CHAPTER 11
ARCHAEOBOTANY AT FARMANA:
NEW INSIGHTS INTO HARAPPAN PLANT USE STRATEGIES

BY STEVEN A. WEBER, ARUNIMA KASHYAP, AND LAURA MOUNCE

1 INTRODUCTION

By around 1600 BC, a highly organized, economically centralized and culturally integrated civilization had emerged in the northwestern part of South Asia. The Indus Civilization flourished in part due to its successful agricultural practices. To date, our knowledge of these agricultural practices is based primarily on an archaeobotanical record that relies almost entirely upon seed grains preserved through carbonization (Fuller and Madella 2002; Weber 2001). Further, fewer than 50 Harappan sites have been extensively or intensively sampled for archaeobotanical remains. The focus of this limited and biased study has been largely on cereal grains and pulses from Southwest Asia. Further skewing our understanding of Harappan plant use strategies is the fact that only few of the many ecologically distinct regions of this civilization have been adequately studied. To help fill in some of these gaps, an archaeobotanical project was initiated at the site of Farmana, located in the Ghaggar valley region of Haryana, India.

Our approach at Farmana was to incorporate multiple threads of evidence to get a clearer picture of the full range of plants being used at the site. The goal was to use the more traditional approach of carbonized seeds to identify general cropping patterns while using starch grains to identify direct evidence for human consumption and understand patterns of interactions between plants and material culture.

Direct evidence of plant use, whether recovered from human remains or the surfaces of implements used for food processing, cooking, serving and storage, is significantly limited or missing from Harappan archaeobotany. As a result, certain questions have not been addressed, such as whether similar types of cereal grains, like wheat and barley, were being used and processed differently, and whether certain foods were associated with status or ritual. The lack of such direct evidence has also impeded our ability to identify patterns of relationships between plants and material culture, for example, whether distinct foods were associated with specific ceramic vessels or tool types, and whether shifts in pottery style reflect shifts in plant taxa. The starch grain analysis at Farmana is allowing us to address these issues, as well as unambiguously demonstrate human consumption of specific plants.

The following paper will initially summarize independently our three distinct avenues of research, the ethnobotanical and experimental, macrobotanical and microbotanical. Although each of these approaches and subsequent data sets can stand on their own and will eventually be published independently, they supplement each other nicely and together form the basis of our interpretation of plant use at Farmana. As the analysis of some of the data is continuing, the results and discussion presented here may eventually need revising.

2 STATUS OF HARA
ARCHAEOBOTANICAL RESEARCH

Archaeobotany is best seen as a subset of archaeology concerned with how plants were obtained, used and describing changes in agriculture strategies over time (see: Hastorf and Gremillion 1997; Pearsall 2000; Weltfish 2002). The archaeobotanica of the Harappan civilization is the focus on macrobotanical data collected from 50 Harappan sites (Kajale 1991; Fuller and Madella 2002; Weber 2003). With these sites the archaeobotanical record was accidental finds representing less than 50% of the plant remains. The focus on specific taxa is rare, which is why we have been able, to a large extent, to systematically collected and interpret the plant remains. The archaeobotanical record is the most important tool for understanding the Harappan diet.

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2 STATUS OF HARAPPAN ARCHAEOBOTANICAL RESEARCH

Archaeobotany is best seen as a sub-specialty of archaeology concerned with reconstructing diets, inferring how plants were obtained and used, and describing changes in agricultural and dietary strategies over time (see: Hastorf and Popper 1988; Gremillion 1997; Pearsall 2000; Weber 1999, 2001; Fuller 2002). The archaeobotanical record of the Harappan civilization is for the most part based on macrobotanical data collected from fewer than 50 Harappa sites (Kajale 1991; Fuller 2002; Fuller and Madella 2002; Weber 2001). While at most of these sites the archaeobotanical material recovered was accidental finds representing less than 50 seeds (Weber 1991, 1992), there are a few examples where large, systematically collected and intensively sampled strategies were employed (Weber 2001). From these sites no more than 100 different species have been identified, of which few were found regularly in large concentrations within a single site. Fewer still occurred regularly from site to site, let alone throughout a given region (Fuller and Madella 2002). Cereals, especially “big cereals” such as wheat and barley have been most widely reported. The “small cereals” like millets and pulses are generally only recovered where flotation has been practiced (Weber 1991, 1998; Fuller and Madella 2002). Other types of crops, including fiber and oilseeds producing plants (cotton, linseed and sesame) and roots and tubers (ginger, turmeric and yams) have rarely been recovered at Harappa sites (Fuller and Madella 2002). Tropical fruits (natives such as mango, jamun and amala) and spices (such as black pepper, nutmeg, cinnamon, clove and asafetida), which might have been a part of the Harappan diet (Kenoyer 1998), are also minimally represented or missing from archaeobotanical record.

All agricultural models for the Indus civilization have been derived from this limited database. These include ideas about how agriculture and cropping strategies influenced Harappan culture and culture change (Kajale 1974; Costantini 1985; Sasaswar 1986; Possehl 2001), and theories that there was a shift to multi-cropping during the Indus civilization (Jarrige 1985; Meadow 1989, 1996). Additionally, the proposition that the introduction of new species from other regions played a prominent role in changing the settlement system (Possehl 1986), or that the shift towards more localized cultural units and away from urban complexes was associated with, or even stimulated by, a “revolution” in agricultural resources and techniques (Jarrige 1985; Possehl 1986; Meadow 1996). The problem with these studies is that the sites they reference were excavated at different times using different methods, collection and analysis strategies, and were overly dependent on macrobotanical remains preserved through carbonization.

