

# Evidence for food storage and predomestication granaries 11,000 years ago in the Jordan Valley

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**Food storage is a vital component in the economic and social package that comprises the Neolithic, contributing to plant domestication, increasingly sedentary lifestyles, and new social organizations. Recent excavations at Dhra' near the Dead Sea in Jordan provide strong evidence for sophisticated, purpose-built granaries in a predomestication context  $\approx$ 11,300–11,175 cal B.P., which support recent arguments for the deliberate cultivation of wild cereals at this time. Designed with suspended floors for air circulation and protection from rodents, they are located between residential structures that contain plant-processing installations. The granaries represent a critical evolutionary shift in the relationship between people and plant foods, which precedes the emergence of domestication and large-scale sedentary communities by at least 1,000 years.**

Near East | Neolithic | forager-farmer transition

New archaeological work at the PPNA (Pre-Pottery Neolithic A;  $\approx$ 11,500–10,500 cal B.P.) site of Dhra', located next to the Dead Sea in Jordan, reveals clear evidence for large-scale storage in sophisticated, purpose-built granaries before the domestication of plants. Evidence for PPNA food storage illustrates a major transition in the economic and social organization of human communities. The transition from economic systems based on collecting and foraging of wild food resources before this point to cultivation and foraging of mixed wild and managed resources in the PPNA illustrates a major intensification of human-plant relationships.

People in the PPNA were the first in the world to develop systematic large-scale food storage. In the Early Natufian period ( $\approx$ 15,000/14,500–12,800 cal B.P.), people used a remarkably wide range of wild plants and animals, lived in relatively large well-made semisubterranean buildings for much of the year, and undoubtedly had a detailed knowledge of the seasonality and availability of these resources (1). Certainly the apparent increased degree of sedentism in the Early Natufian period suggests that people were able to reduce seasonal food risks to the point where they could live in the same areas for 1 or more seasons of the year. There is, however, surprisingly little direct evidence for food storage (2, 3). The strongest is from 'Ain Mallaha (4), where pits are often termed silos although their specific function is unclear. There is indirect evidence in the Natufian for plant food processing, including the presence of sickles, mortars, and pestles. Although Natufian people probably engaged in some form of low-level food storage, they also situated their settlements where they were able to use high-yield food resources from multiple natural ecotones in different seasons. With the onset of the climatic downturn of the Younger Dryas, people in the Late Natufian period ( $\approx$ 12,800–11,500 cal B.P.) returned to more mobile economic and subsistence strategies. Late Natufian people abandoned earlier settlements, adopted new systems seasonal residential movement, and rarely built residential structures that required significant investment of energy.

With the end of the Younger Dryas and with stabilization of climate and increased precipitation, people within the Jordan

Valley once again adopted more sedentary residential practices. Research at several PPNA sites within the Jordan Valley provides evidence for the appearance of large settlements, with buildings that required significant energy investment, and drastically expanded development of food storage compared with the Early and Late Natufian periods (Fig. 1) and increased manipulation of plant food sources. Excavations at Dhra', Gilgal I, Netiv Hagdud, and WF 16 illustrate that at the end of the Younger Dryas climatic period for the first time, to our knowledge, people started to live in larger communities that were based, at least in part, upon systematic large-scale food storage of cultivated plants. These actions initiated changes in wild plant foods, and although not morphologically changed into domesticated plants, some of the plants used in the PPNA were already undergoing changes as a byproduct of economic intensification and selection.

The excavated remains provide new insight into increased human control of plants, the prehistoric storage of plant foods, the earliest stages in material manifestations of plant manipulation leading eventually to domestication, and an important stage in the development of the built landscape. To achieve enhanced resource stability, early Neolithic people constructed simple, yet effective granaries. Excavations at Dhra' indicate that the granaries were located in extramural locations between other buildings. Starting at 10,500 cal B.P., food storage starts to be located inside houses, and by 9,500 cal B.P., dedicated storage rooms appear in Neolithic villages. This transition from extramural to intramural storage system may reflect evolving systems of ownership and property, with PPNA granaries being used and owned communally and with later food storage systems becoming part of household or individual based systems. The evidence for granaries is most clearly seen in the excavations at Dhra' (5), but can be inferred at Netiv Hagdud and Gilgal I. Surprisingly, these granaries provided a means of storing cultivated plants, and predate the appearance of morphologically domesticated cereals by a thousand years (6).

