

Palaeo-Ecological Aspects of Farafra Oasis (Egyptian Sabkha) During the Mid-Neolithic Period (7130–6190 BP): A Multivariate Analysis

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Abstract Studies have been carried out on carbonized plant macro-remains recovered from the Hidden Valley, a Neolithic settlement located on ancient playa shoreline deposits near Farafra Oasis, Egypt. Site contexts have been radiocarbon-dated to 7130–6190 BP. A total of 63 soil samples were collected the total volume of these samples is 81 l collected in two seasons (1996 and 1997), during which a total area of 61 m² was excavated. Soil samples were processed by dry-screening. Recovered plant macroremains were dominated by grains of wild grasses. Multivariate and correspondence analyses were employed to explore the temporal distribution of plant macro-remains and their relationship to archaeological features, including hearths, milling stones, and pot-holes. Two-Ways Indicator Species Analysis (TWINSPAN) of a data matrix of 40 samples × 36 taxa using density values resulted in the recognition of seven floristic groups. Canonical Correspondence Analysis (CCA) was used to examine the relationships between floristic groups and 18 archaeological variables. The highest densities of plant macro-remains characterised sections of the site that had been occupied by human Neolithic inhabitants for longer periods of time (horizons 1 and 2). The highest species diversity indices were that of pot holes, while sediments collected near milling stones had the lowest values. The study indicated that the playa deposition on the archaeological site provided a unique opportunity to preserve the botanical remains underneath. Reconstruction of the past vegetation around the Hidden Valley settlement

increased our knowledge on palaeoecological aspects of the Farafra Oasis during the Mid-Neolithic period.

1 Introduction

Early Neolithic human populations of the Eastern Sahara are known to have inhabited the shorelines of ancient playa lakes as early as 8,000 years ago (Wendorf and Schild 1980). Previous macro botanical studies in Nabta playa by Wasylikowa et al. (1995) have shed the light on their significance for palaeo-environmental studies in the Western Desert of Egypt. Remnants of these settlements are preserved today in playa deposits, such as those found at the site of the Hidden Valley located 65 km north of Farafra Oasis. Excavations conducted at this locality in 1996 and 1997 by Prof. Barbara Barich (University of Rome “La Sapienza”) have produced the remains of a permanent or semi-permanent Neolithic human settlement preserved in playa shoreline deposits. Long-term continuous occupation of this site is indicated by a deep stratigraphy (1 m), which revealed a clear succession of occupation floors containing many hearths. According to Barich (1996) radiocarbon determinations for the site have been done in Silesian Technical University, Gliwice, Poland, they are: 7030 BP (Gd-1170)/6910 BP (Gd- 9629) and 7130 BP (Gd-10505)/6710 (Gd-7820). Carbon dating was followed by radiocarbon laboratory number between practice for documentation. Also, she recognizes three horizons of occupation, all of which have produced notable traces of human activity, including rock-lined hearths, small pot holes, and milling stones. In 1996, 38 m² were excavated using a 10 × 10 m grid, and the work concentrated on the archaeological sectors 96 E

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and 96 F/1. In 1997, excavations were extended further east to cover sectors 97 E and 97 F trench, and a total area of 23 m² was uncovered. A corridor was cut in order to connect the eastern sector with the central area of the settlement, which contained circular structures used by Neolithic inhabitants as dwellings.

At present, the climate of this region is extremely arid. Precipitation records from 1969 to 1989 indicate a mean of 2 mm/year consequently the area around the Hidden Valley is completely devoid of plant cover. The present study aims at finding correlation between the distribution of the recovered plant macro-remains and the excavated archaeological features including hearths, milling stones and pot holes using multivariate analysis techniques. Another goal of the study is to reconstruct past vegetation around the site in question.

2 Materials and Methods

A total of 63 soil samples amounting to 81 l was collected from hearths, pot-holes, milling stone and living floors in 1996–1997. Hearths are spherical holes, about 40 cm in diameter and 20 cm in depth. The inhabitants used these features as primitive ovens. Pot holes are small depressions in which vessels containing food are placed for cooking by piling hot ash around them (Mitka and Wasylikowa 1995). Milling stones are rounded, concave, stony artefacts used to grind grains of wild grasses.

