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# *PROBING THE SEASONALITY SIGNAL IN POLLEN SPECTRA OF ENEOLITHIC COPROLITES (HÂRŞOVA-TELL, CONSTANŢA COUNTY, SOUTHEAST ROMANIA)*

***Abstract:*** Samples from seven stratigraphic units of a midden complex in the Eneolithic (Gumelniţa A2) levels at Hârşova-tell (Constanţa County, southeast Romania) were analyzed to test for seasonality signals in coprolite pollen spectra. The very short interval of pollen rain recorded in coprolites makes them particularly attractive as potential bearers of seasonal signals resulting from the pollination phenology of different plant species. The analyzed midden represents 1-1.5 years of deposition and its stratigraphy is constrained at high spatial and temporal resolution, providing an excellent framework for the test. Coprolite pollen spectra are highly polarized and reveal poor pollen preservation and selective pollen destruction. Pollen taxa resistant to destruction and easily identifiable in degraded state (Chenopodiaceae, *Artemisia*, Poaceae) are present in high amounts often masking signals borne by seasonality-informative taxa, and therefore are not taken into consideration in interpretations of seasonality. Some of the coprolite pollen spectra indicate relatively clear-cut seasonality assignments that coincide with independent inferences based on fish bones and the stratigraphic distribution of coprolite concentration. Other pollen spectra yield equivocal data that cannot be used independently to assign their stratigraphic units to a particular season. Results of this pilot study suggests that short intervals of pollen rain recorded in coprolites, compounded with the vagaries of behavior of individual animals that produced the coprolites, lead to an uneven reflection of the pollen rain in coprolite pollen spectra. Consequently, the power of resolution of these spectra in terms of seasonality varies over a broad range. Although somewhat conflicting, the results of the study suggest that coprolite palynology can potentially be developed as a tool to resolve seasonality, given a better preservation of palynomorphs and if coprolite samples are compounded for each stratigraphic level to minimize the effects of individual behavior of the coprolite producers.

***Keywords:*** pollen, coprolites, seasonality, Eneolithic, Gumelniţa culture, Romania.

Pollen and spore spectra of coprolites represent veritable snapshots in terms of the temporal significance attached to the information they store. Due to the characteristics of animal physiology, the palynological content of a coprolite consists of pollen and spores ingested with food and water over a very short period of time, often less than a day. Correlated with the phenologic variety of flowering seasons or spore-release periods of different plant species, this characteristic should make coprolite pollen and spore spectra particularly good indicators of the season when the coprolites were produced.

Coprolites have been relatively widely used as sources of palynological material to infer Quaternary vegetation history and climate (e.g., Martin and Sharrock 1964; Leroi-Gourhan 1966; Cârciumaru 1973; Moe 1983; Scott 1987; Vivent 1989; Carrion et al. 2001; Gonzalez-Samperiz et al. 2003; Scott et al. 2005).

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Furthermore, several of those authors have pointed out that coprolites potentially enclose valuable information on the seasonal aspects of sediments that include them. However, this hypothesized usefulness of coprolites as seasonality indicators has not been tested empirically and remains a theoretical statement to date. This is most often due to insurmountable difficulties in establishing a stratigraphic framework at high temporal resolution (i.e., sub-annual) in most coprolite-containing deposits.

Midden deposits consisting of finely stratified domestic waste are preserved in proto-urban settlements of the Romanian Eneolithic and have been shown to offer the preservational conditions for stratigraphic studies at very high temporal resolution (Popovici et al. 2000). Particularly, concerted stratigraphic and archeozoological studies have allowed for constraining the time of deposition of a midden complex (C521) in the Eneolithic layers (Gumelniţa A2) at Hârşova-tell (southeast Romania) to an interval of 1-1.5 years. The results of these studies show that deposition of the complex started some time in the spring and ended in the summer of the next year (Popovici et al. 2000; Radu 2000). Coprolites are preserved in large amounts in the same complex, and analysis of their quantitative stratigraphic distribution has revealed significant correlation with the distribution of fish bones, interpreted as reflecting seasonality (Tomescu et al. 2003). Additionally, coprolites represent one of the few types of material that preserve pollen and spores in quantities that allow for statistical treatment of data at Hârşova-*tell* (in most sediments of the settlement palynomorphs are too rare and poorly preserved).

All of these characteristics of the midden complex C521 at Hârşova-tell provide a good foundation for a direct test of the potential and reliability of seasonality signals borne by coprolite pollen and spore spectra: 1) high stratigraphic resolution; 2) a temporal framework well constrained from the point of view of seasonality (Radu 2000; Tomescu et al. 2003); 3) rich coprolite content sampled at the same high stratigraphic resolution. Here I present the results of pilot palynological analyses of eight coprolite samples, and discuss their significance in terms of seasonality.

