

## ALTITUDINAL DISTRIBUTION OF ETHIOPIAN AGRESTALS WITH REGARD TO THEIR LIFE FORMS AND ORIGINS

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### Summary

The proportions of life forms and origins of agrestals depends much on climate and cropping system. This study was conducted to determine the change of the floristic composition of agrestal species with respect to life form and origin within an altitudinal transect. A survey of the agrestal flora in twelve annual grain crops has been carried out on 347 randomly selected farmers fields during three growing seasons from 1983 to 1986 in the central Ethiopian highlands covering semiarid to humid moisture regimes (1330 to 3250 m NN). For species of known origin (n = 318) and life form (n = 378) the floristic composition (%) was calculated from presence and absence data on the species level along the altitudinal transect. African and European species prevail and contribute from 56% in semiarid (below 1600 m NN) to 88% in humid moisture regimes (above 3000 m NN) to the flora. Perennials predominantly originate from Africa (60%). Due to their threefold increase from semiarid (12%) to humid moisture regimes (35%) African species hold maximum absolute shares (about 68%) of the floristic composition at altitudes above 2300 m NN. In the semiarid to subhumid mid-altitude areas (1900 to 2500 m NN) which are most widely used for annual cropping systems European species reach their maximum shares (20 to 35%). They are mainly annuals or biennials (73.5%) and contribute about 30% to the flora of this life form. Species of both, annual and perennial life form keep steady proportions of 25 to 35% throughout the altitudinal transect. The results confirm that many African agrestals are in particular well adapted to subhumid and humid moisture regimes of the highlands where rotations of fallows with annual crops are widely used. The high proportion of European annuals and biennials hints at their adaptation to annual cropping systems and refers to the impact of foreign species' introduction via (crop) seeds.

### Introduction

Ethiopia - areawise the largest part of the African Horn -accommodates various different sites with regard to climatic and edaphic conditions. Its agriculture is still characterized by rather archaic, low input subsistence systems and this is assumed to have promoted the conservation of a highly diverse agrestal flora. Information on composition, life forms and origins of Ethiopian agrestals is scarce compared to other East-African countries. Except for a survey by Parker (1970) representative investigations have rarely been undertaken. This paper is based on three years' survey data which have been examined with regard to life forms and origins of the agrestal flora. Results are compared to those of adjacent countries.

### Methods

A survey of the agrestal flora in twelve annual grain crops has been carried out on 347 randomly selected fields during three growing seasons from 1983 to 1986. At the same time data on climate, soils and on management practices were collected. Investigations were exclusively carried out in farmers fields<sup>1</sup> of the central Ethiopian province, Shewa, which is the most heavily populated region of the country (Fischer 1988). For species of known origin (n = 318) and life form (n = 378) the floristic composition (%) was calculated from presence and absence data along the altitudinal transect (1330 - 3250 m NN).

## Results

The survey covered sites with a fairly high variability of ecophysiologicaly important site factors (Tab. 1).

**Tab. 1: Mean, minimum and maximum values of some site factors for all sites surveyed\* (n = 347)**

site factor	mean	minimum	maximum
altitude (m NN)	2,175	1,330	3,250
annual rainfall** (mm)	966,7	447,5	1350,5
lgp' (days)	192	69	291
moisture regions***	arid	to	humid
pH(H <sub>2</sub> O)	6.7	5.0	8.2
clay (%)	45.1	7.8	80.2
organic carbon (%)	1.6	0.71	3.1
Cation exch. (cmol kg <sup>-1</sup> )	33.4	7.3	67.7
P (Olsen-extr., mg kg <sup>-1</sup> )	11.2	<0.1	116.8

\* for details of soil analysis see Pülschen (1990)

\*\* data of 25 meteorological stations in Shewa; length of the main growing period calculated for 100 mm of stored soil moisture; provided by ILCA, Addis-Ababa;

\*\*\* classification after Daniel (1977)

The sites were exclusively prepared with oxen-ploughs as a sole instrument for soil cultivation. Use of external input factors like improved seeds and artificial fertilizers etc. is scarce (Tab. 2). The frequency of surveys in the different crop species reflects their importance in the province: cereals like tef (*Eragrostis tef* (Zucc.) Trott.), wheat (*Triticum* spp.), barley (*Hordeum vulgare* L.) and the oil crop nug (*Guizotia abyssinica* (L.f.) Cass.) were grown on 77% of the fields surveyed. The remaining sites were planted with eight further crops of minor significance.

