



A question of rite—pearl millet consumption at Nok culture sites, Nigeria (second/first millennium BC)

Louis Champion^{1,2} · Alexa Höhn¹ · Katharina Neumann¹ · Gabriele Franke¹ · Peter Breunig¹

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Abstract

The Nok culture in central Nigeria, dated 1500–1 cal BC, is known for its famous terracotta sculptures. We here present a study on > 11,000 botanical macro-remains from 50 sites, including 343 samples from Nok contexts and 22 samples dating between cal AD 100 and 400, after the end of the Nok culture. With 9,220 remains, pearl millet (*Cenchrus americanus* (L.) Morrone, syn. *Pennisetum glaucum* (L.) R.Br.) is dominant in the Nok samples, followed by cowpea (*Vigna unguiculata* (L.) Walp.), *Canarium schweinfurthii* Engl., *Nauclea latifolia* Sm. (syn. *Sarcocephalus latifolius* (Sm.) E.A.Bruce), wild fruit trees and wild Poaceae. The pearl millet remains consist exclusively of charred caryopses; chaff remains are completely absent. Because we studied all size fractions, including the small 0.5 mm fractions usually containing the involucre, bristles and husks, the absence of pearl millet chaff is real, excluding a methodological explanation, and distinguishes Nok from contemporary other West African sites. We propose that most excavated Nok sites were consumer sites where clean grain was brought in from outside and consumed in a ritual context connected with feasting. This is in line with the archaeological evidence from the larger excavated sites with stone-pot arrangements that are interpreted as ritual places related to mortuary practices. In addition to the known southward branches of pearl millet diffusion from the Sahara we propose a new, hitherto unknown branch directly from the central Sahara to the central Nigerian savannas.

Keywords *Pennisetum glaucum* · *Cenchrus americanus* · Archaeobotany · Crop processing · Feasting · Ritual context

Introduction

In West Africa, the second and first millennium BC were a dynamic period with substantial changes of settlement systems, economy, technology, and land use (McIntosh 2006; Watson 2010; MacDonald 2013; Neumann 2018; Kay et al. 2019; Breunig 2022). Due to increasing aridity, human occupation gradually shifted from the Sahara into the more humid areas of the West African Sahel, savanna and woodland zones, a development that had already begun in the

third millennium cal BC (Casey 2013; Ozainne et al. 2014). Only in a few areas of West Africa, long-lasting, coherent archaeological traditions, including material culture, settlement and socio-economic systems, have been studied for this period. The most distinctive are the Tichitt tradition of Mauritania and Mali (around 2000 cal BC; e.g. Fuller et al. 2007; MacDonald 2013), the Kintampo of Ghana (2100–1400 cal BC; Watson 2010), the Gajiganna culture of NE Nigeria (1800–800 cal BC; Breunig and Franke 2019), and the Nok culture of central Nigeria (1500–1 cal BC; Breunig and Rupp 2016; Franke 2016a). The Nok culture is unique and renowned because of its elaborate terracotta sculptures, which, however, were only made during a limited period after 900 cal BC, while the Nok culture in its entirety is defined by a continuity of ceramic styles between 1500 cal BC and the turn of the common era (CE) (Franke 2016b).

A common element of the four cultural traditions is the presence of pearl millet (*Cenchrus americanus* (L.) Morrone, syn. *Pennisetum glaucum* (L.) R.Br.) in the archaeobotanical assemblages (following recent molecular phylogenetic and taxonomic studies, the valid name of pearl millet is *C.*

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✉ Alexa Höhn
a.hoehn@em.uni-frankfurt.de

¹ Institute for Archaeological Sciences, Goethe University, Norbert-Wollheim-Platz 1, 60629 Frankfurt am Main, Germany

² Laboratoire Archéologie et Peuplement de l'Afrique (APA), Department of Genetics and Evolution, University of Geneva, Quai Ernest-Ansermet 30, 1205 Geneva, Switzerland

americanus (Sosef 2019; POWO 2022)) recovered from archaeological sites associated with each (D'Andrea et al. 2001; D'Andrea and Casey 2002; Klee et al. 2004; Fuller et al. 2007; Kahlheber et al. 2009). This is of considerable interest, given that the four cultural traditions developed far from each other in distinctly different ecological circumstances: Tichitt in the southwestern Sahara; Kintampo in the forest-savanna ecotone; Gajiganna in the floodplains of the Lake Chad area; and Nok in the Guinean woodlands of Nigeria. Pearl millet is also documented from many other archaeological West African sites dating between ca. 2600 cal BC and the turn of the common era (CE), and is often considered as a marker for the agricultural expansion during this period (Kahlheber and Neumann 2007; Ozainne et al. 2014; Neumann 2018; Kay et al. 2019). The overwhelming dominance of pearl millet in ecologically diverse West African sites of the second and first millennium cal BC suggests that, besides its role in subsistence, the crop likely had a broader socio-cultural significance.

Archaeobotanical studies in Europe and the Near East have highlighted the socio-cultural role of crops for community building, social distinction and ritual behaviour from the Neolithic onwards (Palmer and van der Veen 2002; van der Veen 2003; Asouti and Fuller 2013). These are usually based on detailed investigations of botanical remains in well-studied archaeological contexts and/or in established long-term sequences. To our knowledge, no such studies exist for the second and first millennium cal BC in West Africa. Even for the above-mentioned cultural traditions Tichitt, Kintampo, and Gajiganna, the archaeobotanical evidence is fragmentary. For Tichitt and Gajiganna, pearl millet remains are mainly known from impressions in ceramics (Amblard and Pernès 1989; Klee et al. 2004; Fuller et al. 2007; MacDonald et al. 2009). For Kintampo, there is only one site, Birimi, from which larger quantities of pearl millet can be safely attributed to complex archaeological features (D'Andrea et al. 2001; D'Andrea and Casey 2002). Given that archaeobotanical data, including pearl millet, from second and first millennium cal BC West African sites are often based on a limited number of samples, their interpretation is usually restricted to discussions of land use, subsistence, agricultural practices, and ecological conditions (Kahlheber and Neumann 2007; Neumann 2018; Kay et al. 2019; Champion 2020).

Studies of archaeobotanical remains from Nok sites, until now, have also focused largely on these issues. Since the first publications resulting from the Goethe University Frankfurt am Main research project (Kahlheber et al. 2009; Höhn and Neumann 2016), it was clear that pearl millet had been the major crop cultivated by the Nok people. However, the socio-cultural significance of pearl millet within the Nok culture remained unexplored. In part this was because archaeological features in excavated Nok sites often contain

material mixed from different time periods and because the majority of the excavations have been small, yielding only a few botanical samples. As research has progressed, subsequent analysis of some larger sites with complex archaeological features has provided insights into their function as ritual places (Breunig 2018; Höhn et al. 2018; Franke et al. 2020), enabling a wider, culturally nuanced interpretation of the archaeobotanical remains.

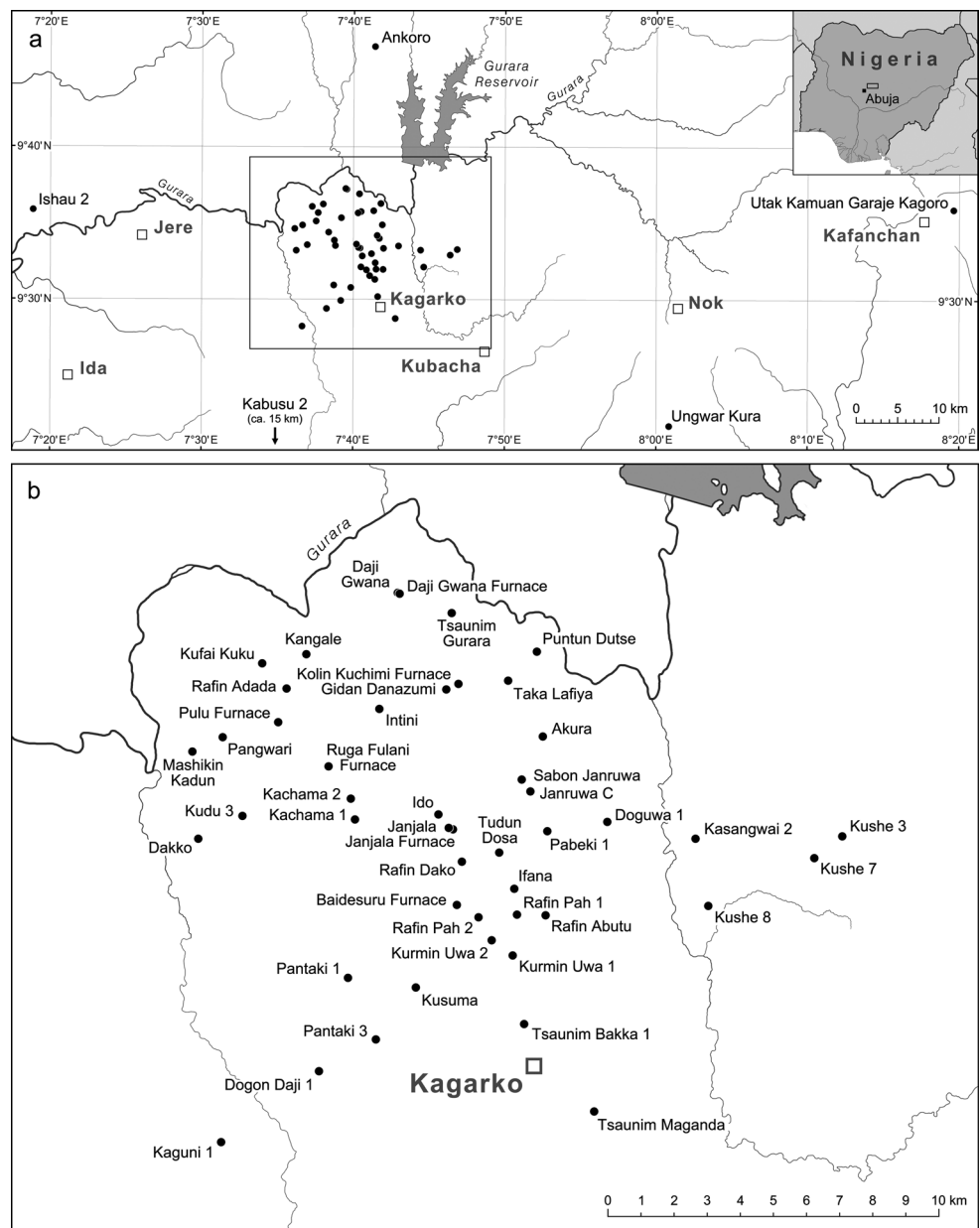
We here present an extensive study of > 11,000 botanical macro-remains from 50 sites in the main study region of the Frankfurt Nok project in central Nigeria (Fig. 1). Due to the large number of archaeobotanical samples and studied sites, our data are representative and, together with archaeological information on relevant find contexts and features, allow an interpretation of the Nok culture plant remains in a wider ritual and social context. The assemblages have been studied in depth, including in particular the analysis of the 0.5 mm fraction, not yet a routine in archaeobotanical studies in West Africa. As reviewed in Champion (2020), less than half of the published studies contain these analyses (e.g. Klee et al. 2000; Kahlheber 2004; Gijanto and Walshaw 2014; Champion and Fuller 2018a; Gallagher et al. 2018; Champion et al. 2021).

