AGRICULTURE IN LOWLAND MESOPOTAMIA IN THE LATE URUK/EARLY DYNASTIC PERIOD

by

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"Much is known about the archaeology and history of this land. Most studies however do not give a good description of agriculture as almost nothing is known on the subject. History is made in the cities. A golden age in history is not always a golden age in agriculture!" (Buringh 1960 p. 60)

Abstract

The thesis reviewed the current state of archaeobotanical research in Mesopotamia and considered its significance for the study of Bronze Age agriculture of Lowland Mesopotamia. The climate, natural hydrology and geology of the area were described, with a view to assessing the impact of irrigation on the soils. The traditional irrigation practices of southern Iraq were discussed in relation to modern theory of irrigation and the applicability of the traditional system to that of the Sumerian's.

The types of agriculture practised in the irrigated arid region of Mesopotamia were examined with reference to modern irrigation agriculture theory. This centered on the agricultural systems seen in Lowland Mesopotamia in the early part of the twentieth-century and the way in which they were adapted to the particular local environmental conditions.

The recovery, nature and possible modes of arrival of the Tell Abu Salabikh plant remains were considered in the light of the seasonality, ecology and potential uses of the plants. The characteristics of the weed seeds used to group the plants according to crop processing behaviour for the statistical analysis were explained.

Statistical analyses of the Abu Salabikh plant remains were undertaken and comparisons were made with data from modern ethnographic studies. The implications of plant material derived from animal dung on the interpretation of crop husbandry and environmental conditions from plant remains recovered from archaeological sites were discussed. The data generated was used to consider currently held views on irrigation agriculture in Bronze Age Lowland Mesopotamia, which have used the existing plant remains and the information derived from the archaeological and cuneiform records.

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Chapter 1 Archaeobotany in Lowland Mesopotamia

The purpose of this dissertation is to study the agriculture of Lowland Mesopotamia in the late fourth and early third millennia B.C. using charred plant remains recovered from the Late Uruk and Early Dynastic levels of Abu Salabikh, a tell site situated in present-day Iraq in what was once the land of Sumer.

In order to interpret the plant remains accurately the material from the site has been compared with a modern ethnographic model, and literature on arid-land agriculture has been surveyed in order to assess the relevance of traditional early twentieth-century farming practices in southern Iraq to that interpretation, especially as such practices have frequently been compared with the agriculture of earlier historical times without due regard to the circumstances of their development.

It was also hoped that the identification of plant species in the contemporary and later cuneiform texts would be facilitated by establishing the identity of the crop types present in the archaeological samples.

By these means it was intended to produce a framework of agricultural information, from the recent and distant past, that would be of use to the study of the early literate societies of the Lowland Mesopotamian Plain in terms of the development of irrigation agriculture and its impact on the local environment, in particular the soil conditions, and the socio-economic consequences of such a system.

Although principally concerned with the agricultural systems of Mesopotamia during the 3rd and 4th millennia the study cannot be complete without some consideration of other archaeo-botanical evidence from closely related areas and periods.

The stages of plant exploitation and the history of the subsequent early phases of cultivation since the last glaciation are described. The scant body of plant remains which form the main source of evidence for plant use during the late pre-historic and early historic periods is assessed.

The change from plant collection to plant cultivation and the subsequent establishment of irrigation agriculture were two processes which were crucial to the development of human society in the Near East, i.e. the transition from nomadic/semi-nomadic hunting and gathering to the year round settlement of groups growing fully domestic crops, and the evolution of the earliest known literate civilisations on the alluvial flood plains of the rivers Tigris and Euphrates.

There are three sources of evidence from which it is possible to reconstruct the events that occurred in Mesopotamia;

i. archaeobotanical,
ii. archaeological, artifacts of crop husbandry e.g.tools and equipment used in plant processing, irrigation channels,
iii. documentary, in the form of cuneiform texts where available and relevant.

In this chapter the previously published archaeo-botanical material has been reassessed in the light of recent research. By showing how the data are distributed we can appreciate upon what solid fact discussion of Mesopotamian plant utilisation can be based. It is hoped to highlight the areas that have been previously neglected and encourage further investigations and systematic recovery of plant remains, as well as "setting the scene", of environmental conditions and plant resources present through the time-span of our study.

The purpose of the reanalysis was to;

i. investigate the 'fact and fiction' of what has already been written about the use of plant foods in Mesopotamia,

ii. identify areas, geographic and otherwise, of which little is known, because of the lack of research,

iii. describe the successful methods of plant recovery,

iv. determine as fully as possible the environmental conditions and the plant resources available for the period of the study.

1.1 The area of study (Fig 1.2)

Mesopotamia is defined here as the area of land between the Tigris and Euphrates from the Persian Gulf up to the foothills of the Taurus mountains (Naval Intelligence Division, 1944 p. 4) and the area East of the Tigris, up to approx. 1000 m. The most important climatic division within this area is between land capable of supporting permanent rain-fed agriculture, i.e. low frequency of crop failure (one-two times out of every five years), and land where permanent agriculture is only possible if the natural rainfall is supplemented artificially.

The minimum average rainfall requirement for rain-fed agriculture is generally cited as 200 mm per annum. It is only in areas with an average annual rainfall of over 300 mm that this minimum fall is received (Oates & Oates 1976 p. 111). In Mesopotamia there is an intermediate area receiving an annual rainfall of between 200 and 300 mm per annum where rain-fed agriculture is possible in one or two years out of every five. In this area crop growing varies in response to each year's rainfall pattern, e.g. seed sown after heavy early winter rains, where possible irrigation is used to make-up any water deficiencies. Climatological data collected from Mesopotamia for this century records average rainfall isohyets which divide the region into three (see Fig. 1.1);

i. land receiving >300 mm/year (rain-fed or "DAIM" land),

ii. land receiving 200-300 mm/yr. (marginal rain-fed land),

iii. land receiving <300 mm/yr. (irrigated lands, desert and semi-desert).

One problem associated with using these figures as a basis for considering the region as it was in the Early Dynastic period is the relevance of modern data, based on such a limited period of recording, to past climates. Although it is generally accepted that the climate has undergone no major transformations subsequent to the warming up period following the last glaciation, small-scale changes are quite probable, and these could have been critical in marginal areas in determining whether rain-fed agriculture was feasible.

To avoid making unwarranted assumptions of past climatic conditions Mesopotamia has been divided on the basis of altitude, i.e.;

i. Upland Mesopotamia, land above 100 m with a present-day rainfall of more than 200 mm,

ii. Lowland Mesopotamia, land below 100 m which has an annual rainfall of less than 200 mm today (some less than 100 mm). This is the flat alluvial plain region of Iraq.

The 100 m contour corresponds roughly to the 200 mm average rainfall isohyet along the East-North East edge of the Mesopotamian region, along the foothills of the Zagros, as far as Mandali and up on to the raised Tigris river terrace. This divides the region approximately into rain-fed and non rain-fed areas.

1.2 Climate, physiography and vegetation of Mesopotamia (Fig. 1.3)

1.2.1 Upland Mesopotamia

This covers three of the four physiographic regions and most of the major vegetation zones described by Guest (1966) for Iraq, the features of the regions and zones are outlined below;

1.2.1.1 The Mountain Region
(altitude 500-1800 m, rainfall 700-1400 mm)

Vegetation zones;

a. The Thorn Cushion Zone
(alt. >1700 m, rnfl. >1000 mm)

Contains little in the way of useful plants, and no archaeological sites with plant remains have been recorded.

b. The Forest Zone
(alt. 500-1800 m, rnfl. 700-1400 mm)

The vegetation is mainly oak forest, with some *Pinus* sp. etc. This zone is the natural habitat of many of the presumed progenitors of modern economic plants e.g. *Triticum boeoticum*, *T. dicocoides*, *Hordeum spontaneum*, wild *Pisum* sp., *Cicer* sp., *Linum* sp., *Lens* sp. as well as many wild fruit trees e.g. *Prunus* and *Pyrus* spp.

Winter cereals and other crops may be grown here quite successfully under normal rainfall conditions.

Many Mesolithic-Early Palaeolithic sites have been found in this area but Jarmo is the only recorded archaeological site with plant remains.

1.2.1.2 <u>The Upper Plains and Foothills Region</u>

(alt. 100-500 (-800 m), rnfl. 200-500 (- 700 m))

This sub-montane belt of steppic land runs from Luristan in the east across to the Anti-Lebanon range in the west. The steppic region is divided by Guest into;

a. The Wet or Moist Steppe

(alt. 200-500 (-800 m), rnfl. 350-500 mm)

Gillet (1948) thought the natural climax vegetation of this zone was probably "an open savannah dominated by Pistachio and other small trees", but that this had been destroyed by fuel gatherers or by grazing etc. This habitat can support luxuriant grassland in high rainfall years and where it abuts onto the forest zone the sward will contain the wild grasses and pulses mentioned above (forest zone):

> "Winter cultivation, without irrigation, normally succeeds in this zone; but much of the land here has been cultivated for millennia, so that the soil is generally impoverished and has often suffered from erosion and leaching." (Guest 1966 p. 72).

There are numerous sites in this zone with plant remains e.g. Ali Kosh, Nimrud, Yarim Tepe, etc. The possibility of crop failure in this region is quite strong, and even small-scale changes in climate could have had significant effects, beneficial or detrimental to crop growing.

b. The Dry Steppe

(alt. 100-200 (-350 m), rnfl. 200-350 mm)

The conditions and vegetation of the dry steppe are very similar to those of the wet steppe but the vegetation is sparser and crop failure more likely. Crop yield can be high when sufficient rainfall does fall as the soil fertility has not been exhausted to the same extent as that of the wetter steppe (and the alluvial lands below). Any change in climate would also be critical here.

The archaeological sites of Choga Mami and Tell Brak are situated in this zone.

1.2.1.3 The Desert Plateau Region
(alt. (0-) 250-400 m rnfl. 75-200 (-300 mm))

There are two vegetational zones;

a. The Desert Zone
(alt. 250-400 m, rnfl. <75 mm)

This is present along the southern margin of Iraq, and falls outside the limits set for Mesopotamia here.

b. Sub Desert Zone
(alt. 0-50 (-150 m), rnfl. 75-150 mm)

This vegetation zone covers the whole of the Lower Iraqi Plain, including the alluvial plain although there it is found in a highly modified form, and extending westward as far as Jabal Anaiza on the S. Arabia/Jordanian border.

The vegetation typically consists of scattered perennial shrubs with little other cover. In a wet spring or where water collects there may be quite a luxuriant growth of annual plants, Guest (1966, p. 71). Agriculture is not possible in this zone without irrigation, and there are no archaeological sites within the sub-desert zone of Upland Mesopotamia. The distinction between desert and steppe is a vague one, but Guest (1966 p. 67-71) lays stress on one point; that there is no clear boundary (or demarcation line) between the two zones, and often there is a tract of transitional land containing a mixture of vegetation from both zones.

1.2.2 Lowland Mesopotamia

This comprises just one physiographic region:-

1.2.2.1 The Lower Mesopotamia Region
(alt. 0-100 m, rnfl. <200 mm)

This area falls entirely within the Sub Desert vegetation zone, the features of which were described above. The vegetation here has, however, been considerably altered by 5000 years of almost continual cultivation. Guest describes it thus;

> "throughout the whole of the Lower Mesopotamian alluvial plain, between the twin rivers and sometimes beyond their present limits, hardly a vestige of natural vegetation remains today: almost the whole of this important agricultural region has at one time or another been irrigated and cultivated."

> "In some parts of the plain there are large or small strips and patches which may appear to be natural but are in reality of secondary origin ...." (1966 p. 66).

The cultivation of cereals and pulses is only possible on a regular basis under irrigation. Along the back slopes of the river levels, areas prone to flooding and other moist or favourable habitats some small-scale opportunist cultivation may be successful.

Sites with records of plant remains range from Tell es-Sawwan in the North to Ur, Eridu and Warka in the South (Fig. 1.2). All the sites used in this study are presumed to have been dependent on irrigation. Guest (1966) describes two types of vegetation related to wet areas of this zone, which contain some natural food plants of the region;

a. Riparian vegetation.

Occurring on or near river banks growing by streams etc. dense mono-species stands of Fraxinus sp., Salix sp., and Populus sp. Coppice of Tamarix sp., Salix sp., and Populus sp. with Rubus sanctus, Xanthium brasilicum, Crypsis alopecuroides. Further inland the common species are Prosopis farcta, Glycyrrhiza glabra and Alhagi mannifera. On saline stretches the dominant species are Suaeda baccata and Nitraria retusa.

b. Lacustrine vegetation.

On lakes, ponds and river back waters. There are large expanses of this habitat in southern Mesopotamia, especially in the Marshes region. Plants there include Phragmites communis, Typha angustifolia, Polygonum salicifolium, Nymphoides indicum, Ceratophyllum demersum, Potamogeton sp., Zannichellia sp., Cyperus rotundus, Phyla nodiflora, Ranunculus peltatus, R. trichopyllus, Salvinia natans.

. . . .

Away from the rivers and marshes the vegetation cover is as described above for the sub-desert zone of Upland Mesopotamia.

1.3 'Traces of plant remains' (A general introduction to the archaeo-botany of Mesopotamia, and a cautionary tale)

The first note of plant remains in Mesopotamia seems to have been made by Henry Field in 1932. Grain had been found in jars at the sites of Kish and Jemdet Nasr in S.Iraq, during excavations in the 1925-26 season, and was submitted to various botanical workers for identification. The samples were dated to approximately 3500 BC, the Proto-literate or Early Uruk period.

In a letter to the Times dated the 1st of February 1927, Professor Stephen Langdon reports their identification as Triticum compactum, and "If this be true", he goes on to say; "then the most ancient Sumerians had succeeded in growing the finest kind of bread-making wheat and were far in advance of the agriculturalists of pre-dynastic Egypt".

This was not the end of the matter, however, and by 1932 when Field published statements received from the experts in which they explain their disparate identifications no firm conclusions had been reached as to the 'true' identity of the grain and, in the absence of the material for reassessment, they have finally to be assigned to an indeterminant wheat category - a poor end for material which promised so much.

This cautionary tale serves to illustrate some of the problems inherent in the study of plant remains from archaeological sites, namely the accurate identification of the material recovered and the subsequent use made of that in the discussion and interpretation of the site, its environment, ecology and the utilisation of plants.

These problems seem to stem from the lack of recorded information regarding the identification, sampling of deposits or the scoring of the remains. There is a growing awareness of the importance of archaeobotany, and an increase in the recovery of plant remains and so it is vital that the records kept allow subsequent use and reinterpretation. The reassessment of the archaeobotanical record of Mesopotamia was hindered by the imprecision of previous reports. It also became apparent how inadequate the material was upon which the study of past agricultural systems in the area had been based.

1.3.1 'Revolutions' in archaeobotany

There are two significant changes which have taken place in archaeo-botany and which might be referred to as revolutions, though this is inappropriate as it refers to processes that have evolved rather than undergone sudden changes, as the term revolution implies.

1.3.1.1 The large-scale recovery of charred plant remains using water flotation

In 1961 Hans Helbaek at the site of Ali Kosh, on the Deh Luran plain of Khuzistan, faced the problem of recovering plant remains where;

"it appeared probable that no concentrated deposits

> of plant material could be expected. Therefore, when called in on the excavation I made up my mind to transfer to the field, for the first time, the laboratory technique for segregating plant remains from mineral samples by means of buoyancy." (Helbaek 1969 p. 385).

Using this method he was able to extract a large amount of material from deposits both "promising or doubtful". This marked the beginning of systematic archaeobotanical investigations in the Near East.

The comparatively simple technique of flotation, whether by hand or machine, to separate charred plant material from the non-organic mineral component greatly reduces the time required to process the sample and increases the chances of recovering weed seeds and fragments of chaff that might otherwise be missed.

The large amount of material produced by large scale flotation can, in itself, be a problem, causing Helbaek to remark;

> "Even to an old hand the analysis of flotation material remains the trickiest challenge in palaeoethnobotany" (1972 p. 48)

On many sites, especially those of early agriculturists and pre-agriculturalists, this approach is necessary to retrieve an adequate assemblage of plant remains.

At the excavations on the Deh Luran plain, a total of approximately 0.5 litres of "carbonized plant debris" were recovered;

> "Tepe Sabz contributed the major portion, but since that material has not been finished and a proper count made of the determinable plant remains, no figures can be given for the investigation as a whole.
>
> However, the sorting of the lesser volume from Tepe Ali Kosh, involving examination of millions of particles, resulted in some 45,000 grains, seeds and spike fragments being picked out." (Helbaek 1969 p. 385).