**Tab. 2: Proportion of sites cultivated with improved seeds, artificial fertilizers and herbicides**

input factor of sites	n	% of sites with respective input factor
improved seeds	300	8
artificial fertilizer	304	26
herbicides	314	14

A total of 444 agrestal species of 60 plant families were identified during the three growing seasons. Species diversity per site ranged between 6 and 59 ( $\bar{x} = 28.5$ ). Most significant families with regard to species number were the Poaceae (82), Fabaceae (63 species) and Asteraceae (60 species), they accounted for nearly half (46%) of the flora. According to their performance as described in the literature 378 of the 444 species have been classified into three groups with regard to their life forms:

- annuals (154 species, accounting for 40.7% of the flora)
- species of varying life form which may be found both, as annuals, biennials or perennials like *Dactyloctenium aegyptium* (L.) Willd., *Poa annua* L. or *Amaranthus graecizans* L. (108 species, i.e. 28.6%)
- perennials (116 species, i.e. 30.7% of the flora).

Compared to lowland areas sites of increasing altitude are characterized by more balanced shares of annuals and perennials (Fig. 1).

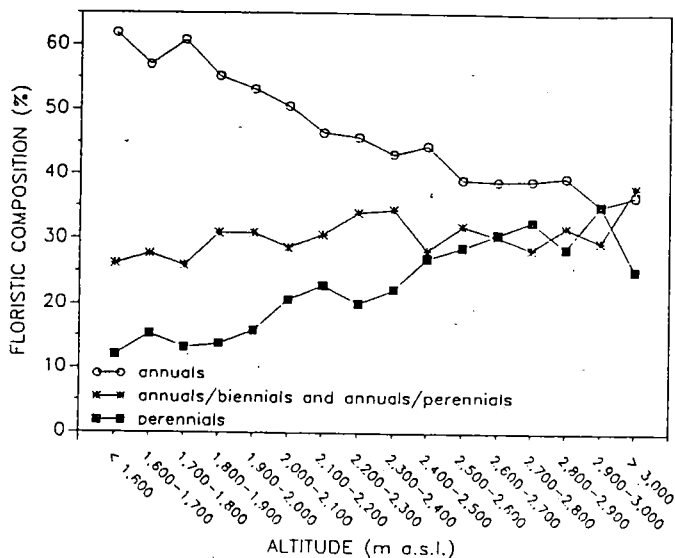


Fig. 1: Floristic agrestal composition with regard to life forms along the altitudinal gradient

Regions of origin or primary distribution areas have been identified for 316 species (71.2% of the flora). Except for a minor group of cosmopolitans, four groups of regional origin have been distinguished. African and European groups were divided into different subzones (Tab. 3).

Tab. 3: Regions of origin for 316 agrestal species of the Shewa Province, Ethiopia

region of origin	% of species based on species number (n = 316)
Africa	61.4
<i>East-Africa</i>	39.2
<i>Ethiopia</i>	11.3
Europe	17.4
<i>mediterranean</i>	49.1
America	8.2
Asia	4.1
Cosmopolitan	8.9

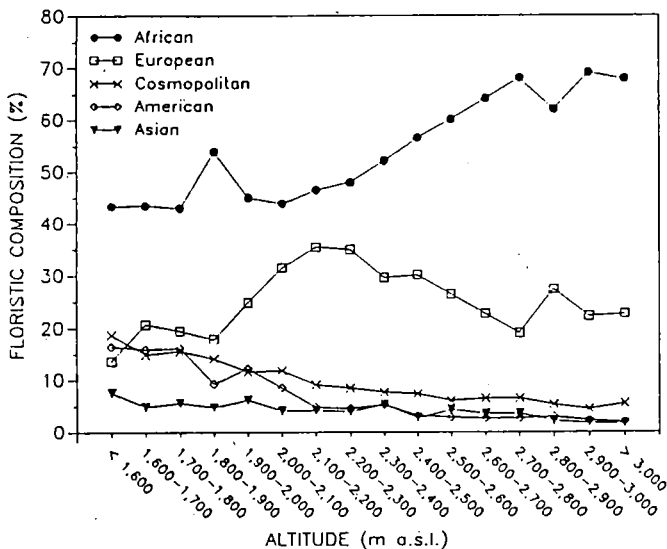
Within the altitudinal gradient a particular pattern of distribution can be noted for African and European species while Cosmopolitans, American and Asian species are of minor general importance and their abundance further diminishes with increasing altitude (Fig. 2).