Over the last few decades, microbotanical analysis, such as starch grain and phytolith studies have become increasingly valuable in balancing the record. Archaeobotanists are using starch grain and phytolith analysis to identify early agriculture, distinguish between wild and domesticated species, differentiate the plant organs producing the microfossils, reconstruct the long distance movements and adoption of plants and past environments, and associate plants directly with human activity by recovering the microfossils from lithic tools, ceramics and even human and animal teeth (Atkinson and Fullagar 1998; Banks and Greenwood 1975; Boyadjian et al. 2007; Kashyap 2006; Cortella and Pochettino 1994; Crowther 2003; Esau 1965; Fullagar et al. 1998; Lok 1994; Lok et al. 1992; Pearsall et al. 2004; Perry 2004; Perry et al. 2006; Piperno 2000; Torrence and Barton 2006; Reichert 1993; Zarillo and Kooymans 2006; 2008; Henry et al. 2007; Piperno and Dillehay 2008; Kashyap and Weber 2010a, b, c). However the systematic study of these plant microfossils for archaeological purposes is still limited in India. Few microfossil studies have been done (for
example phytolith studies by Eksambekar et al. 1997; Eksambekar 1999; Madella 1995, 2003 and starch analysis by Kashyap 2006) and very little attempt has been made to compare the two forms of analysis.

Extensive models have been developed to explain the agricultural diversity and productivity of the civilization (see: Meadow 1986; Weber 1999, 2003; Fuller and Madella 2001). The common thread in these approaches is their focus on levels of precipitation by distinguishing regional moisture patterns and their impact on crop selection. As a result, two agricultural strategies are often proposed. One strategy, the rabi, involves crops sown in the autumn, harvested in the spring, and fed with winter rains. This strategy was most common at Harappan sites found in Baluchistan, Bannu Basin, Sindhi, Punjab, Swat and Kashmir. Many of the winter crops, including wheat, barley, oats, peas, and lentils were introduced into South Asia from Southwest Asia. The second strategy, the kharif, centers on crops sown in the summer and harvested in the fall, making use of summer monsoon rains, and includes the cultivation of millets, rice, cotton, dates, and gram. Many of the summer crops were indigenous to the region or were introduced from somewhere else in South Asia. The agricultural strategy in Gujarat, Kutch, Rajasthan, and Maharashtra focused primarily on the kharif season. While both the rabi and kharif strategies were often practiced in the same area, the emphasis was generally on one season based on location. This pattern of dividing regions by agricultural strategies based primarily on cropping continues through the historic record into modern times. The archaeobotanical remains from Farmana imply that the region of the Ghaggar-Hakra of the Indus civilization was multicropped and incorporated both strategies during the Harappan Period, just as we see today.

3 ETHNOBOTANICAL AND EXPERIMENTAL STUDIES

ETHNOBOTANICAL

Ethnobotanical fieldwork was conducted in the modern village of Farmana and during January to March of excavation seasons 2008 and 2009. We collected information regarding the kinds of plants being consumed and the preparation of the plants for food consumption. We also collected information on hearth fuel, for both cooking and heating purposes. The informants were mostly females, but in households where men were in charge of buying food and gathering wood for the hearth men were also consulted. Over 15 households were interviewed using a semi-structured questionnaire. While most interviews lasted nearly three hours, in two cases we were invited to stay all day and observe the daily activities around the hearth. The interview questions focused on food plants, cooking practices, and fuel for the hearths. The goal was to better understand the archaeobotanical material being recovered from the Harappan occupation at Farmana. All interviews focused on seven general themes: (1) Who was in charge of food preparation and fuel collection; (2) What kinds of foods were consumed and how they were prepared; (3) How much time is spent preparing, processing and cooking food; (4) How many hearths were in the household, what were their functions and where were they located; (5) What were the fuel options, when each type of fuel was used and how fuel was processed and stored; (6) How were hearths maintained. How often was the hearth cleaned and where was the debris deposited; (7) What was fed to the cows and how were dung cakes made, used and stored?

As expected, the data clearly demonstrates that women are mostly in charge of buying and preparing food for the household. Food preparation and cooking for the day are usually done in the morning. The every-day diet includes food crops/cereals such as wheat (during summer used along with wheat in the winter), rice and legumes (Vigna species and vegetables are also consumed deepak is available in the market and what is the vegetable backyard garden. 'bathua' (Chenopodium album) are a for cooking. Chenopodium is a crop in disturbed soils and was present in samples. Its use as a food at Farmana support the idea that its presence a may also have been as a food supplement.

A combination of fuel-wood, and cattle dung was used for cooking. Women, children and young adults responsible for collecting the common wood types were 'shisan' (A 'kikar' (Acacia karro) and 'kair' (Acacia) use of dung depended on hearth size and what was being cooked. Most house which were kept at times within the compound. Cow dung was usually pil space in the village with other veg and household garbage. Some of the in these piles included attached sea materials was then mixed into dung for fuel. All households had multiple least one was specially used for cooking for heating purposes especially for drinking and for other household chores. Households had over 15 hearths av any given time. Most hearths were ch days.