To this day no completed archaeobotanical report for either Tepe Sabz or Ali Kosh exists.

1.3.1.2 Ethnological study of traditional agricultural practices

Comparison of features observed archaeologically, whether present in the architecture, artifacts or the plant remains, with traditional practices still seen or only recently abandoned are a part of the archaeologist's (and archaeobotanist's) 'stock-in-trade'. However, only rarely is the background to these practices given careful consideration and without this consideration the comparison may be highly misleading (Halstead 1987 p. 77).

It was not until the early 1970's that the first comprehensive study of crop husbandry and processing for specifically archaeobotanical application was carried out by Gordon Hillman, in Turkey. He produced a detailed breakdown of the sequence of events involved in the processing of both glume and free threshing cereals, (Hillman 1981, 1984, and 1985).

A similar ethnological study in Greece by Glynis Jones on the free threshing cereals grown there in a traditional manner has produced a comparable ethnographic model and most usefully a database that can be directly applied to other archaeological sites (Jones, 1981, 1982 and 1983).

1.4 Mesopotamian plant remains

The previously published plant remains for the upland and lowland areas of Mesopotamia are discussed below.

1.4.1 Upland Mesopotamia - The source of crop plants

The forest-moist steppe region of Upland Mesopotamia is the natural habitat for a large number of the wild progenitors of the field crop plants cultivated throughout Mesopotamia. It is not the intention here to deal with the process of domestication per se, or the validity and interpretation of the plant remains recovered from archaeological sites. What is of concern is the group of crop plants native to the areas around the lowland alluvial plain and thus available for utilisation from ca. 5000 B.C. on. The wild ancestors of the cereals, pulses and oil plants etc. (such as *Triticum boeoticum*, *T. dicoccoides*) do not grow today on the lowland plain and it is assumed that this was the case at the time of the settlement of the plain.

The plant remains found at Tepe Sabz in the steppic zone (c 5000 B.C.), reported by Hans Helbaek (1969 p. 405-411), are representative of the crop plants present in the Uplands. They include two types of glume wheat, a free-threshing bread wheat, hulled and naked barley, lentil, grass pea (*L. sativus/cicera*) and linseed.

The cultivated plant ancestors are associated today with the margins of oak forest as found above the Deh Luran plain (c. 600 m a.s.l.) and on which Tepe Sabz is located, rather than the lower-lying steppic areas. It should be noted that the vegetation patterns have been drastically altered by fuel gathering and animal grazing (Helbaek 1969 p. 383) and thus the limits of the oak forest could have extended far further down towards the alluvial plain.

In addition to the cultivated plants listed for Tepe Sabz there were four plants that Helbaek placed in a group called 'Arboreal Fruits' i.e. *Prosopis* sp., caper, pistachio and wild almond, the fruits of which it was presumed were collected and eaten. Of these *Prosopis* sp.

and caper occur naturally on the alluvial plain as well as in the steppe zone; the wild almond is common in the lower forest zone of Iraq, occasional in the steppe and steppe-desert transition zone (Townsend & Guest 1966 p. 159) and may therefore have been present in the lowlands in the past; Pistacia spp. are restricted to the forest zone (Townsend & Guest 1980a p. 494-499). Several other types of fruit are found in the plant remains of Upland sites, though not at Tepe Sabz, e.g. grape, fig, pomegranate and olive, all of which are successfully cultivated in the Upland zone. Phoenix dactylifera grows best on the alluvial plain and has a clear temperature boundary preventing fruiting in the upland regions. Some fragments of hazelnut were found at Nimrud but the tree is not found growing in Iraq today.

Cucumber seeds were recovered from 1st millennium B.C. deposits at Nimrud. It is thought that the cucumber is native to India (Simmonds 1976 p. 65) and it is not known whether the plant reached Mesopotamia at a much earlier time than this.

Upland sites also hold evidence of the techniques of early agriculture that could have been transferred to the lowlands. There are archaeological and archaeobotanical features at Tepe Sabz and Choga Mami (another upland site) which have been interpreted as indicating irrigation agriculture.

Both sites are located on the foothills of the Zagros mountains (Choga Mami 137 m a.s.l) and are above the 300 mm rainfall isohyet as shown in the Flora of Iraq (Guest 1966 facing p. 12). The sites are at the boundary of the sub-desert/dry steppe vegetation zones (Guest 1966 p. 64) Mandali, the nearest town to Choga Mami, is included in a 'date palm cultivation' area within the sub desert zone. The development of irrigation systems would mean that plants could be cultivated outside their natural distribution areas, where rainfall levels were higher, considerably extending the area of land that could be farmed.

The archaeological evidence for irrigation at Choga Mami is in the form of traces of water channels, and the archaeobotanical consists of plants which are not thought to have occurred there naturally:

> "viz bread wheat, large grain oat, rye-grasses in the multitude they evidently occurred, probably clover, pea lentil, blue vetchling and linseed. Also naked barley as an important crop plant has not so far been encountered except in settlements that must be supposed to have subsisted on irrigation" (Helbaek 1972 p. 383).

There appears to be no direct archaeological evidence of irrigation at Tepe Sabz, instead features of the plant remains are used to infer the practice, e.g. the size of the linseed seeds and the presence of plant types such as T. aestivum (bread wheat). There is also indirect evidence in the condition of the plant remains;

> "the irrigation water came directly from calcareous mountains with considerable salt deposits and passed through country with solid veins of gypsum in the surface. Owing to the mineral-loaded groundwater, most carbonized plant objects are coated with a heavy gypseous and calcareous deposit, seriously restricting observation of morphological and anatomical details." (Helbaek 1969 p. 406).

1.4.2 The plant remains of Lowland Mesopotamia

Archaeological investigations have been carried out in Lowland Mesopotamia for more than a century, but the recovery of plant material had low priority even when in recent years expansion of the knowledge of plant cultivation was an important objective of the overall research.

The infrequency of charred plant remains being recovered can, in part be explained by;

a. The problems of plant recovery.

These are associated with the extraction of material, sufficiently well preserved, to allow identification. At some sites on the alluvial plain there are records of poorly preserved material which may result from the highly saline nature of the soil (salt crystallisation) and the regular cycle of wetting and drying to which the tells are exposed.

b. The presence of cuneiform texts.

The texts appear to offer more precise details on agricultural practice, but without comparison with other types of material, e.g. archaeobotanical, to confirm or refute the identity of crop types, they can be misleading. The most accurate picture seems to be obtained by combining the information derived from all the available sources (cf. the 'sesame debate' B.S.A. II 1985), including an archaeobotanical input which is required to verify the cuneiform data as well as to provide information on aspects that are not dealt with in the texts and to suggest new interpretations of previously held beliefs.

1.4.2.1 <u>The material</u>

To date, reports on plant remains from 19 Lowland Mesopotamian sites have been published. The material comprises charred plant remains, pottery impressions, one cloth sample and a some "fossilized " remains (Ellison et. al. 1978 p. 168). Table 1.1 shows the plant types present at lower Mesopotamian sites, charred and impressions; Table 1.2 provides a summary of the plant remains for the six millennia for which there are records. Although there are more imprint sample groups than charred ones (23 and 12 respectively) the latter group includes 48 plant types, the former only seven, and these seven are restricted exclusively to cultivated plants. It is worth stressing that the contrasts of the two material types can significantly bias the plant material represented and this has to be considered when discussing agricultural events. So, even though the majority of samples are imprints they only provide evidence of the presence of certain cultivated plants in each period. For information on the details of crop cultivation and by extension, on agricultural practice in the region, the principal source is the charred remains of seeds, fruits, chaff and stems.

1.4.2.2 The method and scale of charred plant recovery

At the majority of the sites where charred plant remains have been found the samples represent (as far as can be ascertained from notes in the report) small quantities of charred seeds, picked out by hand, from storage containers or areas with visibly high concentrations of material. Weed seeds are often absent from these samples, whether as a true reflection of the original material or as a result of the method of sampling. There is a strong contrast between these samples and those recovered by flotation, which suggests that the latter is more likely.

The amount of material found is not always specified, but typically the samples appear to be quite small, e.g. Helbaek comments that samples kept at Reading University, from various sites,, often contained only a few seeds "four barley and one wheat grain(s)";

> "the only specimens in these lists really worth their salt are those from Bazmosian and Nimrud. The latter consist of liters of grain and seeds. And then, of course, Qantara". (Helbaek in Jacobsen 1982 p. 18).

Two sites with comparatively large samples of charred material which include weed seeds in addition to the seeds of cultivated plants are Tell ed-Der, investigated by Van Zeist and Vynchier (1985 p. 119-133), and Tell Yelkhi reported by Costantini (1985 p. 57-60).

The Tell ed-Der material dates to the 17th-20th centuries

B.C. and consists of ash deposits, representing debris from in and around an oven (which yielded few plant remains), as well as a group of samples taken from the rooms of the 'archive' (library), which appear to have been destroyed by fire and which contain the most extensive range of cultivated plants recovered in Lowland Mesopotamia (before those of Qantara, ca. 900 A.D.). These included a number of species not found growing in Iraq today or restricted to the uplands.

Few of the samples are of the sort collected at Abu Salabikh. The material collected at these sites comes mainly from rich deposits, from storage vessels, etc. The investigations at Abu Salabikh involved a large scale sampling programme, taking soil from all the context types and was not limited to features visibly rich in plant remains.

The remains provide valuable comparisons with cuneiform sources, in particular for establishing the identification of crop species which previously relied entirely on linguistic arguments (see Powell 1984 p. 49), and in the case of Tell Yelkhi contain what appear to be crop weed seeds.

1.4.2.3 Identifications - Reliability and cross applicability

The terminology used in archaeobotanical reports varies considerably and the descriptions of criteria used for making identifications are often not included. As far as possible the names present in these reports have been kept although in some cases it is necessary to alter the names or amalgamate some types for which it is difficult to separate on the basis of the remains recorded at that site.

1.4.2.4 Discussion of the Lowland Mesopotamian plant remains

a. Charred remains.

The earliest sites on the alluvial plain where charred remains have been recovered, Tell es-Sawwan and Abada, already possessed the full complement of the major cereal crops of Upland Mesopotamia i.e. Triticum dicoccum, Hordeum sativum (6-row), T. monococcum, T. aestivum/durum, H. sativum (2-row), H. sativum (naked 6-row). The earliest records of leguminous crops are of Pisum sativum and Cicer arietinum at Ur, c. 2500 B.C., the record of C. arietinum is the only one for Lowland Mesopotamia (restricted today to the upland areas). Lens culinaris is first reported at Tell Yelkhi (c. 22-2000 B.C.) together with Lathyrus cicera (here included in the L. sativus group to include the cultivated forms of Lathyrus) which today in Iraq is a crop weed and not usually cultivated.

Phoenix dactylifera is present from the 4th millennium onwards, and is the only fruit tree occurring with any regularity, although there are records of single occurrences of dried rings of crab apple at Ur (c. 2500 B.C.) Pistacia atlantica and Celtis caucalis, two species which today grow in the Upland regions of Iraq, were found at Tell ed-Der (ca. 1650 B.C.). These species may well have been imported onto the alluvial plain. At Qantara (ca. 900 A.D.) there are 10 species of fruit tree, some successful on the alluvial plain and others which are restricted to the cooler, wetter conditions of the uplands. There are also several other cereals (Sorghum vulgare, Setaria sp. and Panicum sp. - there is one other record of this genus, a single imprint at 4th millennium Jemdet Nasr), a pulse (Vicia faba) and possibly the seeds of the egg plant (Solanum sp.).

In addition to emmer and barley, the plant remains at Tell ed-Der contain a few unusual types, some which do not grow in Iraq today, e.g. Coriandrum sp. and Cuminum sp., and some which flourish there, e.g. Allium sativum and Cyperus rotundus. The tubers of Cyperus rotundus, which were found at the site, have a number of potential uses and may be ground up to produce flour that can be eaten after roasting or boiling (van Zeist & Vynckier 1985). The tubers "yield from half to almost 1% of essential oil in distillation; it has a most agreeable smell" (Townsend & Guest 1985 p. 340), "are used for cleaning the teeth and are placed among clothes to keep away insects" (Hooper & Field 1937 p. 112).

One large sample contained ca. 1000 fruits of an unidentified Umbelliferae species, along with cumin, coriander and Allium sativum (garlic) which it is suggested may also be "a kind of spice or at least a cultivated species" (Zeist & Vynckier 1985).

The samples also had six types of wild plant seed which could have been associated with the spice plants, or with other crop plants, most being common in both lowland and upland areas but two, Malabaila (c.f.) and Bellevalia are more common in the Upland areas.

The Tell Yelkhi samples are rich in emmer and barley, lentil and cultivated Lathyrus sp. The wild plant species found in these samples are those typically found as weeds of the winter crops in S. Iraq, e.g. Bromus sp., Lolium sp., Galium sp., Scorpiurus sp. and non-cultivated Lathyrus sp. Three hundred seeds of Aegilops sp. were found in one sample, and the members of this genus are today restricted to altitudes greater than ca. 200 m, the only exception being A. hotschyi which grows in desert depressions and is not mentioned as a crop weed.

b. Imprints.

As has been mentioned only seven types of crop have been recognised in pottery imprints, five of which make a single appearance; Linum usitatisimum, Triticum aestivo-compactum, Phoenix dactylifera, Panicum sp., T. aestivum/durum.

Imprints of T. dicoccum and H. sativum (hulled) occur regularly in pottery from the 5th millennium BC through to the 2nd, and barley continues to be found in 1st millennium A.D. sites although there is no emmer. There are consistently more barley grain impressions than emmer throughout the record of imprints and the dichotomy increases in the later periods. Jacobsen's suggestion that this indicates a greater area of land under barley cultivation, as a response to increasing soil salinisation, can only remain a conjecture. Powell (1985 p. 15) queries the type of material in which the impressions were found, and with reference to comments made on imprints from Proto-literate Uruk pottery says;

> "The number of recorded imprints is too small to be statistically significant by itself, and even if it accurately reflected the relative ratios of use of emmer and barley for the city of Uruk, we would still not know whether the attested ratio of imprints reflects real production ratios or the food preferences of a particular segment of the population or some other factor".

1.4.2.5 Conclusions - Agriculture in Lower Mesopotamia

The small number of archaeobotanical samples, their provenance, composition, and the method of sampling, imposes severe limitations on any subsequent discussion and interpretation, but a few general points can be made regarding the agriculture and conditions in the area. (The following discussion does not include the remains from Qantara unless indicated because the site is so much later in date than the others).

a. Crop plants available.

Many of the crop plants present in the Uplands of Mesopotamia, where they are thought to have been domesticated, were brought down to the lower lying alluvial plain where they (or their ancestors) do not naturally occur. And it would not seem to be postulating too wildly to assume that all the crops of the upland areas were, at some time or other, tried on the Lowland soils. The crops found in more than two of the sites are einkorn, emmer, bread wheat and compact bread wheat, 6-row hulled and naked barley, as well as a large number of grains which are hulled but not identified to 2- or 6- row (2-row positively identified at two sites), lentil, large seeded Lathyrus species, flax/linseed and last the date palm. The meaning of these various plants cannot yet be ascertained accurately but it is important to note that more or less all those present at the earliest site investigated on the alluvial plain, Tell es-Sawwan [which includes most of the above listed species], were also present in the later deposits at Tell Yelkhi (ca. 20-1800 BC) and that these are two of the few sites where plant remains were recovered in sufficient quantities to be regarded a representative of agricultural practice. However, speculation regarding the role of any of the species through time is for the moment premature.

Several of the species are present at only one or two sites, namely 2-row barley, broad bean, chick pea, garlic, coriander and cumin, crab apple and the many species that appear for the first time at Qantara (ca. 900 AD). Some of these plants are not suitable for the climate, e.g. chick pea (Charles 1985 p. 43-44).

The marked present-day climatic contrast between the Upland and Lowland regions of Iraq is evident even now in the distribution of crop growing although the availability of water is no longer a limiting factor. So while some plants, such as apple, do not grow or fruit successfully on the alluvial plain there is a definite altitudinal upper limit for the reliable fruiting of date palms (Charles 1987 p. 1-5).

The effect of these climatic contrasts on past cultivation is not yet well established but the known occurrences of the major crops are shown on Table 1.1.