Environment, modern land use, and vegetation history

The Nok project study region lies between 9°27' and 9°37'N and 7°33' and 7°43'E in the Kaduna Plains, the hilly foreland of the Jos Plateau in the central Nigerian Kaduna state, covering an area of ~ 300 km². The landscape is slightly undulating, with plains, hills and granite outcrops of the Basement Complex (Bennett et al. 1979, p. 14), dissected by numerous, mostly seasonal rivers, except for the perennial Gurara (Fig. 1). The climate is highly seasonal, with the rainy season lasting from April to October, and mean annual rainfall being between 1,100 and 1,500 mm (Blair Rains et al. 1977). Mean annual temperature across the region is 27 °C, and mean annual humidity is between 50 and 60%, increasing to occasionally > 80% in the rainy season (Dalil et al. 2015).

Today most parts of this area are intensively cultivated, either in permanent fields or using a rotation scheme (shifting cultivation) with fields and fallows co-existing at various stages of this cycle. Presently the most important crops are yams (*Dioscorea cayenensis* ssp. *rotundata* (Poir.) J.Miège), manioc (*Manihot esculenta* Crantz) and maize (*Zea mays* L.) (Avav and Uza 2003), but also sorghum (*Sorghum bicolor* (L.) Moench), pearl millet, Bambara groundnut (*Vigna subterranea* (L.) Verdc., syn. *Voandzeia subterranea* (L.) Thouars), and cowpea (*Vigna unguiculata* (L.) Walp.). Cash crops include ginger (*Zingiber officinale* Roscoe), maize, peanut (*Arachis hypogaea* L.), and soybean (*Glycine max* (L.) Merr.). On poor soils, fonio (*Digitaria exilis* (Kippist)

Fig. 1 Sites with archaeobotanical analysis presented in this paper; **a** main study region (box) and sites outside of this area; **b** main study region



Stapf) is occasionally cultivated (Kahlheber et al. 2009), whereas on soils with a permanent water supply, rice (*Oryza sativa* L.) and sugar cane (*Saccharum officinarum* L.) may be found. Fulani herders with their cattle, sheep and goats exploit the harvested fields and fallows for grazing.

Floristically, the study region belongs to the Guinea-Congolia/Sudania regional transition zone (White 1983). Following the vegetation map of Keay (1953), it is located in the Southern Guinea vegetation zone. The natural vegetation of this region theoretically comprises a mosaic of dense woodland and dry forest (Jones 1963; Blair Rains et al. 1977). However, today only small relicts of this former environment remain due to intensive human impact. Instead, the modern landscape is dominated by cultivated

fields and fallows, partly loosely scattered with useful trees (Fig. 2a). Denser woody vegetation is mainly restricted to the river valleys.

Reconstruction of the vegetation during the Nok period is based on analysis of archaeological wood charcoal. Ubiquitous charcoal types such as ANOGEISSUS LEIOCARPA and CAESALPINIOIDEAE 1 represent dry forest as well as woodland. While taxa of secondary regrowth are present in some samples, there is currently no evidence of vegetation degradation throughout the Nok period (Kahlheber et al. 2009; Höhn and Neumann 2016; Höhn et al. 2018; Franke et al. 2020).



Fig. 2 Landscape and excavations at the Nok site Ido; **a** fields after harvest in dry season close to a village near the site; **b–d** typical Nok features as for example excavated at Ido: **b** stone-pot arrangement (feature 09–1) and deep pit (feature 09–5), **c** terracotta deposition with **(d)** adjoining vessel further below (feature 16–3)

Archaeological research on the Nok culture

The enigmatic terracotta figurines of the central Nigerian Nok culture have been known to the general public since the 1940s, but few archaeological excavations had provided information as to the primary contexts in which they were found (Fagg B 1968; Fagg A 1972). This changed with the beginning of the joint research project of the Goethe University Frankfurt am Main, Germany, and the National Commission for Museums and Monuments, Nigeria, in 2005. Since then, about 80 excavations have furnished archaeological and archaeobotanical material, and more than 270 radiocarbon dates have been obtained by the end of the project in 2021. Based on this evidence, the Nok culture is now understood to span a period of 1,500 years, beginning around the middle of the second millennium cal BC and terminating around the turn of the common era (CE). Three phases are discernible: Early Nok (1500–900 cal BC), Middle Nok (900–400 cal BC) and Late Nok (400–1 cal BC)

(Franke 2016a). The Middle Nok phase is considered the height of the Nok culture with the greatest spatial extent of sites, which are characterised by the abundant presence of terracotta figurines, remains of iron metallurgy, pottery, often in large quantities, and stone tools (Breunig and Rupp 2016; Franke 2016b; Männel and Breunig 2016). Based on pottery styles, the Middle Nok phase has been further divided into an early and later stage. The nature of the radiocarbon calibration curve plateau during the middle of the first millennium cal BC hampers absolute age indications, but it is suggested that the earlier phase covers the ninth and eighth centuries cal BC with the appearance of terracotta figurines, while the later stage may have begun as early as the mid-eighth century cal BC, featuring the first evidence of iron metallurgy not later than 550 cal BC (Junius 2016; Fagg Rackham et al. 2017; for phases and pottery groups see Franke 2016b). Early Nok sites or contexts are less numerous, but still well represented in the archaeological record, while Late Nok sites are rare and have little available archaeological and archaeobotanical material, indicating a rapid decline of the Nok culture after 400 cal BC.

Most Nok sites consist of a horizontal cultural layer, rarely thicker than 30–50 cm, which occurs in reddish soil below the disturbed brown-grey topsoil. Only pits reach deeper into the ground, sometimes down to 150–200 cm. Several excavated sites show evidence of multiple occupation episodes, usually through a mixture of Early Nok, Middle Nok and/or CE artefacts. No clear vertical stratigraphies or distinct settlement features such as house structures, ditches or hearths have been found (Breunig 2018). The only features are pits, terracotta depositions and stone-pot arrangements, the latter two occurring only in the Middle Nok phase (for examples of these typical features see Fig. 2b–d). The stone-pot arrangements are considered to be grave features based on the intentional placement of stones, complete vessels and stone beads and on the chemical analysis of soil samples by XRF detecting phosphorus (Franke et al. 2020, pp. 35–37). They are found in spatial proximity to terracotta depositions at sites interpreted as ritual sites or burial grounds (Franke et al. 2020). Pits are the most common feature, present in various shapes with diameters of 1–2 m and found at most Nok sites. However, even the pits may contain cultural material from different time periods. For example, Early Nok material present at a site may have got into the Middle Nok pits either during digging or refilling. In addition, furnace sites were documented. Iron-reduction furnaces often occur in groups, but artefacts other than slag, charcoal, or technical ceramics are generally rare (Junius 2016).

The complex settlement history with multiple occupation episodes, and the nature of features have been especially well examined at the site of Pangwari, the largest excavation of the joint research project (Höhn et al. 2018;

Franke et al. 2020). Here, the occupation history begins around 1500 cal BC and extends into the earlier Middle Nok phase, with CE material found on the surface as well. The Early Nok occupation is determined mostly by potsherds distributed across the entire site in the disturbed top layer (30–50 cm) and in some Middle Nok pits. Only one shallow pit was dated exclusively to the Early Nok phase. The Middle Nok occupation is represented by numerous pits, some stone-pot arrangements, and a terracotta deposition. The precise recording of each find and all features by total station allowed the plotting of detailed 2D and 3D find distributions and, consequently, the definition of several feature types. Pits are divided into deep and shallow pits and smaller find accumulations. They are the most common feature at Pangwari and it is assumed that most of them were not left open for a long period of time (Höhn et al. 2018). The terracotta deposition consists of several large terracotta parts and vessel fragments. Stone-pot arrangements are formed by several arranged natural and/or grinding stones and complete vessel(s) at their base; the surrounding soil is usually void of finds. So-called terracotta-pot placements found in some of the deeper pits are a sub-category. A stone circle, probably the foundation of a hut, and a possible hearth are features associated with the CE occupation (Franke et al. 2020). Deep pits occur in the context of terracotta depositions and stone-pot arrangements; all three feature types are considered to have ritual functions. The absence of typical settlement features such as hearths, house foundations or walls means that none of the Nok sites could be clearly interpreted as the remains of a settlement.

The pattern of repeated occupations and activity phases is visible at other excavated Nok sites and thus seems to be integral to any understanding of the Nok phenomenon. Individual pits and archaeological deposits frequently contain a mixture of Early and Middle Nok material (and sometimes CE material near surface in the disturbed topsoil). While a few undisturbed Early Nok features do exist, clear Middle Nok contexts are generally much more numerous. With the beginning of the CE, archaeological sites with Nok material disappear completely. New ceramic inventories, totally different in decoration, style and clay composition, and the absence of terracotta figurines (Beck 2016; Franke 2016a), in combination with a higher diversity of crops, then including fonio (*Digitaria exilis*), point to a population with different cultural preferences (Höhn and Neumann 2016).

Material, methodology and sampling

From 2006 to 2017, archaeobotanical soil samples (AB) were systematically collected during all field seasons. They varied in size between 2 and 45 L and were taken from features, especially pits, and from artificial excavation

layers. The average amount of soil collected was 9 L, with some smaller contexts, such as pots, being sampled in their entirety. The sediments were processed by bucket flotation using a sieve column with three different mesh sizes usually of 2.5, 1 and 0.5 mm. In addition, large fruits, seeds and charcoal fragments were handpicked during the excavation.