## The Hârşova-tell settlement and midden complex C521

Hârşova-*tell* (Constanţa County, 44º41' N / 27º58' E) is one of the most important proto-urban, tell-type settlements of the Romanian Neo-Eneolithic. Located on the right bank of Danube River (see Tomescu et al. 2003, for a map), the settlement comprises principally Neolithic (Boian culture, ca. 5350-4600 BC) and Eneolithic (Gumelniţa culture, ca. 4600-4000 BC) layers, but also includes a thin Cernavoda I component (fourth millennium BC). Multidisciplinary excavations in this settlement have opened wide perspectives onto the life, economy and dynamics of the Gumelniţa populations (e.g., Popovici et al. 2000). Several middens have been excavated in the Gumelniţa layers and they are characterized by the presence of shells and fish bones in large amounts, together with mammal bones, ash, charcoal, fragments of building material (daub) and a fair amount of coprolites.

The midden complex C521 comprises over 650 stratigraphic units (SU), out of which 257 contained coprolites. The stratigraphic units have been grouped in 118

stratigraphic sequences (SS) that insure high stratigraphic resolution and reflect accurately the stratigraphic relationships within the complex, while providing a simpler stratigraphic framework for straightforward representation and correlation of information on the distribution of the different types of material recovered from the complex. A detailed discussion of the stratigraphic work and of theoretical underpinnings of the grouping into stratigraphic sequences can be found in Tomescu et al. (2003).

**Material and methods**

The stratigraphic sequences totaled 4832.1 $dm^3$ of sediment and yielded 3.37 g of coprolites, unevenly distributed between 48 of the 118 sequences (Fig.1). Coprolites were recovered by wet sieving of the sediment of each SU separately, dried, picked by hand, and stored in paper bags by stratigraphic units. It is important to mention that coprolites recovered using this method represent exclusively cohesive coprolites containing bones fragmented to various degrees (mainly fish bones) included in a yellowish to brown matrix. When present as fragments, coprolites were recognized based on the match of their texture, color and content with those of complete coprolites exhibiting characteristic shapes. Based on the bone content, coprolites in this category could be attributed to carnivores or omnivores and they most probably have a canine origin (Tomescu et al. 2003). Field observations allowed for recognition of a second category of coprolites in the excavation. These are low cohesion coprolites of sandy to dusty texture, found as thin patch-forming crusts. Due to their low cohesion these coprolites did not withstand wet screening being disintegrated in the process.
Seven coprolite samples from seven stratigraphic units representing six stratigraphic sequences were chosen for this study. Stratigraphic sequences were chosen to cover all the inferred seasons (Radu 2000; Tomescu et al. 2003) for which coprolites were available (Fig.1; Tab. 1). The same numbering of stratigraphic sequences used by Tomescu et al. (2003) has been maintained in the present paper. Because the coprolite material was generally fragmented, none of the samples was comprised of only one coprolite. Instead, several coprolite fragments from the same SU were pooled together for each sample in order to achieve weights in excess of 20 g. Sample processing included treatments with hydrochloric acid (40%) and hydrofluoric acid (40%), potassium hydroxide (10%, 10 minutes at 100°C), heavy liquid floatation (1.9 $g/cm^3$), sieving (0.16 mm), fuchsine staining, organic fraction volume measuring (using micropipettes), and mounting in glycerol. Palynomorph concentrations per gram of dry coprolite were extrapolated from counts on one or two slides for each sample, and calculated based on the ratio between the total volume of the organic fraction of that sample and the known volume examined on the slides where palynomorphs were counted. Pollen and spores were identified at x250-400 magnification using the reference collection of the National History Museum of Romania, as well as a number of identification keys and atlases (Faegri, Iversen 1975; Tarnavschi et al. 1981, 1987, 1990; Moore, Webb 1983; Reille 1992; Serbãnescu-Jitariu et al. 1994; Northwest European Pollen Flora, Vol. 1-7). Microscope slides are deposited at the National History Museum of Romania, Bucharest.