Not all the cultivated plants present in the archaeobotanical record and identified from the cuneiform sources are thought to be native to Upland Mesopotamia and their appearance in Lowland Mesopotamian sites implies introduction from other areas. Of the charred remains represented, three of the plants found at Tell ed-Der are not considered native to Iraq: Allium sativum (garlic) which may have originated in Central Asia (Simmonds 1976 p. 187-8); Coriander which "is probably indigenous to western Asia or the eastern Mediterranean" (Neil 1980 p. 112) and is frequently grown in southern Iraq; and cummin which "is indigenous to Ethiopia" (Neil 1980 p. 122) and mentioned for southern Iraq (Rechinger 1964 p. 460).

The summer-grown cereals found at Qantara (c. 900 AD), are not thought to be indigenous to Mesopotamia. Sorghum bicolor is believed to have originated in tropical Africa (Harlan 1989b p. 335-339) and Panicum sp. which may have been domesticated in central or eastern Asia Simmonds 1976 p. 309) though the most likely progenitor, S. viridis (Simmonds 1976 p. 309) grows wild in the lower forest zone of Iraq (Bor 1968 p. 505).

b. Wild plant foods available.

The following wild plants occur in archaeological deposits and are known to be eaten in some form (all are thought to be native to the area, see Flora of Iraq): Capparis spinosa, Cyperus rotundus, Prosopis farcta, Lathyrus sativus/cicera, Medicago sp, Melilotus sp and Malva sp. The only type deliberately cultivated in southern Iraq appears to be Lathyrus sativus/cicera (Guest 1933 p. 55). What status these plants had in the past, weed or utilisable food, is not yet known.

c. Irrigation.

It has been assumed that the crops listed could not have been cultivated on the alluvial plains without irrigation unless there was considerably more rainfall than there is today. Even the most drought tolerant species would need at least twice as much rain as currently falls (ca. 150 mm).

d. Crops and seasonality.

The annual crops are all winter growing barring Panicum, but the possibility of a range of summer crops being grown at these sites cannot be ruled out.

e. Crops, salt and weeds.

Despite the dominance of barley over glume wheat grains in the charred and imprint remains the suggestion that this is evidence of a transition to barley growing in response to an increase in soil salinity levels is by no means proven. There are many factors to be considered, not least whether the barley grown from 5000-0 B.C. was any more salt tolerant than the glume wheat/emmer of the time (Powell 1985 p. 13-14).

The cereal and pulse samples at Tell Yelkhi do not contain wild plant seeds that would indicate saline soil even though there is a markedly greater quantity of barley in the samples than emmer.

Table 1.1 Plant remains in Lowland Mesopotamian sites: charred and pottery imprints

site number	1	2	3	4	5	6	7	8	9	10
site name *	T.S	Ur	Aba	Urk	J.N	Ksh	Urk	J.N	Urk	Agb
Plant type										
T. monococcum	c									
T. dicoccum	i	i	c		i		i	i	i	
T. aestivum/durum	c		?	i						
T. aestivum-compactum								i		
Triticum sp.			c							
H. sativum 2 row		c								
H. sativum 6 row		c								
H. sat. 2/6 row hulled										
H. sativum var. nudum	c					c				
Hordeum sp.		i	c	i	i		i	i	i	i
Hordeum spontaneum			i							
Lens culinaris										
Vicia faba ?sp.										
Lathyrus sativus (cult.)										
Pisum sativum										
Cicer arietinum										
Linum usitatissimum		i								
Allium sativum										
Coriandrum sp.										
Cuminium sp.										
Cyperus rotundus (tuber)										
Capparis spinosa										
Vitis vinifera										
Olea europaea										
Ficus carica										
Phoenix dactylifera										
Punica granata										
Pistacia atlantica										
Celtis caucalis										
Quercus sp.										
Prunus domestica (greengage)										
Juglans regia										
Prunus amygdalus										
Pyrus communis										
Pyrus malus										
Sorghum vulgare										
Avena sp. wild										
Panicum miliaceum								i		
Aegilops sp.										
Lolium sp.										
Phalaris sp.										
indet Gramineae			c							
Setaria italica										
Lathyrus sp.										
Vicia sp.										
Scorpiurus sulcata										
Trigonella sp.										
Prosopis farcta			c							
Medicago sp.										
Malva sp.										
Galium sp.										
Rumex sp.										
Malabaila sp.										
Umbelliferae indet										
Centaurea	c									
Solanum sp.										
Bellevalia sp.										
Liliaceae sp.			c							
Cyperus sp.										

* see key

Plant type	11 Kfj	12 Ksh	13 Ur	14 Erd	15 Ur	16 Esh	17 Ur	18 Npr	19 T.Y	20 Ur
T. monococcum	i	i				i		ic	i	
T. dicoccum										
T. aestivum/durum										
T. aestivum-compactum				c						
Triticum sp.					c					
H. sativum 2 row										
H. sativum 6 row						c				c
H. sat 2/6 row hulled										
H. sativum nudum				c						
Hordeum sp.	i	i	i	c		i	i	i		i
Hordeum spontaneum										
Lens culinaris										
Vicia faba ?sp.										
Lathyrus sativus (cult.)									c	
Pisum sativum					c					
Cicer arietinum					c					
Linum usitatissimum				cl						
Allium sativum										
Coriandrum sp.										
Cuminium sp.										
Cyperus rotundus (tuber)										
Capparis spinosa										
Vitis vinifera										
Olea europaea										
Ficus carica										
Phoenix dactylifera				c	c	i		c		
Punica granata										
Pistacia atlantica										
Celtis caucalis										
Quercus sp.										
Prunus domestica (greengage)										
Juglans regia										
Prunus amygdalus										
Pyrus communis					c					
Pyrus malus										
Sorghum vulgare										
Avena sp. wild										
Panicum miliaceum										
Aegilops sp.										
Lolium sp.										
Phalaris sp.										
indet Gramineae										
Setaria italica										
Lathyrus sp.									c	
Vicia sp.										
Scorpiurus sulcata									c	
Trigonella sp.										
Prosopis farcta										
Medicago sp.										c
Malva sp.										
Galium sp.										
Rumex sp.										
Malabaila sp.										
Umbelliferae indet										
Centaurea										
Solanum sp.										
Bellevalia sp.										
Liliaceae sp.										
Cyperus sp.										

Plant type	21 Npr	22 T.H	23 Kfj	24 Isc	25 T.d	26 A.D	27 Kfj	28 Kfj	29 Ksh	30 T.Y
T. monococcum	c									c
T. dicoccum	i	c		i	c	i		i		c
T. aestivum/durum										c
T. aestivum-compactum					c					
Triticum sp.		c								c
H. sativum 2 row										
H. sativum 6 row										
H. sat 2/6 row hulled										
H. sativum nudum										
Hordeum sp.	i		i		c			i	i	c
Hordeum spontaneum										
Lens culinaris					c					c
Vicia faba ?sp.										
Lathyrus sativus (cult.)										c
Pisum sativum					c					
Cicer arietinum										
Linum usitatissimum							c			
Allium sativum					c					
Coriandrum sp.					c					
Cuminium sp.						c				
Cyperus rotundus (tuber)					c					
Capparis spinosa										
Vitis vinifera										
Olea europaea										
Ficus carica										
Phoenix dactylifera					c					c
Punica granata										
Pistacia atlantica					c					
Celtis caucalis					c					
Quercus sp.										
Prunus domestica (greengage)										
Juglans regia										
Prunus amygdalus										
Pyrus communis										
Pyrus malus										
Sorghum vulgare										
Avena sp. wild										c
Panicum miliaceum										
Aegilops sp.										c
Lolium sp.										c
Phalaris sp.					c					
indet Gramineae					c					c
Setaria italica										
Lathyrus sp.										c
Vicia sp.										c
Scorpiurus sulcata										c
Trigonella sp.										
Prosopis farcta					c					
Medicago sp.										
Malva sp.										
Galium sp.					c					c
Rumex sp.					c					
Malabaila sp.					c					
Umbelliferae indet					c					
Centaurea										
Solanum sp.										
Bellevalia sp.					c					
Liliaceae sp.										
Cyperus sp.					c					

	31	32	33	34	35	36
Plant type	A.Q	Bab	Npr	Ur	Bsm	Qnt
T. monococcum						
T. dicoccum	i					
T. aestivum/durum						
T. aestivum-compactum						c
Triticum sp.						
H. sativum 2 row	c					
H. sativum 6 row	c				c	
H. sat 2/6 row hulled						
H. sativum nudum						
Hordeum sp.	i	i	i		i	c
Hordeum spontaneum						
Lens culinaris						c
Vicia faba ?sp.						c
Lathyrus sativus (cult.)						c
Pisum sativum						c
Cicer arietinum						
Linum Usitatissimum						
Allium sativum						
Coriandrum sp.						c
Cuminium sp.						
Cyperus rotundus (tuber)						
Capparis spinosa						
Vitis vinifera						c
Olea europaea						c
Ficus carica						c
Phoenix dactylifera						
Punica granata						c
Pistacia atlantica						
Celtis caucalis						
Quercus sp.						c
Prunus domestica (greengage)						c
Juglans regia						c
Prunus amygdalus						c
Pyrus communis						c
Pyrus malus						c
Sorghum vulgare						c
Avena sp. wild						
Panicum miliaceum						c
Aegilops sp.						
Lolium sp.						c
Phalaris sp.						
indet. Gramineae						
Setaria italica						c
Lathyrus sp.						
Vicia sp.						
Scorpiurus sulcata						c
Trigonella sp.						c
Prosopis farcta						c
Medicago sp.						
Malva sp.						c
Galium sp.						c
Rumex sp.						
Malabaila sp.						
Umbelliferae indet						
Centaurea						
Solanum sp.						c
Bellevalia sp.						
Liliaceae sp.						
Cyperus sp.						

c = charred remains   i = pottery impressions   cl = cloth

Key to sites included in table 1.1

1	Tel es-Sawwan	6000-5500 B.C.	19	Tell Yelkhi	2200-2000
2	Ur	4200 B.C.	20	Ur	2100
3	Abada	c.4500 B.C.	21	Nippur	2000
4	Uruk	4200	22	Tell Harmal	2000
5	Jemdet Nasr	3500	23	Khafajah	2000
6	Kish	3500	24	Ischali	2000-1800
7	Uruk	3500	25	Tell ed-Der	1650
8	Jemdet Nasr	3300	26	Abu Dibis	1700
9	Uruk	3200	27	Khafajah	1700
10	Agrab	3200	28	Khafajah	1700
11	Khafajah	3200	29	Kish	1700
12	Kish	3200	30	Tel Yelkhi	2000-1300
13	Ur	3200	31	'Aqur Quf	1300
14	Eridu	4th mill.	32	Babylon	600
15	Ur	2500	33	Nippur	600
16	Eshnunna	2300	34	Ur	ca. 500
17	Ur	2300	35	Bismaya	226 A.D.
18	Nippur	2100	36	Qantara	900 A.D.

Table 1.2 Plant remains present in Lowland Mesopotamia sites 5th millenium B.C. - 1st millenium A.D.: charred material and pottery imprints

	millenia											
	5th		4th		3rd		2nd		1st B.C.		1st A.D.	
	chr	imp	chr	imp	chr	imp	chr	imp	chr	imp	chr	imp
T. monococcum	c				c							
T. dicoccum	c	i		i	c	i	c	i				
T. aestivum/durum	?	i					c					
T. aestivum-compactum			c	i			c				c	
Triticum sp.	c				c		c					
H. sativum 2 row												
H. sativum 6 row					c		c		c			
H. sat 2/6 row hulled	c	i		i	c	i	c	i		i	c	
H. sativum nudum	c		c									
Hordeum sp.	c	i		i	c	i	c	i				
Hordeum spontaneum	c											
Lens culinaris					c		c				c	
Vicia faba ?sp.												
Lathyrus sativus (cult.)					c		c				c	
Pisum sativum					c		c				c	
Cicer arietinum												
Linum usitatissimum		i	c				c					
Allium sativum							c					
Coriandrum sp.							c				c	
Cuminium sp.							c					
Cyperus rotundus (tuber)							c					
Capparis spinosa	c											
Vitis vinifera											c	
Olea europaea											c	
Ficus carica											c	
Phoenix dactylifera			c		c	i	c					
Punica granata											c	
Pistacia atlantica							c					
Celtis caucalis							c					
Quercus sp.											c	
Prunus domestica (greengage)											c	
Juglans regia											c	
Prunus amygdalus											c	
Pyrus communis					c						c	
Pyrus malus												
Sorghum vulgare											c	
Avena sp. wild												
Panicum miliaceum				i							c	
Aegilops sp.												
Lolium sp.												
Phalaris sp.												
indet Gramineae												
Setaria italica											c	
Lathyrus sp.												
Vicia sp.												
Scorpiurus sulcata					c		c				c	
Trigonella sp.												
Prosopis farcta	c						c				c	
Medicago sp.												
Malva sp.												
Galium sp.							c				c	
Rumex sp.												
Malabaila sp.												
Umbelliferae indet					c							
Centaurea												
Solanum sp.											c	
Bellevalia sp.												
Liliaceae sp.												
Cyperus sp.												

chr or c = charred remains   imp or i = imprint

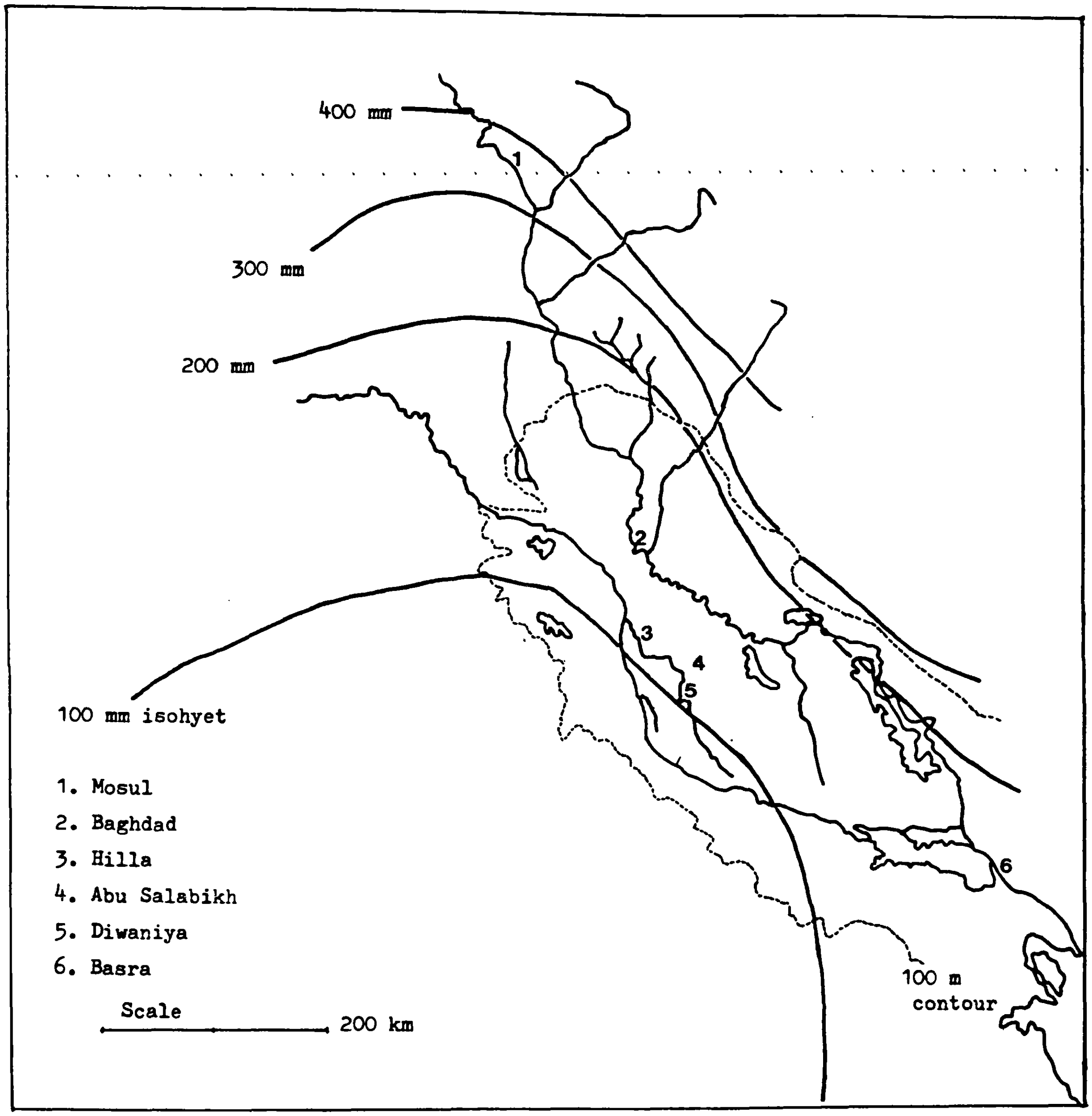


Figure 1.1 Mesopotamia: rainfall isohyets and the 100 metre contour

(after Guest 1966 fig. 5)