The flotation programme provided more than 400 soil samples of which 377, dating from the mid-second millennium cal BC to the first millennium cal AD, are presented here. 343 samples can be securely assigned to the Nok period (ca. 1500–1 cal BC), 12 samples are mixed with some later CE material, and 22 analysed samples date after the end of the Nok culture, between cal AD 100–400, including 14 from the site of Janruwa C (to be published in detail in the future). So, while most of the samples are clearly associated with either one of the three archaeological Nok phases, 71 samples come from mixed contexts, where archaeological material from different phases occurs together. These are categorized as mixed Early/Middle Nok (Mixed E), mixed Middle/Late Nok (Mixed L) and the Nok/CE contexts (Mixed CE).

Following the method described in Champion and Fuller (2018b), each sample was sorted by fraction (> 2.5 mm, 2.5–1 mm, 1–0.5 mm) and quantitatively analysed for charred plant remains with the aid of a low-power stereomicroscope (5–40×). Identification was achieved by comparison with specimens in the modern reference collections at the Laboratory of African Archaeobotany, Goethe University Frankfurt am Main and at the Institute of Archaeology, University College London. Photographs and descriptions of identifications from published literature were also used (e.g. Neumann et al. 1998; D’Andrea et al. 2001; Fuller 2003; Zach and Klee 2003; Kahlheber 2004; Fuller and Harvey 2006). It was impossible to identify all plant remains to species level, and thus some were identified to family level only, especially Poaceae and Fabaceae. “Plants of the World Online” (POWO 2022) was used as reference for taxonomically accepted names of the finds.

In archaeobotanical samples, remains of hardened pericarps are mostly found in a fragmented state, such as nutshells or endocarps (fruit stones), as with *Canarium schweinfurthii* Engl. and *Vitex* sp. For these taxa, we calculated their ‘Minimum Number of Items’ (MNI) by counting the number of fragments by fraction: Larger, characteristic fragments, with apexes and/or bases of *C. schweinfurthii* endocarps were counted as one item. In the 2.5 mm fraction, five smaller fragments without these characteristics were calculated as one item, while it took 15 fragments from the 1 mm fraction to calculate one item. Fragments from the 0.5 mm fraction were too small for identification and are listed as indet. fruit.

For the quantitative evaluation, the total number of items (seeds, fruit stones, chaff elements and calculated MNI) are counted in a list of taxa, from which tables of relative

frequency were constructed, and ubiquity was calculated. The relative frequency is the percentage of total items. The ubiquity is the number of samples in which a taxon is present as a percentage of the total number of samples. For each site, information on fragment counts per sample, and frequency and ubiquity calculations are provided in the ESM, together with the site's archaeological context and available radiocarbon dates (ESM 1).

Results

The archaeobotanical remains

Major carpological finds

Among the 343 Nok samples comprising 3,146 L of archaeological matrix from 50 sites, 50 samples were entirely devoid of macro-botanical remains, as was one from mixed CE contexts. In the remaining 293 Nok samples, 11,155 plant items were recovered, with an average density of 3.6 remains/L of floated soil (Table 1). The highest density was recorded for deep pits, with 7.4 finds/L, while densities below 1 were present in stone-pot arrangements ('burial') and furnaces. The most numerous taxa associated with the Nok period are *Cenchrus americanus*, *Canarium schweinfurthii* (incense tree) and *Nauclea latifolia* Sm. syn. *Sarcocephalus latifolius* (Sm.) E.A. Bruce (African peach). These represent 87.4% of the carpological data set.

Cenchrus americanus (L.) Morrone, pearl millet, Poaceae

Pearl millet caryopses (Figs. 3e–f, 4a–c) represent the most important macro-botanical item of the total Nok data set, with 9,220 remains, representing 83% of the Nok assemblages' remains. Pearl millet is also most ubiquitous, present in 81% of the Nok samples. In these samples, pearl millet evidence is exclusively composed of caryopses. Processing remains, such as bristles, involucre and spikelet bases, are totally absent. In the CE samples, by contrast, pearl millet is represented by caryopses and involucre. Among total 566 CE pearl millet remains in CE contexts, 521 remains are caryopses, while 45 are involucre, all of the latter present in Janruwa C (Table 1). While the ubiquity is even higher than in the Nok samples (95%), the frequency is comparatively low (12%).

Identification of the *C. americanus* caryopses is based on their morphology: broadly club-shaped in longitudinal view and circular in transverse view. The average breadth of the caryopses is 1.4 mm, with a range from 0.6 mm to 2 mm. There are no obvious size changes of the caryopses through the entire duration of the Nok period. The average Nok pearl millet caryopsis size is coherent with the

West African archaeobotanical data sets currently available (Fuller et al. 2021). One of the main archaeologically defined characteristics of pearl millet domestication is an obvious trend of increasing average caryopsis breadth. From 4500 cal BC to cal AD 1500, the average caryopsis breadth in West African sites increases from 0.8 mm to 1.7 mm, with a medium range of 1.1–1.5 mm during the 1500–500 cal BC period (Fuller et al. 2021 and references therein). The size of the Nok pearl millet caryopses thus falls within the range expected between 1500–500 cal BC when the crop was already fully domesticated. In addition, two size groups are conspicuous within the Nok pearl millet caryopses, forming a bi-modal distribution. The first group is composed of smaller caryopses ranging from 0.5 to 0.8 mm, while the second group has larger caryopses from 1.2 to 2 mm. A total of 2,382 caryopses were assigned to group 1, representing 26% of the Nok pearl millet, and 5,751 grains to group 2 corresponding to 62% (ESM 2 Table 1). Group 1 probably corresponds to the 'paired spikelets' that are only observable in domesticated forms of pearl millet. One of the characteristics of pearl millet domestication is the appearance of multiple spikelet involucre, usually in pairs. The paired spikelets lead to smaller grain size, and on the same panicle, the paired spikelet caryopses are generally smaller than the single caryopses (Fuller et al. 2021).

Canarium schweinfurthii Engl., incense tree, Burseraceae

A total of 1,328 *Canarium schweinfurthii* endocarp fragments (Fig. 4d–f) were found in 132 samples. With the ubiquity at 37% presence in all Nok samples, these remains are second to pearl millet. However, the frequency of estimated complete fruits (MNI=241) is small with only 2% (Table 1); an additional five items were recovered in mixed CE contexts. In the clear CE contexts *C. schweinfurthii* is absent.

The endocarp is elongated, 3–4.3 cm long, with a characteristic triangular shape in cross section. Identification is based on the presence of three strong ridges on its surface. The small ovate pores observed by D'Andrea et al. (2006) as criteria of identification are not always visible, and under low magnification, as with the naked eye, the endocarp surface appears smooth in comparison with those of other oil fruits (such as *Elaeis guineensis* and *Vitex* sp.), which usually are striated.

Nauclea latifolia Sm., African peach, Rubiaceae

Nauclea latifolia (Fig. 5) is less ubiquitous than *C. schweinfurthii*, but the second most frequent taxon after pearl millet with 291 seeds overall. In Nok contexts 266 seeds were counted, comprising 2.4% of the Nok assemblage, but with an ubiquity of only 9%. 24 seeds are in mixed CE contexts and one seed is present in the CE samples. The

Table 1 Summary of the archaeobotanical results of the flotation samples

Chronological context	Early Nok	Mixed E	Middle Nok	Mixed L	Late Nok	Nok Total	Mixed CE	CE
No. of samples	25	34	253	25	6	343	12	22
Vol. of soil (L)	332	240	2,243	260	55	3,146	84	168
No. of sites	8	5	39	3	3	50	6	5
<i>Cenchrus americanus</i> caryopsis (involucre)	846	312	6,952	1,074	36	9,220	146	521 (45)
Frequency/ubiquity	82/92	81/79	83/81	85/96	31/50	83/81	50/92	12/95
<i>Vigna unguiculata</i> seed	2		23			25		2
Frequency/ubiquity	0.2/8		0.2/4			0.2/3		0.1/9
<i>Sorghum bicolor</i> spikelet base							1	
Frequency/ubiquity							0.3/8	
<i>Digitaria exilis</i> caryopsis							65	3919
Frequency/ubiquity							22/17	82/68
<i>Nauclea latifolia</i> seed	25	1	176	5	59	266	24	1
Frequency/ubiquity	2/20	0.3/3	2/9	0.4/4	51/33	2.4/9	8/25	0.1/4
<i>Canarium schweinfurthii</i> endocarp	28	36	144	32	1	241	5	
Frequency/ubiquity	3/56	9/65	2/30	3/65	1/17	2/37	2/25	
<i>Elaeis guineensis</i> endocarp								5
Frequency/ubiquity								0.1/18
<i>Vitex</i> sp. endocarp	1	1	31	13		46	1	
Frequency/ubiquity	0.1/4	0.3/3	0.4/8	1/48		0.4/10	0.3/8	
<i>Celtis</i> sp. fruit stone				5		5		
Frequency/ubiquity				0.4/20		0.1/1.4		
<i>Digitaria</i> cf. <i>ciliaris</i> caryopsis			3			3		
Frequency/ubiquity			0.1/1			0.1/0.8		
<i>Eleusine indica</i> caryopsis			34	3	3	40		
Frequency/ubiquity			0.4/6.3	0.2/8	2.6/17	0.3/5		
<i>Brachiaria</i> type caryopsis			4	4		8		
Frequency/ubiquity			0.4/6.3	0.3/12		0.1/2		
<i>Poaceae species.</i> caryopsis	22	3	56	7	6	94	1	10
Frequency/ubiquity	2.1/16	1/9	0.7/7	0.6/28	5.2/33	0.8/10	0.3/8	0.2/9
<i>Spermacoce</i> sp. seed			3	1	3	7	1	
Frequency/ubiquity			0.1/1.2	0.1/4	2.6/17	0.1/1.4	0.3/8	
Indet. seed	4		153			157	1	
Frequency/ubiquity	0.4/4		1.8/5			1.4/4	0.3/8	
Indet. seed fragment	59	29	386	85	1	561	8	2
Frequency/ubiquity	6/32	8/15	4.6/28	7/28	1/17	5/26	3/25	0.1/9
Indet. fruit	6	1	44	22	7	80	5	1
Frequency/ubiquity	0.6/20	0.3/3	0.5/16	1.8/44	6/33	1/17	3/25	0.1/4.5
Undet. endocarp	3		8			11	5	
Frequency/ubiquity	0.3/8		0.1/1			0.1/1.4	3/25	
Total number	1,036	383	8,369	1,251	116	11,155	294	4,797
Density items/L	3.1	1.6	3.7	4.8	2.1	3.6	3.5	28

Total numbers, frequency and ubiquity of identified items summarized according to chronological contexts

fruit is an edible fleshy syncarp with hundreds of small flat-tish seeds (Fig. 5b). The seeds are about 0.6–1.0 mm long and 0.5–0.7 mm wide and show a distinctive reticulate pattern of the testa (Fig. 5c–e). These seeds have been present in several West African sites, but hitherto have remained

unidentified (e.g. Djoutoubaya, see Champion 2020). They are identical to the *Nauclea/Sarcocephalus*-type from the Inner Congo Basin (Neumann et al. 2022).