EXPERIMENTAL

To better understand how processing techniques affect starch and ethnoarchaeological section of this paper conducting a series of experiments and recipes gathered from our ethnographic village of Farmana. Starches
cereals such as wheat (during summer), pearl millet (used along with wheat in the winter), occasionally rice and legumes (Vigna species and Bengal Gram). Vegetables are also consumed depending on what is available in the market and what is being grown in the vegetable backyard garden. Weeds such as ‘bahula’ (Chenopodium album) are also used widely for cooking. Chenopodium is a common weed found in disturbed soils and was present in many flotation samples. Its use as a food at Farmana village helps support the idea that its presence archaeologically may also have been as a food supplement.

A combination of fuel-wood, crop residues, and cattle dung was used for cooking and heating. Woman, children and young adults are usually responsible for collecting the wood. The most common wood types were ‘shisam’ (Dalbergia sissoo), ‘kikar’ (Acacia karroo) and ‘kair’ (Acacia chundra). The use of dung depended on hearth shape, function and what was being cooked. Most households had cattle, which were kept at times within the enclosed living compound. Cow dung was usually piled into an open space in the village with other vegetable material and household garbage. Some of the straw observed in these piles included attached seeds grains. These materials was then mixed into dung cakes and dried for fuel. All households had multiple hearths – at least one was specially used for cooking and another for heating purposes especially heating water used for drinking and for other household chores. Some households had over 13 hearths available for use at any given time. Most hearths were cleaned every 7-10 days.

**Experimental**

To better understand how cooking and processing techniques affect starch morphology (see macrobotanical section of this paper) we have been conducting a series of experiments using clay pots and recipes gathered from our ethnographic research at the village of Farmana. Starches are organic and fragile nature. Thus food processing, preparation and cooking techniques can easily affect starch granules resulting in structural and morphological damage and gelatinization (breakdown of intermolecular bonds of starches) (Babot 2003; Campus-Baypoli 1999; Ratnayake and Jackson 2007; Takahashi and Shirai 1982). This is especially true when water and heat are involved. On the other hand alkali cooking techniques and use of salt and sugar can augment granular stability and increase the gelatinization temperatures, resulting in the survival of starches in the cooking-pot residues. Through experimentation, we are identifying the changes in the starch grain structure and morphology resulting from various cooking practices, and then attempting to identify these markers in the archaeobotanical record.

The cooking experiments have focused on vegetable curries, chutneys, roasting and boiling roots and tubers, making ‘kheer’ or pudding from rice, wheat pudding, making rotis (flat bread) from wheat flour, and brewing barley. All experiments were conducted in the archaeobotanical laboratory at Washington State University Vancouver (WSUV), with support from the National Science Foundation. The experiments are still continuing with additional support from WSUV. Our experiments with eggplant, ginger, turmeric and mango have all indicated that cooking does cause specific structural and morphological changes in starch granules. Further, the amount of time the plants were cooked, and the material in which the plants were cooked in, directly impact starch preservation (Kashyap and Weber 2010). Since many of these cooking markers (microscopic features) are also present in the macrobotanical samples, Harappan processing and cooking practices may be recognizable. Once the experiments are completed (late 2011) and all the ethnobotanical data is processed and analyzed, a comprehensive publication will be produced.
4 MACRO-BOTANICAL

While macro-botanical remains account for the majority of the archaeological plant material collected from an excavation, this is especially true at Farmana where a more balanced approach was applied. Carbonized seeds, chaff, and other macro-botanical materials make up only one avenue of research and thus are only a small part of the Farmana plant material.

Over a two-year period, during the 2008 and 2009 field seasons, 143 soil samples were collected for macro-botanical material. A flot was constructed during the 2008 excavation, and an old 50-gallon oil drum. Our flot was processed on a standard Sirof type machine to recover the heavy residue. A metal mesh sieve for the lighter plant materials was used. By using nearby wells, we were able to process the samples on a regular basis. The goal was to collect 20 liters of samples from all the stratigraphic layers. In some smaller features, including pits and hearths, only a few liters were collected.

Quantifiable and comparative databases were established. One hundred and forty soil samples were collected and floated. Five of these were from the cemetery, the rest from settlement mounds. The heavy residue was collected, dried, and processed during the excavation. Charred bones, artifacts, and small terracotta cakes were collected. Little botanical remains were found, identified, weighed, and distributed to specialists. The light fraction samples were shipped to the archaeobotany lab at State University of Vancouver (WSU) for analysis. A powerful dissecting microscope was used to identify the seeds and charcoal was removed for analysis.

The sampling strategy was developed...
4 MACRO-BOTANICAL ANALYSIS

While macro-botanical remains typically account for the majority of the archaeobotanical data collected from an excavation, this was not the case at Farmana where a more balanced approach was applied. Carbonized seeds, chaff and charcoal -- the bulk of the macro-botanical materials -- represented only one avenue of research and thus only a portion of the Farmana plant material.

Over a two-year period, during both the 2008 and 2009 field seasons, 145 soil samples were floated for macro-botanical material. A flotation machine was constructed during the 2008 excavation season using an old 50 gallons oil drum. Our design was based on a standard Sefar type machine that used a 5 mm mesh to recover the heavy residue and a mm cloth sieve for the lighter plant materials (Williams 1973; Watson 1976; Nesbit 1993). By using a pump and a nearby well we were able to process large volumes of soil on a regular basis. The goal was to systematically collect 20 liters samples from all floor, features and stratigraphic layers. In some smaller contexts, such as features including pits and hearths, however, samples of only several liters were collected. The result was a quantifiable and comparative database.

