

THE *ULMUS* FALL AT THE TRANSITION ATLANTICUM-SUBBOREAL IN POLLEN DIAGRAMS¹

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SUMMARY

The views of previous authors on the elm fall, especially backgrounded by TAUBER'S (1965) theory on differential pollen dispersion, are discussed. Five possible explanations are given: climate, competition and edaphical factors, human influence, diseases, selective pollen filtering.

For the time being the present author concludes that the most probable explanation for the elm fall is human influence, eventually in interaction with a change in climate. Depending on local, edaphic and ecological conditions, the various factors which may be held responsible for the elm fall, are probably of unequal importance for different regions.

INTRODUCTION

Following JESSEN (1934) and IVERSEN (1941) most pollenstratigraphers put a zone-boundary at the considerable fall of *Ulmus* at the end of the Atlantic (zone VIIa/VIIb: MITCHELL, 1941; GODWIN, 1948; JESSEN, 1949; zone VII/VIII: JESSEN, 1938; FIRBAS, 1949). The Subboreal thus is defined solely in terms of vegetation development (compare also WATERBOLK, 1954).

Many ¹⁴C dates indicate that the *Ulmus* fall occurred between 3,900 B.C. and 2,600 B.C.; 50% of these dates comprise the period between 3,150 B.C. and 3,350 B.C. GODWIN (1960) and NILSSON (1964) summarized all available dates.

The Ulmus fall

In the following part five explanations of the elm fall, that were expounded in the past, are discussed.

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Climate

IVERSEN (1941, 1944, 1960) showed the sensitivity of *Hedera* to low winter temperatures. In Denmark the *Hedera* percentages decrease at the transition of zone VII/VIII. According to him thus, winter temperature would have decreased at the transition. On the basis of higher percentages of *Viscum*, summer temperatures would have been ca. 1.5°C higher in the Atlantic and 2°C higher in the Subboreal than at present. This points to an increasing continentality at the transition from zone VII to zone VIII. Throughout this paper zone VII and zone VIII are equivalent to the Atlantic and Subboreal Periods. According to LAMB (1964) a dry period at the start of the Subboreal (this explanation is also favoured by TAUBER, 1965) would be the result of a changing air-circulation. There would have been a northward shift in the pathways of cyclones. Such a shift means also an increasing continentality, which in regression areas, like northern Denmark, caused a decrease of *Hedera*. GODWIN (1956) assumes that the prevention of the formation of seed is a result of an increasing number of days with late frost in spring (another aspect of a continental climate). FIRBAS (1949; p.181) states that *Fraxinus* is also sensitive to late frost. VAN ZEIST (1959) remarks that the *Fraxinus* percentages often rise at the transition zone VII/VIII.

JESSEN (1949) showed that in Ireland, *Hedera* and *Ilex* pollen are more abundant in the Subboreal than in the Atlantic. According to him, this means a higher summer temperature in the Subboreal. The winter temperatures would not have any influence, because of the extreme oceanicity of Ireland (compare also western Norway; FAEGRI, 1944). GODWIN (1956), however, assumes a colder climate in zone VIIb on account of a decrease of *Hedera* (doubted by IVERSEN, 1960) and *Ulmus*, and an increase of *Fraxinus*. MITCHELL (1956) emphasizes the fact that many Irish diagrams show a regeneration of *Ulmus* after an initial fall. He therefore is of the opinion that the elm fall is not caused by climate only. Also man would have been responsible for it.

According to IVERSEN (1941) a fall in winter temperature would affect *Ulmus carpiniifolia*, a species with a southern distribution. In Norway, *Ulmus glabra* was probably the species involved, which species nowadays reaches even more to the north than *Fraxinus*. In this case, a fall of *Ulmus*, conditioned by a change in climate, must most likely also be accompanied by a decrease of *Fraxinus*. However, this is not true in the Oslo-fjord region, where pollen diagrams show a substantial rise of *Fraxinus* (HAFSTEN, 1956). According to VAN ZEIST (1959) these contradictions may be explained by different flowering behaviour. The *Ulmus* fall also in the Oberharz (Germany), cannot easily be explained by assuming the suppression of one species (WILLUTZKI, 1962). KUBITZKI (1961) is of the opinion, (on the basis of the recent distribution of *Ulmus montana* and *Ulmus carpiniifolia*) that it is very unlikely that the lowest winter temperature is the limiting factor in the distribution of *Ulmus*. Sometimes there is a distinct litho-stratigraphical change at the transition Atlantic-Subboreal (CONWAY, 1954; SMITH, 1958). In

