COENOSES 6 (3): 127-130, 1991
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IMPLICATIONS OF PHOTOSYNTHETIC PATHWAYS OF SOME GRASS SPECIES IN ETHIOPIA TO LANDUSE

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Keywords: Andropogoneae, Classification, Landuse, Zones

Abstract. 323 grass species in 81 genera and 21 tribes in Ethiopia are classified into those with Kranz syndrome and those without Kranz syndrome. An important environmental variable considered is altitude which affects moisture, temperature and light intensity, all of which are closely tied with plant establishment, growth and performance. Three broad altitudinal zones of grassland vegetation have been recognized. Two tribes, Andropogoneae and Paniceae, are predominant in the middle altitudes at 1750-2750 m.a.s.l.. Most members of these tribes are valuable pasture plants owing to their high diversity and high grazing value. This altitudinal range is designated as the Andropogoneae zone. Areas below and above the Andropogoneae zone are recommended for uses by industrial forestry. Integration of the agricultural systems, and possible readjustments within the systems, however, are deemed mandatory to increase overall production.

Introduction

The existence of plant groups with distinct photosynthetic pathways and photosynthetic production capacities have been known for more than 25 years (Kortchak et al. 1965, Hatch and Slack 1966, Hatch et al. 1967, Black 1971). These plant groups may primarily be divided into C_3 and C_4. Plants in the C_3 group have phosphoglyceric acid as the first stable product of photosynthesis, while plants in the C_4 group produce a variety of four carbon compounds. In addition C_4 plants have specialized forms of leaf anatomy in which the well developed parenchymatous bundle-sheath cells (PBS) are rich with organelles such as large chloroplasts, mitochondria and peroxisomes (Laetch 1974, Chollet and Oregon 1975, Hattersley and Watson 1976, Brown 1975, Ellis 1977). C_4 plants are characterised by the absence of release of CO_2 in light, the absence of the effect of high concentration of O_2 on a photosynthetic assimilation of CO_2 (Black 1971) and lower discrimination of ^{13}C (Smith and Brown 1973). The assortments of these interrelated anatomical and biochemical characters, which distinguish the C_4 from the C_3 species, are referred to as the Kranz syndrome. C_4 species generally show a high photosynthetic water use (A/E, ratio of weight of photosynthetic products to that of water lost by transpiration) and a high nitrogen use efficiency (dry weight of plant per unit weight of nitrogen in the plant, Brown (1978)). The presence of these properties in C_4 plants has given rise to the assertion that the Kranz syndrome is an adaptation to the tropical environment, since C_4 plants occur infrequently in temperate and cooler climates. C_4 grasses can further be divided into two major groups depending on the relative quantity of malate and aspartate formed during photosynthesis (Hatch et al. 1975, Hattersley and Watson 1976, Ellis 1977). Accordingly, among the important grass tribes in Ethiopia, the Andropogoneae and Paniceae are malate formers (NADP-ME), whereas Sporoboleae, Chlorideae, Eragrostideae and Aristideae are aspartate formers (NAD-ME). The distinction between the two C_4 groups is as important as the distinction between C_3 and C_4 species as far as distribution and productivity are concerned. Aspartate formers are strictly related to the environmental adaptation associated with the Kranz syndrome, whereas many of the malate formers occur in relatively mesic environments. A very useful property of the photosynthetic pathway of grasses is that C_3 and the two different types of C_4 grass species are uniformly distinct at the tribe level. In this work, the uniformity of C_4 grass species at the tribe level is considered fundamental to understanding their ecology. Exceptions to this general rule can be found in the tribes Danthoneae and Paniceae.

There is a long history of human activity in Ethiopia, as a result of which, undisturbed original vegetation types can be found in only a few places. The vegetation in these few undisturbed places shows altitudinal zonation (Pichi-Sermolli 1957, Hedberg 1964, Friis 1986, Zerihun et al. 1989). Only C_3 grass species are found in the herb layer of the predominantly forest vegetation. C_4 grass species, which are now the predominant plant species in the open and anthropogenic landscape, may have invaded the highland regions of Ethiopia partly from the neighbouring lowlands following the disappearance of the forests.