One hundred and forty soil samples were collected and floated. Five of these samples were collected from the cemetery, the rest from the main settlement mound. The heavy residue from the samples was collected, dried, and sorted at the site during the excavation. Charred bone fragments, beads, small terracotta cakes were common, but very little botanical remains were found. The finds were identified, weighed, and distributed to the various specialists. The light fraction samples were dried and shipped to the archaeobotany lab at Washington State University Vancouver (WSUV). Under a low powered dissecting microscope the seeds, chaff and charcoal were removed for analysis.

The sampling strategy was devised to examine temporal changes in crop use strategies over the occupation of the site. Yet it became evident during the excavation that the site was quite shallow, occupied only during the Mature Harappan Period and was heavily disturbed. Based on the stratigraphy, ceramics and the carbon (AMS) dates, the site was occupied between 1600 and 1200 BCE. While a number of distinct Harappan phases could be identified, the site was occupied for a relatively short period. As a result we saw little reason to analyze all collected samples. Our goal shifted from understanding change over time to describing cropping and plant use strategies at one point in time. At this point in time, 67 of the flotation samples have been analyzed.

The results from flotation suggest that preservation was an issue. While ubiquity was high, at nearly 97 percent, seed density was relatively low. The average seed density for Farmana was less than 5 seeds per liter of soil. This was significantly below what was observed at the site of Harappa, where it averaged nearly 40 seeds per liter of soil (Weber 2005). The low density at Farmana might be a result of less intense fire exposure leading to fewer seeds being carbonized or a result of the site being smaller with a less dense population. The shallow nature of the cultural deposits and constant impact from later activities may also be an issue. Less than twenty different taxa were represented in the seed record (See Table 11.1). Of these, only 9 were definitively food crops. Like other Harappan sites, cereals made up the majority of the carbonized seeds. The primary cereals were wheat (Triticum sp.), barley (Hordeum sp.) and several small millets (Panicum sp. and Setaria sp.). One fragmented rice grain was observed in the upper levels of the site. Its context and the lack of additional grains suggest that rice did not play an important role at Farmana. Seeds from a variety of pulses and fruits were also identified (Table 11.1). Green gram (Vigna sp.), horse gram (Macrotyloma sp.) and sesame (Sesamum sp.) were the most frequently recovered crop seeds after the cereals. It is clear that the cropping pattern for
Farmana was one based on both sur watered crops.

The few flotation samples collect from the cemetery area contained result we focused our attention on area. Two trenches from the setti and sC1t, represented the least dist and contained the best-preserved material. Efforts to identify shifts i primarily based on material from Because of the narrow time frame 400 years of occupation, and the 1 of many of the sequences, we comp levels of occupation (Phases 1 and 2) levels (Phases 4 and 5) to get some shifts occurring at Farmana. Using el then compared the ubiquity and se winter and summer cereals (Table 11 of samples with wheat and barley from 61 percent to 10 percent while
Farmana was one based on both summer and winter watered crops.

The few flotation samples collected and analyzed from the cemetery area contained few seeds. As a result we focused our attention on the settlement area. Two trenches from the settlement area, 1D3 and 3C11, represented the least disturbed sequences and contained the best-preserved macro-botanical material. Efforts to identify shifts in cropping were primarily based on material from these trenches. Because of the narrow time framework, less than 400 years of occupation, and the disturbed nature of many of the sequences, we compared the earliest levels of occupation (Phases 1 and 2), with the later levels (Phases 4 and 5) to get some sense of cropping shifts occurring at Farmana. Using this framework we then compared the ubiquity and seed density of the winter and summer cereals (Table 11.2). The ubiquity of samples with wheat and barley grains declined from 61 percent to 28 percent while their seed density declined from an average of 1.5 to 0.7 seeds per liter of soil. Together, the implication is a dramatic decline in winter cereals. In contrast, the summer cereals had only a minor decline in ubiquity and a slight increase in seed density. Over all, the implication is that there was not only a decline in seed crops but a shift in seasonal emphasis from a winter based strategy to one more equally dependent on both seasons.

Charcoal and chaff were also collected from the flotation samples. Charcoal, a good indicator of climate, is still being identified. Preliminary analysis has led to the identification of two species, Tamarix sp. and Salvadora sp. Both are typical of a thorn forest with semi-arid trees and shrubs. Chaff made up a very small portion of the macro-botanical material either due to issues of crop processing or preservation. A single carbonized fragment of what appears to be a garlic clove (Allium sp.) was also recovered.

One of the most interesting finds at Farmana was a very small fragment (1 mm) of woven plant material
Table 11.1 Plant taxa identified at Farmana. Species identification was not always possible. In such circumstances, the remains were categorized by family.