northern Ireland (JESSEN, 1949), and west Norway and Denmark (FAEGRI, 1944), there is a simultaneous transgression with the elm fall. Of course, changes in the gross stratigraphy of bogs may represent natural succession in bog development, but it also may mean a change in climate. The climate may have turned humid, for in Ireland *Alnus* rises in the Subboreal (JESSEN, 1949). MITCHELL (1941), and CONWAY (1954), observed a temporary rise of *Alnus* at the close of the Atlantic.

OVERBECK (1952) reported a similar pattern in the Subboreal of the Gifhorner peatland. In his diagram there is a correlation between hygrokline phases and increases of *Hedera* and *Fagus*, and between xerokline phases and an increase of *Tilia*. In the "Hohe Moor" (central Germany), however, a correlation between *Ulmus* (and *Tilia*) and alternating dry and wet periods, is absent, although there is a dry period at the fall of *Ulmus* (SCHNEEKLOTH, 1963). It must be admitted, however, that in the majority of pollen diagrams *Alnus* does not rise. Usually no correlation between the *Ulmus* fall and recurrency surfaces can be found.

Another explanation of the *Alnus* increase was given by SMITH (1961; p.39, 44). Deforestation on the uplands results in a decreasing deposition of other tree-pollen grains. *Alnus* occurs on the wettest sites, which are less suitable for agricultural practices, and thus it tends to be more overrepresented. NILSSON (1964) points out that the oldest ^{14}C date of the *Ulmus* fall, is from central Sweden. If climate is responsible for the elm fall, then the latter would have started in the north. There is, however, no gradual trend in the dates from north to south.

SMITH (1961) pointed out that the effect of change in climate depends strongly on the climate existing in a region. The fact that the changes are not synchronous, or restricted to one region, does not mean, according to him, that an explanation in terms of climate has to be abandoned altogether. If ecological conditions for a taxon or vegetation type are close to its threshold, then a change in climate would more easily result in a change in vegetation (SMITH, 1965).

Smith also draws attention to the fact that a climax forest shows a kind of inertia, not easily affected by any influence from outside.

Competition and edaphical factors

According to TAUBER (1965), *Ulmus* will be affected more seriously than *Tilia* when the groundwater level drops. *Ulmus* has a horizontal rootsystem; during a dry period, the vessels are blocked irreversibly by the formation of callous tissues. The rootsystem of *Tilia* is not so superficial and thus would suffer less. For similar reasons *Quercus robur*, edaphically similar to *Ulmus*, would gain upon *Ulmus* at the lowering of the waterlevel (MORRISON, 1959). But according to IVERSEN (1941), soil factors can not be held responsible for the fall of *Ulmus*. *Fraxinus* rises, although it shows similar edaphical requirements. IVERSEN (1960) also pointed out that often there is a rise of *Fraxinus* at the expense of *Alnus*, indicating a lowering of the groundwater. This may be in agreement with the opinions of Iversen (1960) and Hafsten (1956), who consider the Subboreal in

Denmark and the Oslo-fjord region as being more continental. The continuous *Fraxinus* curve in Great-Britain (for instance in GODWIN et al., 1957; GODWIN, 1960; SMITH and WILLIS, 1962; DEWAR and GODWIN 1963), may also be explained by the degree of shade tolerancy. *Fraxinus excelsior* is less shade tolerant than *Ulmus carpinifolia* and may expand when *Ulmus* diminishes.

Finally leaching of the soil, accelerated by deforestation by man, may be the reason for the *Ulmus* fall. By this process, the lime in the top soil is leached out. As a result, the soil conditions for elm will become less favourable (TROELS-SMITH, 1964).

Human influence

The fact that in Norwegian diagrams, indicators of human occupation are absent, at least at the time of the beginning of the elm fall, led FAEGRI (1944) to the conclusion that a first elm fall is conditioned by climate. However, he also mentions the fact that elm leaves are an excellent fodder for cattle. After the start of the elm fall there would have been a further reduction of elms by the agricultural practice of cutting elm leaves. The latter explanation has been strongly favoured by TROELS-SMITH (1954, 1955, 1960).