Archaeological excavations have revealed that by 11,500 cal B.P. in the southern Levant PPNA people used at least 2 types of storage systems: small bins and larger storage silos. Excavations at Dhra' have uncovered the remains of 3 distinct types of structures, 2 of which were used as food processing locations and residential buildings, and the third that served as a simple granary (Fig. 2). Excavations have identified at least 10 food processing/residential structures characterized by walls made of mud or upright stones, mud floors, and inset cupholes or grinding stones. Excavation of approximately 3% of the site, which covers 6,500 m<sup>2</sup>, also revealed the remains of at least 4 granaries that are interspersed between the oval/circular food

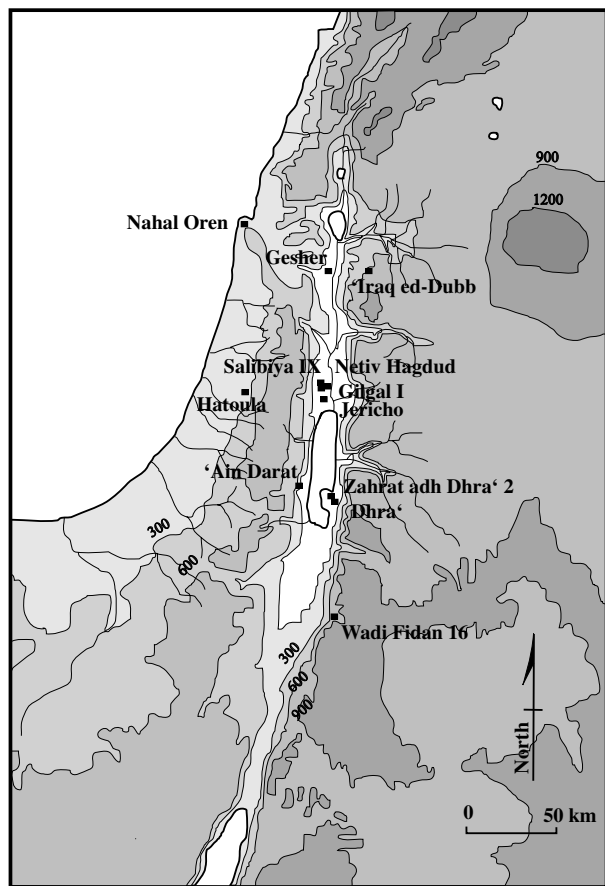
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**Fig. 1.** The location of the prepottery Neolithic A site of Dhra', other sites with granaries, and other significant sites from this period.

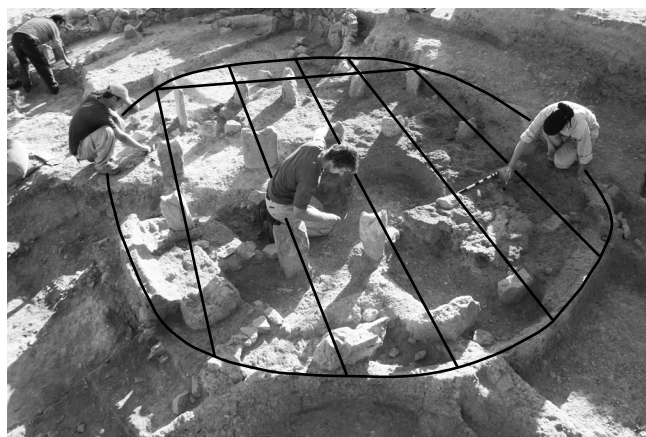
processing/residential buildings. All of the granaries were circular structures  $\approx 3 \times 3$  m on the outside and were built with suspended floors for air circulation and protection from rodents

and insects. This design was achieved by constructing an outer mud (or pisé) wall; where structures were terraced into a slope, the revetting wall was of stone. There is some evidence that the upper parts of the walls may have had a light weight organic frame (or wattle) to support the mud, although the walls appear to have been more substantial than the wattle and daub screen walls of some of the processing structures. Although there are no in situ preserved remains of the roof, experimental research and the lack of any central post holes suggests that the roof was probably flat and covered with a protective coating of mud to shed rain water.