<table>
<thead>
<tr>
<th>Macro-botanical</th>
<th>Micro-botanical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CEREALS</strong></td>
<td></td>
</tr>
<tr>
<td>Hordeum vulgare (hulled barley)</td>
<td>S</td>
</tr>
<tr>
<td>Hordeum sp. (barley)</td>
<td>S</td>
</tr>
<tr>
<td>Triticum aestivum (bread wheat)</td>
<td>S</td>
</tr>
<tr>
<td>Triticum sphearoacoccum (dwarf wheat)</td>
<td>S</td>
</tr>
<tr>
<td>Triticum sp. (wheat)</td>
<td>S</td>
</tr>
<tr>
<td>Panicum sumatrense</td>
<td>S</td>
</tr>
<tr>
<td>Panicum sp.</td>
<td>S</td>
</tr>
<tr>
<td>Brachiaria rumosa</td>
<td>S</td>
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<tr>
<td>Setaria sp.</td>
<td>S</td>
</tr>
<tr>
<td>Sorghum sp.</td>
<td>S</td>
</tr>
<tr>
<td>Oryza sativa</td>
<td>S</td>
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<tr>
<td><strong>PULSES or VEGETABLES</strong></td>
<td></td>
</tr>
<tr>
<td>Vigna sp. (gram)</td>
<td>S</td>
</tr>
<tr>
<td>Vigna radiata (green gram)</td>
<td>S</td>
</tr>
<tr>
<td>Solanum sp. (eggplant)</td>
<td>S</td>
</tr>
<tr>
<td>Macrotyloma sp. (horse gram)</td>
<td>S</td>
</tr>
<tr>
<td>Lens culinaris (lentil)</td>
<td>S</td>
</tr>
<tr>
<td>Lathyrus sp.</td>
<td>S</td>
</tr>
<tr>
<td><strong>FRUITS, OIL SEED or FIBER</strong></td>
<td></td>
</tr>
<tr>
<td>Cucurbita sp.</td>
<td>S</td>
</tr>
<tr>
<td>Mangifera sp. (mango)</td>
<td>S</td>
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<tr>
<td>Sesamum indicum (sesame)</td>
<td>S</td>
</tr>
<tr>
<td>Linum sp. (flaxseed)</td>
<td>S</td>
</tr>
<tr>
<td>Unknown</td>
<td>S</td>
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<tr>
<td><strong>SPICES, HERBS</strong></td>
<td></td>
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<tr>
<td>Allium sp. (garlic clove)</td>
<td>S</td>
</tr>
<tr>
<td>Zingiber sp. (ginger)</td>
<td>S</td>
</tr>
<tr>
<td>Curcuma sp. (turmeric)</td>
<td>S</td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td></td>
</tr>
<tr>
<td>Cyperus sp.</td>
<td>S</td>
</tr>
<tr>
<td>Dioscorea sp.</td>
<td>S</td>
</tr>
<tr>
<td>Rumex dentatus</td>
<td>S</td>
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<tr>
<td>Aegilops sp.</td>
<td>S</td>
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<tr>
<td>Abutilon sp.</td>
<td>S</td>
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<tr>
<td>Cleome sp.</td>
<td>S</td>
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<tr>
<td>Chenopodium album</td>
<td>S</td>
</tr>
<tr>
<td>Chenopodium sp.</td>
<td>S</td>
</tr>
<tr>
<td>Trianaema portulacastrum</td>
<td>S</td>
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<tr>
<td>Trianaema friguetra</td>
<td>S</td>
</tr>
<tr>
<td>Tamerix sp.</td>
<td>S</td>
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<tr>
<td>Salvadora sp.</td>
<td>S</td>
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<tr>
<td>Unknown</td>
<td>S</td>
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</table>

(Figure 11.4). The cloth fragment wa found at the lower levels of Trench 1D5 and dates to around 2500 BCE. While the cloth was being analyzed, it appears to be made of hemp.

5 MICRO-BOTANICAL

Two types of micro-botanical were studied at Farmana, starch grains (commonly carbohydrates) and phytoliths (op. cit.). Although starch grains and phytoliths are being studied for nearly two centuries, the use of these plant microfossils for archaeological analysis dates only to the last few decades (Es 1911; Schleiden 1849). Increasingly, phytoliths are being used in the analysis of additional plant species that are preserved in the carbonized remains from the site of Fullagar 1998; Barton et al. 1996; 1998; Hall et al. 1989; Kashyap 1992; Pearsall 2004; Piperno et al. 1992). Our emphasis at Farmana has been on starch grains, which were successfully recovered from all contexts and were well preserved. Our main thrust has been to identify starch grains that serve as the plant's principal source of food and are genetically

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S=Seed  C=Charcoal  Clove=V  Fabric=F  P=Possible But Fragmented
T=Starch on Teeth  L=Starch on Stone  P=Starch on Pottery
Table 11.2: Seed rates for Farmana cereals

<table>
<thead>
<tr>
<th></th>
<th>Seed Density</th>
<th>Ubiquity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Levels</td>
<td>1.5</td>
<td>61</td>
</tr>
<tr>
<td>Late Levels</td>
<td>0.7</td>
<td>20</td>
</tr>
<tr>
<td>Summer Cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Levels</td>
<td>0.6</td>
<td>38</td>
</tr>
<tr>
<td>Late Levels</td>
<td>0.7</td>
<td>30</td>
</tr>
</tbody>
</table>

(Figure 11.4). The cloth fragment was recovered from the lower levels of Trench 1D5 and appears to date to around 2500 BCE. While the cloth fragment is still being analyzed, it appears to be made of either jute or hemp.