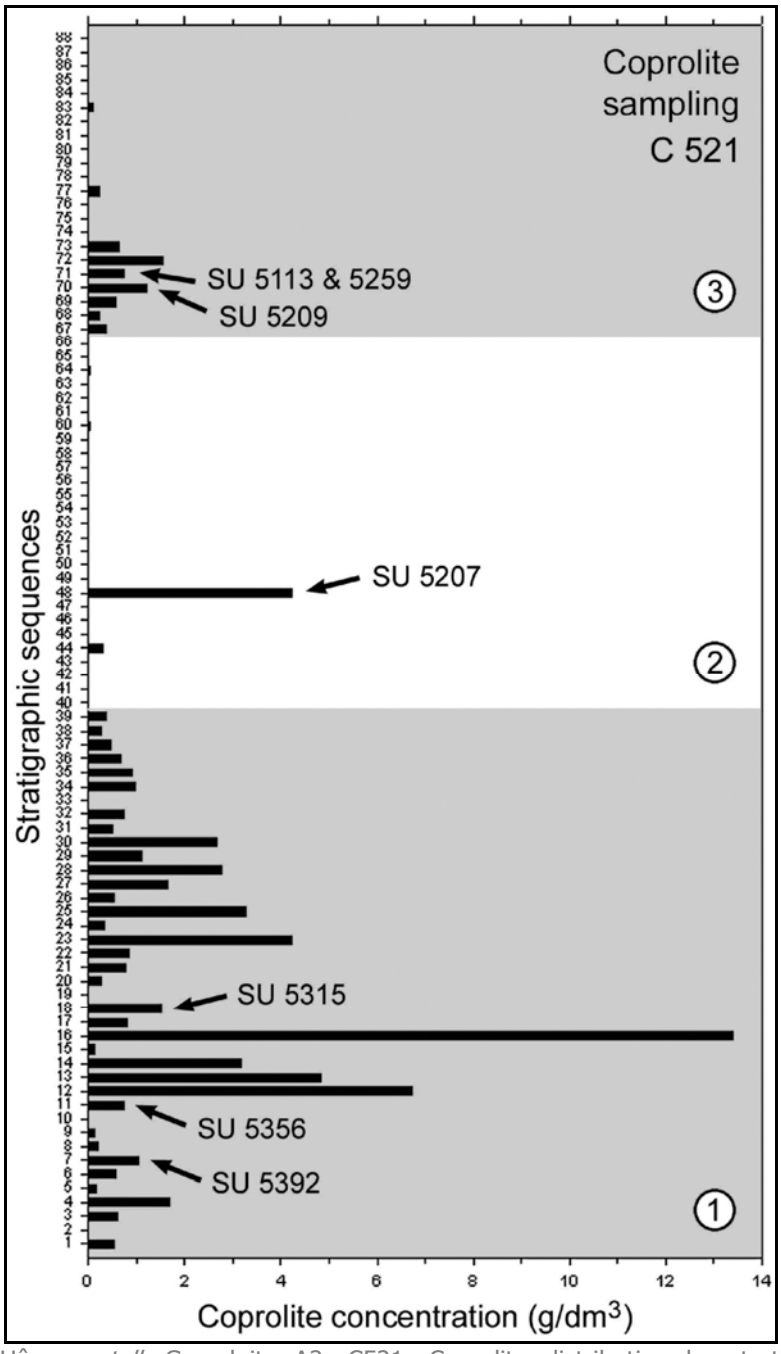


Fig.1 Hârşova *tell*. Gumelniţa A2. C521. Coprolite distribution by stratigrphic sequences, and stratigraphic units (SU) sampled in this study. Intervals numbered 1-3 represent season inferred based on fish bones and coprolite concentrations (Radu 2000; Tomescu et al. 2003): 1.= (spring?) –summer – first part of fall; 2.= fall – winter – first part of spring; 3.= spring – (summer?).

The flowering period of each identified taxon was assessed using the Flora of Romania (Ciocârlan 1988, 1990). In multi-species taxa (genera, groups of genera, families) the flowering period was assessed based only on those species whose area of distribution included our site of interest (cultivated and introduced species excluded). For most of the multi-specific taxa the resulting flowering periods were too wide to be of any help in assessing the seasonality of coprolites. In the case of Poaceae the flowering period covers the entire year. Two steps were taken in order to elude this situation. (1) For each multi-specific taxon a peak flowering period was defined as the period where most of the species in that taxon (> 30%) are flowering. The peak flowering period of a taxon represents the period of the year where the pollen of that taxon is most likely to be encountered in the pollen rain. (2) Taxa were retained as seasonal indicators only if they had flowering/peak flowering periods shorter than or equal to three months. Among taxa with longer flowering periods only *Artemisia* was retained (peak flowering period 4 months) for being the only taxon to cover the month of October.

**Results**

Total palynomorph concentrations vary widely between the samples, from 30 palynomorphs/gram of dry coprolite (p/gdc) in SU 5259 to 171732 p/gdc is SU 5209 (Tab.1). Variability of total palynomorph concentrations is present within stratigraphic sequences (30 p/gdc in SU 5259 and 145 p/gdc in SU 5113, both included in SS 71), as well as within stratigraphic units (two samples analyzed separately in SU 5356 but subsequently pooled together yielded 13300 and 1856 p/gdc respectively). The low palynomorph concentrations are generally reflected in low numbers of palynomorphs counted and identified.

Percentages of unidentifiable palynomorphs also vary within a broad range (25-68%) and exceed 40% of the total counted in all but one of the samples (SU 5259). In terms of types of deterioration, unidentifiable palynomorphs are most often corroded or degraded (*sensu* Diot, 1991), and more rarely broken. These high proportions of unidentifiables indicate poor palynomorph preservation despite the fact that coprolites are considered to provide some of the best conditions for pollen preservation at Hârşova. Even among identified palynomorphs the percentages of those that are not very well preserved (deteriorated: corroded, degraded) are very high (42-95%). Given these characteristics of the palynomorph spectra, some of them reflect unexpectedly high taxonomic diversity (Tab. 2). However, some of the stratigraphic units exhibit medium to low taxonomic diversity (e.g., SU 5392, 5113).