Remarkably well preserved remains from Structure 4, phase I, help us understand how these granaries were constructed at Dhra', and by extension, probably at Gilgal I and Netiv Hagdud. The suspended-floor inside structure 4 was built by placing notched stones upright along a subfloor. The stones were placed between 1.0 and 1.2 m apart, in lines, so that wooden beams could be held in place along the notches (Figs. 3 and 4). Apart from the upslope end of the structure, which is oriented perpendicular to the other beam lines, all of the beam lines were parallel. The floor slopes at a  $7^\circ$  angle. This design appears to be intentional, and would have been useful for storing and gathering loose material, but not helpful for either working or residential purposes. Some of the 35–50-cm high upright stones were reused grinding (quern) stones, whereas others were specially made. Large pieces of burned wood recovered in situ, and lumps of burnt mud with wood and vegetation impressions, suggest that this structure had a raised floor of wood, covered with smaller plant matter and mud. Field and laboratory observations, including micromorphological analysis, indicate that the sediments recovered from inside the structure were linked to the collapse of the floor, roof, and walls. Micromorphology also shows numerous voids of straw and glumes, whose size indicates barley. It appears that a temper has been incorporated into the mud, highlighting both the careful manufacture of the building and large scale harvesting (5). Preliminary phytolith analysis shows a concentration of barley husks from the mud floor, not identified elsewhere on the site. A radiocarbon sample from an intact wood beam associated with the burning and abandonment of the phase I construction produced a radiocarbon date of  $9,913 \pm 59$



**Fig. 2.** Structure 4, phase 1, Dhra', Jordan looking north. The outer walls of the structure, which was constructed  $\approx 11,300$ – $11,200$  B.P., are defined by a partially preserved mud wall. Inside the structure are used grinding stones in upright position that have been notched to hold wooden beams. With the exception of the back row, where the beams would have run from west to east, the other support beams would have run north to south and been bonded into the mud wall.

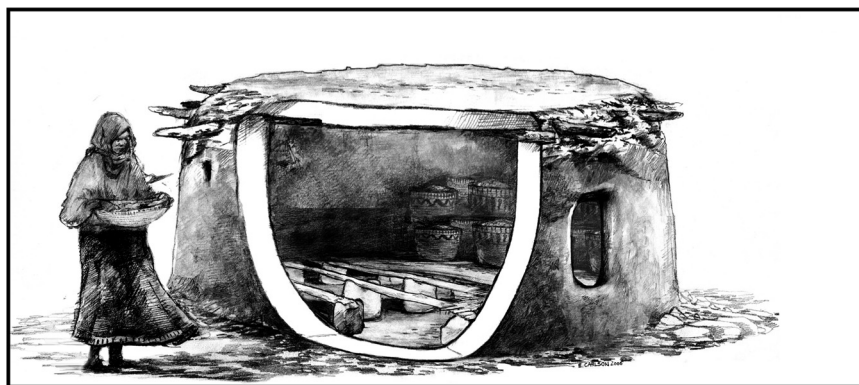


**Fig. 3.** Structure 4, phase 1, Dhra', showing the likely placement of major floor beams to hold up the suspended floor.

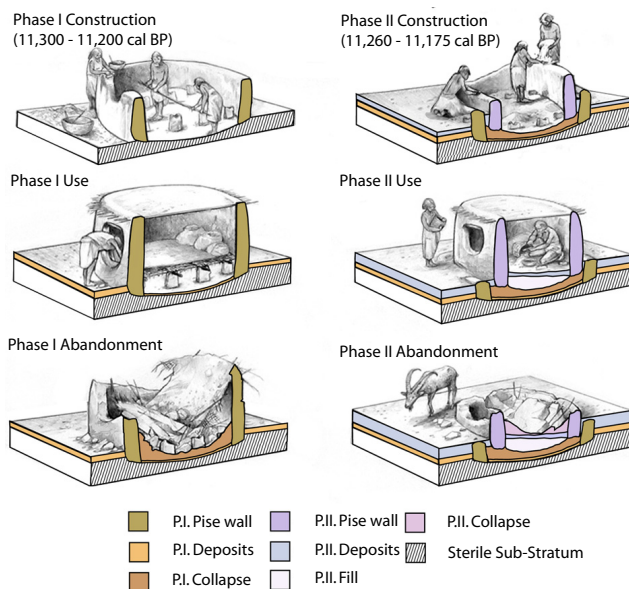
B.P. (ISGS-A0246). Excavation revealed other granaries that predate structure 4.