The relationship between photosynthetic pathways of grasses, environmental factors and anthropogenic influences can be used to understand the unique requirements of some of the plant groups and to formulate guidelines to put land to its most beneficial use. In the present study, attempts have been made to

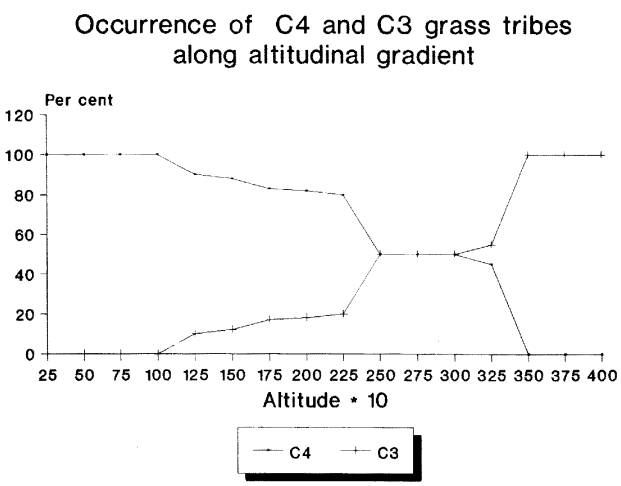

Fig. 1. Occurrence of C_3 and C_4 grass species in the altitudinal ranges in Ethiopia.

establish the relationship between altitude and photosynthetic pathways of grass species in Ethiopia, using information from various sources with the primary aim of proposing rough guidelines for ensuring that these resources are put to the most beneficial use. The broad characterization of the extensive secondary vegetation types by the photosynthetic pathways of grasses may also contribute to a better understanding of the interaction between climate and vegetation in space and time.

Materials and methods

A list of grass species in Ethiopia, excluding crop plants, was compiled from Fröman and Person (1974), Zerihun (1985, 1986), and the holdings of the National Herbarium of Addis Ababa University. The altitudinal range and the relative grazing value of each species was

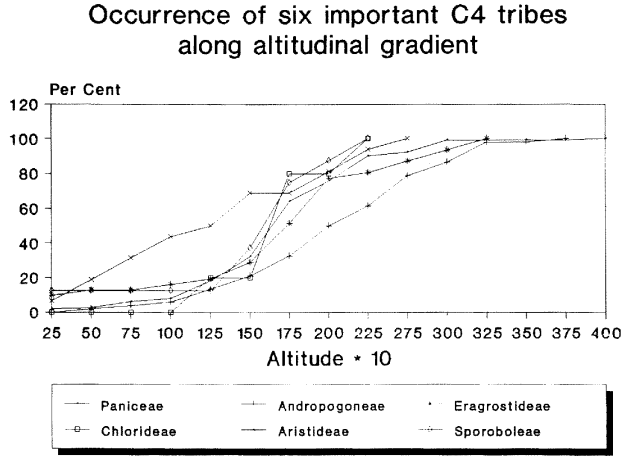

Fig. 2. Occurrence of six important C_4 tribes along altitudinal gradient.

Table 1. C_3 and C_4 Tribes and their relative grazing values in Ethiopia. Legend: alt. - altitudine; m - medium; h - highest.

C3 Tribes	No. of genera	No. of species	Lowest alt. range for the tribe	% of m - h values of grazing
Agrostideae	4	14	2750	36.5
Arundinaceae	2	3	1500	66.6
Aveneae	7	12	2750	33.3
Bambuseae	2	2	2000	00.0
Brachipodeae	1	1	3500	00.0
Bromeae	1	4	3000	50.0
Danthoneae	4	10	1500	10.0
Ehreteae	1	1	2750	00.0
Phalarideae	2	4	2500	50.0
Paniceae	9	19	500	16.0
Poeae	6	16	2500	31.0
Stopeae	1	1	2500	00.0
Zoyseae	4	6	250	00.0
C4 Tribes			Highest alt. range for the tribe	
Andropogoneae	32	80	3500	72.5
Aristideae	2	15	2500	80.0
Arundinelle	1	3	2500	00.0
Chlorideae	10	22	2500	45.4
Danthoneae	1	1	—	00.0
Eragrostideae	16	48	3000	27.0
Paniceae	16	131	4000	41.0
Pappophoreae	2	4	2000	100.0
Sporoboleae	2	20	2500	35.0
Total 21	81	323	—	—

obtained from the same sources. The grass species were classified into C_3 and C_4 (Kranz and non-Kranz) according to their respective tribes. The altitudinal ranges were divided into intervals of 250 m. The number of species in each tribe occurring in each interval were summed up separately. This work is not an exhaustive survey of all the grass species in Ethiopia, given there is no complete flora of the grasses yet.