A countrywise comparison of this flora with those of adjacent countries underlines the rather unique character of the Ethiopian agrestal flora (Tab. 4).

Tab. 4: Proportion (%) of common agrestal species in Shewa (Ethiopia) and adjacent regions (altered from Pülschen 1990)

adjacent region	proportion <sup>1</sup>	number <sup>2</sup> of species	source
East-Africa <sup>3</sup>	73.0	63	Terry & Michieka 1982
Kenia	52.9	87	Bogdan 1950
East Africa <sup>3,4</sup>	48.2	199	Ivens 1967
North-Yemen	35.8	187	Chaudry & Revri 1983
Uganda <sup>5</sup>	32.7	275	Tiley 1970
Sudan <sup>6</sup>	31.5	149	Jansen 1983
Togo	28.7	195	Schmid 1987

- <sup>1</sup> relative to the total species number of respective source  
<sup>2</sup> of the respective source  
<sup>3</sup> Kenia, Tanzania, Uganda  
<sup>4</sup> from chapters "Cyperaceae", "Gramineae", "Herbaceous Weeds"  
<sup>5</sup> only species indicated as agrestals



**Fig. 2: Floristic agrestal composition with regard to origin within the altitudinal gradient**

## Discussion

### *Species composition and diversity*

Investigations of agrestals for East-African and Arabian countries including Kenya, Sudan, Tanzania, Uganda and North-Yemen by Bogdan (1950), Ivens (1967), Jansen (1984), Terry & Michieka (1987), Tiley (1970), and Chaudhary & Revri (1983) confirm the high proportions of Poaceae and Asteraceae of this study. "American" Asteraceae have a particularly high share (30%) which is in line with results from East-Africa by Popay & Ivens (1982). The proportion of species common in Ethiopia and adjacent countries is not only influenced by the spatial distance of the respective countries to Ethiopia but also due to the total number of species recorded in the datasets: The more extensive lists available from other countries just include 50% (or less) of species common with Ethiopia.

The overall species richness in Ethiopia and the high relative and absolute abundance of Fabaceae in this study are remarkable. Three facts related to the surveyed area may be of particular importance and may serve as explanations in this context:

- the survey covered sites with quite a high number of widely differing site factors (see Tab. 1)
- the land use pattern varied from a semipermanent cropping system with a large proportion of fallow pastures to sites of permanent annual cropping
- weed control is mainly done mechanically (oxen ploughing, hand weeding). The use of herbicides and mineral fertilizers which may seriously confine species diversity was restricted to 14 and 26% respectively of the sites surveyed (Tab. 2). The high number of Fabaceae recorded may be in part due to the limited use of N-fertilizers and the low N-level of most Ethiopian cultivated soils (Murphy 1963; Westphal & Desta 1973).

*Life forms*

It is suggested that agrestals known to occur with varying life form like Poa annua L., Cyanotis barbata D. Don. or Corrigiola litoralis L. are best suited to the varying climatical situations in the study area and hence may be recorded under widely varying moisture regimes. Walter (1968) defines them as climatical ecotypes. Their proportion of the flora is reasonably stable with altitude varying from 26 to about 37% (Fig. 1). Together with the "obligate" perennials they contribute from 35 to 65% to the flora in lowlands and subafroalpine habitats respectively (Fig. 1) and it is obvious that the climatic change with altitude (see above) leads to this shift of life forms.

In this context mention must be made to a very common feature of the arable heavy clay soils in the plains of the humid Ethiopian highlands: Waterlogging commonly prevails for the first four to eight weeks of the main growing season in plateau regions of the highlands. It was found that species adapted to such sites by regrowth of stolons are particularly abundant in such habitats, for example Alchemilla pedata A. Rich., Commelina africana L., Dichondra repens J.R. & G. Forst., Limosella africanum Glück and Ranunculus multifidus Forsk. Particularly troublesome grasses of African origin are Cynodon dactylon (L.) Pers. and Pennisetum clandestinum Hochst. (Popay & Ivens 1982). They hold a "double strategy" since they may form both, stolons and rhizomes.