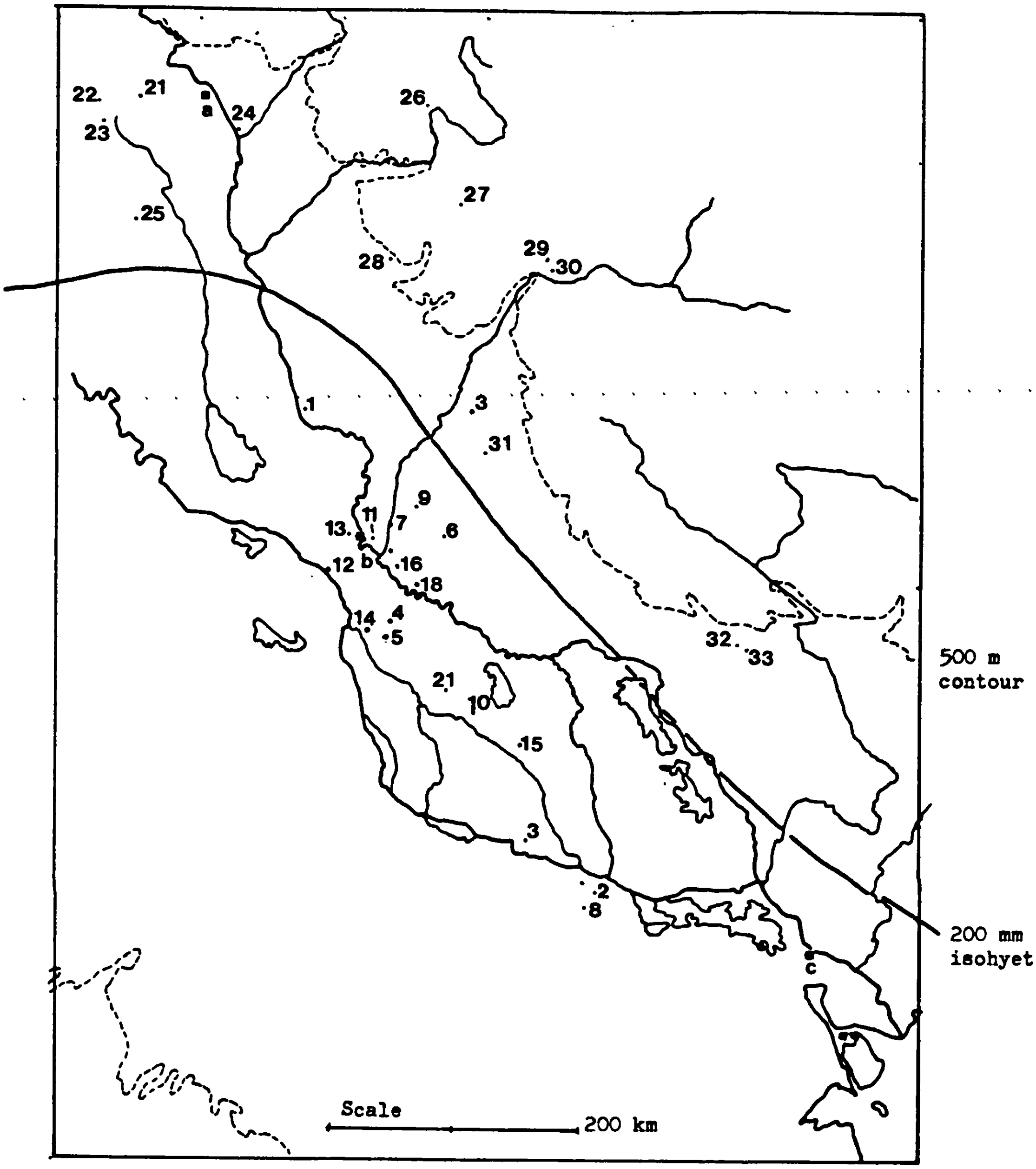


Figure 1.2 Map of Mesopotamia showing archaeological sites from which plant remains have been reported

Key to sites included in Figure 1.1

1	Tel es-Sawwan	12	Tell ed-Der	23	Tel Taya
2	Ur	13	'Aqur Quf	24	Yarim Tepe
3	Uruk	14	Babylon	25	Nimrud
4	Jemdet Nasr	15	Bismaya	26	Umm Dabaghiyah
5	Kish	16	Qantara	27	Tel Bazmosian
6	Agrab	17	Abada	28	Jarmo
7	Khafajah	18	Abu Dibis	29	Matarrah
8	Eridu	19	Tell Yelkhi	30	Tel Chragh
9	Eshnunna	20	Ischali	31	Tel Qurtass
10	Nippur	21	Abu Salabikh	32	Choga Mami
11	Tell Harmal	22	Tel Arpachiyah	33	Tepe Sabz
				34	Ali Kosh

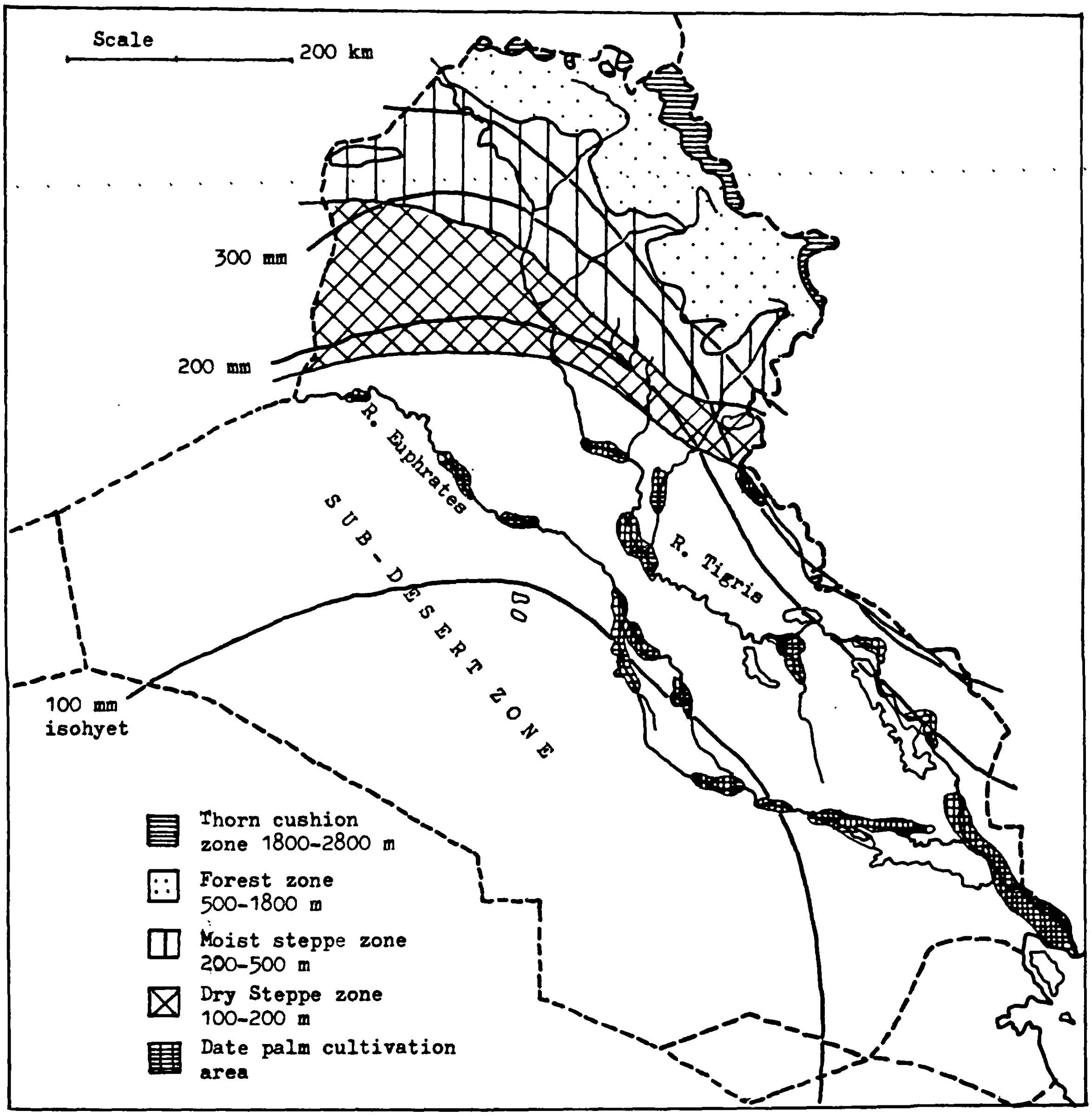


Figure 1.3 Mesopotamia: physiographic regions and vegetation zones
(after Guest 1966 fig. 15)

Chapter 2 Irrigation in Lowland Mesopotamia

2.1 Introduction

There was a considerable amount of activity on the part of soil scientists, agriculturalists and irrigation engineers in central and southern Iraq during the 1950's (A.D.) which generated a large body of data on the soils, vegetation, irrigation and, to a lesser extent, the traditional agricultural system. Several of these surveys are relevant to our studies of Sumerian agriculture, namely NEDECO (1959), Dielman et al. (1977), Russel (1957), Schilstra (1962) and Hunting Technical Services (1958). The soils of the area were also described in some detail by Buringh (1960). These sources have been used in an attempt to establish the particular local conditions of the Euphrates flood and delta plains, though in some cases it was necessary to deal with more generalised accounts of arid-land agriculture.

This chapter takes the form of an outline of the area's climate and hydrology, notes on irrigation theory, a description of the practices observed in Iraq until recently, and an evaluation of those practices in the light of modern theory. This information is then assessed as a basis for interpreting historical and pre-historical events.

2.2 Climate

Lowland Mesopotamia is in the sub-desertic region of the Near East. The low rainfall and high temperatures mean that irrigation is a necessity for agriculture to take place on a reliable basis. The area under study is well outside the limits of dry-land farming that have been proposed (section 1.1).

2.2.1 Rainfall

The average annual rainfall for the area is in the range of 115-135 mm for the years 1929-1959 (Buringh 1960 p. 44, and Nedeco 1959 p. 277) which was some 50-80 mm below the minimum water requirement for crop growing as stated by Lockwood (1985 p. 129) of "240 mm annual rainfall with an inter-annual variability of 37 per cent". The reliable rainfall season, i.e. with a monthly figure in excess of 25 mm, as defined by Lockwood (1985 p. 130), runs from December to April.

Dealing only with average monthly figures over a 20 or 30 year period fails to show up the variability of the rainfall through the winter crop growing season which was of crucial importance to agriculture in the area. An examination of the distribution of rainfall in Baghdad for four consecutive years (Table 2.1 from MacDonald 1958 in Adams 1965 p. 5) is useful when considering the reliability, or otherwise, of the precipitation of southern Iraq. The total rainfall of the years varies from 93 to 277 mm, and in 1956 and 1957 there was less than five mm per month until January The 'reliable rainfall season' (>25 mm/month) ran from November to March in 1954, from December to April in 1955, and from February to May in 1957. In 1956 only March and April had more than 25 mm.

Comments on two winters of crop growing in the Dujailah region of Iraq, directly west of Hillah on the Tigris, highlight the contribution that rainfall can make to the crops and at that the same time show how variable the distribution can be;

> "the precipitation still appears to be an important factor for winter growth. During the first winter (1956/57) the precipitation contributed as much as 50% to the total C.U. (consumptive use). Owing to the rainfall the crop could be sown without irrigation during the second season and received its first watering after about a month; in total the rainfall

accounted for 26% of the C.U." (Dielman 1977 p. 73-4).

The amount of rain falling in Baghdad and Dujailah during the winter of 1956-57 was 230 and 200 mm respectively. Taking crop consumptive use as 450 mm/year then rainfall provided approximately 46% in 1954-55, 27% in 1955-56 and 48% in 1955-57. Only in the first year could the first irrigation be delayed significantly, in this case until February, though early sowing would have been possible in both of the first two years.

Much of the rainfall occurs in the form of violent storms, which are as likely to damage the crops as to benefit them, flooding the lower lying areas of the landscape, rendering roadways impassable, and causing considerable soil erosion; in particularly heavy storms the crop may be directly damaged. The highest recorded fall in a single day in Baghdad was 56 mm, 40% of the yearly total (Buringh 1960 p. 44).

Hailstorms throwing down stones the size of golf balls are not unknown, and one exceptionally violent case was described by Evan Guest (1966 p. 75) which had produced "a wide expanse of completely barren land where even the perennial bushes had been reduced to blackened stumps"; as well as destroying the vegetation of the desert area for several kilometres it also killed many sheep, "and some human beings as well"! "Rainfall during the winter 1956-7, though ill-distributed, was not far below the average in this district".

2.2.1.1 Effective rainfall

Having accepted that the rainfall cannot be relied upon to meet all the crops water requirement on a regular basis, the potential contribution that rainfall can make to crop growing should be considered. Effective rainfall is that which falls in large enough quantities over short periods to soak the soil and be taken up by the crops, rather than be evaporated off. For example concentrated showers where 5-25 mm fell in 2-3 days, and 70 of the 105 mm "total average precipitation during the winter growing season", were described in the Hillah-Diwaniya region (Nedeco 1959 p. 171). Such falls are, however, rare; for the most part the rain fell in small showers;

> "It is for this reason that generally the irrigation supply is continued or delayed after rainfall has occurred, although in theory the irrigation requirement can be reduced by the effective precipitation" (Nedeco 1959 p. 171).

2.2.1.2 Rainfall and sowing

After the hot dry summer months the soil has been baked hard, dried to a depth of some 2-3 metres and compacted by animal trampling. The traditional Iraqi plough of the lowlands, a lightweight parting plough pulled by one or two small animals, was virtually unusable when the soil was in this condition and farmers must "wait for cool weather and high humidity and a possible shower of rain" (Russel 1957 p.14) to enable ploughing to start which was frequently not until late November. The winter crops need to be sown as close to October as possible to ensure a good yield (Guest 1933 p. 3).

> "The likelihood of sufficient rain falling by October is rare and in most years the land has to be irrigated before ploughing can start" (H.T.S 1958 p. 223).

2.2.2 Water and plant development

The principal function of the water is in the photosynthetic process of the plant which produces the basic energy units that are used in plant development. The water taken up by the plant also includes nutrients from the soil in the immediate vicinity of the plant, e.g. nitrogen from nitrogen fixing plants, nutrients from the breakdown of other plant material or fertilizer, and minerals from various soil components.

The water requirement and sensitivity to water stress of a plant is not constant through its development and differs for each crop type. The amount of water available at one point in a plant's development will have a direct bearing on its size, rooting characteristics, rate of growth and ultimately its yield: e.g. a shortage of water during early development may dramatically reduce root growth subsequently the plant's ability to fully utilise soil moisture, reducing yield or even killing the plant. The minimum water of a plant also varies from species to species and between varieties of the same crop.

Each plant has an optimal level of water supply at which it can develop successfully and give maximum yields. Any failure to meet this requirement has a detrimental effect on the plant's development, the extent of the response being decided by the relative tolerance of the plant to that degree of water stress at that stage of its life cycle. The greatest impact will be during a critical growth periods.

Water requirement, rainfall and the effect of water stress is now considered at three stages in the life cycle of annual plants.

2.2.2.1 Rainfall and germination

Though sufficient rain may fall to allow ploughing and sowing to proceed in October or November, it is very unlikely to provide sufficient water to do away with the need for an initial irrigation. For successful germination of the seed and establishment of the seedling the soil around the seed must be;

i. free of excess salts,
ii. pliable enough for root growth and penetration, roots being unable to grow into a dry hard soil,

iii. lacking a surface crust which would prevent seedling emergence into the atmosphere,

iv. sufficiently moist to meet the water requirement of the young plant.