According to him low percentages of Poaceae and *Plantago lanceolata* would indicate that the neolithic cattle were not allowed to roam around freely. Instead they were fed with elm twigs inside the farm-house. Arguments for such a practice are found in excavations of dwelling places. The practice still seems to hold out in remote areas (Himalayas; HEYBROEK, 1963). VAN ZEIST (1959) pointed out that especially in elm, the flowering capacity will be reduced by cutting branches. *Ulmus* will not flower within eight years after the cutting of side-branches. Mostly there will have been renewed cutting before the restoration of flowering. In contrast *Fraxinus* and *Tilia* will already flower in 2, and 3–4 years respectively. Heybroek indeed found in the Himalayas no flowering elms. However, in the Oberharz (Germany), (WILLUTZKI, 1962) and in Scotland (DONNER, 1962), there can have been no human influence when *Ulmus* decreased after its Atlantic optimum. Indeed, it is not very probable that in these mountainous regions man would have settled so early. Here, thus, climate would have been responsible for the elm fall, at least in the beginning.¹

There is, however, much that agrees with Troels-Smith's opinion. Almost everywhere *Plantago lanceolata* and *Cerealia* appear when *Ulmus* declines. In addition, the decrease of elm at some sites is clearly correlated with cultural stages (Fallahogy: SMITH, 1964; Langeland: JESSEN, 1938). Smith agrees that elm reaches its previous Atlantic level again in the regeneration stages after land occupation. This does not point to any influence of the climate. Moreover in his Fallahogy

¹ According to GROENMAN-VAN WAATERINGE (1968), *Plantago lanceolata* and *P. maior* occur in natural, unstable contact zones and thus would not always point to human activities.

diagram, the correlation between *Plantago lanceolata* and *Ulmus*, is so obvious that one can not but accept an elm fall caused by man.

A regeneration of elm also is shown in some diagrams of northern Holland (VAN ZEIST, 1959), Sweden (NILSSON, 1964) and southeastern Holland (JANSSEN and TEN HOVE ms.). According to VAN ZEIST (1959) later invasions of herdsmen, indicated by high percentages of *Plantago lanceolata*, interfered with the regeneration of elm.

In northern Ireland (MORRISON, 1959) there is a strong negative correlation between *Ulmus* and *Plantago* from top to bottom of the diagrams. This negative correlation between *Ulmus* (and *Tilia*) and *Plantago* is also mentioned by Iversen. Here *Quercus* and *Fraxinus* are scarcely affected, but *Betula* and *Corylus* (pioneers after a clearing) increase simultaneously with the rise of *Plantago lanceolata*.

It is remarkable that in some cases scattered occurrences of *Plantago lanceolata* and *Cerealia* are reported before the decline of elm (England, Ireland: GODWIN, 1956; SMITH, 1958; MORRISON, 1959; Germany: MÜLLER, 1953, 1962). But still, the curve of these indicators of human activities becomes continuous only when the elm starts to decrease. These scattered occurrences are most easily explained by long distance transport from outside the area that constitutes the source of most of the tree-pollen grains. Beyond the effective source area, agricultural practices were going on without influencing the deposition of the regional tree-pollen types. It is not very likely that around 3,250 B.C., all of a sudden, the population increased to such an extent that elm was affected everywhere. It must be kept in mind that a pollen diagram often represents a relative small area (cf., p.364).

However, it must be admitted that the variations of the available ^{14}C dates may indicate that the elm fall lasted at least several centuries. GODWIN (1960) concedes in this connection that—when several radiocarbon dates in various regions are very close—influence by man only, is less probable. MITCHELL (1956) assumes selective cutting of elm, because the tree thrives on sites most suitable for agriculture. IVERSEN (1960) accepts a mixed *Ulmus*–*Fraxinus*–*Quercus* forest on gley-soils. In that case selective cutting of elm does not make sense. MORRISON (1959) therefore, is of the opinion that *Ulmus* and *Quercus* thrived in separate groups, *Ulmus* on the better sites, and thus were easily affected by cutting. But even when there is no selective cutting of elm, still there may be an elm decline by protection of *Quercus* (IVERSEN, 1949, 1960). He point out that the wood of *Quercus* is hard, not easy to cut and that moreover the tree may have been protected because of its acorns (fodder for pigs).