A second granary was built above the original Structure 4 granary (Fig. 5). This phase II structure was slightly smaller than the original phase I building and had a thicker mud wall. Most of the subfloor space had filled in with collapse, and several of the uprights were incorporated within the new wall-line. Some of the upright stones may still have been used for a marginally raised floor, although there appears to be a solid floor surface sitting directly on the collapsed material. It is possible that these modified structures were used for a more informal system of food storage that was raised above the ground. Wood charcoal material recovered stratigraphically above the phase I radiocarbon sample has produced a radiocarbon date of  $9,835 \pm 65$  B.P. (ISGS-A0248). Thus, the first granary was constructed  $\approx 11,300$ – $11,200$  cal B.P. and was abandoned between  $11,260$ – $11,175$  cal B.P. Each granary was probably used for no more than 50 years at most, a use-life that fits well with detailed micromorphological analysis and radiocarbon dating of other Neolithic settlements (7).

Stratigraphic evidence indicates that some granaries were rebuilt above earlier granaries, while others on the site were built inside abandoned food processing structures. In at least one other structure (Structure 8), a stone wall was replaced by a mud wall, but again the floor may have reused the same stone uprights, this time possibly in exactly the same fashion as in the earlier phase. The stratigraphic and spatial separation of the granaries



**Fig. 4.** Interpretive reconstruction of Structure 4, phase 1, Dhra', Jordan. The exposed area illustrates the upright stones supporting larger beams, with smaller wood and reeds above, and finally covered by a thick coating of mud. The suspended floor sloped at  $7^\circ$  and served to protect stored foods from high levels of moisture and rodents (Illustration by E. Carlson).



**Fig. 5.** Life-history of Structure 4 granary Dhra', Jordan. This illustration shows the cyclical process of construction, use, and abandonment over several hundred years (Illustration by E. Carlson).

indicates that several were probably used sequentially. However, given the overall size of the settlement, this patterning suggests that many granaries would have been in use simultaneously.

Beyond the granaries, several PPNA sites provide evidence for small volume storage bins. Excavations at Netiv Hagdud and Jericho provide evidence for the use of small clay bins ( $<0.5 \times 0.5$  m), possibly, but not unequivocally, linked to food storage. Two of these (Locus 44 and Locus 45) were identified at Netiv Hagdud (8) and appear as small areas enclosed by mud walls preserved up to a height of  $\approx 20$  cm. Due to limited preservation conditions it is not clear how high these walls stood, nor for that matter if they were located inside or outside of structures. The excavators believe that they were used for some form of food storage or preparation and that they were located inside structures. Similarly, Kenyon reports numerous small stone bin features at Jericho, such as those of phase DI.xxix (9). At Dhra', we uncovered a stone bin next to a structure and several clay-lined features that may have been used for small-scale storage.

Evidence for PPNA storage complements studies that document the cultivation of plants in the Jordan Valley (6, 10). These studies have focused on the morphological changes in subsistence plants from individual settlements through time. Weiss et al. have identified a series of “pioneer crops” of cultivated plants in the early PPNA. Drawing upon archaeological datasets from the wider Levantine context, they argue that research can trace the transformation of wild plant varieties, including wild barley (*Hordeum spontaneum*), lentil (*Lens orientalis*), and oats (*Avena sterilis*), into domesticated forms in the later PPNB. These morphological changes are the byproduct of shifts in human practices and the development of a new package combining the active management and extraction of plant resources such as cultivation, with new systems for food processing and storage. The increasingly “built world” of the Neolithic sees important transitions with the PPNA, and although much debate has focused on the emergence of the home, an equally important transition is seen in the appearance of built-in plant food processing and storage features. These practices collectively reflect a significant increase in energy invested in buildings and the permanence of these settlements.