In order to create these conditions an irrigation of 50-80 mm is usually required. If it is the first irrigation of the season the amount of water applied is increased to 80-147 mm to leach salts from the upper soil layers (Boumans 1977 p. 73). It is unlikely that this amount of rainfall could be relied upon in October or November so an initial irrigation would be necessary for an early sowing.

2.2.2.2 Rainfall and vegetative growth

Once the plant is established there is a period of rapid vegetative growth when the water requirement increases rapidly. Water stress at this time is likely to have a permanent effect on the plant. If root development is slowed down the volume of soil moisture that can be tapped later on will be diminished, and a reduction in the number or size of the leaves decreases the plants photosynthetic area and thus its potential for 'food' production.

The monthly rainfall (Table 2.1) during the period of vegetative growth is more reliable than that of the autumn months, but it is the intensity of the rainfall which determines its usefulness to the crop.

2.2.2.3 Flowering and fruiting

Watering of the crops needs to continue until the fertilization of the flower, ca. 2-4 weeks before the harvest, whereafter the soil can be allowed to dry out while the crop matures. "No water is consumed by the plants [cereals] during the last two weeks before the harvest" (Nedeco 1959 p. 170).

In the period just prior to flowering through to pollination it is vital that the plant experiences no water shortage as this is the critical stage of water-stress sensitivity in many cereals. Such stress at this time dramatically reduces the final yield.

The number of flowers and the viability of the pollen depends on the nutrient and water status of the plant. In some species a period of water stress may be required to initiate the onset of flowering, but more usually the plant is very susceptible to water stress at this stage and any shortage of water causes a marked decrease in yield. Water is required to fill out the fruit after fertilization but once this has been completed a dry period is often necessary for maturation or ripening off to occur.

2.2.2.4 Conclusions

Although the role of rainfall in providing water for crop plants is generally small due to the highly unreliable nature of its distribution through the winter months, it can still have a considerable impact on the agriculture of the region; witness the dependence of farmers on the autumn rains to make the first ploughing possible. For the remainder of the growing season heavy falls can upset the irrigation cycle (causing waterlogging etc.) and even result in damage to crop plants, a delay in harvest, land flooding, and the erosion of the topsoil.

2.2.3 Temperature

2.2.3.1 Climate and evaporation

Evaporation can reach very high levels in the hot dry climate of Lowland Mesopotamia. Water moves from the soil into the atmosphere in two ways and these each have consequences for agriculture;

a. Soil surface evaporation.

The potential evaporation rate (P.E.R.) from the soil can be as much as 10-12 mm/day in arid regions, (Withers and Vipond 1974 p. 79), and these rates are achieved in southern Iraq during July and August. Rates are lowest in the months December to February.

Evaporation from the bare soil can dry the topsoil to a depth of 1.5 m over two years or so, the rate of evaporation being rapid while the topsoil is moist but decreasing as the top layer dries out.

b. Evapotranspiration.

The movement of water through the plant and consequently its uptake from the soil, which accounts for most of the crop water uptake, is powered by transpiration. The amount of water transpired by a plant greatly exceeds the amount it retains. The transport of the water provides a mechanism for the uptake of nutrients but the majority of the loss is a result of the uptake of CO_2 for use in the photosynthetic process which takes place across a moist cell surface and causes the large scale loss of water by evaporation.

The rate of transpiration is a feature of the temperature and relative humidity of the atmosphere immediately around the plant. In the hot arid conditions of Lowland Mesopotamia the evapotranspiration rate is very high. The rates of evapotranspiration roughly correspond to those of evaporation (Table 2.2) from a free sheet of water, and greatly exceed the rainfall for the area. The discrepancy is most marked during the summer months, the average consumptive use being approximately four times greater. The rate of water loss from a vegetated surface may even exceed that from open water (FAO 1973 p. 225) and the total amount of water removed from the soil can be considerably greater than from a bare soil surface. This is because the plants have access to deeper lying water supplies, and evapotranspiration may continue long after the top soil has dried out. Under a normal winter annual crop the soil may be dried to a depth of ca. 0.5 metres, while the summer growing deep-rooted perennial legumes that infest the fields in southern Iraq can remove the water from the top two metres or so (Nedeco 1959 p. 127).

Factors affecting the rate of evaporation;

a. Temperature.

It has been calculated that the rate of water evaporation will double for every 10 degree centigrade rise in temperature (Raven 1976 p. 532). A rise in temperature increases the capacity of the air for holding water thereby lowering its relative humidity which allows further water uptake from the plant/soil surface (Table 2.6 shows mean temperatures for southern Iraq).

b. Wind.

As water evaporates from the plant/soil surface into the atmosphere the layer of air next to the plant becomes saturated and when the water vapour levels of the two are equivalent evaporation stops. Any wind movement which replaces the saturated air with dry air accelerates the rate of evaporation (Raven 1976 p. 532). Winds in Lowland Mesopotamia are strong and often warm causing exceptionally high evaporation rates (Buringh 1960 p. 46).

c. Humidity (Table 2.7).

The rate of evaporation decreases the greater the humidity of the air in contact with the plant or soil (Raven 1976 p. 532). In general the humidity of Lowland Mesopotamia is low, less than 15% in the summer.

2.2.3.2 Temperature and vegetation

Each crop species has temperature limits for growth and within these an increase in temperature will accelerate growth and development (Arnon 1972 p. 41). The "critical point" (temperature) for plant life in Iraq is considered to be 10°C and if the mean January temperature is not above 10°C the development of the winter flora is delayed until spring (Guest 1966 p. 20). This may be the case for the natural vegetation but crop plants can grow at lower temperatures. On the Lowland Plain the mean monthly temperature never drops below 10°C in Diwaniya or Basrah (Guest 1966 p. 20). Germination and tillering takes place before the onset of cold weather and frosts occur rarely so growth may continue through the winter albeit at lower rates than in the spring.

The optimum conditions for wheat are around 25°C with a maximum of c. 30-32°C, while barley can tolerate ripening temperatures of up to 40°C. High temperatures in conjunction with dry winds can cause damage to wheat ears and temperatures greater than 25°C may depress grain production. The most sensitive phase of development seems to be during fertilization, after which successful grain maturation occurs at 12-25°C. The average temperatures in southern Iraq do not exceed 25°C until the middle of May, by which time the crop has usually been harvested. The other major winter crops of Lower Mesopotamia have similar requirements and have generally completed maturation by the time the temperature rises above 30-35°C.

The most common summer crops are well adapted to the extremely hot conditions prevalent and providing they are well watered can usually grow successfully. During periods of very high temperatures and strong hot winds there may be damage to the crop.

2.3 Hydrology

The uncertain nature of the winter rainfall of Lowland Mesopotamia, already discussed, makes it essential that irrigation water is available at crucial stages of the agricultural cycle in order to compensate for deficiencies in the precipitation. At the time when the water is most needed for irrigation the river levels are at their lowest. The situation was aptly described by Ionides (1937);

> "The distribution of river supplies throughout the year does not well fit the needs of agriculture. Winter grown crops require irrigation from November to May, but the first rise in the rivers may be delayed well into December, and the season's crops must then be sown on what is in effect the rivers' meagre summer supply. Once the sowing season is successfully over, however, supplies are usually ample, and in fact increase till the harvest. About this time the river takes the other extreme, and more often than not threatens with inundation the crops it was with difficulty persuaded to germinate. For the summer crops, which need irrigation from April to September, the conditions are reversed; the supply is at first ample, but dwindles steadily as the season progresses. The potential useful water supply is, therefore, far in excess of that which can now be utilised".

The principal concern here is with the natural regime of the Euphrates river because it is believed to have been the major water source for irrigation agriculture during the fourth and third millennia B.C. However, it has not always been possible to find hydrological data for the Euphrates and therefore some data from the Tigris have also been used (as indicated). The Euphrates receives water from the Central Anatolian Plateau and there are no large tributaries in Iraq, its last feeder being the Khabur, some 400 km NW of Baghdad, in Syria.

The Euphrates derives much of its water from melting snow, and its floods are not as violent and unpredictable as those of the Tigris which are caused by relatively short lived rainstorms (Buringh 1962 p. 52). The Euphrates also travels for several hundred kilometres through arid unwatered lands which mitigates against extreme rises of water level.

The Euphrates is better suited to the extraction of irrigation water than the Tigris because, it is raised above level of the plain, has lower levee banks, and a winding course which makes it easier to construct take of canals. The division of the Euphrates into several small branches on its delta plain makes the exploitation of the river considerably easier and also means that a large area can be irrigated with only relatively small irrigation works.

The average monthly discharge rates for the Euphrates (Table 2.5) show a slow discharge for the period July to December, increasing steadily through to March before reaching peak rates in April, May and June, roughly four times that of the summer and autumn, before declining again. These figures translate themselves into a 5-6 m change in the river level over the year. The annual cycle is repeated fairly consistently, i.e. the pattern of discharge rates varies comparatively little from year to year, but in terms of irrigation use and flood risk there is fair amount of inter-annual variation in the river levels for the flood months.

2.3.1 Stages of the river (after Buringh 1960)

The Euphrates enters the Lower Mesopotamia Plain from the region of river terraces near Hit, and moves across its flood plain as far as Shinafiya, near Hillah, where it reaches its delta plain.

2.3.1.1 Flood plains

The Flood Plain (of the Euphrates), extends from Ramadi to just south of Hillah. Here the river meanders but is still undivided. It is raised above the level of the plain, and is liable to change course when flooding occurs. Above Hit the average land slope is roughly 30 cm/km, once on the flood plain this is reduced to ca. 10 cm/km and the river follows a meandering course though still single. In the spring months the river floods once every three or four years spreading over the surrounding countryside for quite a distance and leaving a thin layer of sediment. During such an event the river may change its course, and the course of the river also moves as a result of lateral channel cutting (Adams 1981 p. 8).

2.3.1.2 Delta plains

Just below Hillah the land slope becomes less steep, and the Euphrates enters its delta section where the river starts dividing. The slope is reduced to only 3 cm/km, the river slows further and splits into a number of branches, as was formerly the case on the Euphrates just below Diwaniyah, where the river divided into three main branches forming a large area of marsh. The river course also becomes very winding and narrow in places.

As is seen later this division, which cuts the alluvial plain into two, produces distinct soils and has implications for agriculture in the area.

2.3.2 River borne material

The quality of the river water, i.e. the amount of sediment and salt it carries, also has an effect on the land and agriculture in the long and short term.

2.3.2.1 Sediment (Table 2.3)

The Euphrates carries sediment from the uplands of Turkey where it is fast flowing and scouring, the sediment comprises material from the different rocks it and its tributaries pass over, and consists of a range of soil particles from fine sand to clay held in suspension. When the river levels are high e.g. April to June, the high water speed keeps the majority of the material in suspension. When the river water floods its banks the it loses velocity and the particles are deposited, the coarse particles first and the fine ones further from the river. This process has the effect of producing raised river banks or levees of relatively coarse textured soils along the river sides with finer textured basin soils in the depressions beyond.

2.3.2.2 Salt (Table 2.4)

The salt content of the Euphrates and Tigris is far lower than the quantity of sediment carried, generally being within the range 2-400 ppm in both rivers, a minimum of 10-50 ppm being recorded at periods of peak discharge (Buringh 1960 p. 50). The salt content of the Euphrates appears to be more variable than that of the Tigris, and it increases to the south as a result of evaporation.

Even at the comparatively low levels of 100 ppm the quantity of salt added to the soil is still quite large when using intensive irrigation e.g. 1 m of water (depth of irrigation) applied to land = 1000 kg of salt per ha. (Buringh 1960 p. 85), and even though not all the salt is directly harmful to plants the overall effect is still to make it more difficult for the plant to extract soil water (see section 2.7.1).

2.3.3 River soils

2.3.3.1 Flood plain

a. River levee soils

The levee soils are formed from the heaviest, coarsest sediment which is the first to be deposited as the river floods. They consist of relatively coarse textured soils such as fine sand, coarse loam and silty clay loam (Buringh 1960 p. 148-151, Nedeco 1959 p. 60-61). They are elevated above the river and plain so the ground-water level is usually low (i.e. far from the soil surface), and drainage is usually good due to the height of the levees above the river and plain and the coarse nature of the soils. Ground-water salt content is diluted by seepage of fresh water from the river.

b. River basin soils.

After topping the levees the river water spreads over the land, covering several kilometres, until the discharge and spread ceases and the water is left standing on the soil surface before it infiltrates the soil, is evaporated off or drains to lower lying land or back into the river and canal. Five to ten cm of sediment can be deposited by a single flood. Where standing water remains for sometime the finest clay particles become concentrated in the deposit.

The basins are below the river and the levees and are therefore closer to the ground water which, combined with the lower permeability of finer soils, makes them more prone to waterlogging. The soil types are in the range of silty clay loams to clay (Buringh 1960 p. 150), their suitability for cultivation depending largely on their position relative to the river. Closer to the river the water table is still quite deep (1.5-2.5 m) and the soils are fairly coarse, but further away the land level slopes down coming into closer contact with the ground water and the soils are the finer and less suitable for crop growing.

2.3.3.2 Delta plain

There are also a number of changes which affect the soils adversely making the land more prone to salinisation, waterlogging and soil deterioration. The basic pattern of sedimentation is the same, though the braided nature of the river means that there are more sources of flooding. The water table is closer to the soil surface and the soils frequently become waterlogged, as there is little natural drainage, and large bodies of standing water are a common sight. Also, the likelihood of soil salinisation, resulting from ground water being drawn to the surface by capillary action and evaporated off leaving salts in the top layers of the soil, is greatly increased. So though the soils are basically the same as on the flood plain they are overall of a poorer quality, and can be expected to have a shorter productive life.

2.3.3.3 Agricultural suitability of river soils

The river foreland, i.e. the area between the levee and the river, is used for summer vegetables after being flooded in the spring/early summer. The water table is fairly close to the surface but not close enough to provide water for the roots of the annual crops, though it can be utilised by the fruit trees (Buringh 1960 p. 150). The river banks, which are uncovered as the water level drops in the summer months, can be used for growing vegetables which extract the water left in the soil and from the declining ground water. The basin soils are generally used for the growing of winter cereals, legumes, linseed and a range of vegetables in an alternation of crop and fallow and they afford none of the advantages described for the levee orchards.

2.4 Irrigation theory

2.4.1 Introduction

It has already been pointed out that the amount of rainfall falling in Lowland Mesopotamia is well below the limit needed for reliable agricultural production, and this is likely to have been the case in Uruk and Early Dynastic times as there is no evidence of a climate change on a scale large enough to have put the lowland alluvial plain in the rain-fed zone. For successful agriculture, based on the available crops, it was essential that they receive water at regular intervals through their life cycle. The natural flood regime is not advantageous to crop growing and does not meet the water requirement of either winter or summer crops. The moisture content of the soil bordering the river and its distributaries is unlikely to provide sufficient water to the shallow rooted crop plants. These factors combined make it essential that there are artificial means of watering the fields if crop cultivation is to be established permanently, and these must be able to overcome the problems of low river-water levels in the periods when water is required most, namely November to April, and June to September.

In addition to supplying the crops with water the process of irrigation also moistens the upper-soil layers thus aiding the roots which otherwise cannot penetrate the dry hard soil, but this may cause crust formation as a result of soil-structure collapse. If the water percolates through the topsoil and into the subsoil it will leach out soluble salts including harmful ones and those which are plant nutrients. In an intensive agricultural system measures must be taken to replace these nutrients, by the application of plant material and fertilizer, otherwise yield will be reduced.

2.4.2 Types of irrigation in Southern Iraq

2.4.2.1 Surface or flood irrigation

This is the principal form of watering crops practisced in Lowland Mesopotamia. It involves water passing over the soil surface, a proportion of which infiltrates into the topsoil where it can be extracted by the plant from its rooting zone.

In surface irrigation;

> "the objective is to spread a thin sheet of water over the surface of the land. The water should 'pond'

for long enough to refill the storage capacity of the root zone", (Arnon 1972 p. 217).

At the same time there should be "just sufficient deep percolation for the effective leaching of harmful salts", (Withers & Vipond p. 36), producing a salt-free rooting zone at least during seed germination and seedling development when salt tolerance is generally at its lowest in crop plants.