Quantities of individual soil samples ranged from 0.75 to 4.00 l. Ashy layers were targeted for the recovery of plant macro remains including, seeds, grains and culm fragments. All samples were dry-screened in the field using a 3 mm mesh to separate stones, potsherds, and charcoal fragments, after which they were transported in plastic bags to the laboratory. Although samples collected in 1997 were entirely examined, those excavated in 1996 were sub-sampled in 100 ml units using a 5 ml spatula. Each sample (or sub-sample) was sieved through 1.0 and 0.5 mm mesh sieves and preliminary sorting was completed using a binocular objective magnification (8–25 X). Plant macro-remains were examined in more detail using a Wild stereoscopic microscope with a range of magnification from 20 to 50 X. Identifications were made using descriptions and illustrations in publications concerned with the flora of Egypt (Täckholm 1974; Boulos 1999; Cope and Hosni 1991).

Some illustrations in these contributions are provided with drawings of spikelets, grains and seeds of living plants, which have been used by the first author to narrow the scope of identification into definite species or genera. On the other hand, illustrations, photos and descriptions of plant macro-remains from the Nabta playa by Wasylikowa (1992, 1997) and Wasylikowa and Kubiak-Martens (1995). According to Wasylikowa (1997) identification categories include the qualification “type” following plant name, which means that morphological resemblance to a taxon named but without excluding the possibility that similar fruits, seeds may be found in other taxa which were not examined by the first author. On the other hand, the abbreviation “cf” means closer identification than type. Identifications were confirmed through comparison with modern reference collections of Egyptian plants housed at the Department of Botany, University of Helwan, Cairo.

Two-Way Indicator Species Analysis (TWINSPAN; Hill 1980) a polythetic divisive classification method; was applied on a data matrix comprising 40 samples × 36 taxa using their density values. Here, density is the number of plant macro remains per liter of soil sediment retrieved from the archaeological site in question. TWINSPAN program was run using the default options, with the exception of the pseudospecies cut levels which were altered to: 0, 5, 10, 20, 40, 60 and 80. The computer program CANOCO 3.12 (ter Braak 1991) is used for all ordinations, and plots were drawn using CANODRAW 3.0 (Smilauer 1993).

Preliminary analyses were made by applying Detrended Correspondence Analysis (DCA) to check the magnitude of change in species composition along the first ordination axis (i.e., gradient length in standard deviation units). All default settings were used for CCA, except the samples scores that are the weighted averages of species scores. The variables in the CCA bi-plots are represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of change (ter Braak 1986) Each arrow determines an axis on which the species points can be projected (ter Braak and Prentice 1988). In general, these projection points estimate the optima of species distribution for each archaeological variable. Intra-set correlations were used to assess the importance of the archaeological variables. All data variables were assessed for normality prior to the CCA analysis (Berk 1994), and appropriate transformations were performed

when necessary to improve normality according to (Zar 1984) In total 18 archaeological variables were used: 4 archaeological artefacts (AF), including hearths (H), pot holes (PH), milling stones (MS) and corridors (C); and 13 depths below surface (D), including D₁ (10 cm), D₂ (15 cm), D₃ (20 cm), D₄ (25 cm), D₅ (30 cm), D₆ (35 cm), D₇ (40 cm), D₈ (45 cm), D₉ (50 cm), D₁₀ (55 cm), D₁₁ (60 cm), D₁₂ (65 cm), D₁₃ (70 cm), D₁₄ (75 cm) and D₁₅ (80 cm). We checked all archaeological variables for multicollinearity problems, and two depths: D₁₀ and D₁₅ are removed from the analysis. Monte Carlo permutation tests (99 permutations) were performed to test the significance of the first canonical axis.

The species diversity within each recognized floristic group was assessed using two indices expressing species richness and relative evenness of species abundance. Species richness was expressed as the average number of species per sample, while relative evenness was calculated using the Shannon–Wiener index ($H' = -\sum pi \log pi$) where pi is the relative density of the i -th species (Pielou 1975).