Fig. 3 Archaeobotanical remains, examples from Nok sites and one CE site; **a** *Vigna unguiculata* seed, Taka Lafiya, AB 407; **b** *Vigna unguiculata* seed, Ankoru, AB 512; **c** *Spermacoce* sp. seed, Kurmin Uwa 1 (AB 275); **d** *Elaeis guineensis* endocarp fragment, Janruwa C, AB 237; **e–f** *Cenchrus americanus* caryopses, Doguwa 1, AB 294,

e large caryopsis (Group 2, 1.2–2 mm), **f** small caryopsis (Group 1; 0.5–0.8 mm); **g** *Eleusine indica* caryopsis, Janjala, AB 18; **h** *Brachiaria*-type caryopsis, Ido, AB 189; **i** *Digitaria* cf. *ciliaris* caryopsis, Kurmin Uwa 1, AB 266; **k** *Digitaria exilis* caryopsis, Janruwa C, AB 237; **l** *Sorghum bicolor* spikelet base, Janruwa C, AB 214

Other carpological finds

This section describes the less frequent archaeobotanical finds, representing 12.6% of the total assemblage (1,428 items).

Vigna unguiculata (L.) Walp., cowpea, Fabaceae

The number of cowpea remains (Fig. 3a–b) recovered was very low, with only 27 seeds. The 25 seeds from Nok contexts comprise less than 0.2% of the botanical macroremains, present in only 8 samples (3% ubiquity). Two seeds were preserved within the CE assemblage. The cowpea seeds have flattish cotyledons, predominantly sub-rectangular in shape, but occasionally ellipsoid. The hilum is ovate and generally positioned asymmetrically on the longer side. The

seed coat was rarely preserved intact, and most of the finds consisted of a single cotyledon only. The measurements of 26 cowpea seeds (Table 2) shows that the Nok cowpeas are generally consistent in comparison with other available data from Burkina Faso, Ghana and DR Congo.

Digitaria exilis (Kippist.) Stapf., fonio, Poaceae

Digitaria exilis caryopses (Fig. 3k) were exclusively found in CE and mixed CE contexts. The 3,919 CE finds represent 82% of the CE finds but with 68% ubiquity are less constantly present than pearl millet (95%). The caryopses are 0.8–1.5 mm long and 0.4–0.7 mm wide. They are subglobose, with a round small hilum on the bottom of the ventral side and a round embryo on the dorsal side. The length of the embryo is less than 1/3 of the total caryopsis length.

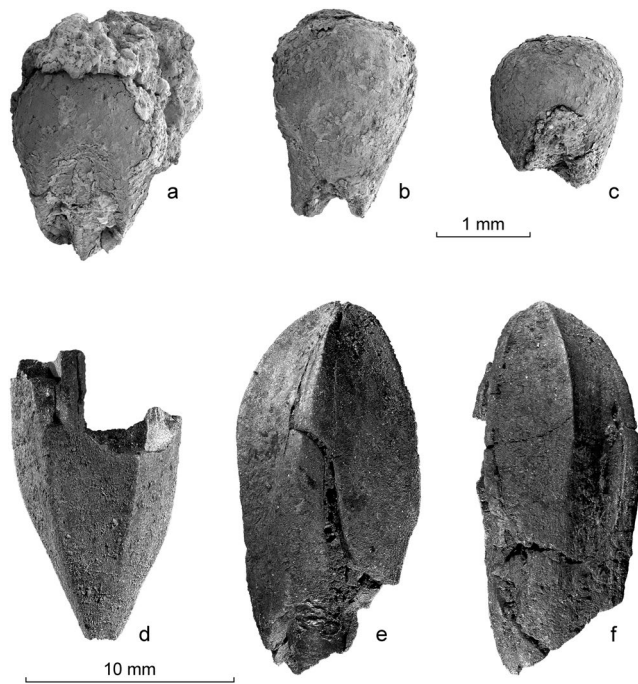


Fig. 4 SEM illustration of archaeobotanical material from Pangwari; **a–c** *Cenchrus americanus*, three charred caryopses, AB 1352, **a** dorsal position, **b** ventral position, **c** dorsal position; **d–f** *Canarium schweinfurthii*, two endocarps, **d** base (find no. 5133), **e**, **f** apex from two sides (find no. 5137) (adapted from Franke et al. 2020)

Only preliminary measurements of these caryopses were taken, as full analysis of the CE samples is still ongoing.

Digitaria cf. ciliaris, Poaceae

Three charred caryopses of *Digitaria cf. ciliaris* (Fig. 3i) were identified from three Middle Nok samples. The caryopses are ovoid, with a roundish embryo not exceeding more than half of the caryopsis length. The hilum is not visible.

Eleusine indica (L.) Gaertn., Poaceae

A total of 40 charred caryopses of *Eleusine indica* (Fig. 3g) were found in seven Nok samples. The caryopses are generally ellipsoid with a truncated apex and a triangular cross section composed of three longitudinal ridges running from top to bottom. The surface is formed of transversal striae and the furrows between them are covered with tiny granules. The hilum is roundish, with an elongated embryo cutting the caryopsis in two.

Brachiaria-type, Poaceae

Eight carbonized caryopses from seven Nok samples were attributed to *Brachiaria*-type (Fig. 3h). Most of the

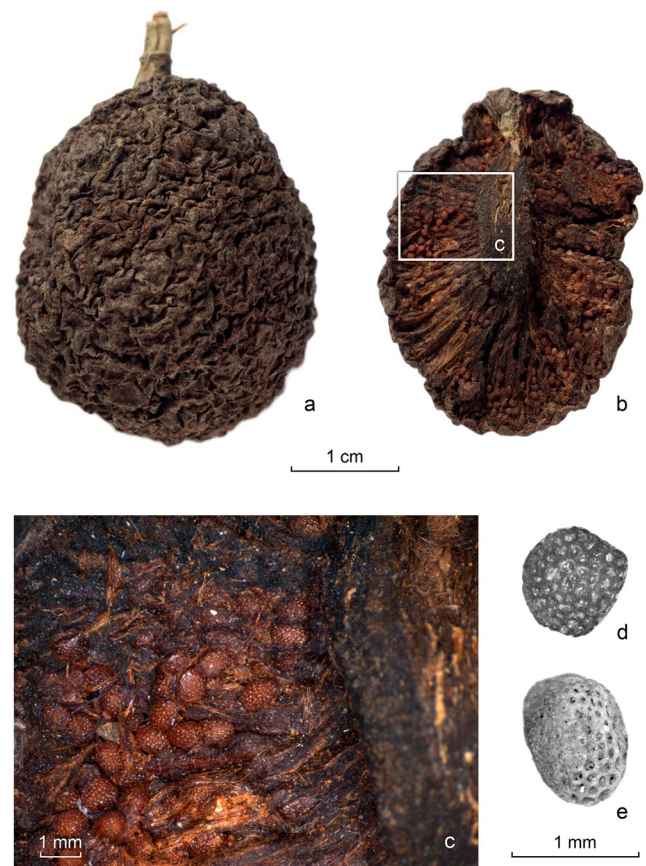


Fig. 5 *Nauclea latifolia*; **a–d** modern fruit and seed collected in Burkina Faso, **a** fruit in dorsal position, **b** fruit in longitudinal section, **c** close-up of the fruit section, **d** seed; **e** archaeological seed from Kurmin Uwa 2 (AB 268)

caryopses were partially damaged, only two were complete. The caryopsis' shape is oval, being broadest in the middle. The length of the scutellum is around half that of the caryopsis, with a small round hilum. All the caryopses recovered were unfortunately without glumes. The glumes facilitate identification of several key grass genera, enabling a more confident differentiation between *Setaria* sp., *Brachiaria* sp., and *Urochloa* sp. (Zach and Klee 2003). Thus, in the absence of glumes, classification as *Brachiaria*-type is based on the general shape of the caryopses.

Sorghum bicolor (L.) Moench., sorghum, Poaceae

Sorghum bicolor ssp. *bicolor* (Fig. 3l) was only attested in a CE context. The single torn rachilla, or spikelet base, indicates domesticated sorghum and likely comes from the dehusking process.

Table 2 Size ranges of *Vigna unguiculata* seeds from Early Nok, Middle Nok and Common Era assemblages in comparison with archaeological cowpea finds from DR Congo (Neumann et al. 2022), Ghana (D'Andrea et al. 2007) and Burkina Faso (Kahlheber 2004)

	Early Nok (n=2)	Middle Nok (n=23)	CE (n=1)	Iyonda, DR Congo	Kintampo B-sites, Ghana	Oursi region, Burkina Faso
Length (mm)	3.7–3.8	3.8–5.9	5.2	4.1–5.9	5.0–6.3	3.7–9.7
Breadth (mm)	2.2–2.24	2.1–3.7	3.2	4.0–5.3	3.6–4.6	2.4–6.6
Height (mm)	2.6	2.0–3.4	3.0	3.2–4.3	3.4–4.2	3.0–6.1
Length/height	1.4	1.50–1.90	1.7	1.2–1.9	1.5–1.6	0.9–2.1
Breadth/height	0.8–0.86	1.05–1.08	1.06	1.0–1.4	0.9–1.1	0.7–1.4
Length/breadth	1.68–1.69	1.6–1.8	1.62	0.9–1.4	1.4–1.8	1.0–2.3

Spermacoce sp., syn. *Borreria* sp., Rubiaceae

Seven charred seeds from Nok and Mixed CE contexts were identified as *Spermacoce* sp. (Fig. 3c). The shape of the seed is elliptical with a central longitudinal protuberance on one side. Following the description by Kahlheber (2004: vol 2, p. 201), the Nok *Spermacoce* sp. seeds correspond to the second type of her classification scheme.