5 MICRO-BOTANICAL ANALYSIS

Two types of micro-botanical data were available at Farmana, starch grains (complex insoluble carbohydrates) and phytoliths (opal silica bodies). Although starch grains and phytoliths have been studied for nearly two centuries, the systematic study of these plant microfossils for archaeological purposes dates only to the last few decades (Essar 1965; Reichert 1913; Schleiden 1849). Increasingly, archaeobotanists are using phytoliths and/or starch grains to identify additional plant species that are not necessarily preserved in the carbonized seed record (Atchinson and Fullagar 1998; Barton et al. 1998; Fullagar et al. 1998; Hall et al. 1984; Kashyap 2006; Loy 1994; Loy et al. 1992; Pearsall 2004; Piperno et al. 2000, 2004). Our emphasis at Farmana has been on starches, which were successfully recovered from a variety of surfaces and were well preserved. Our starch analysis is still continuing but should be completed in late 2011.

STARCH GRAINS

Starch grains are complex insoluble carbohydrates that serve as the plant’s principal food storage mechanism. They have distinctive features (size, shape and structure) that are genetically controlled and, when carefully studied, can be used to identify plant taxa (Banks and Greenwood 1975:142; Cortella and Poschettno 1994: 173; Hardy et al. 2008; Loy 1994: 87-91; Reichert 1913: 165; Zarrillo and Kooyman 2006: 484).

In the last two decades starch grain extracted from various archaeological contexts has become a very useful and widely applicable technique around the world for studying direct evidence of plant use and consumption. Starch-grain analysis has been used to study plant diet and use, plant domestication, cultivation and processing, food preparation, ceramic residue analysis, tool use and site organization in various parts of the world (Atchinson and Fullagar 1998; Babot and Apella 2003; Barton et al. 1998; Fullagar et al. 1998; Henry and Piperno 2007; Kashyap 2006; Loy et al. 1992; Perry 2004, 2005; Perry et al. 2006; Piperno and Holst 1998; Piperno et al. 2000; Zarrillo and Kooyman 2006; Zarillo et al. 2008). Starch grains are also increasingly being used as markers of diet (Boynadjian et al. 2007; Hardy et al. 2008; Henry and Piperno 2007; Piperno and Dilley 2008). Our starch study at Farmana was the first for a Harappan site. Our goals were to demonstrate that starch grains could be successfully recovered from artifact surfaces, to identify plant-processing activities, and to directly identify dietary practices.

At Farmana we collected samples from 140 surfaces that could be studied for both starch grains and phytoliths. The samples were collected from both the living and cemetery regions of the site. All samples were collected during the 2009 excavation season. These included 54 burial vessels (of various shapes and
Table 11.3  Sample sources for starch analysis

<table>
<thead>
<tr>
<th>Type of Sample</th>
<th>Occupational Phase</th>
<th>Archeological Context</th>
<th>Samples Studied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Teeth</td>
<td>Mature Harappan</td>
<td>Cemetery Burials</td>
<td>9</td>
</tr>
<tr>
<td>Pottery</td>
<td>Mature Harappan</td>
<td>Habitation Area Floor</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trash</td>
<td>8 storage pots</td>
</tr>
<tr>
<td>Storage or Cooking Pots</td>
<td></td>
<td>Hearths</td>
<td>8 cooking pots</td>
</tr>
<tr>
<td>Stone Artifacts</td>
<td>Mature Harappan</td>
<td>Structures</td>
<td>4 Sherds</td>
</tr>
<tr>
<td>blades</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>grinders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pounders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediment Sample</td>
<td>Mature Harappan</td>
<td>Around sampled artifacts</td>
<td>11</td>
</tr>
<tr>
<td>or Control Sample</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

sizes and types, 100 ceramic vessels (of various shapes and sizes and types), 10 grinding tools, 16 stone blades, and 40 human teeth/dental calculus.

So far we have studied 50 samples (including human tooth calculus, pottery and stone artifacts) from Farmana (Table 11.1). We sampled nine teeth (1 premolar, 1 molar and 1 incisor) from three human burials belonging to the Mature Harappan Phase at Farmana. In total 20 ceramic vessels or pottery sherds were studied for the pilot project. The analyzed ceramics came from a variety of contexts including mud brick structures, living floors, trash areas and hearths. Studies have shown that food residues most often occur as consolidated and blackened material accumulated on the walls and the base of the ceramic vessels. They also appear in the form of whitish crusts on the exterior of the vessels or charred residues on the work surface of the pottery fragments. The cooking and storage pots were examined very carefully for such residues. Stone implements including two lithic blade tools, four grinding stones, four pounders and the soil sediments adhering to some of these tools were also studied for the pilot project. The stone implements were collected from various contexts (house floors, area around the hearth and other features) at the site. We also studied control samples collected from directly beneath and around the periphery (to a distance of 5-10 cm) of the ceramic and stone implements to assess if non-use contamination may be an issue (Kashyap 2006; Perry 2004; Piperno 2006; Zarillo et al. 2008).