3 Results

Seven floristic groups (A–G) were recognized after the application of TWINSpan technique. Group A includes three samples dominated by *Sorghum* grains, and represent the corridor in sectors 97 E corridor and 97 F trench as well as a hearth in sector 97 E. It is. Group B comprised seven samples dominated by *Echinochloa* and *Setaria* grains belonging to sectors 97 E, 97 E corridor, 96 E and 96 F/1, and were all retrieved from hearths. Group C includes 13 samples, nine of which are dominated by *Setaria* while *Echinochloa* prevailed in four. Specimens originated from hearths and pot holes from sectors 97 E, 97 E corridor, 96 E and 96 F/1. Group D includes samples dominated by seed fragments of *Acacia* type, recovered from sectors 97 E, 97 E corridor and 97 F. Group E includes six samples dominated by grains of *Panicum* and *Sorghum*, and collected from hearths at 97 E, 97 F corridor and 96 E. Group F includes one sample that had fruits (siliqua) of *Coronopus* which was recovered from a hearth in sector 96 F/1. Group G had four samples clustered in this group, dominated by Leguminosae type-seeds. The sediments were excavated near a milling stone and from hearths in sector 96 F/1 and sector 97 E.

The highest densities of plant macro remains occur in sectors 96 E and 96 F/1, both of which were inhabited for longer periods than sectors 97 E, 97 E corridor and 97 F trench.

4 Discussion

The present study shows that plant macro-remains appear in higher concentrations in the stratigraphic levels 10, 25, 35, and 40 cm below surface. In particular, the remains of *Echinochloa*, *Setaria*, and *Brachiaria* appear to cluster at a depth of 40 cm (D₇). Stratigraphic levels 10–40 cm correspond to the first and second horizons of occupation recognized through artifactual evidence by Barich (1996). Consequently, densities of plant macro-remains appear to support the archaeological interpretation that the first and second horizons were occupied for a longer periods than others, perhaps due to the prevalence of favourable environmental conditions, such as summer rainfall associated with low temperatures.

The associations of macro-remains with archaeological features including hearths, pot holes, milling stones, and corridors. Grains of *Digitaria* and *Sorghum* are clearly associated with hearths at 10 cm below the surface (D₁). Perhaps these grains were deposited in the hearths as the result of cooking accidents. In addition, there is a high correspondence between the seeds of Cruciferae-type and *Schouwia* with recovered pot holes (AF₂). This pattern could suggest that these vessels were used to prepare foodstuffs, which included wild grasses and *Schouwia* seeds. There is another possibility that parts of these seeds could have been introduced into the deposits via being burned as ash for fuel.

The results of DCA indicate a reasonable segregation among groups along the ordination plane of axes 1 and 2. The eigenvalue for the first DCA axis 1 was relatively high ($\lambda = 0.675$), indicating that it captured the greater proportion of the variation in the taxa composition among the floristic groups. Statistical analysis of the samples under study reveal that wild grasses are highly represented in most of the studied samples. The 289 caryopses identified are attributed to 8 taxa: *Digitaria* type, *Sorghum*, *Echinochloa* cf. *colona*, *Setaria*, *Stipagrostis* type, *Brachiaria*, *Panicum* cf. *turgidum*, and *Cenchrus* type. In particular, *Sorghum*

grains show a highly significant p value (0.001), indicating that this taxon must have been a common plant in the area during the various periods of habitation.

Canonical correspondence analysis (CCA) was performed on 40 samples, 34 taxa and 16 archaeological variables. The eigenvalues for the first two CCA axes (1 = 0.395 and 2 = 0.350) indicate acceptable levels of separation of sample scores along the measured archaeological variables. The successive eigenvalues of the first three axes (1 = 0.395, 2 = 0.350 and 3 = 0.330) of the CCA decrease rapidly, suggesting a well-structured data set. In general, intra-set correlations are low.

Although medicinal uses of *Schouwia* species have considerable antiquity (Fahmy 1995), based on this evidence alone, it is not possible to argue convincingly that this species was used as a medicine during the Neolithic occupation of Hidden Valley. Indeterminate grains and milling stones (AF₃) are highly correlated (results not shown). This pattern could be attributed to the fact that grains are destroyed in the grinding process, making them difficult to identify to definite taxonomic categories.

The highest species diversity indices are recorded from pot holes while sediments recovered near milling stones show the lowest. Because of their association with cooking (Mitka and Wasylikowa 1995), it is not surprising that pot holes produced highest species diversity values. Possible sources of seeds in these features are foods lost during cooking as well as plant materials in the ashes used to heat the pots. The ash layer surrounding the pot holes would have provided a gentle charring environment where grains could fall into the hot ashes surrounding the vessels. In case of hearths, grains are more apt to fall directly into fire resulting in their destruction. This could explain the high number of taxa recorded from pot holes compared to hearths. The low species diversity indices of milling stones are attributed to the fact that grinding results in the deposition of fragmentary grains, making them difficult to identify. The relatively high number of species recorded from the corridor is probably related to the large quantities of soil samples (17 l) examined from this context.