Elaeis guineensis Jacq., oil palm, Arecaceae

A total of 15 endocarp fragments of *E. guineensis* kernels (Fig. 3d) were found in four CE samples from Janruwa C; they represent an estimated total of at least five items. The surface of the endocarp fragments is longitudinally striated with the characteristic network of vein-like reticulations, described by D'Andrea et al. (2006). A further single *E. guineensis* endocarp fragment was hand-picked during the excavation at Sabon Janruwa and was directly dated to 907–806 cal BC (see ESM 1), and thus to the Middle Nok phase. It attests the presence of oil palm in the environment during the Nok period, despite its absence from all flotation samples from Nok contexts.

Vitex sp., Lamiaceae

136 carbonised fragments of *Vitex* sp. from 33 samples were identified, representing a MNI of estimated 47 entire fruits, one in mixed CE contexts. The total frequency within Nok contexts amounts to less than 1%. Ubiquity is around 10%, comparable to that of *Nauclea latifolia* (Table 1). The endocarp shape of modern *Vitex* sp. is ovoid with a sub-acute apex with longitudinal furrows. The cross section of the endocarp shows four distinctive compartments. In the archaeobotanical samples, we found two categories of remains. The first one, comprising the majority of finds, consists of endocarp fragments with a longitudinal furrow on the outside; the other category comprises fragments of the acute apex showing the characteristic four compartments in cross section.

Celtis sp., Cannabaceae

Five charred endocarp fragments of *Celtis* sp. were identified from five samples, all from the Nok site of Ungwar Kura. The fragments are curved, suggesting a globoid shape of the endocarp. The surface is reticulate-foveate.

Poaceae species

105 charred Poaceae caryopses were recovered, ten finds coming from CE assemblages, one from mixed CE. In both Nok and CE chronological contexts, Poaceae species are present in low frequency, but in about 10% of the samples. In most cases, the base of the caryopsis was missing, and a more precise identification was not possible.

Unidentifiable (indet.) and unidentified (undet.) remains

The unidentifiable fruit and seed categories contain 86 carbonized endocarps, 158 seeds and 571 carbonized seed fragments. It was not possible to identify them due to the lack of reference material. 422 endocarp fragments (16 estimated items) were undeterminable, being too fragmented and damaged for any further identification. One large bean-shaped seed (Nok-1) from Pangwari (feature 2) remains unidentified. It is described and illustrated in ESM 2 Fig. 1.

Change through time

Nok period

The archaeobotanical assemblages do not show significant differences between the different phases of the Nok period. In all chronological contexts, pearl millet caryopses largely dominate in frequency as well as in ubiquity (Figs. 6, 7). This dominance clearly reflects the importance of pearl millet in all phases of the Nok period. While most of the samples are clearly associated with either one of the three archaeological phases, more than 60 samples come from mixed contexts, where archaeological material from different phases

Fig. 6 Frequency; percentage of items per taxon based on n = total number of items per chronological context

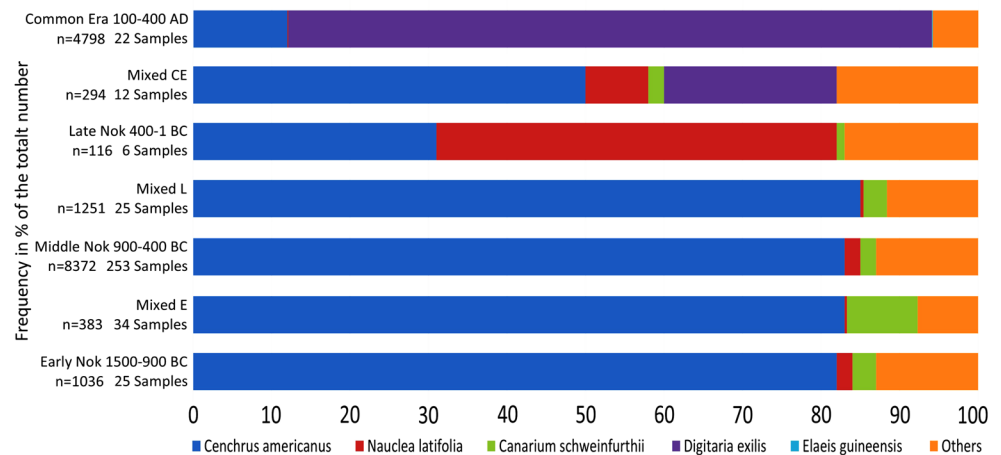
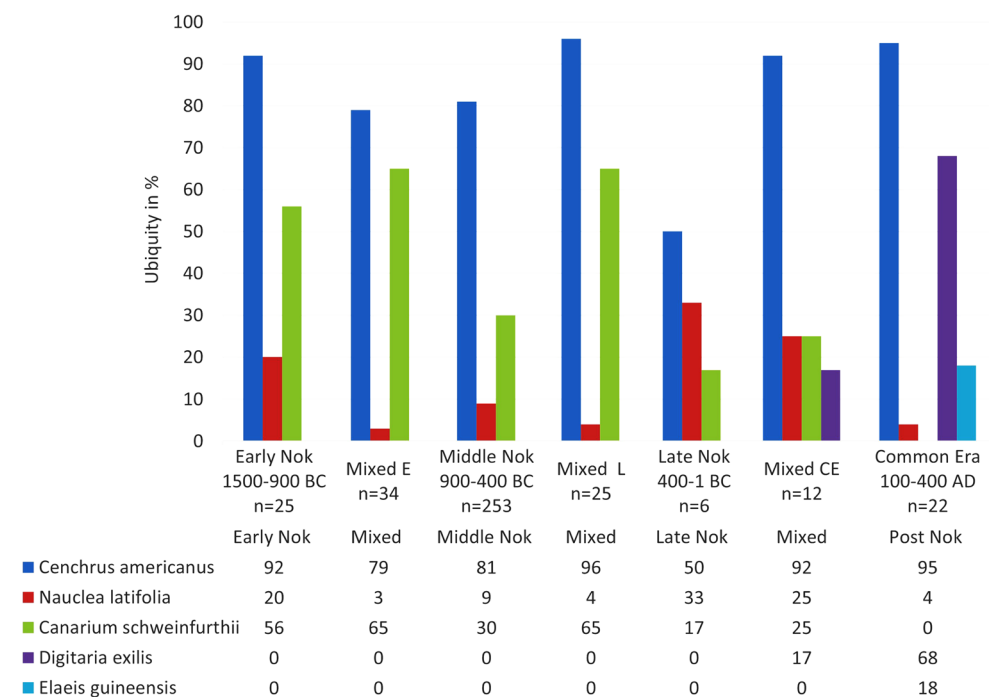


Fig. 7 Ubiquity of the five main species; percentage of samples per species based on n = total number of samples per chronological context



occurs together. With 254 samples, clear Middle Nok contexts furnished the highest number of samples by far, Early Nok contexts delivered only 25 samples and Late Nok just six (Table 1). Average find densities per phase lie between 1.6 and 4.8 items/L. Comparing frequencies and ubiquities per chronological context, it becomes evident that the plant spectra among the five major taxa remain quite similar. Only the Late Nok assemblage is dominated by *Nauclea latifolia* seeds with 51% instead of pearl millet (31%). This difference is also visible in ubiquity, where all chronological contexts show values between 79 and 96% for pearl millet, but pearl millet is only present in half of the samples of the Late Nok contexts. The reason for these peculiarities of the Late Nok assemblages is the small number of just six samples,

together with the high frequency of *N. latifolia* seeds in two samples from two sites (Dakko and Kaguni 1, see ESM 1). As described above, *N. latifolia* is a multi-seeded fruit, and the high frequency could well result from a few fruits, each with a large number of seeds.

Canarium schweinfurthii endocarp fragments are present in low frequencies, between 1 and 9% in the different chronological contexts (Table 1, Fig. 6). The ubiquity is medium (30–65%), but quite consistent, and lower only in the already discussed Late Nok contexts and in Middle Nok (Fig. 7). *N. latifolia* seeds usually are present in slightly lower or similar frequencies and in lower ubiquities than *C. schweinfurthii*, except for the Late Nok and Mixed CE contexts (Figs. 6, 7).

Vigna unguiculata is the only crop besides pearl millet attested in the Nok assemblage. Preserved only in some Early and Middle Nok contexts it represents 0.2% of the total frequency of Nok remains (Table 1). Overall the highest diversity of macro-remains is present in the Middle Nok phase: *Celtis* sp., *Vitex* sp. and various wild Poaceae (*Eleusine indica*, *Digitaria* cf. *ciliaris*, *Brachiara*-type) are found in contexts containing Middle Nok material, whether clean or mixed (Table 1). *Spermacoce* sp. is present in contexts with Middle Nok material and Late Nok contexts, while Poaceae species are present in all chronological contexts.

Common era

The CE assemblages are distinctly different from those from the Nok period. Table 1 shows the results of Janruwa C dating between cal AD 100 and 400 and from CE contexts at four Nok sites. The most noticeable, if not to say drastic change from Nok assemblages to the one at Janruwa C is the occurrence of fonio (*Digitaria exilis*). The 3,919 caryopses largely dominate the data set, with an overall frequency of 82% of the finds and are represented in ca. two thirds of the samples (Figs. 6, 7).

Another striking difference is that *C. americanus* involucres are present. They are lacking from all analysed Nok samples but occur in two thirds of the samples from Janruwa C (63% ubiquity), while absent in those mixed with Nok material ('mixed CE'). Compared to the Nok period, the frequency of pearl millet caryopses decreases to 12% but ubiquity remains high in CE contexts (95% of the samples).

Concerning possible plant oil sources, *Canarium* exploitation seems to have ceased. Instead, *Elaeis guineensis* endocarp fragments are present. Though frequency is low (0.1%), partly due to the high number of *Digitaria exilis* caryopses, the ubiquity of 18% indicates a regular presence and stands in stark contrast to the one oil palm endocarp from Nok contexts.

Another 'newcomer' in the CE contexts is *Sorghum bicolor* of which a single spikelet base was present in one sample from Janruwa C. Another difference between Nok and CE contexts is the find density. The highest density in Nok contexts of almost five items per litre of sediment was present in the mixed Middle/Late Nok samples. With 28 items/L, density in CE contexts is at least five, but in general about eight times higher than that of Nok contexts.