For the recovery of the starches from dental calculus we followed the strategy outlined by Piperno and Dillehay (2008: 19616). The sampled teeth were brushed with a soft toothbrush and water to remove adherent soil and other particles. A dental pick was used to scrape different areas of teeth (crown of molars, gum lines etc.) with visible calculus. The extracted residue was directly transferred to a microscopic slide with a few drops of water on it. Before putting on the cover slip, one drop of 50% water/glycerin was added to the residue water suspension to slow the drying of the grains and allows the grains to be easily rotated when encountered (Piperno and Dillehay 2008). Residues and processed for starch grains from vessels by a multiple-step method: successive washes to loosen residue, to concentrate the residue, and to prepare them to microscopic slide for observation (Piperno 2006). Charted residues were then help of a dental pick from the inner sherds by gently scraping with a steel. A pretreatment with mild oxidation, and then by a heavy-density liquid separation were obtained and processed for from ground stones by a multiple step involved a fine point needle to 1000 cracks and crevices, using a centrifuging the residue, and then transferring the slide for observation (Piperno 2006). Starches from the control samples from pottery vessels were extracted from sherds by an ultrasonic bath to completely dissolve sediment and starch. We then isolate starches by adding a heavy liquid solution.

Starch grains from the soil extracted by using the following method: the sediment was mixed well with Cal and left overnight to settle. The supernatant and liquid was poured into the mixture a heavy liquid solution it was centrifuged. The supernatant was centrifuged with reverse osmosis of any chemicals. The residue was mounted on a microscope slide thoroughly studied with research grade light microscopy under polarizing (scanned at 100X until the entire area covered was examined). When a stain was located, it was studied under 400X, was rotated using pressure to view and notes were taken describing the starches for identification purposes. It was also photographed. When the complete colorless nail was used to...
(Piperno and Dillehay 2008). Residues were extracted and processed for starch granules from storage pottery vessels by a multiple-step method that involved successive washes to loosen residue, using a centrifuge to concentrate the residue, and then transferring them to microscopic slide for observation (Piperno 2006). Charred residues were removed with the help of a dental pick from the interior surfaces of the sherds by gently scraping with a sterilized dental pick, pretreated with mild oxidation, and the starch isolated by a heavy-density liquid separation. Residues were obtained and processed for starch granules from ground stones by a multiple-step method that involved a fine point needle to loosen residue from cracks and crevices, using a centrifuge to concentrate the residue, and then transferring them to microscopic slide for observation (Piperno 2004). Starch grains were extracted from pounders by shaking them in an ultrasonic bath to completely dislodge adhering sediment and starch. We then isolated the starches by adding a heavy liquid solution.

Starch grains from the soil samples were extracted by using the following method. 2 g of dry sediment was mixed well with Calcium Carbonate and left overnight to settle. This mixture was centrifuged and liquid was poured off carefully. To the mixture a heavy liquid solution was added and it was centrifuged. The supernatant was extracted and centrifuged with reverse osmosis water to get rid of any chemicals. The residue was removed and mounted on a microscopic slide. The extracts were thoroughly studied with research grade transmitted light microscopy under polarizing lights. Slides were scanned at 200x until the entire area under the glass cover was examined. When a starch granule was located, it was studied under 400x. Each starch grain was rotated using pressure to view all dimensions and notes were taken describing the attributes of the starches for identification purposes. Each starch grain was also photographed. When the examination was complete colorless nail was used to seal the slide and curate for future analysis (Kashyap 2006; Perry 2004).

The identification of the starch granules to plant taxa involved the use of photographs and descriptions as well as comparative starch specimens from modern plants (Kashyap 2006; Perry 2004:1071). The initial step was the identification of the study of the basic morphology of the starch granule. The next step was to note the more detailed characteristics of the granule such as:

1) overall grain type (simple or compound) and shape (bell-shaped, circular, lenticular or oval)
2) contour and surface features,
3) position and form of the hilum (the botanical centre of the grain) and fissure (internal cracks emanating from the hilum of some starch grains, formed when the grain begins to grow outward from the hilum and quite literally cracks),
4) number and characteristics of pressure facets present on compound grains,
5) the birefringent or Maltese cross pattern which is clearly visible under polarized light, and,
6) the presence or absence of demonstrable lamellae (rings formed during starch grain growth) (Piperno et al. 2004: 672).

Identification was based on a modern reference collection of over 100 different species from 40 families that Dr. Kashyap has put together. In addition, we made use of other databases and plant keys collected and published from other regions of the world (see: Cortello and Pochettino 1994; Henry and Piperno 2007; Piperno et al. 1004; Reichert’s 1913; Seidemann 1966).

The starch grain research at Farmana is providing the first direct evidence for plants being used, processed and consumed at the site. We have successfully identified starches belonging to barley, small and large millets, and mango from a variety of grinders and pounding stones. Starches of lentils and large and small-grained cereals were recovered from...
the interior surface of storage jars, as for example the starch from *Macrotyloma sp.*, *Solanum* (cf. eggplant), *zingiber* (cf. ginger) and *carumna* (cf. turmeric) from a cooking pot or handi (a deep narrow-mouthed cooking vessel) (Kashyap and Weber 2010). Our success in extracting and identifying starches in human calculus from burials represents an innovation in South Asian archaeology. The study of 10 different individuals shows that the Harappans had a broad diet which included small grain cereals, pulses, fruits, vegetables and roots and tubers, with wheat and barley apparently underrepresented in the starches (Kashyap and Weber 2010a) (Table 11.1).