Palynomorph spectra of all samples are highly polarized, in that one or very few taxa account for great proportions of each spectrum (Tab.1, 2). In three of the stratigraphic units studied (SU 5356, 5315 and 5209) the dominant taxon represents more than 50% of the total identified palynomorphs. In three other stratigraphic units (SU 5392, 5259 and 5113) the two most frequent taxa account for over 50% of the spectra, and in SU 5207 more than half of the identified palynomorphs belong to one of the three most frequent taxa. The dominant taxa in the different stratigraphic units are the Poaceae (grass family), Chenopodiaceae (goosefoot family), *Salix* (willow), *Potamogeton* (pondweed) and *Artemisia* (sagebrush). *Abies* (fir), *Picea* (spruce), *Pinus* (pine) and *Betula* (birch) pollen (very likely representing long-distance transport), and fern spores were considered

irrelevant in assessing seasonality and were excluded from the totals used to calculate percentages.

The selection of flowering/peak flowering periods shorter than or equal to three months (except for *Artemisia*; see Material and Methods) produced a list of 17 taxa (Tab.3) considered potentially useful in detecting seasonality signals in the coprolite pollen spectra. These seasonality-informative taxa cover the period of February through October. Although the number of taxa retained for each sequence as a result of this selection varies between 4 (SS 7) and 13 (SS 11 and 18), all six stratigraphic sequences show a wide coverage of seasons by the flowering phenology of these taxa (Tab.3). Even for SS 7 where only four taxa were retained, their phenology covers a wide interval that includes March-May and July-October.

## Discussion

The high proportions of unidentifiable palynomorphs and the high frequencies of deteriorated palynomorphs among identifiables, that characterize all samples (Tab.1), convey a general image of poor palynomorph preservation. Poor preservation of pollen and spores is the norm in most types of material analyzed at Hârşova-tell (Tomescu 2000a). In this context, even with such high values of unidentifiable and deteriorated palynomorphs, coprolites represent one of the few resources for palynological data, as shown by the generally high pollen concentrations of the analyzed coprolites (except for SUs 5259 and 5113).

Considered in the context of these high percentages of unidentifiable and deteriorated palynomorphs, the dominance of Chenopodiaceae, Poaceae and *Artemisia* pollen in five of the seven spectra is indicative of selective pollen destruction (discussed by Tomescu 2000a, 2005). Conditions related to the lithology of the archeological deposits that contain the coprolites at Hârşova (high pH and high porosity) have been shown to be unfavorable to palynomorph preservation and to promote selective pollen destruction (Havinga 1964, 1967; Gruger 1976; Bottema 1975; Bottema, Ottaway 1982). Additionally, the technique of repeatedly humidifying the surface of the excavation while digging (to enhance contrast and allow for better understanding of stratigraphic relationships), undoubtedly plays a part in the destruction of pollen. Experimental studies conducted by Holloway (1989) and Campbell and Campbell (1994) have shown that moisture conditions alternating form wet to dry (as those produced by the above-mentioned technique) rapidly lead to the alteration of palynomorphs and loss of pollen from sediments. Because of the relatively low speed of excavation and frequent humidification of sediment, each coprolite in the midden was exposed to several wet-dry cycles prior to removal from the excavation and wet sieving (which added yet another wet-dry alternation).

Although it biases pollen spectra strengthening the relative participation of degradation-resistant palynomorphs, at least in theory selective pollen destruction should not completely obliterate the seasonal signals borne by the analyzed spectra. Physico-chemical conditions were similar in the soil around all coprolites, and all samples underwent the same coprolite separation and pollen extraction treatments. The selective destruction bias should have acted therefore in the same direction for all samples. Even if differences between spectra due to less resistant

pollen are eliminated, the spectra should still reflect those differences (potentially due to phenology seasonality) due to pollen taxa more resistant to deterioration.

Another aspect that needs to be discussed is the potentially different pollination phenology of plant species due to differences between the climate of the Gumelniţa period and present-day climate. This is complicated by the fact that the Gumelniţa period (ca. 4600-4000 cal. BC) probably witnessed variations of the climate. The end of the period was marked by an increase in the frequency of warmer and longer summers (starting around 4100 cal. BC), and such conditions probably existed between 4450-4350 cal. BC as well. Also, the beginning and end dates of the Gumelniţa period closely bracket an interval (4500-4050 cal. BC) characterized by higher occurrences of humid summers (Tomescu 2000b). These reflect a rather complex climatic evolution that very likely determined changes in plant phenology during the Gumelniţa period. Experimental studies (Peñuelas et al. 2004; Llorens, Peñuelas 2005) have shown that plant phenology changes under changing climatic factors, but that the patterns of change are complex and difficult to quantify at the scale of whole plant communities. Additionally, available data do not allow for exact temporal placement of the midden C521 within the Gumelniţa period, so we do not know how different or similar was the climate during deposition of C521 to the present-day climate of the region. However, we know that the midden represents 1-1.5 years of sedimentation, and therefore its content should reflect the succession of seasons and corresponding plant phenologic phases, irrespective of how different or similar these were to present-day seasons.