*Origin of species*

African and European species dominate the flora contributing more than three fourth to the dataset (Tab. 3). Their significance has been stated earlier by Knapp (1973) and Popay & Ivens (1982). This hints at their ecological adaptation in the surveyed area. However, the low proportion of American and cosmopolitan species is contradictory to findings of Knapp (1973) and Popay & Ivens (1982) and the following facts may serve as explanations for these deviating results:

- The survey was mainly carried out in fields located in subtropical to temperate climatic regions. This is suggested to be the main cause for the low share of (tropical) American species in favour of agrestals from temperate to subtropical Europe including mediterranean countries. As can be seen from Fig. 2 the European group obviously finds most suitable growth conditions within the subtropical and temperate climatical zones (1,800 m a.s.l). The Woina Dega (1,800 - 2,400 m a.s.l) is the most intensively cropped region of highest crop diversity and maximum population density (Amare 1978). The share of temperate to subtropical European agrestals is particularly high in this region which corresponds climatically to European conditions (Fig. 2).

- Around 91% of the fields were grown to crops endemic to Ethiopia which is a centre of origin for all crop species surveyed except for Zea mays L., Phaseolus vulgaris L. and Avena sativa L. (Westphal 1975). This holds also true for various sorghum races which have been cultivated in Ethiopia by the 7<sup>th</sup> or 12<sup>th</sup> century AD according to Stemler et al. (1977) and Doggett (1988) respectively. The cultivation of barley and wheat reaches back into pre-Christian times (Westphal 1975). Hence the significance of African agrestals in this study is understandable: the ancient agricultural history implies that many of the associated agrestal species may have established already a very long time ago and hence were able to infest various ecologically different habitats. Maize and haricot bean which are the only crops of New World origin surveyed in this study are restricted to the lowlands and mid-altitude areas. It is noteworthy in this context that the nine agrestals of New World origin are only occurring in low altitude areas too with just two exceptions of indifferent altitudinal reaction: Amaranthus hybridus L. and Galinsoga parviflora Cav. The latter species is of extremely high steadiness in the study area (61%!). Its date of introduction into Ethiopia is not known. However this

might have been quite recently, provided that it spread as fast as it did in Europe where Galinsoga parviflora Cav. was introduced only at the end of the 18<sup>th</sup> century and became a very common weed (Hanf 1982).

Regarding introduction and spread of foreign species the import of weed seeds as impurities in crop seeds must have played a major role. Deliberate import as food plants or ornamentals was of lower significance (Popay & Ivens 1982). Crop seeds are still a major source of weed infestation in Ethiopia as various investigations have shown. For instance field trials proved that barley yields increased by 14% due to proper seed cleaning techniques (CADU 1968). Actually a high number of weed species registered in this study are ample seed producers and many of them are difficult to separate from crop seeds with the simple seed cleaning techniques available in Ethiopia. E.g. Bromus pectinatus Thunb. and Lolium temulentum L. are quite similar in shape to seeds and young plants of wheat and barley, Eragrostis spp. and Amaranthus spp. are difficult to discriminate from tef seeds and their high abundance in the respective crops may be explained in part by this fact.

Within the 444 species recorded in total the share of annuals and biennials depending on seed production as the sole means for multiplication is particularly high within the European agrestals (73.5% !). The opposite is true for species of African origin: They predominantly regenerate vegetatively or are able to realize both reproductive strategies: this holds true for 61.4% of the African species. These figures confirm the above assumption regarding the introduction of the majority of European species via crop seeds and moreover they may serve as an evident explanation for the fact that many African species are particularly well adapted to the humid subafroalpine region: Here they are tremendously gaining in steadiness, dominating the weed complex with a share of 70% at altitudes around 3.000 m a.s.l. (Fig. 2). Commonly encountered are species like Anthemis tigreensis A. Rich., Cyanotis barbata D. Don., Festuca abyssinica A. Rich., Haplocarpha schimperi (Sch. Bip.) Beauv. and Rumex abyssinicus Jacq., just to mention some representatives for this region.

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<sup>1</sup> Plantation crops like cotton, sisal, tea etc. are more common in other East-African countries. In Shewa and in the country as a whole they are of negligible importance except for coffee that is of tremendous significance for the Ethiopian economy, however the crop is generally grown wild.