### 6 SIGNIFICANCE OF FARMANA PLANT DATA

The diet at Farmana appears to have included a variety of crops likely grown locally. Like most Harappan sites, the focus was on cereals and pulses. What is clear is that a combination of indigenous millets and Southwest Asian cereals led to a secure multi-cropping strategy that was in place from the beginning of the occupation of Farmana. This strategy incorporated both summer and winter crops. Rice does not appear to be part of that strategy. With the addition of starch analysis we have an even clearer picture of cropping and diet as a number of species were identified that were not present in the seed record (Table 11.1). Millets, barley and gram were crops that were absolutely being consumed at Farmana as they were found in human dental calculus. Ginger, turmeric, mango, eggplant and possibly sorghum were all identified in the starch record but not found in the seed record. These results clearly demonstrate the need for incorporating different approaches. Independently, the seed grain or a starch grain approach would have missed some species for different reasons. Our study implies that many spices, herbs, fruits and root crops may have played a more important role in Harappan agriculture that previously realized.

Further, specific species correlate well with specific types of artifacts. Eggplant and mango were more often found on long narrow stone blades. Some blades were covered with just eggplant starches and nothing else. In contrast, spices and herbs were only found on the surfaces of ceramics. Different shaped vessels with different design elements seem to be associated with specific plants. At Farmana, we are only just beginning to understand the link between plant use and the material record. Much more work needs to be done along these lines before we truly understand this relationship.

Over the short occupation of the site, a cropping shift appears to have occurred. Wheat and barley decline in use by nearly 60 percent while millet use remains constant. The net result is an increasing emphasis on the summer crops. This observed shift in the carbonized seed record may be a result of a number of different natural and cultural processes. The disturbed nature of the site and a flawed sampling strategy could skew our results. Yet the sample was large and diverse enough that any bias should have been accounted for. A change in crop processing methods or locations might also alter the recovery of seed crop. Yet the lack of any significant shift in weed seeds, chaff or seed density would suggest that plant processing was not the cause. A change in climate or specifically a decline in winter rains might be a factor. If a shift in moisture patterns were the sole cause and if the population remained stable, then there should have been an increased presence in summer crops. A slight decline in population associated with a decline in winter rains would account for the shifting seed pattern.

Archaeobotany at Farmana is also contributing to our understanding of Harappan plant economy in the Haryana region. Other sites in the region, like Bala, were successfully sampled and archaeobotanical remains were recovered (Saraswat and Pokharia 2002). While the data from that quantifiable, they do contain crops. The biggest difference appears in dependence on wheat, barley and found for Farmana. This discrep result of sampling, methods of difference in crop choice. Because set, no real overreaching plant been developed for the Haryana civilization.

To adequately understand the region of the Indus civilization independently. One unique characteristic was that it incorporates in ecology and culture. Soils, climatic patterns differentiate one region. Subsequently crops varied. As shifted and climates changed, e differently. In the Haryana region particular, people had access to a summer and winter crops. As a in the region might have been by climatic shifts.

### 7 CONCLUSIONS

Analysis of the Farmana data and will for some time. No archaeobotanical data has been some important conclusions and foremost, the project needs to incorporate different approaches. Seeds, charcoal, etc. represent different parts of a plant differently in the archaeological record. does identify the different kind the Indus Valley civilization clearer and broader picture of many of the internal biases of
While the data from these sites are not quantifiable, they do contain many of the same crops. The biggest difference appears to be a greater dependence on wheat, barley and rice than what we found for Farmana. This discrepancy could be the result of sampling methods or actual difference in crop choice. Because of the limited data set, no real overarching plant use model has yet been developed for the Haryana region of the Indus civilization.

To adequately understand Harappan cropping and their agricultural strategy, each individual region of the Indus civilization needs to be studied independently. One unique characteristic of the civilization was that it incorporated great diversity in ecology and culture. Soils, climates and moisture patterns differentiate one region from another and subsequently crops varied. As moisture patterns shifted and climates changed, each region adapted differently. In the Haryana region, and at Farmana in particular, people had access to a great variety of both summer and winter crops. As a result, people living in the region might have been better able to adapt to climatic shifts.

7 CONCLUSION

Analysis of the Farmana data is still continuing and will for some time. Nonetheless, enough archaeobotanical data has been analyzed that some important conclusions can be made. First and foremost, the project clearly demonstrates the need to incorporate different archaeobotanical approaches. Seeds, charcoal, starches, and phytoliths represent different parts of a plant, since they preserve differently in the archaeological record, they can help us identify the different kinds of activities during the Indus Valley civilization. Together, a much clearer and broader picture emerges, one in which many of the internal biases of any single approach is nullified. Starch remains from ginger, turmeric and eggplant represent species that would not normally be preserved in the seed record. Ultimately, Farmana starches will allow us to better link plant use to the material culture.

With large volumes of systematically collected and floated soil we were able to identify wheat, barley and millets as the primary cereal crops for Farmana. Over the occupation of the site, the winter cereals declined in importance. Millets remained important and rice never played an important role. This shift may have been a result of changes in the moisture pattern. Specifically, Farmana might have experienced a decline in the winter rains during the later phases.

The distinctiveness of the Farmana data clearly demonstrates that understanding regional and temporal variability is an important key to modeling Harappan agricultural practices. Our tendency to focus on general moisture patterns that impact large regions of South Asia often fails to recognize how local environments and different regional ecosystems determine diverse and distinct agricultural communities. There were many distinct agro-zones during the Indus civilization (Weber et al. 2010). Each developed their own unique agricultural strategy and responded differently to changes in climate. With the addition of each individual Harappan site, like Farmana, regional patterns become clearer. It is only after we understand these regional patterns that we can clearly explain the evolution of Harappan agriculture.

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Excavations at Farmana


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