THE EFFECT OF CLIMATE ON THE COMPOSITION OF PASTURE PLANTS*

RECENT investigations [1] [2] have shown that the mineral and protein content of pasture plants vary widely according to (a) species, (b) growth stage, (c) soil type, (d) fertilisers.

Different species grown in pure cultures under similar controlled soil conditions and harvested at a definite stage (flowering) show wide variations in mineral and protein content. Growth stage exercises a dominating influence on both the nitrogen and mineral content of pasture species. The composition of individual species grown on different soils tends to follow the major differences in the available supply of nutrients in each soil type. The composition of a species in any given climatic region will therefore be dependent upon the fertility of the soil. The application of fertilisers, particularly nitrogenous and soluble phosphatic fertilisers, has a marked effect on the protein and phosphate content of a species.

This effect is more marked on soils low in nitrogen or phosphate than on soils rich in these nutrients.

The precise influence of the climatic factors on the composition of pasture has not been determined. Apart from the influence of soil type, stage of growth, and fertilisers, it would appear that pasture species grown in tropical and sub-tropical climates are lower in protein and in soluble ash than those in temperate regions.

The Rowett Research Institute has analysed samples from many pastures in Britain and from many Empire sources. Godden's [3] conclusions on the composition of British pastures are summarised in the following table:

Table Showing the Nitrogen and Mineral Content of British Pastures

British pastures	Nitrogen N	Phosphoric Acid P_2O_5	Potash K_2O	Lime CaO	Soluble ash
A. Good cultivated pasture	2·82	·735	3·177	1·004	6·64
B. Natural hill pasture (grazed)	2·50	·67	2·66	·65	5·85
C. Poor hill pasture (partly grazed)	2·54	·60	2·60	·56	5·49

Aiyer and Kayasth [4] in India conclude that, though the grasses grown on rich black soils are richer in mineral nutrients than those grown on light soils, the grasses of both areas are poor in phosphoric acid and lime

* By A. E. V. Richardson, M.A., D.Sc., Waite Agricultural Research Institute, South Australia. Occasional Communication No. 1.—Circulated by the Imperial Bureau of Animal Nutrition, Rowett Research Institute, Aberdeen, June, 1933.

compared with British pastures, and that they are very deficient in nitrogen. The silica free ash of the species investigated ranged from 2·77 to 3·69 per cent. on the black soils, and those on light soils from 1·19 to 1·69 per cent. The corresponding range for phosphoric acid was ·18 to ·21 for black soils, and ·035 to ·073 for the light soils. The mean content of grasses from thirteen centres was ·55 per cent. nitrogen, ·187 per cent. for P_2O_5 and 3·04 per cent. for soluble ash.

The Government Chemist for the Sudan [5] states that the chemical examination of fodder grasses grown in the Sudan showed a low mineral content when compared with European pastures. The most striking deficiencies are in nitrogen and phosphorous, the average being only 40 per cent. and 50 per cent. respectively of that of a good pasture. All grasses in the White Nile Province showed a marked phosphate deficiency.

Follett-Smith [6] states that in an investigation at Waranama, British Guiana, seven pasture species from savannah areas were markedly deficient in silica free ash, phosphoric acid and nitrogen. The silica free ash ranged from ·83 per cent. to 4·9 per cent., with an average value of 2·3 per cent., the phosphate content from ·01 per cent. to ·15 per cent., with an average value of ·08 per cent., and a nitrogen content ranging from ·5 per cent. to 1·31 per cent., with a mean value of ·73 per cent. The samples were collected during the rainy season, and Follett-Smith stated that the phosphate content would probably be even lower during the dry season.

In an unpublished report to the Rowett Research Institute natural pastures from the Samaru district (Nigeria) average ·13 per cent. P_2O_5. The pasture from seventeen other centres in Northern Nigeria showed an average content as follows—soluble ash 3·01 per cent., nitrogen ·85 per cent., phosphoric acid ·34 per cent.

Husband and Taylor [7] found that the crude protein content of normal Veldt grass was much below the standard of average of European grass. The crude protein content at maturity reached the extraordinarily low value of 1·73 per cent. The natural grasses suffered from a decided mineral deficiency, especially from March onwards.

Henrici [8] shows that even the average percentage of phosphoric acid in the hill pastures of Great Britain is about four times higher than the average percentage of the best grasses in the Veldt.