Discussion

Pearl millet caryopses and chaff—the evidence of absence

Two features of the Nok archaeobotanical assemblages are especially remarkable: 1) pearl millet is dominant (with 83% overall frequency) and there are only few other plant remains; 2) pearl millet is exclusively represented by caryopses, while chaff remains separated during the initial processing after harvest, such as involucres, bristles, and husks, are completely absent. We do not believe that this absence is related to biases in charring or post-depositional process, but rather indicative of some specific cultural activities regarding the processing of pearl millet.

The striking absence of pearl millet chaff in the samples is unlikely to result from methodological bias, and instead seems to be real evidence of its absence at the sites. For each sample, the small fractions (0.5–1 mm) were carefully sorted and analysed. These small fractions contain small pearl millet (0.5–0.8 mm) and other small Poaceae caryopses of similar size, but neither involucres, nor bristles and husks. This stands in contrast to the assemblage of the CE site of Janruwa C in the Nok region, as well as other West African archaeobotanical assemblages, where after sorting and analysing the small fraction, pearl millet chaff remains (around 0.5–0.8 mm in size) are usually found (see Gallagher et al. 2018; Champion 2020). It therefore seems that pearl millet caryopses entered the sites *after* the initial stages of crop processing, i.e. threshing and winnowing, had already been conducted elsewhere.

Several different plant parts are good indicators of post-harvest processing of a crop. After the harvest, the aim of processing is to separate the edible parts of the plant from the inedible, to liberate the grain from the chaff (Hillman 1984; Harvey and Fuller 2005; Fuller and Stevens 2009). For pearl millet, this involves a combination of pounding/threshing and separation by winnowing and/or sieving. In West Africa, pearl millet is currently often harvested and stored in granaries as whole panicles (Jolly 2004; Douny 2014; Champion 2020). From the storage, the panicles are processed into clean grain on a daily or weekly basis. The chaff, including bristles, involucre bases and husks, is separated from the grain during the threshing and winnowing steps. As observed by the authors today in West Africa, these steps result in large amounts of chaff waste in the house and village vicinities. When processing is conducted within the household, the chaff is often deposited by burning within house fires, after which it ends up on middens and/or in rubbish pits (Douny 2014; Champion 2020). In this case, the archaeobotanical assemblage contains chaff remains with some caryopses. The

fact that Nok pearl millet remains exclusively consist of caryopses implies that the crop was processed in a way clearly different from the procedures described above. The absence of chaff in the Nok assemblage thus indicates a different organization of crop processing activities. This implies that pearl millet arrived within all Nok sites as clean grain already processed. The homogeneity of the archaeobotanical assemblages throughout the whole period of the Nok culture suggests that these routines and organization were deeply embedded within Nok society.

Nok sites as consumer sites

The arrival of clean pearl millet grain on Nok sites suggests that these sites functioned as consumer sites, places where larger quantities of grain were handled in bulk for consumption and where grains were consumed but not processed. Within a limited area, clean grain can be generated in satellite farming settlements, processed in a central settlement and then redistributed and consumed in households or at sites with special function. This has been suggested for Iron Age and Roman sites in Britain, where the presence of clean grain assemblages has led to the identification of consumer sites (Stevens 2003; van der Veen and Jones 2007; Fuller and Stevens 2009). Aspects of these models can be transferred to pearl millet at Nok sites. Like free-threshing wheats in Europe, the threshing of pearl millet results in naked grain that does not need further processing before being cooked as whole grain or ground to flour.

Ritual context and feasting

In line with the archaeological data suggesting the interpretation of at least several Nok sites as places with a ritual function (Franke et al. 2020), the exclusive presence of clean grain might point to special activities, such as feasting. This becomes most evident at the intensively studied site of Pangwari (Höhn et al. 2018; Franke et al. 2020). At Pangwari, the association of grave features with terracotta depositions clearly indicates a ritual use of the site. Although the majority of the Nok sites have not been excavated in such detail and often provide no archaeological evidence for a ritual context, the homogenous assemblage of plant remains with dominant pearl millet caryopses suggests that many sites may have had a similar function. People came from their settlements to these sites to bury their dead and carry out ceremonies/rites. The use of clean grain might have been pragmatic, to reduce the bulk transported from the settlement to the ritual sites. However, it also might have acted to emphasize the separation between the sacred place and the profane settlement, making it mandatory to bring clean naked grain to avoid any contamination. We suggest that the Nok people were coming with fully threshed, naked pearl

millet grain on a regular basis to celebrate (mortuary) rituals, connected with feasting.

The low diversity of the archaeobotanical assemblages is another argument for non-settlement functions of most excavated Nok sites. In contemporary West African settlement sites of the second and first millennium cal BC, e.g. in Burkina Faso (Kahlheber 2004), Mali, Benin (Champion 2020), and the Nigerian Chad Basin (Klee et al. 2000, 2004), the diversity of useful plants in the assemblages is much higher than at Nok sites. We expect this pattern for settlements where everyday activities were practised, associated with archaeological features, like houses and hearths, creating a species-rich ‘settlement noise’. Specialized plant use at ritual sites, on the contrary, is more likely to create ‘depleted’ archaeobotanical assemblages, such as the ones with the absolute dominance of clean pearl millet grain at the Nok sites. The other archaeobotanical finds point into the same direction. Fruit remains from wild trees are present only in very low frequency and ubiquity in the Nok sites, possibly resulting from local gathering activities during the duration of a ritual.

The regular presence of grinding stones at the sites and even as part of stone-pot arrangements would support on-site preparation of pearl millet rather than bringing along already prepared food for feasting (see below regarding food preparation at Nok sites). Organic residue analysis has shown that the vessels deposited in terracotta depositions or stone-pot placements were used for cooking, probably more than once (Dunne et al. 2022). Otherwise, no detectable levels of organic residues would be present. Supposedly, the use of such vessels was not limited to feasting events. They may have been in everyday use before being deposited in a grave.

We may also interpret the deep pits in Nok sites as refuse pits connected to feasting. Not only do they have the highest density of finds among all Nok archaeological contexts, but they also contain exceptionally high numbers of pearl millet caryopses, like Ido, feature 9 (ESM 1). The connection to feasting is also corroborated by wood charcoal and ceramic assemblages pointing to rather quick refilling (Höhn et al. 2018; Franke et al. 2020). This speaks against refuse pits in a domestic context, as for instance discussed for West Central Africa (de Saulieu et al. 2017). In the ethnographic record, one special attribute of feasting is the unusual consumption of copious quantities of food and/or drink, often resulting in large waste deposits (Twiss 2008, and the references therein). Comparative archaeological examples for deep pits connected with feasting are known for example from the Near Eastern Neolithic (e.g. Goring-Morris and Horwitz 2007; Bangsgaard et al. 2019), where they are associated with concentrations of animal bones as waste from extensive meat consumption. Whether the Nok people consumed large quantities of meat during feasting remains a speculation as no bones are preserved in the acidic soils of the Nok area.

In modern Africa, feasting is usually associated with large amounts of food consumed by groups of extended family and neighbours (Griaule 1948; Dieterlen and Calame-Griaule 1960; de Garine 1997; Jolly 2004). In this context, it is often not special foods and luxury goods which are offered, but rather a larger amount of the food that is usually consumed every day. The high ubiquity and frequency of pearl millet in Nok sites thus point to pearl millet as a staple or at least an important part of the diet.

The homogeneous composition of the archaeobotanical assemblages, showing no major variation over time, space and context throughout the Nok period, with the overall dominance of clean pearl millet grain, suggests that Nok archaeological sites excavated by the project were primarily funeral feasting places and as such sacred sites. This does not exclude the existence of profane settlements, which, however, are difficult to detect given the lack of typical settlement features as mentioned above. Many excavations were small and did not reveal distinct features related to rituals. The project's focus on excavating sites where terracotta figurines had previously been recovered might possibly have led to a bias in the types of sites that are known from the Nok culture. However, given some 15 years of survey and excavation without clear evidence of settlement sites, we suggest that the bias is related more to the nature of Nok sites and/or the taphonomy of preservation than to survey methods. We propose that the people of the Nok culture were living in a dispersed settlement system formed of small entities of few dwellings that have not left clear visible traces in the archaeological landscape (Breunig and Rupp 2016; Breunig 2022). Consequently, most excavated sites may have been detected because of the larger amount of remains, especially terracotta parts and pottery, indicative of ritual/feasting sites.

The ritual context of Middle Nok terracotta deposits and associated stone–pot arrangements and deep pits is quite convincing and offers a plausible explanation for the presence of clean pearl millet grain. However, the presence of clean pearl millet grain in all of the few Early Nok contexts excavated (as in Ankoro 1, Doguwa 1, Kachama 2, Pangwari and Puntun Dutse, ESM 1) needs to be discussed separately since no terracotta figurines nor features related to rituals are attributed to the Early Nok phase. Terracotta figurines first appear around 900 cal BC with the beginning of the Middle Nok phase. Except for a couple of shallow pits at Pangwari featuring Early Nok pottery and respective radiocarbon dates (Höhn et al. 2018; Franke et al. 2020), no clear Early Nok contexts have been identified. At Pangwari, the interpretation of the Early Nok occupation as settlement activity relies mainly on the ubiquitous presence of Early Nok pottery across the entire site. The remains of a stone circle at the Early Nok site of Puntun Dutse have been interpreted as the remains of a dwelling (Rupp 2014). Whether it is related to the Early Nok occupation at the site or much younger

in age remains unclear. The presence of clean pearl millet grain in Early Nok sites, in line with the interpretation of Middle Nok sites, suggests a similar interpretation of feasting in a ritual context during the Early Nok phase as well. Yet, no supporting archaeological evidence has been found. Either, the Middle Nok ritual contexts have a predecessor in the Early Nok phase, but without terracotta figurines (and instead possibly with objects of perishable materials no longer visible in the archaeological record), or the presence of clean pearl millet has another, more profane explanation based on a particular way of storing and processing pearl millet outside of settlements, not common in other parts of West Africa. Either way, the homogeneous composition of archaeobotanical remains between Early and Middle Nok sites is another line of evidence for the continuity in cultural development from the mid-second millennium cal BC to the last centuries cal BC.