Diseases

ALETSEE (1959), TROELS-SMITH (1960) and WATTS (1961) mention the possibility that elm disease may be held responsible for the elm fall. On the basis of the rapid regeneration of elm in Irish diagrams, other people oppose this

hypothesis. But it is not known how fast new resistant races are formed. The disease spreads by means of insects (in Holland the elm-bark beetle). It is not impossible that the spread of the disease is stimulated by a change in climate. A relatively short change in climate may have been disastrous for elm, because it could stimulate the dispersal of fungi or insects (SMITH, 1961). Keen (cited by Smith) showed that certain species of bark beetle prefer the bark of dead trees. Thus the beetles may spread because man killed trees (fires). It will remain extremely difficult to show that in the past a tree disappeared by disease.

Selective filtering

On the basis of the observations that (1) a sticky slide placed vertically catches 10–20 times as many pollen grains as a horizontally placed one; (2) the rate of deposition is 1–10 cm sec but that wind speeds are often 100 times higher, TAUBER (1965) concludes that the dispersion of pollen grains occurs mainly by horizontal transport (p.8). According to Tauber, three components in the total pollen deposition may be considered:

- (1) Horizontal transport through the trunk space of a forest.
- (2) Horizontal transport above the canopy.
- (3) "Rain out" pollen, higher in the troposphere which acts as a starting point for condensation. This includes also "wash-out" pollen, pollen grains from (1) and (2) caught by raindrops.

On this basis, and from meteorological data, Tauber assumes differential filtering of trunk space pollen when they pass various vegetation types. Heavy grains would be more likely to be filtered out than light ones. Also the width of the vegetation belt, the structure of the vegetation, and the meteorological conditions are supposed to have an effect on the filtering of pollen grains. Tauber calculates that *Fagus* pollen is more sensitive to filtering than *Betula* pollen (from a 50% mixture, 18% of the *Betula* grains against 84% of *Fagus* may be filtered out). This of course would result in a more than usual underrepresentation of *Fagus* when these conditions prevail. As a result of filtering, *Quercus*, *Corylus*, *Betula* and *Alnus* may increase slightly in percentages, but *Tilia* and *Ulmus* decrease up to 77% and 65% of the values without filtering. According to Tauber most of the pollen grains found in sediments in small-sized basins, have been transported through the trunk space of the surrounding forest. Under normal meteorological conditions, most grains from the two remaining components are deposited beyond several hundred meters from the source. Moreover, Tauber argues that in small basins thermic convection prevents deposition of pollen grains. But this clearly applies also to the trunk space-component. In small sized basins the "rain out"-component would account for only 10% of the total pollen deposition.

It is possible to calculate the effective dispersion of pollen grains on the basis of the rate of deposition and the wind velocity. For instance, most of the pollen grains of *Fagus* settle down within 100 m from the source. Studies on pollen

deposition at an increasing distance from the source, support this. In other words: in a small basin, the trunk space-component (extra-local pollen values: JANSSEN, 1966) may be larger than in a larger sized basin. Thus in such a small basin, most of the pollen comes from a smaller area than generally is realized. In larger basins the contribution of the trunk space-component to the total pollen deposition decreases and, that of the component above the canopy and the "rain-out"-component increases. As a result pollen diagrams from large bogs or lakes are primarily regional in character. In the work of SMITH (1964), two pollen diagrams 5 km apart are shown. In the Fallahogy diagram, from a fertile area, there is a distinct landnam with a temporary *Ulmus* fall. In the Cannons Lough diagram, from a less fertile region, there is a gradual decrease of *Ulmus* without a clear landnam-level. Although the size of the basins from which these diagrams were obtained is not mentioned, still the pollen deposition of these two sites at such a short distance from each other is a reflection of the area immediately surrounding the basins. According to Tauber, conclusions in terms of vegetational changes from relative diagrams may be drawn only in the case that:

(1) The total deposition of the pollen types included in the pollen sum, is constant in space and time represented by the diagram.

(2) The physical factors determining pollen deposition, pollen dispersion and pollen filtering, remain similar throughout the diagram; for instance wind velocity, wind direction and a vegetation belt around the depositional area.