Brunnich [9] analysed a large number of grasses from the pastoral areas in sub-tropical Queensland, where the rainfall has a marked summer incidence. Thirty-eight samples of pasture grasses of various species, taken mostly in the growing stage, gave a mean value of 1·5 per cent. nitrogen and ·46 per cent. phosphoric acid. Forty samples of old grass from similar areas gave mean values of ·56 per cent. nitrogen and ·16 per cent. phosphoric acid. Four samples of grass hay conserved in stacks, gave values of 1·1 per cent. for nitrogen and ·336 per cent. for phosphoric acid. The mean values for fifteen samples of Mitchell and Flinders grass taken in various centres in Western Queensland during a droughty period in 1927 were—nitrogen ·87 per cent, and phosphoric acid ·20 per cent.

The results of analyses of pastures by the Rowett Institute [10] from Otjornbindi S.W. Africa, show the following mean values for ten species—nitrogen ·43 per cent., phosphoric acid ·065 per cent., potash ·41 per cent. and soluble ash 1·89 per cent.

Samples of grass hay from British Somaliland and analysed at Rowett Institute gave nitrogen ·86 per cent., phosphoric acid ·24 per cent., and soluble ash 3·07 per cent. Low values for nitrogen, phosphorus and soluble ash have also been recorded by Orr [11] for Athi Plains, Makura and Molo in Kenya.

These analyses, representing pasture species and mixed pastures in regions of summer rainfall (tropical and sub-tropical) show that the values for nitrogen, phosphoric acid and silica free ash are strikingly lower than those recorded by Godden for pastures of Britain (Table 1), and very much lower than a series of analyses of Kent pastures by Woodman [12] of Cambridge. These latter showed a range of nitrogen 3·5 to 4 per cent., phosphoric acid ·75 to ·98 per cent., lime ·79 to 1·21 per cent. and potash 3·9 to 4·1 per cent.

It would thus appear, from such records as are available, that the protein and mineral content of pastures from tropical and sub-tropical areas are, in general, lower than those recorded for pastures in cold temperate regions.

Pastures in Britain are more intensively grazed than those of countries of summer rainfall and winter drought. Moreover, tropical and sub-tropical pastures, in comparison with those of temperate countries, are notably poor in leguminous components, which normally have a high protein content.

It may be that *climatic* factors, apart from those already discussed, affect the protein and mineral contents of a pasture; and it is proposed to show that the difference in mineral content of pastures in tropical and temperate regions may be caused by a differential effect of climate on the rate of nitrogen and mineral uptake on the one hand, and the rate of growth on the other. We may consider the latter aspect first.

In tropical and sub-tropical climates the growth of pasture is rapid and frequently the plant approaches maturity a few months after the onset of the wet season. In cool temperate or winter rainfall climates growth proceeds much more slowly and the reproductive stage is reached only after many months of slow vegetative growth. This might be interpreted as an effect of temperature on carbon assimilation; the rate of carbon assimilation, and hence the rate of growth, within certain limits increases with temperature. The amount of carbon assimilated per unit leaf area need not, however, alter, unless there is an alteration in the ratio of leaf area to total dry weight. The actual facts are as yet undetermined.

Another habitat factor that may affect the growth rate is the length of day. It is known that short day types of plants are found in tropical regions and long day types in polar and cold temperate regions, [13] and Auchter and Harley [14] have shown that in temperate regions the pasture plants are of a type that form reproductive organs only during periods of long days. Moreover, Tincker [15] has shown that the long day types of plants may be kept in the vegetative stage by exposing them to short day conditions. While the length of day is known to have a complex effect on the growth and development of the plant, we do not know the precise relationship it bears to carbon assimilation in the pasture plants under consideration.

We may turn now to the question of mineral uptake. This process is known to follow a fundamentally different course from that of carbon assimilation. Thus, Richardson, Trumble and Shapter (2) have shown that in pasture plants in South Australia, the rate of absorption of nitrogen and phosphoric acid, i.e. total amount absorbed in unit time, is much greater in the early vegetative stages than the rate of synthesis of organic matter; nitrogen and phosphoric acid are utilised in considerable amount during the tillering and root establishment characterising the early phase of development. After this early tillering stage, the rate of absorption falls rapidly.