The very high variability of palynomorph concentrations (spanning four orders of magnitude) among all samples, and particularly between samples thought to represent the same season (e.g., SS 7 and 11, or SU 70 and 71), suggests that the time interval represented by the palynomorph content of a coprolite is too short to reflect the average pollen rain and therefore to allow for repeatability of samples. Additionally, the vagaries of individual behavior, such as the different locations visited and different food ingurgitated by individual animals during the same time interval, certainly entail differences in coprolite contents in terms of palynomorph types and quantities. In this context, the compounding of several coprolites from the same stratigraphic unit in order to reach a minimum sample weight required for palynological analyses may be therefore beneficial, in that it leads to a better averaging, and hence to a more reliable image, of the pollen rain corresponding to the time of deposition of the unit. This is corroborated by the spectra of two samples analyzed in SU 5356, both of which are dominated by *Potamogeton* (with 51 and 67% of total identified palynomorphs; results from the two samples not shown separately, but pooled together in Tabs.1-3). In the same line of thought, the two spectra obtained for SS 71 from SU 5113 and 5259 are both dominated by Chenopodiaceae followed by Poaceae with similar percentages (40 and 33% Chenopodiaceae, respectively 27 and 30% Poaceae). All of these indicate that pollen spectra obtained from the same SU or same SS are comparable, at least in terms of the dominant taxa, for samples consisting of several coprolites each.

Stratigraphic sequence 7 is dominated by *Artemisia* and Chenopodiaceae totaling over 50% of the total identified palynomorphs, and indicating that the sequence was deposited in the second half of the year, which is not in contradiction with the gross seasonal assignment of this sequence to the Summer season (Tab.1). However, it is important to note that the pollen of *Artemisia* and Chenopodiaceae is among the most resistant to corrosion and will tend to be over

represented as a result of selective pollen destruction (Tomescu 2000a and references therein). Also, both these groups include numerous ruderal species which were very likely abundant in the strongly anthropogenic environment of the Gumelniţa settlement. These suggest that *Artemisia* and Chenopodiaceae pollen has potentially very high persistence in the sediment, in the particular context of the Gumelniţa deposits at Hârşova. This hypothesis is corroborated by the presence of this pollen, along with Poaceae pollen (another pollen type resistant to degradation), in all analyzed samples, often in high proportions. If we consider the fact the these three pollen types are at the same time some of the most easily identifiable even in advanced stages of deterioration, it becomes clear that the pollen of *Artemisia*, Chenopodiaceae and Poaceae very likely represents a background presence, often quantitatively important, in the palynomorph spectra at Hârşova throughout the year. This background noise will tend to be overrepresented particularly in samples characterized by poor palynomorph preservation and low taxonomic diversity, such as SS 7. These are strong enough reasons to ignore *Artemisia* and Chenopodiaceae pollen when assessing the seasonality signals of the coprolite pollen spectra at Hârşova (Poaceae have been already taken out of the equation as seasonality-uninformative).

In this improved perspective, the high percentages of *Quercus* (oak) and *Salix* (the only other seasonality-informative taxa) in SS 7 add some more resolution to previous seasonal interpretations, indicating that the sequence was deposited sometime during the Spring season. The spectrum of SS 11, strongly dominated by *Potamogeton* pollen (59%), is in agreement with the stratigraphic position of this sequence overlying SS 7, as well as with the initial assignment of SS 11, based on fish bones and coprolite distribution (Radu 2000; Tomescu et al. 2003), to the Summer season.

The spectrum of SS 18 is characterized by an overwhelming dominance of seasonality-uninformative taxa. Poaceae represent over half of the identified pollen, and together with the Chenopodiaceae and *Artemisia* account for 61% of the spectrum. The rest of the spectrum presents a relatively even distribution between other seasonality-uninformative taxa and taxa that bear conflicting seasonality signals. The next most frequent taxon, *Salix* (5.61% of identified palynomorphs) would indicate the Spring season, which is in contradiction with deposition after SS 11 and placement of SS 18 in the Summer season. Stratigraphic sequence 48 yielded a spectrum highly similar to SS 18 (Poaceae, followed by *Artemisia* and Chenopodiaceae totaling 58%, and *Salix* following with 6.41%), despite its initial assignment to a different season (Fig.1). Interestingly, along with SS 71, SS 48 has the highest participation of *Corylus* (hazel), *Alnus* (alder) and *Ulmus* (elm) (totaling 5.61% in SS 48 and 6.56% in SS 71), taxa that indicate the end of Winter-beginning of Spring, an interval not in disagreement with the gross seasonal assignment of SS 48, but neither in total agreement with the finer stratigraphic placement of the sequence.