The record for ritual consumption of clean pearl millet grain in the Nok sites constitutes the oldest archaeological evidence for feasting in Africa so far. Feasting and its archaeological correlates are a common theme in archaeology (e.g. Hayden and Villeneuve 2011; Kassabaum 2019). In West and East Africa, several archaeological sites have delivered data from plant and animal remains, pottery and special contexts that can be interpreted in terms of feasting (Fleisher 2010; Walshaw 2010; Gijanto and Walshaw 2014; Gokee and Logan 2014; Monroe and Janzen 2014; Dueppen and Gallagher 2021; Dueppen 2022), but all of them are younger than 2,000 years. The clean pearl millet grain of the Nok sites shows that the tradition of feasting connected to mortuary practices, so important in modern Africa (Jindra and Noret 2011), is deeply rooted in the past, going back to at least 1500 cal BC.

Alternative interpretations

IF we assume that at least some of the excavated Early and Middle Nok sites were settlements and not ritual sites, another explanation for the exclusive presence of clean pearl millet grain would be necessary. Based on this premise, the absence of chaff would then reflect a system of crop storage and processing, for example storage and threshing near the fields and as such outside of the settlements and away from household fire, or threshing in bulk in the field, directly after the harvest, with only the clean grain stored at the settlements. In West Africa today, such storage of clean grain is rather the exception, but described for instance for the northern highlands of Cameroon (Seignobos 2005). Other than that, processing in the field may become necessary when the fields are located too far from the settlements. Bringing whole panicles from the bush-fields back to the settlements may be regarded as too costly in terms of labour invested. An ethnographic example are the Hausa of northern Benin,

whose fields are sometimes far from their homesteads, forcing them to thresh in the fields (Champion 2020, p. 225). As they are latecomers in northern Benin, the Hausa only cultivate fields that are more marginal, and often not near their villages. However, it is less likely that the people of the Nok culture needed to practise this method since we assume that they were the first agriculturalists in the area, and that their fields were in close proximity to the settlements.

Post-harvest processing in the field can be less visible for another reason in archaeobotanical assemblages. Threshing in the field, prior to the storage of the crop, is usually conducted only once or twice a year during a limited period. The waste generated from this will rarely be preserved in archaeobotanical assemblages in comparison to waste from those activities carried out every day (Stevens 2003). Threshing in the field implies inter-household or village cooperation, with the mobilization of a workforce, comprising larger parts of the inhabitants during the harvest season. As already pointed out, there is no archaeological evidence of complexity at Nok sites, such as larger nucleated population, central settlements, granaries, social hierarchy, functional and social differences, or specialized economy (Breunig and Rupp 2016; Franke et al. 2020). Even terracotta production was not centralized (Beck 2016). Yet, the very similar style of the terracotta figurines speaks for strict rules and regulations in the production and possibly the use of the figurines and thus for a society with a common ritual system and continuous contact between the individual groups living together. Such a society would have been able to organise large threshing events, if necessary.

Another interpretation of the data is based on the assumption that sites with and without chaff differ in social and economic organisation (compare Valamoti 2005), or in social status, where a particular segment of a society was receiving clean grain. Archaeologically speaking, this might imply that we excavated and sampled only sites related to a specific part of the society, perhaps higher status households, but there is no further evidence to support this idea. If society was structured in this way, at least some samples/sites should show a different archaeobotanical signature, either with chaff or with additional plant species. This is not the case, and it seems very improbable that 377 botanical samples from 50 archaeological sites should record the same part of a segmented society.

Food preparation at Nok sites

We suggest that the clean grain was prepared on site for food; otherwise, the large amounts of carbonized caryopses would not be explicable—except if they were burned as an offering. Given the large quantity of grinding stones usually present at Nok sites (Rupp 2014; Breunig and Rupp 2016), we assume that preparation included grinding of

the grains to flour, to be cooked afterwards in pots as porridge, or as a malted flour for beer. Today, preparation methods of pearl millet also include deep-fried pancakes and couscous blended with pulses, besides the more common thick porridge or thin-fermented porridge, and fermented and non-fermented beverages (Jolly 2004; McCann 2009; Champion 2020). Based on the evidence at hand, it is not possible to state definitively what type of pearl millet product was consumed. Phytolith analyses of five grinding stones from the site of Ungwar Kura showed that only two contained grass short cell phytoliths that might result from the processing of Poaceae, including pearl millet (Radomski and Neumann 2011; Radomski unpubl. laboratory report). This does not speak against the general use of the stones for processing pearl millet. It must be considered that grass short cell phytoliths are present only in the culms, leaves and husks of cereals, while the clean unhusked caryopses are completely free of them. If only clean grain was processed on the stones, it would not leave any significant phytolith signature. We therefore assume that the association of large grinding stones and clean pearl millet grain at the sites is an indication for this type of processing. Processing of pearl millet and other grain crops with large grinding stones is ethnographically well documented in West Africa (Jolly 2004; Zurro et al. 2005; McCann 2009).

The chemical study of food residues in Nok ceramics shows several different lipid profiles, pointing to the processing of animal products, honey and/or beeswax, possibly underground storage organs, such as tubers, and numerous different plant species and plant parts, indicating more diverse foodstuff than reflected in the archaeobotanical samples alone (Dunne et al. 2021, 2022). Pearl millet cooking would not leave any unequivocal chemical signal, but there is evidence in some pots for enriched $\delta^{13}\text{C}_{16:0}$ and $\delta^{13}\text{C}_{18:0}$ values, pointing to an origin from a plant with a C_4 photosynthetic pathway. Because of its ubiquity in the archaeobotanical assemblage, we deem pearl millet the most probable candidate for the C_4 -plant signal, even more so since the remaining candidates in the surroundings of Nok sites that might have been processed in the pots are mostly C_3 -plants (herbs, leaves and fruits from trees etc.).

Origin of Nok pearl millet cultivation in a West African context

The absolute dominance of pearl millet in the Nok assemblages, with high frequency and ubiquity, is unique among the 34 West African archaeological sites dating to the second and first millennium cal BC from which archaeobotanical data are available (Fig. 8). To our knowledge, only at eight sites, other than the Nok sites, samples larger than two litres were processed by flotation with 0.5 mm mesh size and results from the small fraction published. Among these, five sites

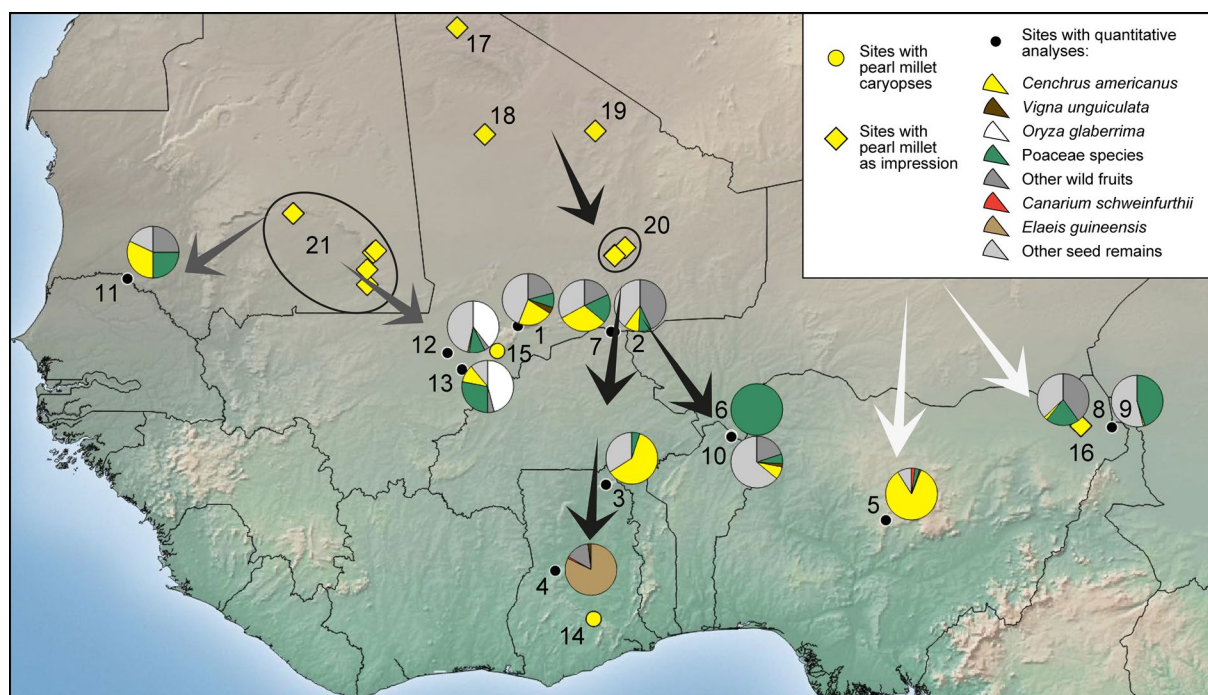


Fig. 8 West African sites with archaeobotanical remains from third to first millennium cal BC. The arrows indicate directions of pearl millet diffusion into sub-Saharan West Africa. Black arrows: central branch from Tilemsi, after 2500 cal BC, with a central Sahara origin (3500 cal BC); grey arrows: western branch from Tichitt, after 2000 cal BC; white arrows: potential origin for the Chad Basin and for the Nok region. Site regions: 1 Winde Koroji, 2 Tin-Akof, 3 Birimi,

4 Kintampo B-Sites, 5 Nok region sites, 6 Kozoungou, 7 Oursi West, 8 Kursakata, 9 Mege, 10 Alibori, 11 Walade, 12 Dia, 13 Jenne-jeno, 14 Bosumpra Cave, 15 Ounjougou, 16 Gajiganna, 17 AZ 22, 18 MT 25, 19 MK36, 20 Tilemsi region sites, 21 Tichitt region sites (adapted from Fig. 9.1 in Champion 2020, details and references in ESM 2 Table 2)

contain pearl millet chaff (Tin-Akof, Oursi West, Kursakata, Alibori, Walade), while for Winde Koroji, Kozoungou and Bosumpra Cave, chaff is missing just as at the Nok sites. At 19 sites, pearl millet is evidenced by pottery impressions and six have not been systematically analysed, as discussed in more detail in Champion (2020). Within this data set, only Birimi in northern Ghana (1950–1400 cal BC, D’Andrea et al. 2001; D’Andrea and Casey 2002) furnished pearl millet with a relatively high frequency (61% of the assemblage). Pearl millet is present though in most of the other contemporaneous sites, but only in low frequency, with assemblages often dominated by wild plants, i.e. tree fruits and wild grasses (Fig. 8, see Kahlheber 2004; Champion and Fuller 2018a; Champion 2020). Pearl millet becomes more numerous only in the West African Iron Age sites of the first and second millennium AD (e.g. Kahlheber 2004; Champion 2020).