Result and Discussion

The list of C_3 and C_4 the tribes, number of genera and species, their relative grazing values, the maximum altitude for the C_4 tribes and the minimum altitude for the C_3 tribes are displayed in Table 1. Fig. 1 maps the occurrence of C_3 and C_4 grass species along an altitudinal gradient. Fig. 2 shows the cumulative occurrence of six important C_4 tribes along the altitudinal range.

Detailed analysis of the data reveals that:

1. Only 5% of the C_3 species occur below 2500 m.a.s.l. and only 9% of the C_4 species occur above 3500 m.a.s.l. The few C_3 species which occur at low altitude occupy special habitats such as marshes, riparian sites, and understories of tree canopies.

2. There are more tribes but fewer genera and species of C_3 grasses than C_4. The higher diversity of C_4 grasses may corroborate their invasive property. C_3 tribes such as Agrostideae, Bromeae, Ehreteae, Aveneae, and Brachipodeae are strictly high altitude tribes whereas some members of Stipeae, Paniceae, Bambuseae, Phalarideae, Danthoneae and Poeae can be found at lower altitudes.

3. There are some differences in altitudinal distribution among the C_4 tribes. A few members of the tribes Andropogoneae and Paniceae are found at high altitude, whereas the tribes Chlorideae, Sporoboleae and Aristideae are exclusively low altitude tribes. The Eragrostideae are intermediate between the two extremes. The last three tribes appear to be restricted to lower altitudes by the low average minimum temperature above 2500 m.a.s.l. which in some places can present severe frost conditions. The transition zone of the C_3 and C_4 species is between 1000 m and 3500 m. This zone is wider than that reported for Kenya (Tieszen et al. 1979) (Fig. 1). The lower range of the transition zone appears to be the result of the mosaic of microclimates in the ragged terrain and the occurrence of forest canopy which favour C_3 grasses at lower altitudes. The upper range may suggest that the highland plateau is becoming more of a C_4 environment partly because of the high grazing pressure and the consequent desiccation.

4. Nearly 50% of the species in both Andropogoneae and Paniceae occur between 1750 and 2750 m (in the transition zone of the C_3 and C_4 grass species). This constitutes about 49% of the total C_4 grass species or 41% of all grass species in the range specified. The diversity of grass species in this narrow altitudinal range is striking. Although the total number of species in Paniceae is higher than that in Andropogoneae, the latter has more species with high grazing values (71%) as opposed to the Paniceae which has only 41% of its members with high grazing values. This zone is here designated as the Andropogoneae zone.

Conclusions and recommendations

In Ethiopia, where most of the original vegetation disappeared long ago, the distribution of grass species along altitudinal and moisture gradients make it possible to recognize three broad ecological zones. Recommendations for land use in this region require an integrated evaluation of the different agricultural activities on the plateau in which agronomists, economists, and ecologists should be involved. It should particularly be noted that grassland management can compete with other sectors of agriculture in the Andropogoneae zone as human density and pressure appear to be highest here. The following suggestions are issued as guidelines to formulate proper land use planning.

1. Steep slopes in the Andropogoneae zone which are not suitable for either farming or grassland management, can be used for protective and subsistence forestry. Such forests can supply fire wood, building poles and wood for other domestic uses.

2. Gentle slopes and flatter areas in the Andropogoneae zone which are presently devoid of forest cover may be used for grassland management and growing food crops. The low fertility level, especially that of nitrogen, in this overused range makes the zone more suitable for C_4 grasses than for crop plants. Some unproductive land tilled for cereal and perennial crops might better be restored to grassland.

3. Areas below and above the Andropogoneae zone may be put to industrial forestry and other economic and aesthetic uses.

4. A global rise in temperature may favour the preponderance of C_4 tribes and may cause an increase in the upper limit of the Andropogoneae zone.

5. The validity of the present taxonomic knowledge about the genus *Panicum* and the tribe Danthoneae appear to require rigorous assessment, since some species in these groups have C_4 while others have C_3 photosynthetic pathways. Leaf anatomy and photosynthetic pathway of the species in these two tribes warrant the division of the tribes into two tribes each.

Acknowledgements. The author is grateful to Prof. E. van der Maarel, Dr. I. Friis and Dr. T. Wilson for their critical reading of the manuscript. All expenses incurred in the data collection were covered by the Swedish Agency for Research and Cooperation with Developing Countries (SAREC).

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Manuscript received: June 1991