The strong participation of *Salix* in SS 70 (61%, the highest percentage of any taxon in the studied samples) is indicative of the Spring season, as suggested for this stratigraphic sequence by the study of fish bones and coprolite distribution. However, SS 70 is directly overlain by SS 71, where *Salix* is completely absent and which is characterized by the highest amounts of somewhat earlier Spring taxa, *Corylus*, *Alnus* and *Ulmus*. This apparent stratigraphic inversion may be the result of limitations of stratigraphic resolution brought by the fact that some of the

stratigraphic units were thinner than the thickness of coprolites, which introduced a certain degree of uncertainty in the assignment of the latter to a particular unit.

## Conclusions

This pilot study shows that in the context of selective pollen destruction existing at Hârşova the pollen taxa resistant to degradation, persisting in the sediment for longer periods and more easily recognizable in advanced states of degradation, form a seasonality-uninformative background noise even in spectra that represent snapshots of the pollen rain, such as coprolites. This noise often reaches levels that mask signals borne by less abundant seasonality-informative taxa and therefore has to be subtracted when assessing seasonality based on pollen spectra. Even after subtraction of these taxa, the very short time interval of pollen rain recorded by coprolites, and the vagaries of the behavior of individual animals that produced the coprolites, are compounded leading to an uneven reflection of the pollen rain in coprolite pollen spectra. As a direct result, the power of resolution of these spectra in terms of seasonality varies over a broad range. In some (fortunate) instances (e.g., SS 7, 11, 70), ingestion by the coprolite-producing individual of high pollen quantities of taxa with strong seasonal significance, led to results consistent with the seasonal assignment provided by independent methods (fish bones, the stratigraphic distribution of coprolite concentration). In other instances (e.g., SS 18, 48, 71) the spectra show relatively even distribution of percentages between all taxa, some of which are seasonality-uninformative, while others indicate different and often conflicting seasons, conveying equivocal signals.

Although somewhat conflicting, the results produced by this study suggest that the palynology of coprolites can potentially be developed as a tool to resolve the seasonality of deposits where the stratigraphy is well constrained at high temporal resolution. The quality and significance of such analyses would be undoubtedly improved by better preservation of palynomorphs. Compounding of many coprolites for each of the stratigraphic intervals analyzed is recommended to minimize the effects of the individual behavior of coprolite producers. This would very likely ensure a better averaging of the pollen rain of the moment for each interval, improving the internal consistency of results within a given stratigraphic succession. The spectra obtained from coprolites also should be tested against palynomorph spectra of the sediments containing the coprolites, although these are more prone to contamination with recent material. More studies of this type, based on larger amounts of material and combining independent methods for assessing seasonality will undoubtedly lead to a better characterization of the potential of coprolite palynology and eventually to calibration of the method. Crucial in this context will be the experimentation with different data processing methods to identify the statistics that best emphasize seasonality signals borne by coprolite pollen spectra.

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| Season | Stratigraphic sequence | Stratigraphic unit | Palynomorph concentration (per g dry coprolite) | Identified palynomorphs (per g dry coprolite) | Counted palynomorphs | Unidentifiable palynomorphs (% of total counted) | Deteriorated palynomorphs (% of total identified) | Most frequent taxon (% of total identified) |
|---|---|---|---|---|---|---|---|---|
| Spring | 71 | 5113 | 145.24 | 46.35 | 47 | 68.09 | 86.67 | Chenopodiaceae (40.00) |
| Spring | 71 | 5259 | 29.75 | 22.19 | 63 | 25.40 | 51.06 | Chenopodiaceae (32.61) |
| Spring | 70 | 5209 | 17732.46 | 8899.07 | 540 | 49.81 | 84.87 | *Salix* (61.25) |
| Fall/Winter | 48 | 5207 | 541.84 | 320.65 | 681 | 40.82 | 49.50 | Poaceae (36.41) |
| Summer | 18 | 5315 | 2887.77 | 1699.48 | 1079 | 41.15 | 42.05 | Poaceae (50.48) |
| Summer | 11 | 5356 | 3643.64 | 1244.57 | 1335 | 65.84 | 69.15 | *Potamogeton* (59.16) |
| Summer | 7 | 5392 | 570.40 | 181.91 | 185 | 68.11 | 94.92 | *Artemisia* (30.51) |

Table 1. Hârşova-tell. Gumelniţa A2. C 521. Synopsis of palynomorph content of selected coprolite samples; season assignment based on Radu (2000), Tomescu et al. (2003).