2.4.2.2 Sub-surface irrigation

This method occurs in the estuarine region of southern Iraq. It depends on tidal-water movement raising the river level, pushing water through a series of water channels and ditches to irrigate the date palm orchards and associated crops. The water soaks sideways from the channels to be utilised by the plants and there is a natural process of drainage as the tides recede so that waterlogging does not become a problem (Naval Intelligence 1944 p. 440).

There are two components to water movement as it floods into a field:

i. the flow across the soil surface which is determined by the rate of water discharge, the slope of the irrigation run, the surface roughness and the rate of water loss to the soil,

ii. the flow of water that has infiltrated into the soil. Most of the water moves vertically due to gravity but some moves horizontally as a result of capillary action, the amount depending on the permeability of the soil. The infiltrating water forms a 'wetting front' which trails behind the surface stream down the field or furrow (Withers & Vipond 1974 p. 37).

In some irrigation techniques (e.g. wild flooding and border strip) water infiltration is a minor component in comparison with surface flow. In others (basin and occasionally furrow) the water is allowed to stand and soak into the soil, where the major component is the downwards infiltration of the water.

2.4.3 Factors affecting irrigation decisions

Ideally the amount of water applied should be sufficient to reach the end of the irrigation run with a minimum of runoff water, and to wet the soil to the required depth without excessive loss to the ground water. A number of hydraulic and soil factors are listed by Withers and Vipond (1974 p. 36) which are important in assessing the amount of water to be applied in an irrigation.

2.4.3.1 Hydraulic factors

a. Discharge rate.
The rate of water discharge into the irrigation unit should be adjusted such that the run reaches the end of unit with a minimum of soil erosion and runoff.

b. Slope of run.
An increase in the slope of a field or channel increases the water's velocity over the soil surface and the likelihood of erosion but it decreases the depth of stream and the infiltration rate. An evenly sloping field is essential if the whole area is to be covered equally, as raised land will be left dry and depressions waterlogged. Land levelling is a time-consuming process but was presumably practiced at least on a small scale in the past.

c. Surface roughness.
This can be controlled quite precisely by cultivation. Water infiltrates a rough soil surface more rapidly than a smooth one but the stream velocity is decreased and the water stream may not reach the end of the unit. A rougher

surface will also increase the stream depth. The size of earth lumps left on the surface of the an irrigation unit is also affected by such factors as sowing and there may be a conflict of interest.

d. Field channel shape.
This is influenced by the type of crops grown and the soil's textural, structural and salinity characteristics. On more or less level ground (up to 3% slope) soil erosion can be reduced by using rectangular channels with a flat bottom rather than 'V'-shaped ones. Channels which are 'U'-shaped have a larger surface area for infiltration than do 'V'-shaped ones.

2.4.3.2 Soil factors

The resistance of the soil surface to infiltration is another factor that can be strongly influenced by tillage, fertilizers and organic material, the aim being to produce a permeable surface which allows rapid water infiltration. One process that can hinder infiltration is the collapse of the soil when brought into contact with water. this occurs when the soil structure is poor. Improvements in the soil's condition can be achieved by suitable techniques and by avoiding overly fine seed beds (Russel 1957 p. 12).

2.4.4 Movement of water into the rooting zone

Water flowing into an irrigation unit either infiltrates the soil, evaporates off, or continues through and is lost as runoff to waste ground, ditches etc. (Nedeco 1959 p. 127). In an efficient system most of the water infiltrates the soil where it is available to the crop. Some of the water entering the soil is lost to the crop as it percolates through the rooting zone and into the ground water. Irrigation relies on two types of water movement into the soil to reach the rooting zone, the relative importance of which varies for each method of irrigation. They are:

a. Vertical water movement.

A major component in basin, wild flooding and border strip methods. The surface of the irrigation unit is covered by water, in some cases standing, and infiltration occurs by downward movement, due to gravity, into the upper soil layers. There is some horizontal water movement which helps to soak the soil but it has a minor role in the irrigation process.

b. Horizontal water movement.

Water moves laterally by capillary forces, from a furrow or ditch filled with water, into the rooting zone. There is inevitably some downward percolation and whether this is used by the plant depends on where the plant is placed in the furrow; if at the side or top then horizontal movement is of greatest importance, if on the bottom, vertical movement is most important. The ratio of horizontal to vertical water movement depends on the soil texture, the proportion of sand:silt:clay, and the soil structure which produces a characteristic wetting front around the furrow (Withers & Vipond 1974 p. 38). This same phenomenon is seen with irrigation ditches and canals.

After irrigation the soil should be saturated in the upper layers, with all the pores between the soil particles filled; drainage then begins of the so called 'drainage water' from the larger soil pores. When this has gone the soil is at its Field Capacity (F.C.). The process usually takes place in 1-4 days from the time the water supply is stopped, although it can usually be measured after two days, (Etherington 1972 p. 134). Drainage is most rapid on coarse sand soils which have large soil pores. The remaining 'capillary water' is "held by surface tension in the pores between the (soil) particles", and " is the principal source of water to the plant", (Withers & Vipond

1974 p. 69).

The amount of water contained in a soil at Field Capacity is determined by the proportion of small particles present, the greater the number the greater the percentage of the irrigation water that will be retained in the soil. Coarse textured soils e.g. sands and coarse silts, will have a lower soil moisture content, than finer textured silts and clays. The texture of the soil will also affect the ease with which the water can be taken up from soil, the forces holding water being greater in small pores so that water is more difficult to extract from a fine textured soil:

> "Ideal soils are loams which possess good moisture holding properties but release their moisture at low suctions and have good internal drainage and aeration" (Withers and Vipond 1974 p. 63-64).

The suction pressure exerted by a plant increases as its moisture content is lowered by transpiration enabling it to draw up water previously unavailable.

The area of the soil exploited for its moisture depends on the rooting depth of the crops, which ranges from 0.7-3 m. for the majority of field crops on normal soils. The upper soil layers dry first, where the majority of the crop roots are, and greater suction pressures are applied by the plant increasing water uptake from the lower soil layers (Withers and Vipond 1974 p. 73).

2.5 Irrigation practice in southern Iraq 1900-60 (A.D.)

Understanding of the manner of water extraction by the crop is not a prerequisite to success in traditional agriculture and remains an invisible process. However, the farmer does need to know when to water the crop, and, especially when water is in short supply, which is the most efficient time to irrigate in order to maximise the crop yield. This knowledge comes from long experience of cultivation and forms a part of locally adapted agricultural practice; it is understood that a well timed irrigation will give more benefit than several badly timed ones.

2.5.1 Description of the irrigation methods

The traditional irrigation systems of Lower Mesopotamia are principally of surface type with some sub-surface irrigation occurring in the estuarine region near Basrah.

2.5.1.1 Wild flooding

The sides of the irrigation ditch were broken down at one or more points along its length and the water allowed to flood the adjoining land on which may have been prepared smaller irrigation ditches to divide the field into smaller strips (Arnon 1972 p. 218). Despite the inherent inefficiency of this technique it was, until recently, used on unlevelled land to irrigate close growing crops such as the cereals, pasture and fallow land. The uneven nature of the land meant that elevated areas of the field were left dry while depressions had pools of standing water which could be used to reveal the parts of the field that needed levelling (pers. comm. Boumans 1987). It was not easy to alter the water flow and there would have been a high percentage of waste, leading to salinisation by the evaporation of water from standing pools and from the consequent rise of the water table.

This technique can be used on land with a slope of upto 8% and is best on coarse-medium textured soils with a fairly rapid infiltration rate. "Wild flooding requires much manual labour, has a low water application efficiency and gives very uneven distribution", but it is "the only practicable method on unlevelled ground" (Adams 1981 p. 5).

2.5.1.2 Border strip irrigation

This technique resembles wild flooding but low parallel earth banks are formed at right angles to the irrigation ditch dividing the field into narrow strips, up to 20 m wide (Withers & Vipond 1974 p. 41). Water should run down the strip as a uniform sheet of water which is only possible if the strip is even across its width, and there is a slope of >0.1% away from the irrigation ditch. A small band of level ground at the head of the strip spreads the water laterally before it moves down the slope, otherwise it may run as a "pattern of streams between dry islands" (Withers & Vipond 1974 p. 42);

> "In very primitive irrigation agriculture, the strips are very narrow and short - approximately 2 x 10 m Only very small streams can be used, and the amount of labour involved is enormous" (Arnon 1972 p. 218).

The strips can be longer in modern systems.

This method is suitable for close growing crops such as winter and summer cereals, legumes, oil crops and pasture on fairly permeable soils with a slope of between 0.1-3%.

One of the methods of irrigation used in Lowland Mesopotamia is described as "controlled flood irrigation". It is distinguished from uncontrolled irrigation because it is regulated "by the number of openings in the dykes and by the distances of the small dykes and irrigation ditches", it;

> "is practically the same as the overflowing in strips, whereby the irrigation water is supplied at the high side of long, narrow and slightly sloping strips, separated from each other by small dykes" (Nedeco 1959 p. 272).

2.5.1.3 Basins

The land is divided into rectangular basins by building low earth levees on pieces of flat land; these are filled to the required depth and the water left to percolate into the soil. The technique is suitable for "highly permeable soils and for soils with a very low infiltration rate" and according to Arnon (1972 p. 219) it has several advantages over other techniques, namely;

i. uniform water distribution on a range of soils by adjusting the amount of water allowed into each basin,

ii. flexibility, the basin size can be adapted to a wide range of crops, soils and cultivation methods,

iii. tolerance of heavy rainfall, which can function as additional irrigation,

iv. ease of operation, though the initial work may be labour intensive, once the basins are constructed they are easily maintained and a high level of control can be exerted over the water supply into each basin.

Basin irrigation is best suited to flat land, slopes of 0-0.1%, and for maximum efficiency the land within each basin should be levelled as carefully as possible otherwise there will be uneven water distribution. On land with up to 0.1% slope it can be used in the form of contour checks or terraces.

In southern Mesopotamia, the land is generally flat and basin irrigation is used on cereals , fruit trees, cucurbits, various Alliaceae, etc. (Buringh 1960 p. 249). The earth walls or dykes are constructed, using spades, after ploughing (Russel 1957 p. 18) and are considered useful for producing a salt-free germination zone, by flushing the salts into the ground water. Buringh (1962 p. 249) describes plots of land approximately 15 x 30 metres along each side of the irrigation ditch for winter crops. Although these basins are generally used as individual irrigation units, it is implied by Poyck (1960 p. 45) that they are a means of regulating water flow over the field, in which they would function almost like border strip irrigation.

2.5.1.4 Furrow irrigation

The furrows run down slope from the irrigation ditch, and water is introduced into the furrows from the ditch by breaching the ditch wall, siphoning or some form of lifting device; there may be a "tail ditch at the end of the run to collect water for re-use at lower levels" (Withers & Vipond p. 40). The length of the irrigation run should be gauged to allow adequate watering with the minimum of runoff, and to do this the soil and hydraulic factors described in Section 2.4.3 have to be considered. "In general long runs are more efficient than short ones but the optimum length of furrow varies from 50 to 300 m", (Arnon 1972 p. 219).

The use of horizontal water movement by capillary action, in addition to vertical, distinguishes furrow irrigation from the other three techniques described where the water is spread over the soil surface and moves predominantly downward into the rooting zone. The relative proportions of water supplied to the plant by these two components of water movement will depend on the plant's position. If the crop is sown along the ridge between the furrows then the furrow will need to be left full of water to allow adequate soaking of the rooting zone by horizontal water movement. Furrows can also be used to compensate for certain soil conditions, e.g. in saline soils sowing is along the side of the furrows, the distance between the furrows is increased and the salts are pushed into the centre of the ridge producing a salt-free rooting zone (Russel 1957 p. 19).

Furrow irrigation can be used on land with up to a 5% slope but gentler gradients are recommended to minimise erosion when "the furrow is not protected by vegetation", (Arnon 1972a p. 219). It is suitable for a large range of row crops, vegetables, annual fruits and fruit trees, etc., the shape, size and distance between the furrows being varied according to the plant species grown. Examples from southern Iraq include fruit trees, onions, garlic, poppy, fruits such as melons, tomatoes, peppers, cucumbers, squashes and other cucurbits, vegetables and other row crops. Some details of melon growing are given below to illustrate the major principles involved.

On saline soil the depth and width of the ditches may be enlarged to increase the water available for pushing the salts into the centre of the ridge (and the sides slope at an angle of up to 30°).

2.5.2 Water lifting machinery

> "Many smallholders own a water-lifting-device, their farms being mainly situated on the borders of the rivers and canals",
>
> "The common water lifting device used in those parts of the project-area where the irrigation canals are situated below the level of the surrounding fields, is the Persian wheel. Naturally, these devices are mainly used along the big main canals, the Shatt al Hillah, the Shatt al Diwaniya and the Daghghara canal", (Nedeco 1959 p. 274).

These are powered by animals and lift the water to a height of five metres at a rate of 13-16 litre/second.

The Naval Intelligence report (1944) mentions two other types of lifting devices irrigation being used in southern Iraq;

i. a SHADUF, lifts to 2 m, consisting of a bucket on a counterweighted lever which is pivoted around,

ii. a SAKIA, an animal driven hoist where a bucket is pulled over a pulley.

"Land irrigated by lift is reckoned to be more valuable and is now more extensive than land irrigated by flow", (Great Britain 1944 p. 441), though by this time diesel pumps were in use.

A further instance of lift irrigation is described by

Smith and West (1957) for the date palm orchards of southern Iraq near Basrah where SHADUFS are used as well as horse or water powered NAHOORS, much smaller than those of northern Iraq. A NAZUHA, which is a shallow basket suspended on ropes, is used to water land not reached by gravity flow in the marsh areas of southern Iraq (Salim 1962 p. 87).

2.5.3 Water stress and the frequency of irrigation

In normal irrigation and rain-fed agriculture in semi-arid areas all crops will almost certainly be exposed to some water stress, at some stage of their life cycle, because even where irrigation is being used the farmer does not have full control over the water supply. The stress periods may occur on very hot days even if water is available because the rate of water movement is unable to keep up with transpirational loss (Arnon 1972a p. 185), but they do not necessarily damage the plant or have an adverse effect on yield provided that the moisture content of the plant does not reach permanent wilting point. Under conditions of moderate stress the plant may wilt each day and regain full turgor each night without any detrimental effect and it has been observed that "maximum yields are possible even when the level of soil moisture is not constantly maintained at, or somewhat below,field capacity" (Arnon 1972a p. 191).

Thus in irrigation farming the cycle of soil flooding/ drainage/drying has to be timed to meet the water requirements of the crop as it moves through its development. In an efficient system the water levels would be kept within the limits necessary to give maximum growth and excess water is minimal. It has been calculated that as a 'rule of thumb' soils should be irrigated before 50% of the available water has been depleted (Withers & Vipond 1974 p. 73) though the actual value may vary considerably for different soil types. In practice this level of moisture depletion can be assessed reasonably well from the "the appearance and 'feel' of the soil", a technique based simply on observing whether the soil will stick together in a ball when squeezed firmly.

2.5.4 Winter and summer cultivation

So far the discussion has concentrated almost entirely on winter cultivation, yet summer cultivation is an important part of the traditional agricultural system. The antiquity of the system is unknown and the date of introduction of a number of the major summer crops is still a matter of controversy. The potential role of spring and summer cultivation and a description of practices associated with it, is presented in the next chapter but the water requirement of the two seasons are described here.

a. Spring cultivation.

The spring growing season extends from late January to mid June, and the average rainfall for the period was 60-80 mm from 1929-59 in the Hillah-Diwaniya region. The consumptive use through the growing season is calculated at 400-500 mm, not greatly in excess of the winter use. The rate of evaporation rises to 235 mm/month by May (Nedeco 1959 p. 170), though the river water levels are high from April to June making irrigation easier.

No figures are given for the losses that occur on the farm and during conveyance, but they are likely to be closer to those for the winter months and may be estimated at roughly 30% of farm delivery, a figure of 20% of delivery conveyance losses is used in their report for calculations. Leaching requirement is put at 20% of the total irrigation requirement which makes the total water required to be applied to the land 480-600 mm. This gives a total farm delivery of approximately 750 mm.

b. Summer crops.

The summer growing season lasts from June to September and the minimum water requirement is approximately 1200 mm. This means that over 2000 mm must be delivered to the farm because farm losses are reckoned to be 40% of the farm delivery in the summer season. Rainfall in the period is negligible and makes no contribution to the plants' growth.