### Discussion

The remarkably well-preserved granaries at Dhra' and evidence from other PPNA sites shows that people developed a simple, but effective storage technology that allowed the accumulation of a significant food surplus based on the intensive collection and the cultivation of select wild plants. Excavation of house 11 at Gilgal led to the recovery of >260,000 wild barley and 120,000 wild oat grains (6). Based on the number of recovered grains, and the architectural evidence, Weiss et al. argue that this evidence reflects predomestication cultivation. We suggest that this structure may have been a granary not a house. Research at Netiv Hagdud, dating to 11,300–10,900 cal B.P., led to the recovery of large quantities of wild barley (8). Excavations at Netiv Hagdud also produced evidence of a similar structure (Locus 26), in this case a 3 × 3-m structure defined by a mud wall, to the granary seen at Dhra'. With the exception of the absence of upright stones, which may have been robbed for later buildings, the building is remarkably similar to the granaries at Dhra'. Similarly, excavations at Jericho revealed 2 large (3.0–4.0-m diameter) circular mud installations next to the PPNA Jericho tower. Based on differences between these mud installations and residential buildings, Kenyon (9) interprets these 3.0–4.0-m circular mud installations as storage structures.

The combined evidence for PPNA food storage represents a major break from the Early and Late Natufian periods, and significant evolutionary development in economic and social systems of human communities. The transition from economic systems based on collecting and foraging of wild food resources to cultivation and foraging of mixed wild and managed resources illustrates an important intensification in the relationship between humans and the foods they manage and consume. We note several implications of this transition. First, the presence of these sophisticated, and substantial, granaries represents a form and scale of food storage not found in earlier Natufian period communities (1). PPNA people were storing food seasonally, if not annually, on a scale that would have at least served as an important new buffer for food shortages, but also have created the context for potential social change. Second, it is important to note that while these granaries focused on the storage of wild plant resources, they reflect the active intervention in normal plant cycles. Although the oats and barley from Gilgal I are morphologically wild, their active selection and management reflects both intentionality and the initial stages of the morphological and behavioral transformation to domestication (6). Third, excavations at Dhra' indicate that the granaries were located in extramural locations between other buildings. Else-

where Kuijt (11) argues that starting at 10,500 cal B.P. food storage starts to be located inside houses, and that by 9,500 cal B.P. dedicated storage rooms appear in Neolithic villages. These data may reflect evolving systems of ownership and property, with PPNA granaries being used and owned communally with later food storage systems becoming part of household or individual based systems. Fourth, these sophisticated storage systems with subfloor ventilation are a precocious development that precedes the emergence of almost all of the other elements of the Near Eastern Neolithic package—domestication, large-scale sedentary communities, and the entrenchment of some degree of social differentiation.

Food storage is an essential development for food production, sedentism and farming, and represents a major evolutionary threshold for human civilization (12). Archaeologists have only recently started to document food storage among cultures before the appearance fully developed agro-pastoralist economies, and assess whether, when, or even if, people were able to regularly store food beyond their annual consumption needs, including banking grain to overcome spoilage, and to provide seed for planting and potential years of crop failure. In some cases storage necessitates, or is necessary for, changes in social systems, invoked both in increasing corporate activities and for the development of hierarchical structures. Storage also represents a critical form of risk management and economic intensification. Zeder (13) argues that the shift to domestication of plants and animals involves a relationship between humans and targeted plants and animals, with increasing control, both intentional and unintentional, over the reproduction, movement and protection of targeted species. Critical to this perspective is the identification of when shifting human practices result in unanticipated byproducts, such as altering changing barley reproduction due to local harvesting of plants around a settlement, to the intensified intervention in the life cycles of plants with the goal of increasing the production of specific plants. Smith (14) argues that the transition to Near Eastern food production was gradual and initially involved low-level food production and targeting of select plants. The appearance of storage technologies helps us trace the development of systems of human control over plants and animals, and progressive developments in low-level food production.

Testart (12) argues that food storage, population growth, sedentism, and social inequality are often interlinked. With greater sedentism, increased birth rates, and increased quality and quantity of domesticated foods we see the foundation for economic developments. An excess or surplus, that is to say an amount or quantity beyond what is considered normal or sufficient (15), results in production beyond the immediate annual household needs. To be a true excess or surplus, it is necessary to produce enough yearly food resources to cover the subsistence needs of the group, to secure sufficient stored food to overcome any seasonal or yearly shortage, and still have remaining amounts that can be used for trade, exchange, or some form of social currency (16).

Following Smith and Zeder, we see the development of PPNA granaries as reflecting new forms of risk reduction, intensification, and low-level food production. People in the PPNA were not using new food sources, rather by developing new storage methods, they altered and intensified their relationship with traditionally used food resources, and created the technological context for the later development of domesticated plants and an agro-pastoralist economy. Building granaries may, at the same time, have been the single most important feature in increasing sedentism that required active community participation in new life-ways.

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