(3) The area-extent and location of the pollen sources remain constant. Sometimes condition (1) can be met, by selecting a pollen sum including types that are supposed to have a constant absolute pollen deposition in a short time interval because of their regional character (cf., JANSSEN, 1966). However, it is not possible to meet condition (2) and (3).

Tauber applies his theories to explain variations in the pollen curves. In the Weier diagram (Switzerland), there is a negative correlation between *Fagus* and *Salix*. Competition can not be the reason, because the ecology of *Salix* is quite different from that of *Fagus*. Moreover *Salix* is an insect-pollinated shrub, and thus high *Salix* values in a pollen spectrum, almost always are a result of local occurrence. Tauber explains a *Fagus* minimum by selective filtering of *Fagus* pollen grains in a wide belt of *Salix* around the basin. Such a belt may be the result of a lowering of the water level, by which *Alnus*, *Betula* and *Salix* may expand on the bare soils around the lake, or on marginal peaty soils. CLAPHAM and GODWIN (1948) indeed showed local occurrence of *Betula* simultaneously with the elm fall. JESSEN (1949) found a relation between *Betula* and *Alnus* maxima and recurrency surfaces. *Betula* would have expanded in dry bogs, *Alnus* in successive wet stages in bog development. It cannot be denied that in Ireland, *Alnus* rises after the elm fall, but it is difficult to decide whether this *Alnus* rise is a result of a lowering, or of a rise of the groundwater level. In the ca. 30 diagrams of JESSEN (1949) there are twelve cases in which a negative correlation between *Alnus*, *Betula*

or *Salix* and *Ulmus* is shown. Seven times there is a rise of the three lowland types, but without any effect upon elm. In evaluating these diagrams, one must take into account that as a rule Jessen's diagrams are from large bogs, where filtering can be of minor importance only. Also in the many northwest European diagrams, a fixed correlation between *Alnus*, *Betula* or *Salix* and *Ulmus* is absent. An example for a negative correlation between *Salix* and *Ulmus* would be, according to Tauber, the work of IVERSEN (1949) or that of SMITH and WILLIS (1962). But in Iversen's paper, only one out of seven diagrams shows the correlation. In Smith and Willis I was unable even to find it. Sometimes there is a maximum of either *Betula* or *Salix*, but more often there is not. It is also difficult to explain why *Ulmus* sometimes decreases, but *Tilia* (also relatively heavy pollen) remains constant (cf., TROELS-SMITH, 1942; HAFSTEN, 1956). It must be admitted, however, that usually *Tilia* fluctuates in the period of the elm fall. Anyway, in order to conclude filtering from a negative correlation of lowland types and *Ulmus*, the size of the basin must be known.

CONCLUSIONS

The circumstantial evidence accumulated by Troels-Smith c.s., and later also by IVERSEN (1960) is impressive. In contrast, a direct relation between the elm fall and a change in climate, is not so clear. Therefore, at the moment, an elm fall as a result of human activities, seems not impossible. It is, however, unlikely that this is caused exclusively by cutting the elm leaves. It seems more realistic to explain the elm fall by a complex of factors such as:

- (1) Cutting of the branches of elm trees reduces the pollen production of elm; this will also render the elm less fit for competition (prevention of seed formation).
- (2) Cutting of trees, because elm is found on the better soils.
- (3) Leaching of the soil, because some areas in the forest remain open for a long time.

On account of the work of IVERSEN (1944), the synchronism of the elm fall, and an increased frequency of stratigraphic changes in the Subboreal, a change in climate also seems probable. For instance, a dry period may have favoured *Quercus* at the expense of *Ulmus*. In Ireland, in the Oslo-region, and in the mountains of central Germany, elm declines very regularly in diagrams, without indication of human influence. This may be explained by climate. Tauber's theory of selective filtering, may be correct in principle for small sized basins, but in most west European diagrams, the theory does not seem to be valid. A complete evaluation, however, is impossible since most papers do not mention the size of the basins concerned. Tauber himself concedes that the effect of selective filtering may not be sufficient to explain the elm fall completely. In the future, pollen analysis from many sites (small basins etc.) must be carried out, paying special attention

to a possible negative correlation between *Alnus*, *Betula*, *Salix* on the one side and *Ulmus*, *Tilia*, *Fagus* on the other side.

It remains possible that the various factors that may be held responsible for the elm fall, do not carry the same weight for various regions, depending on local, edaphic and ecological conditions.

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