Despite their uniqueness, the Nok archaeobotanical data fit well into the general developments, including the trajectory of plant cultivation, from the third to the first millennium cal BC in West Africa. The cultivation of pearl millet diffused from the desiccating West and Central Sahara into the West African savanna zone after 2500 cal BC, in the context of southwards population movements (Ozainne et al. 2014; Neumann 2018; Fuller et al. 2021). Previously

published evidence proposed three main branches of pearl millet diffusion, based on archaeobotanical data (Neumann 2018; Champion 2020; Fuller et al. 2021), but also on recent genetic studies (Oumar et al. 2008; Burgarella et al. 2018) and archaeological data (Ozainne et al. 2009, 2014). The two best documented are a western branch from Tichitt/Mauritania, after 2000 cal BC (Fuller et al. 2007; MacDonald et al. 2009) and a central branch from Tilemsi/Mali, after 2500 cal BC (Manning et al. 2011). Pearl millet cultivation spread quickly throughout the Niger River Basin, from the Tilemsi Valley in Mali to northern Burkina Faso (Tin-Akof, Oursi West) and to the rainforest of Ghana between 2500 and 1000 cal BC (Fig. 8). In the Niger River Basin and northern Burkina Faso pearl millet diffusion ceased abruptly, with many sites showing evidence of abandonment, followed by a gap in the occupation record, from around 1000 cal BC (Ozainne et al. 2009, 2014; Breunig 2013; Neumann 2018; Champion 2020).

Another more easterly diffusion branch is represented by the emergence of pearl millet in the Gajiganna complex in the southwestern Lake Chad Basin by about 1500 cal BC (Breunig and Neumann 2002; Klee et al. 2004; Breunig 2013; Neumann 2018), roughly contemporary with the first appearance of pearl millet in Nok sites. For establishing a

potential link between the two regions, comparison of their pottery traditions might provide a clue (Franke 2016b, pp. 207–208). Similarities in some decoration styles are opposed by major differences in vessel forms and temper. Although this seems to exclude the Chad Basin as the area of origin of the Nok culture, we should not dismiss the probability too quickly, and this line of inquiry definitively warrants further investigation of the regions in-between.

In the two western branches of pearl millet diffusion, it is often associated with a dominance of chaff-tempered and roulette-decorated ceramics (Ozainne et al. 2014; Champion 2020). It seems that this package reached neither the Nok area nor the Chad Basin. Following the new absolute-ceramic Nok chronology by Franke (2016b), there are only some cord-impressed but no roulette-decorated ceramics present during the Nok period, and wood roulette and fibre roulette ceramics appear only after the end of the Nok culture in CE sites. This is an important point pertaining to the pearl millet package diffusion hypothesis. The presence of pearl millet without roulette decorations or chaff temper, as seen in the Nok and early Gajiganna sites, suggests that the third diffusion originated directly from the central Sahara and possibly split before reaching northern Nigeria, accounting for the differences in Nok and Gajiganna pottery (Fig. 8; and see Champion 2020, p. 462).

The uniformity and uniqueness of plant exploitation during the Nok Period

While we argue that the sampled Nok sites are special sites in terms of consumption, we still regard the archaeobotanical results as indicative for subsistence practices during the Nok period. As argued before, in West Africa feasting does not necessarily include special foods but is usually associated with large amounts of food consumed. While these sites may not contain all kinds of plant food consumed, the archaeobotanical assemblages, together with the results from organic residue analysis, do allow conclusions on general patterns of plant food consumption. The archaeobotanical assemblages with dominant pearl millet, some cowpea, and wild tree fruits including *Canarium schweinfurthii*, do not show any changes between 1500 and 400 cal BC. Neither the appearance of the first terracotta figurines around 900 cal BC, nor the beginning of iron production sometime between 750 and 550 cal BC had any impact upon subsistence practices. We postulate that in terms of subsistence, the people of the Nok culture were conservative. This is emphasized by the beginning of oil palm exploitation and of fonio cultivation only after the end of the Nok period. Evidence for the cultivation of fonio together with pearl millet in Central Nigeria in the early first millennium AD, well after the end of the Nok culture, is contemporaneous with the evidence at Cubalel, Senegal (Murray et al. 2007; Gallagher and Murray

2016). Possible movement of people or agricultural practices including fonio cultivation into Central Nigeria at that time will be evaluated in a future publication. Puzzling though is the lack of oil palm at Nok culture sites. In many contemporary West and Central African archaeological sites, like those from the Kintampo culture, oil palm endocarp remains are continuously present in large quantities (Stahl 1985; D’Andrea and Casey 2002; D’Andrea et al. 2006, D’Andrea et al., 2007). The absence of oil palm in the Nok sites is remarkable, as *Elaeis guineensis* is found growing today in the river valleys of the research area, e.g. near the site of Janruwa C, and it was probably an element of the natural vegetation in the second and first millennium cal BC, as evidenced by an endocarp directly dated to 907–806 cal BC from the excavation at Sabon Janruwa (ESM 1). If palm oil and/or palm kernel oil had been used for cooking in the pots, organic residue analysis would have delivered a distinctive oil lipid profile (from palm kernel oil) or we should have seen very high abundances of fatty acids from the use of palm oil, which we did not (Dunne, personal communication). It thus seems that the oil palm did not belong to the set of accepted useful plants of the people of the Nok culture.

The association of *C. schweinfurthii* with pearl millet in the Nok sites stands in stark contrast to the Kintampo sites in Ghana. These also revealed pearl millet remains but in extremely low quantity. In the B-sites only one single pearl millet caryopsis was found while oil palm and *C. schweinfurthii* represent 83% of the remains (D’Andrea et al. 2006). So far, no other West African sites show any association of pearl millet with *C. schweinfurthii* (Fig. 8, and for a review of the West African sites see Champion 2020). Even if considering the ritual character of most Nok sites, the combination of the dry savanna crop pearl millet with a tree from the semi-evergreen forest is as unique for West Africa as are its terracotta figurines.

Conclusions

From the 50 Nok sites that have been studied for their plant remains, the most distinctive feature is the absolute dominance of *Cenchrus americanus* in comparison with other taxa, accompanied by the evidence of absence of chaff. Almost 9,000 pearl millet caryopses, clearly from a domesticated form, furnish a solid base for the interpretation of the archaeobotanical assemblages. *Vigna unguiculata*, the second domesticate, occurs in much lower numbers, which is probably due to its differential preservation. The combination of pearl millet and cowpea also occurs in other West African sites during the second and first millennium cal BC and indicates an advanced agricultural system with cereals and legumes, as in other parts of the world.

In contrast to cowpea, the initial domestication area of which is still unknown, new archaeobotanical data indicate that *C. americanus* pre-domestication cultivation was already underway in the Malian Sahara in the fourth millennium cal BC from where the crop spread eastwards throughout the southern Sahara in the third millennium cal BC (Fuller et al. 2021). In several sites of the West African savanna zone, including Ghana, Mali, Burkina Faso, and the Lake Chad region in northern Nigeria, pearl millet appears almost contemporaneously between 1800 and 1500 cal BC, probably resulting from several diffusion processes. In the Early Nok sites, dated around 1500 cal BC, pearl millet appears together with inorganic-tempered ceramics, suggesting a southwards diffusion independent of the Chad Basin.

The Nok archaeobotanical finds are unique in comparison to contemporaneous assemblages from West African sites. A striking feature is the low diversity of archaeobotanical macro-remains with only a few taxa, including the dominant pearl millet, with additional cowpea, *Canarium*, and some wild fruit trees. The absence of pearl millet chaff, detected through the study of the finer 0.5 mm fraction, is remarkable and seems to indicate real evidence of absence. We conclude that the Nok sites, at least those studied in detail, were consumer sites, and that major processing steps of the harvested panicles, including threshing and winnowing, occurred elsewhere. Together with the archaeological evidence of terracotta depositions and burials in the Middle Nok phase, the large quantities of clean grain point to the function of these sites as ritual places, probably for funerary practices connected with feasting. Despite the absence of any archaeological evidence, the presence of clean grain in Early Nok sites may also point to ritual use, starting already at the beginning of the Nok occupation around 1500 cal BC, several hundred years before terracotta production began. Final processing for food, including grinding and cooking, might have been practiced at the sites themselves. Pearl millet cultivation probably took place not far from the sites, but the exact location of the fields and of Nok settlements is still unknown.

The archaeobotanical assemblages are homogenous over the full chronological range of the Nok culture until the beginning of the CE. Neither the development of terracotta production in the Middle Nok phase from 900 cal BC onwards nor the introduction of iron metallurgy around the middle of the first millennium cal BC was associated with a change in plant food consumption. Plant exploitation practices remained stable over more than 1,000 years, pointing to a remarkably conservative character of Nok society, at least as far as their mortuary practices are concerned. While we cannot exclude oil palm and fonio (*Digitaria exilis*) consumption in the still unidentified Nok settlement sites, evidence of oil palm together with fonio only appears in CE

sites around cal AD 100–400, most probably connected with the arrival of a new population.

Our study does not only furnish basic data about the subsistence of the people of the Nok culture, but it also demonstrates how archaeobotany can contribute to highlight and reconstruct social practices. A prerequisite for meaningful interpretation is the analysis of a large number of samples from representative archaeological contexts, involving the finer 0.5 mm fraction. The archaeobotanical data are an important jigsaw puzzle piece for our understanding of the enigmatic Nok culture, although many aspects, including its settlement system and its disappearance in the last centuries cal BC, remain to be explored.

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Author contributions LC and AH contributed in equal amounts to the paper and should both be regarded as joint first authors. Co-first authors can prioritize their names when adding this paper's reference to their résumés. The project was conceived by PB (archaeology) and KN (archaeobotany). LC did by far most of the macro-remains analysis, AH collated the archaeobotanical data created by LC, SK and herself and discussed the archaeological contexts with GF, who contributed the archaeological information in the text and the catalogue of sites. LC, AH and KN wrote the manuscript with contributions from all authors.

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Declarations

Conflict of interest The authors declare that they have no competing interest.

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