5 Palaeo-Economic Interpretations

The recovery of several wild grasses from hearths, pot holes, and milling stones strongly suggests that

Neolithic inhabitants of the Hidden Valley gathered them for food consumption. The eight wild grasses identified in site deposits are: *Brachiaria*, *Cenchrus* type, *Digitaria* type, *Echinochloa colona*, *Panicum turgidum*, *Setaria*, *Sorghum*, and *Stipagrostis* type. Many of these taxa have been identified at other Saharan sites, and this, in addition to ethnohistoric evidence, further indicates the widespread use of these species by Saharan populations from ancient to recent times (Barakat and Fahmy 1999). *Sorghum* represents 41.5% of the total number of grasses identified in the Hidden Valley samples. The caryopses are well preserved by carbonization. They are dorsally flattened, obovate to oval elongate in outline, and some are still enclosed by coriaceous glumes. Morphologically, these *Sorghum* grains compare very well with those recovered from Nabta Playa (8,000 BP), Wasylikowa and Kubiak-Martens (1995), Wasylikowa et al. (1995) and Wasylikowa (1997) attribute the Nabta remains to *Sorghum bicolor* (L.) Moench. subsp. *arundinaceum* (Desv.) De Wet and Harlan, a species whose distribution extends across the African savanna (Wendorf and Schild 1980; De Wet 1978). Further investigations are underway to more precisely identify the Hidden Valley *Sorghum* grains. Neolithic inhabitants may have intensively collected its panicles for food due to its big grains in comparison to the associated wild grasses.

From an ecological point of view, the dominance of *Sorghum* during the Neolithic period is expected, as this grass is characterized by wide ecological amplitude due to its remarkable physiological features. *Sorghum* can cope with hot and dry conditions, and it is a high salt tolerance. Furthermore, it can withstand high rainfall, and even temporary water-logging. Its penetrating multi-branched roots are very useful to compete for water with other plants at different depths of the soil (National Research Council 1996).

The macro-remains of eight wild species are represented at Hidden Valley in relatively low frequencies: *Acacia*, *Coronopus niloticus*, *Juncus*, *Phragmites*, *Tamarix aphylla*, *Typha*, *Carex*, and *Cyperaceae* type. This assemblage of plants probably formed part of the natural vegetation in the vicinity of the site during the mid-Holocene. Although many of these wild plant remains have not yet been identified to the species level, some ecological inferences are possible. The relative profusion and assortment of the recovered specimens may indicate that regional plant cover was rich in species

and that compared to modern times, a much wetter environment was in existence during the Neolithic. Rainfall is estimated to have been between 100 and 250 mm annually during the wet phases of the early and middle Holocene (Neumann 1989). Also it is very interesting to note that the assemblage of wild grasses identified from the Hidden Valley are recorded in studies on recent vegetation of North and Central parts of the Sudan (Schulz 1988; Wilson 1978). These areas of the Eastern Sahara enjoys precipitation ranges between 100 and 250 mm (Walter 1979).

The present data indicate that two types of vegetation existed in the vicinity of the playa, one dominated by reeds and the other by thorny vegetation. Reed vegetation probably existed along the playa margins and may have experienced some fluctuation in water levels, but for the most part remained waterlogged throughout the year. *Typha* and *Phragmites* dominated this vegetation type. The wet fringes around the playa probably provided a favorable habitat for the growth of associated species, such as *Tamarix* and *Juncus*, as well as water loving species such as *Carex* and *Coronopus niloticus*. This reconstruction is based on modern vegetation analysis around water bodies (e.g. springs) in the oases of the Western Desert (Zahran and Willis 1992). Thorny vegetation probably occurred on the plain surrounding the playa. Trees of *Acacia* grew on the upstream sections of water runnels that dissected the plateau towards the playa. Several wild grasses including, *Digitaria sanguinalis*, *Sorghum*, *Echinochloa cf. colona*, *Setaria*, *Stipagrostis type*, *Brachiaria*, *Panicum cf. turgidum*, and *Cenchrus type* would have dominated the herb layer.

6 Conclusions and Recommendations

The present study provides archaeobotanical evidence on the relationship between man and their Neolithic environment in the Egyptian Sahara. Also, it increases our knowledge regarding economy and ecology of settlements, where, the settlers lived close to sabkhas collecting wild grasses and herding animals.