On the other hand, the rate of carbon assimilation, i.e. the total amount of carbon assimilation in unit time, is dependent, apart from temperature, light and carbon-dioxide supply, mainly upon the area of green leaf surface and as this normally increases till the approach of flowering, the rate of carbon assimilation correspondingly increases and attains a maximum shortly before this stage. Thus the maximum rate of nitrogen and phosphorus absorption on the one hand, and carbon assimilation on the other, occur at two different periods of the plant's development. As a consequence, the percentage of nitrogen and phosphorous, expressed in terms of dry matter, gradually falls from a maximum value in the earliest vegetative stage to a minimum value at maturity. The amount of nitrogen and phosphorus absorbed by a gramineous pasture plant is limited by the amount that can be rendered available by the soil during the vegetative phase. If nitrogen is available and soil moisture conditions are favourable tillering proceeds to the limit of the available nitrogen supply and to a lesser extent to the limit of the available phosphate supply.

In temperate regions and winter rainfall climates a long period of slow vegetative growth precedes the reproductive phase, and it is probable that under such conditions the normal pasture could secure the necessary nitrogen and minerals from the soil at a sufficiently rapid rate to keep pace with the somewhat slow photosynthetic activity of the plant except on the poorest types of soil, and except during late spring or early summer when the flush of growth occurs.

An application of nitrogen just prior to this stage normally increases both the yield of dry matter and the protein content of the herbage in British pastures. In tropical and sub-tropical regions of summer rainfall and winter drought, growth commences with the onset of the wet season towards midsummer, and is exceedingly rapid from the outset on account of high temperatures and favourable soil humidity, and the demands of the pasture for nitrogen and phosphate are correspondingly great.

Very little is known of the rate at which nitrification or denitrification proceeds in pasture land under tropical conditions, or of the precise effects of comparatively heavy tropical rains and occasional periods of drought on the available nitrogen and phosphate supply of the soil. It is possible that the demands of the rapidly growing pasture for nitrogen and phosphorus may, for various reasons, exceed the rate at which supplies are made available in the soil in which case the amount of tillering will be adjusted to the available nitrogen supply.

Photosynthetic activity, however, on account of high temperature and favourable light conditions continues at a relatively high level under tropical and sub-tropical conditions, with the final result that the nitrogen and phosphorus content, and to a lesser extent the silica-free ash content, expressed in terms of dry matter produced, will be relatively low.

It is possible, therefore, that the explanation may be found in terms of difference in the effect of the two contrasting types of climate on the uptake of nitrogen, phosphorus and other minerals on the one hand, and assimilation of carbon on the other, the carbon-nitrogen ratio tending to be high in tropical and sub-tropical climates, and low in the temperate and winter rainfall climates.

REFERENCES

1. Orr, J. B.—Minerals in pastures and their relation to Animal Nutrition.—(Lewis, London), 1929.
2. Richardson, A. E. V., Trumble, H. C. and Shapter, R. E.—Factors affecting the mineral content of pastures.—*Bull. 49, Council for Sci. and Ind. Research*, Melbourne.
3. Godden, W.—*Journal of Agric. Sci.*, 1926, 16, 78.
4. Aiyer, A. R. P. and Kayasth, R. N.—Mineral composition of fodders of the Central Provinces and Berar.—*Agriculture and Livestock in India*, 1931, 1, 526-532
5. Report of Sudan Government Chemist.—*Tropical Agriculture*, Trinidad 9, 11, p. 355.
6. Follet-Smith, R. R.—*Agricultural Journal, British Guiana*, 1930, 3, 142-159.
7. Husband, A. D. and Taylor, A. P.—*Journal of Agriculture, Southern Rhodesia*, 1931, 154-169.
8. Henrici, M.—16th Report of Director of Veterinary Services, South Africa, pp. 435-499.
9. Brunnich, F.—Annual Reports of Department of Agriculture and Stock, Queensland, 1927-28; 1928-29.
10. Rowett Research Institute.—*Private Communication.*
11. Orr, J. B.—Sixth Report of Committee on Mineral Content of Natural Pastures—Economic Advisory Committee, 1931.
12. Woodman, H. E.—*Private Communication.*
13. Maximov, N. A.—*Biol. Zentr.*, 49, 513-543.
14. Auchter, and Harley.—*Am. Society Hort. Sc.*, 21, 199.
15. Tincker, M. A.—*Annals of Botany*, 39, 1925, pp. 721-754.