.1.1925	Open, 24 cm. long.........			48·0	0·153	Woolly absorptive tissue....	0·046	Spikes seeding............	0·180	0·210

TABLE III—(*continued*).

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	P_2O_5. %	Remarks.	P_2O_5. % of Stalks.	P_2O_5. % of Spikes.
		Dry Matter. %	P_2O_5. %	Dry Matter. %	P_2O_5. %					
19.1.1925	Few green leaves, very dry			62·0	0·183	Absorptive tissue, looks dead, woolly	0·075	Spikes dry, but seeds not ripe	0·087	0·246
26.1.1925	Rolled and very withered, 16 cm. long			57·0	0·177	Woolly absorpt. tissue, missing in parts	0·069	Spikes dry and falling off...	0·072	0·189
3.2.1925	Open, 30 cm. long..........			54·0	0·145	Thick woolly absorptive tissue	0·055	Spikes dry and falling off, some hard seeds in spikes	0·099	0·205
10.2.1925	Old leaves open, 18 cm., young leaves rolled	50·0	0·222	50·0	0·242	Absorpt. tissue thick, covered with soil	0·096	Spikes dry and falling off, some hard seeds	0·087	0·219
17.2.1925	Except the youngest leaves, all open	33·0	0·306	42·0	0·162	Thick absorpt. tissue, covered with soil	0·098	Spikes dry, seeds falling, if ripe ?	0·091	0·230
25.2.1925	Few green leaves, rolled....			63·0	0·167	Absorptive tissue, woolly, dry	0·080	Old haulms from which spikes have nearly all fallen, new haulms...............new	0·090	0·230
								old	0·062	0·168
10.3.1925	Old leaves open...........	28·0	0·312	35·0	0·277	Absorptive tissue with root hairs, new roots	0·063	Spikes before flowering......	0·125	0·222
20.3.1925	Old leaves open...........	36·0	0·385	42·0	0·277	Absorptive tissue with root hairs	0·089	Spikes before flowering......	0·163	0·429
30.3.1925	Old leaves open...........	36·0	0·280	40·0	0·217	New roots, absorptive tissue with root hairs	0·058	Spikes before flowering.....	0·147	0·250
9.4.1925	Old leaves open...........	32·0	0·292	33·0	0·241	Absorptive tissue wth root hairs	0·068	Spikes before flowering......	0·137	0·263
20.4.1925	Old leaves open...........	38·0	0·366	40·0	0·230	Absorptive tissue with root hairs	0·056	Spikes before flowering.....	0·102	0·294
4.5.1925	Old leaves open, young leaves rolled	27·0	0·280	40·0	0·183	Absorptive tissue with root hairs	0·075	Spikes have flowered........	0·089	0·200
15.5.1925	Old leaves open, red, young leaves scarce, rolled	46·0	0·230	46·0	0·273	Absorptive tissue with root hairs	0·073	Spikes green with unripe seeds, stalks green	0·059	0·189
29.5.1925	Old leaves open, apex dry, red			40·0	0·158	Absorptive tissue with root hairs	0·059	Grey and green haulms, spikes of green haulms	0·082	0·300
15.6.1925	Green leaves rolled, came up after rain	42·0	0·187			Absorptive tissue with root hairs	0·059	Spikes dry with shrivelled seeds	0·079	0·200
	Brown leaves..............				0·091					
29.6.1925	No green leaves, brown leaves				0·095	Absorptive tissue with root hairs	0·058	Spikes dry................	0·093	0·167
13.7.1925	No green leaves, brown leaves				0·103	Absorptive tissue with root hairs, secondary root through absorptive tissue	0·064	Spikes dry................	0·061	0·183
27.7.1925	No green leaves, brown leaves				0·068	Some roots with absorptive tissue, and fine root hairs	0·074	Haulms dry, with few spikes	0·063	
4.8.1925	Very few green leaves, open, brown leaves	35·0	0·254		0·064	Very thick absorptive tissue with root hairs	0·069			

TABLE IV.

Cymbopogon plurinodis, Armoedsvlakte. Phosphorus content as percentage phosphoric oxide on plant dry matter throughout the year

Date.	Leaves.					Roots.		Stalks and Spikes.		
	Remarks.	Young.		Full-grown.		Remarks.	Roots. P_2O_5.	Remarks.	Stalks. P_2O_5.	Spikes. P_2O_5.
		Dry Matter. %	P_2O_5. %	Dry Matter. %	P_2O_5. %		%		%	%
29.8.1924	Green folded..............	33·4	0·300			Removable tissue without hairs, strong turpentine smell	0·150			
4.9.1924	Long folded, apex open and dry	35·0	0·230			Removable tissue without hairs	0·143			
10.9.1924	Mostly open, reddish, 8–20 cm. long	46·0	0·218			Scattered root hairs on tissue	0·105			
19.9.1924	Rolled, rather withered, 12–15 cm. long	30·0	0·280			Secondary roots............	0·094			
25.9.1924	Open, ca. 21 cm. long.....	33·0	0·234			Secondary roots............	0·263			
2.10.1924	Open, 26 cm. long..........	32·0	0·393			Secondary roots............	0·211			
14.10.1924	Half folded, 40 cm. long....	39·0	0·312			New roots, few root hairs...	0·139			
21.10.1924	Folded with dry tips, to 55 cm. long	35·0	0·200			Dry no root hairs and few secondary roots	0·110			
28.10.1924	Folded, withered at tip, 40–50 cm. long	52·0	0·211			Dry, no root hairs and few secondary roots	0·107	Young green haulms with flowering spikes	0·106	0·326
31.10.1924	Open, tip brown, to 60 cm. long	45·0	0·230			Root hairs and secondary roots	0·150			
11.11.1924	Open, 57 cm. long, tip brown, young leaves fresh	39·0	0·333	40·0	0·273	Root hairs at top, secondary roots	0·088	Very young haulms, young stalks from flowering spikes	stalks: 0·136	0·306 0·326
18.11.1924	Open, old leaves 60 cm. long	40·0	0·300	45·0	0·250	Secondary roots............	0·096			
26.11.1924	Half open, old leaves 54 cm. long, with brown tip	48·0	0·273	48·0	0·208	Root hairs on absorptive tissue, other roots with secondary roots	0·084	Stalks from flowering haulms, young haulms............	haulms: 0·170	0·385 0·250
8.12.1924	Open, fresh...............	39·0	0·375	40·0	0·219	Few root hairs, dry, secondary roots	0·073	Spikes after flowering.......		0·195
17.12.1924	Open, old leaves 55 cm. long	35·0	0·280	45·0	0·280	Rather dry, secondary roots	0·127			
29.12.1924	Open, old leaves dry at tip, 55 cm. long	40·0	0·176	39·0	0·246	Absorptive tissue peeling off, no root hairs, secondary roots	0·084	Stalks from flowering spikes.	0·120	0·341
5.1.1925	Half folded, old leaves 55 cm. long	45·0	0·214	45·0	0·192	Very dry, no root hairs, nor secondary roots	0·068	Spikes after flowering.......	0·167	0·250
12.1.1925	Open, old leaves to 60 cm. long	42·0	0·214	42·0	0·136	Dry, absorptive tissue peeling off, no root hairs	0·081	Spikes seeding, seeds in dough state	0·079	0·241
19.1.1925	Folded, but fairly fresh, old leaves to 45 cm. long	50·0	0·230	50·0	0·177	Absorptive tissue dry, peeling off, no root hairs	0·084	Spikes seeding, seeds soft, new young haulms............	haulms: 0·058	0·300 0·180