The leaching requirement is estimated at 20% of total irrigation requirement, but it is best to leach the soil in the winter season when evaporative loses are smaller. Summer crops have a water requirement four and a half times that for typical winter crops. The overall efficiency of irrigation in the summer seasons is between 20 and 25% of the water entering the system.

The Euphrates level is near its peak in June and declines rapidly through July, August and September when it is necessary to raise the level using temporary dams made out of vegetation and soil (McDonald 1959 p. 13).

Summer irrigation is likely to increase rates of soil salinisation by raising the ground water level, and because the higher rates of evaporation from the soil and from any standing water cause salt accumulation in the upper soil layers. If the water table is within 1 or 2 m of the surface then evaporation from the soil surface causes capillary movement of water from the ground water.

2.6 Soils and irrigation in southern Iraq

2.6.1 Soil texture and structure

The texture and structure of a soil are characteristics of the size and arrangement of the soil particles and they influence the physical and chemical condition of the soil, e.g. the water holding capacity, aeration, permeability and nutrient status.

The general consensus of soil scientists and agricultural writers on Lowland Mesopotamian soils in the 1950's was that the soil structure was poor with very little particle aggregation. This highlights the effect of excessive soil cultivation and causes considerable problems when irrigating. The natural soils of Lowland Mesopotamia, especially the coarsely textured river levees, had a reasonable structure, produced by the covering of deep rooting grasses and legumes, but this declines when they are intensively cultivated.

2.6.2 The mechanical action of water on soil

When water comes into contact with soil of poor structure and a fine texture such as that common on the plains of Mesopotamia, most of the soil aggregates break down leaving a soft sticky mass of silt particles, which on drying takes the form of a fine powder;

> "This same fine powder develops in the field when rains come, and the finer the dry soil is at the start, the quicker it develops. At the surface where the soil gets soggy wet and is pounded by the raindrops. this powder forms a seal, and this seal interferes with seed aeration, germination, seedling emergence, and moisture in take. In the spring when plants begin to grow rapidly this seal obstructs normal root aeration and restricts the oxygen supply which micro-organisms must have to convert nitrogenous materials in the soil over onto available soil nitrates", (Russel 1957 p. 12).

To minimise this process the farmers leave a seed bed with large lumps of soil, up to 10 cm in diameter, which then breaks down to a reasonably fine bed.

Irrigation water flowing along dry furrow will inevitably erode some of the surface soil, the amount depending on the speed of water flow, the roughness of the soil surface and the area of soil that is in contact with the water. On more or less level land the degree of erosion is minimal, provided that the rate of flow is not excessive. Flat bottomed, rectangular furrows have a lower rate of soil loss than "V"-shaped ones (up to 3% slope). Erosion can be reduced or controlled by using irrigation methods suitable to the land conditions (Withers & Vipond 1974 p. 138).

2.6.3 Irrigation soils

> "Protracted controlled-irrigation has superimposed a secondary meso-relief on the original features of the Lower Mesopotamian Plain. In accordance with the principles which underlie sedimentation, controlled irrigation caused this meso-relief to consist of levees and basins." (Schilstra 1962 p. 188).

When the water arrives in the irrigation basins all the classes of sediment, including silts and clays, are deposited, preventing the accumulation of clays. This process distinguishes the soils of the lowland plain "from river deposits in other parts of the world", by their low sand content, high silt percentage, and lack of heavy soil textures (Delver 1962 p. 195).

The sediment carried by irrigation water consists of part only of the sedimentary spectrum of the river water, due to the constant rate of flow in the canals. As river water enters a canal, it slows and the coarser soil particles are deposited in the upper part of the canal; thereafter the water flow is fairly constant and the remaining finer particles find their way on to the irrigated land (Buringh 1960 p. 155). This new type of soil is called 'irrigation sediment' and "forms the top few metres of the Lower Mesopotamian Plain", (Buringh 1960 p. 155).

The process of sediment deposition by irrigation shares a number of common features with that of river flooding, namely the formation of levees and basins. The material carried in the irrigation water is, however, generally finer and this has the effect of producing soils with distinct characteristics, e.g. sands in the irrigation levees are fine compared with the coarse and medium-coarse sands of the river levees. Where the heterogeneity of the river soils is maintained by shifts in the river course and the location of the floods along the river, in irrigation soils it arises from the silting up and abandonment of canals and variation in the patterns of irrigation employed on the land. Given the localised nature of cultivation this can be quite extreme, producing abrupt horizontal and vertical changes in the soil types (Schilstra 1962 p. 188).

A study of the soils in the Hillah-Diwaniya region of southern Iraq by Dutch engineers distinguished four types of irrigation soils (Nedeco 1959 p. 50-60);

a. Irrigation canal banks (ARGUBS), consisting of sediment deposited in the irrigation canal and dug out at intervals forming high banks along the canals.

The sediments tend to be of the densest particles dropped when the river water slows on entering the canal, the bulk of the material being deposited at the canal intakes, or at any point where the water velocity is reduced significantly. The canal banks are not suitable for cultivation due to their "irregularity and elevation" and often "form widespread irregular, uncultivable and practically unremovable obstacles in the field" (Nedeco 1959 p. 52).

b. Irrigation levee soils, formed by sediment deposition near the canals during irrigation.

They resemble river levees with a relatively coarse texture and low ground water levels. The soils consist of silt loams to silty clay loams, i.e. one class finer than those of river levees, and have good internal and external drainage, permeability and moderate salinity. They are suitable for date palm orchards with fruit, vegetable and cereal under-storeys. These soils frequently overlie more finely textured soils as new canals are constructed through former irrigation basins, the thickness of the layer depending on the age and size of the canal. Some areas are not cultivated due to surface irregularity, salinity or the problem of raising water to a sufficient height.

c. Irrigation levee-basin transitional soils.
These are of medium to fine texture and consist of silty clays and clay soils. Elevation is medium to low and they have a fairly regular macro-relief, with slight slopes. The drainage and permeability is moderate to poor and salinisation occurs where the ground water level is high. Although these soils are generally easy to irrigate, date palms do not grow well and cultivation is limited to vegetables and cereal crops.

d. Irrigation basin soils (GILGAI).
Occurs on low lying, more or less flat land with fine soils usually clays. The internal and external drainage is poor and there are often areas of standing water. These conditions frequently produce saline soils which are unsuitable for cultivation. Gilgai gullies develop from old irrigation furrows where water collects and may become very pronounced as the gullies deepen and the land is rendered unusable.

2.7 The impact of irrigation on the soils of the Lower Mesopotamian Plain

Soil are irrigated to increase the amount of water available to the plants, but there are a number of more or less unavoidable side effects which can become serious problems to the continuance of successful cultivation. Chief among these side effects is the addition of salts and sediment to the top soil/rooting zone which can reduce soil quality. The application of the water to the soil brings about many changes in its structure, texture and chemical composition, flushing finer soil particles, plant nutrients and colloids out of the top soil, as well as raising the ground water level, and washing away the soil it is intended to moisten.

One or all of these processes, compounded by unsuitable tillage practices, can cause the productivity of an area to decline or go out of cultivation, especially where local conditions of climate and topography exacerbate the problems.

Good structure can be maintained or produced by suitable cultivation practices such as the incorporation of organic material, the use of deep rooting grasses and legumes, and perhaps most importantly a level of tillage appropriate to the existing soil conditions. These practices are essential if agriculture is to be sustainable on a long-term basis and are particularly relevant where irrigation is being used (Arnon 1972 p. 307-348):

> "In view of the breakdown in the past of many civilizations that were based on irrigation agriculture, and the numerous cases of rapid soil deterioration under irrigation in modern times - both in countries with a primitive agriculture and in those with the most advanced technologies doubts are frequently expressed as to the possibility of maintaining irrigated agriculture permanently", (Arnon 1972 p. 236).

Yet irrigation agriculture is seen to have continued on the lower Mesopotamian Plain despite the fact that "almost all soils are saline, most of them even strongly saline and large areas are out of production" Buringh (1960 p. 15). The level of cultivation is much lower than it was in the past, but by looking at the cultivation practices that have persisted it is possible to understand some of the processes involved in the deterioration of soil conditions and to distinguish those favorable to the maintenance of permanent irrigation agriculture:

> "The effectiveness of cultivation by locally directed irrigation in Southern Iraq must not be underestimated for this kind of cultivation may well have preceded and continued long after the advent of 'high' civilization with outstanding urban expressions in Mesopotamia", (Fernea 1970 p. 162)

> "It is often amazing to see how simple [sic] farmers have reached by long experience a high degree of perfection in the art of irrigation" (FAO 1973 p. 42).

The agricultural techniques employed are adjusted, either as a result of trial and error or sheer necessity, to meet changes in the soil and this may require an alteration of the methods of irrigation and cultivation, the use of crop rotation and fallow, the introduction of new crops or a change to more tolerant ones. The traditional agriculture of southern Iraq (as witnessed by Russel 1957), contained many examples of practices that have evolved to meet the local conditions and which have changed as those conditions have;

> "These methods of farming on saline land are of fundamental importance for Iraq. I do not think that any better methods could be developed at the present time" (Buringh 1960 p. 251).

2.7.1 Salt and irrigation agriculture

> "Experience and research have shown unequivocally that the basic causes of the failure of crop production under irrigation are the combined and related effects of excessive salt-accumulation in the root-zone and the development of a high water-table" (Arnon 1972 p. 237).

The soils of the lower Mesopotamian Plain have a low infiltration rate due to the high percentage of fine silt and clay particles and low organic matter content. The water holding capacity is high and this makes salt leaching more difficult. Many of the regularly cultivated soils are prone to crust formation as they usually lack any aggregate structure and collapse when brought into contact with water. The finer the soil the worse these conditions become and the problems are acute on irrigation soils deposited on the river soils.

As was mentioned we saw before (section 2.3.2.2) the salt content of the Euphrates is considered low though there may be times and sections of the river or canal where it is considerably higher. Even at the lowest levels the addition of salt to the soils is still appreciable, e.g. 1 m of irrigation water at 100 ppm = 1000 kg salt/ha. This salt is washed from the top soil into the subsoil before eventually accumulating in the ground water. If the water table is far enough from the soil surface there is no long term effect on the topsoil because the salts can always be leached out.

Conditions suitable for the development of saline soils (FAO 1973 p. 67) depend on the distance between the water table and the soil surface which varies according to the salt content of the ground water and the level of evaporation. Salt contents greater than 3-5 g/lt will result in salinisation (2-3 g/lt for the more toxic types of salt). At a salt content of 10-15 g/lt. the ground water has to be 2-2.5 m from the surface, but the distance can be decreased to 1-1.5 m when the salt level is 1-2 g/lt.

On the lower Mesopotamian Plain where the potential rate of evaporation is 2000 mm/year, (Buringh 1960 p. 87):

irrigation water salt content = 200-400 ppm
ground water salt content = 10,000-60,000 (-80,000) ppm
critical ground water depth = 354 cm.

The conditions are thus predisposed towards soil salinisation. Not all the salts are detrimental to the crops, but a fair percentage are chlorides and carbonates, which are toxic. (FAO 1973 p. 274-277). The mechanism of salt accumulation is described by Withers and Vipond (1974 p. 115).

There are 2 types of saline soils distinguished by the farmers of southern Iraq;

i. SABAKH soils with a high percentage of deliquescent salts, which retain moisture even in the summer months, and are dark brown. They are common in central and southern Iraq particularly where ground water is in contact with surface soil,
ii. SHURA soils (SOLANCHAKS) which include all soils with

a white salt crust or efflorescence. The characteristics of the different SOLONCHAK types are described in detail by Buringh (1960 p. 88-89).

The majority of the soils of southern Iraq are saline to some degree. There is considerable variation over short distances and they are affected by many localised factors. One source of variation is the creation of 'isolated salt areas' created when pockets of cultivated land are left fallow while the surrounding land is irrigated and the salts move from the irrigated fields to the fallow land along a hydraulic gradient (Buringh 1960 p. 250).

The yield of sensitive crops is reduced in soils with 2000-3000 ppm, and above 6000 ppm only tolerant crops can grow. Southern Iraq abounds with soils in this latter category and soil samples with salinity values upto 64 mmhos (=40-50,000 ppm) are known. Soils with above 6000 ppm equal or outnumber those with lower values (Delver 1962 p. 204).

The effects of salt in the soil are manifold, some working directly on the plants, others indirectly. The indirect effects include difficulties for the plant in obtaining certain key nutrients, and soil micro-organisms may also be killed off (Arnon 1972 p. 253). The major problem is the increase in concentration (osmotic potential) of the soil solution which proportionally increases the pressure the plant needs to apply to extract water from the soil; so although there may be water present in the soil it is unavailable to the plant. At high salt concentrations there are direct effects with the plants suffering physical or physiological damage from the salts.

The texture of the soil influences the effect of the salt on the uptake of water e.g. 0.1% salinity (=1000 ppm) which "does not influence plant growth in fine textured soils, whereas it is strongly harmful in the coarse textured soils", (Buringh 1960 p. 103).

2.7.2 Amelioration of soil salinity

2.7.2.1 Tillage and salinity

The quantity and distribution of salts in the upper soil layers varies significantly through the year when the land is irrigated. Cultivation methods can be used to temporarily overcome the high salt level, enabling crops to grow in soils in which they would otherwise not grow.

At the beginning of the growing season land that was cultivated previously will probably have a raised salt content in the surface layers, When the soil is irrigated these salts are washed downwards and, if there is sufficient water, out of the rooting zone altogether. The water in the soil is taken up by the plants or evaporates from the surface. In the former case the salts will enter the plant with the water but in the latter they are left in the topsoil. The depth to which the evaporation occurs depends on the potential evaporation rate and the formation of a dry layer at the surface which prevents further evaporation. The amount of salts left at the time of the next irrigation will be much less than at the start of the growing season, provided that the previously accumulated salts were adequately leached and that the ground water was not close enough to the surface to have been involved in the evaporation process.

This cycle of salt movement is repeated between each irrigation and can be used to create a salt-free zone around the individual crop plants by altering the position of planting so as to avoid the areas of salt concentration e.g. the top of the ridges, Russel noted two ways in which irrigation methods were adapted to produce a salt free environment for plant growth;

i. the application, in basin irrigation, of excess water to wash the salts out of the rooting zone,

ii. in furrow irrigation seeds are placed on the sides of the ridge, the furrow is then filled with water to just below the level of the seeds and maintained there until the water has soaked laterally into the ridge pushing the salts beyond the seed.

For some fruits and vegetables salt-free soil is sometimes put around the growing plant to increase the amount of 'clean' soil available to the plant.

It was observed by Buringh that the farmers of southern Iraq described a soil as saline only;

> "When nothing can be grown and land is out of production due to the high salt content. Other saline soils even those with salt efflorescence are not called saline if crops can be grown" (1960 p. 103).

He also mentions that a strongly saline soil can be recognised by the salty taste of the soil and that salt crystals will form on the surface of a moderately saline soil which has wetted and dried (1960 p. 108).

The methods discussed so far, for improving soil conditions for crop growth are all temporary measures for removing salts from around the plants. They rely on the natural lowering of the ground water level, by evaporation and plant transpiration, which is critical to the short-term elimination of salts and to the longer term success of the cultivation of the area. There are no records or evidence to suggest that artificial drainage has ever been used on a significant scale though traces of it would be difficult to identify. The role of the ground water in the development of salinisation is discussed in Section 2.7.3.

2.7.2.2 Soil fertility and salinity

The fertility of the soils in the fourth and third millennia will have depended on the human practices superimposed on the natural river soils up to that time and they could have varied considerably according to the intensity of irrigation or cultivation that had occurred in any one region. These conditions can only be inferred from the present soil types which are believed to most closely resemble the original ones.

A soil's fertility may regarded as a measure of the total amount of plant nutrients contained in the soil, or as the overall potential of the soil for sustaining agriculture in which case the general condition of the soil, it s organic matter content and the cycling of nutrients must also be considered.

In land left fallow for several years there is a build up of the soil nitrogen content, by wild legumes, and of salt. In the Hillah-Diwaniya region it was observed that there was "a fairly close relationship between soil salinity and nitrate content " (Nedeco 1959 p. 114).

On soils with roughly the same salinity level crops grown on soils with a high nitrate level gave greater yields than those on soils with a low nitrate content. The nitrate enables the plants to overcome, partially, the presence of the salts, though yields are reduced on very saline soils (class >5) even where the nitrate content is high (Nedeco 1959 p. 116). The soils with a high nitrate content are called 'strong' by the farmers when they are brought back into cultivation, while those regularly cropped are 'weak'. However, soil fertility of the former group is rapidly reduced during cropping by leaching and nutrient uptake by the plants.