| Taxa | SS 7 | | SS 11 | | SS 18 | | SS 48 | | SS 70 | | SS 71 | | SS 71 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SU 5392 | | SU 5356 | | SU 5315 | | SU 5207 | | SU 5209 | | SU 5259 | | SU 5113 | |
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| *Abies* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| *Picea* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Abies\|Picea* | - | - | 2 | - | 6 | - | 3 | - | - | - | - | - | - | - |
| *Pinus* | - | - | 1 | - | - | - | 2 | - | - | - | - | - | - | - |
| *Aristolochia* | - | - | - | - | 2 | 0.32 | 1 | 0.26 | - | - | - | - | - | - |
| *Nymphaea* | - | - | 9 | 1.99 | 2 | 0.32 | 3 | 0.77 | - | - | - | - | - | - |
| Ranunculaceae | - | - | - | - | 1 | 0.16 | 4 | 1.03 | - | - | - | - | - | - |
| *Ulmus* | - | - | - | - | 9 | 1.44 | 3 | 0.77 | - | - | 1 | 2.17 | - | - |
| *Cannabis* | - | - | 4 | 0.88 | - | - | 3 | 0.77 | 1 | 0.37 | - | - | - | - |
| *Urtica* | - | - | 3 | 0.66 | 3 | 0.48 | 3 | 0.77 | - | - | - | - | - | - |
| *Quercus* | 6 | 10.17 | 10 | 2.21 | 8 | 1.28 | 18 | 4.62 | 8 | 2.95 | 1 | 2.17 | - | - |
| *Betula* | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - |
| *Alnus* | - | - | 2 | 0.44 | 4 | 0.64 | 5 | 1.28 | - | - | 2 | 4.35 | - | - |
| *Corylus* | - | - | 2 | 0.44 | 8 | 1.28 | 10 | 2.56 | 1 | 0.37 | 1 | 2.17 | - | - |
| *Carpinus* | - | - | - | - | 8 | 1.28 | - | - | - | - | - | - | - | - |
| *Juglans* | - | - | - | - | 1 | 0.16 | 1 | 0.26 | - | - | - | - | - | - |
| Caryophyllaceae | - | - | 2 | 0.44 | 10 | 1.60 | 2 | 0.51 | 6 | 2.21 | - | - | - | - |
| Chenopodiaceae | 12 | 20.34 | 18 | 3.97 | 34 | 5.45 | 42 | 10.77 | 1 | 0.37 | 15 | 32.61 | 6 | 40.00 |
| *Rumex* | - | - | - | - | 9 | 1.44 | - | - | - | - | - | - | - | - |
| Rosaceae | 1 | 1.69 | 1 | 0.22 | 6 | 0.96 | - | - | - | - | - | - | - | - |
| Fabaceae | - | - | 14 | 3.09 | 23 | 3.69 | 15 | 3.85 | 7 | 2.58 | 2 | 4.35 | 1 | 6.67 |
| Rhamnaceae | - | - | 2 | 0.44 | 1 | 0.16 | - | - | - | - | - | - | - | - |
| *Vitis* | - | - | 9 | 1.99 | - | - | - | - | - | - | - | - | - | - |
| Apiaceae | - | - | - | - | 5 | 0.80 | - | - | - | - | - | - | - | - |
| *Hypericum* | - | - | - | - | 1 | 0.16 | 1 | 0.26 | - | - | - | - | - | - |
| Brassicaceaae | 5 | 8.47 | 4 | 0.88 | 27 | 4.33 | 26 | 6.67 | - | - | 1 | 2.17 | - | - |
| *Salix* | 3 | 5.08 | 10 | 2.21 | 35 | 5.61 | 25 | 6.41 | 166 | 61.25 | - | - | - | - |
| *Tilia* | - | - | 1 | 0.22 | 2 | 0.32 | - | - | - | - | - | - | - | - |

Table 2. Hârşova-tell. Gumelniţa A2. C 521. Palynomorph spectra of selected coprolite samples; taxa in shaded cells (representing long distance transport or with inconclusive spore-release periods) not included in the sums on which percentages are based.