Results obtained from Nabta and the Hidden Valley (Fahmy 2001; Barakat and Fahmy 1999) add important dimension to the sabkha ecosystem research. Understanding the subsistence strategy of these early groups of people can be achieved only through archaeological and archaeobotanical studies.

References

- Barakat H, Fahmy AG (1999) Wild grasses as "Neolithic" food resources in the eastern Sahara. In: Van der Veen M (ed) The exploitation of plant resources in ancient Africa. Kluwer/Plenum, New York, pp 33–45
- Barich B (1996) Early to Mid-Holocene occupation at Farafra (Western Desert, Egypt): a social approach. The Italian Archaeological Mission in Cairo An official report to the Egyptian Antiquities organ pp 45
- Berk KN (1994) Data analysis with student SYSTAT Windows Edition. Course Technology, Inc. pp 595
- Boulos L (1999) Flora of Egypt, vol I. Al Hadara Publishing, Cairo, Egypt, pp 287
- Cope T, Hosni H (1991) A key to Egyptian grasses. Royal Botanic Gardens, Kew, London, pp 75
- De Wet J (1978) Systematics and evolution of *Sorghum* sect. *Sorghum* (Gramineae). *Am J Bot* 65(4):477–484
- Fahmy AG (1995) Historical Flora of Egypt. Ph.D. Thesis, Cairo University. pp 248
- Fahmy AG (2001) Palaeoethnobotanical studies of the Neolithic settlement in Hidden Valley, Farafra Oasis, Egypt. *Vegetation Hist Archaeobot* 10:235–246
- Hill MO (1980) TWINSPLAN – a fortran program for arranging multivariate data in an ordered two-way table of classification of individuals and attributes. Cornell University, Ithaca, NY, pp 90
- Mitka J, Wasylikowa K (1995) Numerical analysis of charred seeds and fruits from an 8000 years old site at Nabta Playa, western desert, south Egypt. *Acta Palaeobotanica* 35(1):175–184
- National Research Council (1996) Lost crops in Africa. National Academy Press, Washington, DC
- Neumann K (1989) Holocene vegetation of the Eastern Sahara. *The African Archaeological Review* 7:97–116
- Pielou EC (1975) Ecological diversity. New York: John Wiley. pp 165
- Schulz E (1988) Der Südrand der Sahara. *Würzburger Geographische Arbeiten* 69:167–210
- Smilauer P (1993) CANODRAW 3.0, user's guide. Microcomputer Power, Ithaca, NY, pp 118
- Täckholm V (1974) Student's flora of Egypt. Cairo University, Giza, Egypt, pp 888
- ter Braak CJF (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *J Ecol* 67:1167–1179
- ter Braak CJF (1991) CANOCO version 3.12. Agricultural mathematics group, Wageningen, The Netherlands, p 35
- ter Braak CJF, Prentice IC (1988) A theory of gradient analysis. *Adv Ecol Res* 18:271–317
- Walter H (1979) *Vegetation und Klimazonen*. Ulmer, Stuttgart, pp 342
- Wasylikowa K (1992) Exploitation of wild plants by prehistoric peoples in the Sahara. *Würzberger Geographische Arbeiten* 84:247–262
- Wasylikowa K (1997) Flora of the 8000 years old archaeological site E-75-6 at Nabta playa, Western Desert, southern Egypt. *Acta Palaeobot* 37(2):99–205
- Wasylikowa K, Kubiak-Martens L (1995) Wild sorghum from the early neolithic site Nabta Playa, S. Egypt. In: Kroll H, Pasternak R (eds) *Rescherches Archaeobotanicae*, 9th Symposium IWGP, pp 345–358

- Wasylikowa K, Schild R, Wendorf F, Krolik H, Kubiak-Martens L, Harlan JR (1995) Archaeobotany of the Early neolithic site E-75-6 at Nabta Playa, Western Desert, South Egypt (preliminary results). *Acta Palaeobotanica* 35(1):133-155
- Wendorf F, Schild S (1980) *Prehistory of the Eastern Sahara*. Academic, New York
- Wilson RT (1978) The "Gizu" winter grazing in the South Libyan Desert. *J Arid Environ* 1:327-344
- Zar JH (1984) *Biostatistical analysis*, 2nd edn. Prentice-Hall, Englewood Cliffs, NJ, pp 718
- Zahran M, Willis J (1992) *The vegetation of Egypt*. Chapman and Hall, London, pp 424