| Taxa | SS 7 | | SS 11 | | SS 18 | | SS 48 | | SS 70 | | SS 71 | | SS 71 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SU 5392 | | SU 5356 | | SU 5315 | | SU 5207 | | SU 5209 | | SU 5259 | | SU 5113 | |
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| *Malva/ Althaea* | - | - | 1 | 0.22 | - | - | - | - | - | - | - | - | - | - |
| Other Malvaceae | - | - | 1 | 0.22 | - | - | - | - | - | - | - | - | - | - |
| *Gentiana/ Blackstonia* | - | - | - | - | 1 | 0.16 | - | - | - | - | - | - | - | - |
| *Lithospermum/ Cerinthe* | - | - | 4 | 0.88 | - | - | - | - | - | - | - | - | - | - |
| Other Boraginaceae | - | - | 6 | 1.32 | - | - | - | - | - | - | 1 | 2.17 | - | - |
| Lamiaceae | - | - | 2 | 0.44 | - | - | 2 | 0.51 | 1 | 0.37 | - | - | - | - |
| *Callitriche* | - | - | 2 | 0.44 | - | - | - | - | - | - | - | - | - | - |
| Solanaceae | - | - | - | - | 4 | 0.64 | - | - | - | - | - | - | - | - |
| Asteraceae asteroideae | 1 | 1.69 | 5 | 1.10 | 19 | 3.04 | 21 | 5.38 | 1 | 0.37 | 1 | 2.17 | - | - |
| Asteraceae cichorioideae | 6 | 10.17 | 5 | 1.10 | 25 | 4.01 | 6 | 1.53 | 2 | 0.74 | - | - | 2 | 13.33 |
| *Artemisia* | 18 | 30.51 | 12 | 2.65 | 32 | 5.13 | 42 | 10.77 | 1 | 0.37 | 7 | 15.22 | 2 | 13.33 |
| *Sagittaria* | - | - | 1 | 0.22 | - | - | - | - | 39 | 14.39 | - | - | - | - |
| *Potamogeton* | - | - | 268 | 59.16 | 3 | 0.48 | 1 | 0.26 | - | - | - | - | - | - |
| Liliaceae | - | - | 1 | 0.22 | 2 | 0.32 | 1 | 0.26 | - | - | - | - | - | - |
| *Allium* | - | - | - | - | - | - | 1 | 0.26 | - | - | - | - | - | - |
| *Muscari/ Asparagus/ Leucojum* | - | - | 1 | 0.22 | - | - | 1 | 0.26 | - | - | - | - | - | - |
| Cyperaceae | - | - | 7 | 1.55 | 9 | 1.44 | 2 | 0.51 | - | - | - | - | - | - |
| *Sparganium* type | - | - | 7 | 1.55 | 10 | 1.60 | 7 | 1.79 | 36 | 13.28 | - | - | - | - |
| *Typha latifolia* type | - | - | - | - | 1 | 0.16 | 2 | 0.51 | - | - | - | - | - | - |
| Poaceae | 7 | 11.86 | 39 | 8.61 | 315 | 50.48 | 142 | 36.41 | 1 | 0.37 | 14 | 30.43 | 4 | 26.67 |
| *Acorus calamus* | - | - | - | - | 1 | 0.16 | - | - | - | - | - | - | - | - |
| *Calla palustris* | - | - | - | - | 1 | 0.16 | - | - | - | - | - | - | - | - |
| *Pteridium* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| Monolete spores | - | - | - | - | 2 | - | 2 | - | - | - | - | - | - | - |
| Trilete spores | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - |
| Total | 59 | 100 | 456 | 100 | 635 | 100 | 403 | 100 | 271 | 100 | 47 | 100 | 15 | 100 |

Table 2 (continued).

| Taxon | Flowering/peak flowering period | | | | | | | | | % of total identified palynomorphs (from Table 2) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | February | March | April | May | June | July | August | September | October | SS 7 | SS 11 | SS 18 | SS 48 | SS 70 | SS 71 |
| *Corylus* | X | X | X | I | I | I | I | I | I | – | 0.44 | 1.28 | 2.56 | 0.37 | 1.64 |
| *Alnus* | I | X | X | I | I | I | I | I | I | – | 0.44 | 0.64 | 1.28 | – | 3.28 |
| *Ulmus* | I | X | X | I | I | I | I | I | I | – | – | 1.44 | 1.77 | – | 1.64 |
| *Salix* | I | X | X | X | I | I | I | I | I | 5.08 | 2.21 | 5.61 | 6.41 | 61.25 | – |
| *Carpinus* | I | X | X | X | I | I | I | I | I | – | – | 1.28 | – | – | – |
| *Quercus* | I | I | I | X | I | I | I | I | I | 10.17 | 2.21 | 1.28 | 4.62 | 2.95 | 1.64 |
| *Juglans* | I | I | I | X | I | I | I | I | I | – | – | 0.16 | 0.26 | – | – |
| *Lithospermum/Cerinthe* | I | I | I | X | X | I | I | I | I | – | 0.88 | – | – | – | – |
| *Vitis* | I | I | I | X | X | I | I | I | I | – | 1.99 | – | – | – | – |
| *Tilia* | I | I | I | I | X | X | I | I | I | – | 0.22 | 0.32 | – | – | – |
| *Potamogeton* | I | I | I | I | X | X | X | I | I | – | 59.16 | 0.48 | 0.26 | – | – |
| *Sparganium* type | I | I | I | I | X | X | X | I | I | – | 1.55 | 1.60 | 1.79 | 13.28 | – |
| *Rumex* | I | I | I | I | X | X | X | I | I | – | – | 1.44 | – | – | – |
| *Cannabis* | I | I | I | I | I | X | X | I | I | – | 0.88 | – | 0.77 | 0.37 | – |
| Chenopodiaceae | I | I | I | I | I | X | X | X | I | 20.34 | 3.97 | 5.45 | 10.77 | 0.37 | 34.43 |
| *Malva/Althaea* | I | I | I | I | I | X | X | X | I | – | 0.22 | – | – | – | – |
| *Artemisia* | I | I | I | I | I | X | X | X | X | 30.51 | 2.65 | 5.13 | 10.77 | 0.37 | 14.75 |

Table 3. Hârşova-tell. Gumelniţa A2. C 521. Flowering/peak flowering periods of taxa used as indicators of seasonality and their participation in the palynomorph spectra of selected coprolite samples.