Work on the effects of fertilizers on saline soils in terms of crop yield carried out in the Dujailah region (Dielman 1974 p. 58) concluded that nitrogen caused an increase in crop yield over non fertilized soil at all but the highest salt levels. This is discussed in more detail in the next chapter.

2.7.3 Leaching and drainage

As irrigation water percolates through the upper soil layers it takes with it any soluble salts. Given a sufficient input, the percolating water will reach the ground water. If this is far enough below the soil surface then the harmful salts will have been effectively removed from the rooting zone for the duration of the growing season. Under these circumstances an 'over irrigation' is a boon to crop growing.

Where the ground water level is high, i.e. close to the surface these salts will then be returned to the topsoil when water evaporates from the soil surface causing capillary movement of the ground water to the soil surface. It has been calculated that the ground water depth required to prevent this process occurring is c. 3.50 m for lower Mesopotamian Plain soils in the summer, less in the winter (Buringh 1960 p. 84), while Nedeco (1959 p. 24) estimated the depth to be >3.0 m in the winter and >2 m at the start of the summer (cf. >1.5 m Adams 1981 p. 4).

In southern Iraq the soil is dried to several metres by a combination of evaporation and transpiration when the land is left fallow, and evapo-transpiration rises to 2-4(-5) m Nedeco (1959 p. 127). Eighteen months of fallow dries the top 2-3 m of the soil, and after several years of abandonment the top 5-7 m became dry (Buringh 1960 p. 250). Russel (1957 p. 14) records that evapotranspiration dries the soil to 1.2-1.5 m in first summer, and up to 2.1 m by the following autumn. This may provide a sufficient depth of leaching for a few years' cultivation, but overall the water table level rises even in a low-intensity system.

2.7.3.1 Leaching requirement

In order to remove harmful salts sufficient water must be applied to saturate the soil, dissolve the salts and then wash the saline solution to the required depth. Russel observed that approximately 80% of the water applied was needed to saturate the soil, the remaining 20% washing out the salts. Boumans (quoted in Buringh 1960 p. 259) estimated that 10 cm of water was sufficient to leach salts below 60 cm, and that in field experiments 80 cm of the 160 cm of water applied to a soil, evaporated and the remaining 81 cm reduced the salt concentration of the top 30 cm from 6.4% to 0.24% (and the top 100 cm from 3.7-0.32%). Buringh (1960 p. 259) suggests that "it probably takes 2-4 years before all salts are leached to a convenient depth";

> "The minimum amount of water that should percolate through the root zone toward the subsoil water table in order to remove the excess salt from the root zone and to establish and maintain in the long run a favourable salt balance in the root zone, is put at 20% of the total irrigation requirement", Nedeco (1959 p. 172).

It is desirable to apply the leaching requirement during the colder wetter months as there will be less evaporation from the soil surface and less salt accumulation. It is recommended that the leaching for summer crops should take place before the seed sowing (West 1958 p. 23). In southern Iraq this occurs at the same time as the high river levels of late spring/early summer. For winter crops leaching prior to sowing or in the first irrigation after sowing coincides with low river levels which may prove difficult, so instead the leaching requirement is spread through the growing season.

2.7.3.2 Method of leaching

The types of irrigation best suited to leaching are those where the water stands on the soil surface ensuring even saturation of the soil and percolation of the leaching water and the salts through the rooting zone. The water level in the basins or furrows should be maintained for long enough to allow proper leaching to occur. Flooding and border strip irrigation done efficiently have a low percentage of water reaching the ground water and will not be so useful for leaching purposes.

The method of leaching suggested by West (1958 p. 21) is similar to the normal methods of crop irrigation;

> "Dikes, are constructed around a basin. Fifteen to thirty centimetres of water is turned into the basin. The water is permitted to percolate into the soil. The next application is not made until the surface soil has dried out and cracks begin to appear. Then another application of fifteen to thirty centimetres of water is applied".

The process takes roughly 3-6 month in medium textured and 12-24 (or more) on fine textured soils.

2.7.4 Silt and irrigation agriculture

2.7.4.1 Sediment deposition

The fine sediment particles left after the larger denser material has been 'sieved out' at the entry point of the river water into the canal system is distributed over the fields, according to the method of irrigation used, e.g. in basin irrigation all the sediment is evenly distributed over the surface from the standing water, whereas in the flooding methods the denser particles accumulate at the beginning of the irrigation run. A large percentage of the sediment carried by the Euphrates ends up in the fields, even though some will have been deposited in the canals, and, as has already been mentioned, this represented the most potentially damaging of the river's sediment load.

2.7.4.2 The impact of fine sediment on the soils of the lower Mesopotamian Plain

The addition of fine irrigation sediment particles to the original river soils of the lowland plain affects a number of the soil characteristics, and ultimately the cultivation and productivity of the soil. In southern Iraq the effect is damaging in the long term because it assists the development of saline conditions.

The fine sediment settles out on to the soil surface or moves into the deeper soil layers through cracks. At the surface this layer of fine sediment may hinder water infiltration and the emergence of seedlings. When the sediment becomes incorporated in the soil by ploughing, downward washing and by biological activity, it increases the overall percentage of fine silt and clays in the soil and this can have a quite marked effect, especially on the soils of the basins and levee-basin transitional areas which are already fine textured.

The effect of regularly irrigating such fine textured soils is to produce poor structure, with little particle aggregation or organic material. The pores between the soil particles are small, reducing the amount of air available to the plants. The infiltration rate is slow both at the surface and within the soil and they rapidly become waterlogged. Leaching is difficult as the water is held in the small pores and there is only slow drainage, all of which promotes salt accumulation. The poor structure of the soils means that they are likely to become compacted easily when tilled and the addition of water causes a collapse of the surface layers producing surface crusts, which make the soils more difficult to work and to reclaim.

The input of fine sediment on the scale witnessed in Lowland Mesopotamia results in a steady worsening in the condition of the land all the time irrigation is being practised. The role of sediment in exacerbating the problems of soil salinisation in Lowland Mesopotamia and subsequent land abandonment and the relocation of settlements should not be overlooked. When an area of land is abandoned conditions are improved by a return to the natural flood regime, the drying of the upper soil layers, and the growth of natural vegetation, though the extent of the soil recovery may only be very small. It is not clear whether the part played by sediment, in the traditional agricultural system of southern Iraq was recognised by the farmers.

To reduce the amount of sediment reaching the fields large scale settling tanks would be needed, and soils with a poor texture would have to be exposed to a large scale reclamation programme including draining, leaching and the introduction of various deep rooting plants to dry the soil, improve the structure and increase the organic matter content. Tillage practices would also have to be sensitive to the problems of soil compaction and the breakdown of soil structure.

2.7.5 The life expectancy of soils of the lower Mesopotamian Plain under irrigation

Russel estimated that land in southern Iraq could be cultivated in a crop:fallow system for about 450-500 years, before;

> "salt accumulation will become dangerous and the farmers will have to abandon the land for a long time, during which the ground water level will fall to a depth of 5 or 7 metres, and from that time it will be possible to wash the salts out of the upper 2-3 metres down to a depth of 5-6 metres and the land will become suitable for a new cycle of farming" (quoted in Buringh 1960 p. 250).

Buringh thought that this type of farming was restricted to areas where the ground water was normally several metres below the land surface, i.e. the northern section of the lower Mesopotamian Plain.

A more pessimistic view of the time scale for the salinisation was given by Webster in 1921, (in Buringh 1960 p. 84) who thought that "land in Iraq can become saline in 7 to 25 years as a result of irrigation". Where there is intensive summer irrigation land may become too salty for vegetable cultivation after just 2-3 years (Smith and West 1957 p. 84).

In the delta and marsh region,

> "Special sections of a cultivated area are left idle. They are surrounded by irrigated fields with SHITWI (winter) crops. In giving some extra irrigation water to the cultivated plots, salts are leached from the surface soil, and as there is a hydraulic gradient, the saline water is 'pushed' to the idle fields, where salts are accumulated at the surface" (Buringh 1960 p. 250).

Table 2.1 Rainfall Figures for Baghdad and Diwaniya (mm).

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
Diwaniya (Nedeco 1959)													
1929-59	tr.	0.8	15.7	26.1	18.8	17.2	16.2	14.5	11.8	0.2	0.1	0.3	122 mm
Baghdad (Guest 1966)													
1937-52	0	3	20	26	24	26	28	10	4	0	0	0	140 mm
Baghdad (McDonalds 1958)													
1953-4	/	/	/	/	14	44	70	22	tr.	0	0	0	na.
1954-5	0	11	27	90	54	11	15	32	13	3	0	tr.	253 mm
1955-6	0	11	13	28	8	9	26	45	0	0	0	tr.	140 mm
1956-57	0	0	tr.	5	12	52	59	73	29	tr.	0	0	230 mm
1957	0	3	0	0	/	/	/	/	/	/	/	/	na.
mean	0	6.3	10	30.8	22	29	42.5	43	10.5	0.8	0	tr.	195 mm

Table 2.2 Rates of Evaporation (mm)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	total
Baghdad (Nedeco 1959)													
	220	140	70	45	45	65	110	160	235	300	350	320	2060
Abu Dibbis (Buringh 1960)													
	272	93	177	125	103	92	165	130	142	249	318	304	2170

Table 2.3 River Sediment Content (ppm)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Euphrates (Ionides 1937)												
@Ramadi	130	130	170	250	250	340	480	1500	1800	1100	320	170
Tigris (Dielman 1963)												
Baghdad	200	200	200	350	500	1100	1750	2500	2100	800	200	200
Tigris (Buringh 1960)												
Baghdad	180	170	220	320	380	650	1400	2300	2100	1200	380	240

Table 2.4 River Salt Content (ppm)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Tigris (Dielman 1963)												
@Baghdad	450	460	470	475	450	450	360	300	300	310	350	390

Table 2.5 Euphrates Water Levels at Shinafiyah 1928-32 (Ionides 1937)

river height (in metres)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1927-28	/	/	/	/	9.58	9.50	10.59	12.61	15.66	13.01	10.75	9.95
1928-29	/	9.80	9.74	/	10.09	10.92	11.49	12.77	15.60	15.00	12.00	10.07
1929-30	9.17	9.53	9.55	9.86	9.72	9.82	9.69	9.58	10.76	9.84	8.77	8.40
1930-31	8.21	8.29	8.14	8.47	9.64	10.36	10.35	13.30	14.53	13.63	11.25	9.58
1931-32	8.63	8.57	8.75	8.70	8.90	8.74	9.87	11.96	13.51	11.96	9.40	8.23
1932-33	8.05	8.17	8.05	7.90	/	/	/	/	/	/	/	/
mean	8.52	9.14	8.85	8.73	9.59	9.87	10.39	12.04	14.01	12.69	10.43	9.25
+/-	0.4	0.6	0.7	0.7	0.4	0.7	0.6	1.3	1.8	1.7	1.2	0.8

. . . .

Table 2.6 Monthly Temperature Means (degrees centigrade).

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Diwaniya (Nedeco 1959)												
1929-59	31.0	25.7	18.4	11.9	10.0	12.2	16.4	22.2	28.0	31.5	32.9	33.3
Baghdad (Nedeco 1959)												
1929-59	30.5	25.2	17.4	11.0	9.3	11.5	15.2	21.7	28.3	32.5	34.4	34.4

Table 2.7 Monthly Relative Humidity Mean (percentage).

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Diwaniya (Nedeco 1959)												
1929-59	32	39	56	72	70	63	53	46	35	29	28	29
Baghdad Guest 1966												
1937-52	28	36	56	71	71	63	56	47	33	24	23	24

Table 2.8 Crop water requirements (after Nedeco 1959 p. 273)

crop	no. of irrigations	total water applied (mm)
wheat	4 - 7	320 - 560
barley	4 - 8	320 - 640
vegetables	36 - 40	c. 2000
sesame	3 - 4	240 - 320
millet	4 - 5	320 - 400
sorghum	5 - 6	400 - 480
dates	2 - 3	200 - 300
pasture	1 - 2	80 - 160

Chapter 3 Traditional crop husbandry in southern Iraq 1900-1960 A.D.

3.1 Introduction

In the same way that Chapter Two dealt with the traditional irrigation practices of southern Iraq 1900-1960, so this chapter deals with the traditional agricultural practices of the area. Particular attention is paid to the ways in which the agriculture was adapted to the local environment and thus to the limitations imposed when using information from this century to interpret past events.

Although it might well be the case that some of the agricultural systems of Sumerian (Early Dynastic) times have parallels with those in 20th-century Iraq, it is possible that it is the intensive tractor-combine harvester farming that most resembles the Sumerian situation, in terms of scale and manner of organisation if not the equipment, rather than the localised Sheik-led extensive farming system that was widespread in the earlier part of this century.

The traditional agricultural system of Lowland Iraq prior to the introduction of diesel-powered equipment has been the subject of various studies including those by Buringh (1960), Fernea (1970), MacDonald (1959), Naval Intelligence (1944), Poyck (1962), Russel (1957), West (1958), and Wirthe (1962).

The system was described by Adams as being "overwhelmingly of an extensive rather than an intensive variety" (1965 p. 13), i.e. the return from the land (per area cultivated and total area) is low as a result of the low intensity farming techniques used.

The cultivation practised in the Hillah Diwaniyah area, near to Abu Salabikh in the 1950's (A.D.);

> "is still the old 'Niren-Niren' system by which 50% of the field is cropped and 50% is left fallow in winter time. The summer crops are planted in the same field that has been used for winter crops but as the percentage of summer crops is very small (only 5-10% of the total fields) the greater part of these fields is left fallow in summer." (Poyck 1962 p. 19),

> "In this particular area it has appeared that the economic structure of the farm unit is closely related to the cultural practices and the cropping pattern and consequently the land use. Many actions of the farmers appear in reality to be based on agricultural methods which through the years have undoubtedly proved to be correct under the given conditions and well adapted to their social, economic and natural environment" (p. 38).

The land under cultivation comprised a fairly narrow band along the rivers and its branches and extended for only 10-20 miles into the plain from the river. Table 3.1 shows that just over 50% of the Hillah-Diwaniya area was not cultivated, partly as a result of salinisation (21%), insufficient irrigation water or inaccessibility (18%), while the remainder was used for houses, roads, etc. The percentage cultivated during the winter months exceeded the amount under fallow which meant that some land (c. 20%) was used in successive years. The area under specifically summer cultivation was about 1/4 due to the lack of water during the summer.

> "The general assumption is that the Niren system:
>
> 1. reduces the danger of salinisation in the absence of drainage;
> 2. recovers the fertility of the land by its over year of fallow
> 3. provides grazing land;
> 4. combats weeds and provides sufficient time for ploughing" (Poyck 1962 p. 38),

and that this system enabled the land to be cultivated, if not indefinitely, for much longer periods than would be possible under a more intensive, continuous one.

The winter cropping outlined in the pages below was that carried out for the two staples of southern Iraqi cultivation, i.e. wheat and barley. These are both free-threshing cereals grown separately throughout Iraq under rain-fed conditions on the Uplands and irrigation on the Lowland alluvial plains. The other winter crops cultivated in a similar way are Linum usitatisimum (linseed), Vicia faba (broad bean), Laythyrus sativus (grasspea), and Lens culinaris (lentil).

As mentioned previously, the alternation of cropping and fallow has a number of advantages to the farmer and as it is obviously in their interest to maintain this system it is worth noting some of the variations reported by Poyck, and how they related to the type of land ownership, which was divided between landowners, large and medium, who had tenants working the land, and farm-owners who farm their own land. The larger the area of land owned or farmed as a single unit the greater the percentage allowed to stand fallow each year and thus the greater the crop yield because the soil was less saline and had a higher level of fertility. The farmers in the smaller holdings usually owned their land and due to the comparatively high population had to keep more land under cultivation than was beneficial to soil condition. Where groups of families farmed communally then these pressures were dissipated and the percentage of land left fallow was higher. There were also considerable differences in the types of crops grown according to the scale of land ownership (Table 3.2), with more barley being grown by the individual farm owners (47%) than the landowners (30-38%) and the communal farmers (33%). This also affected the amount of crop rotation, etc.

Agriculture, the environment and social conditions were all strongly linked, and need to be considered when using these studies in interpreting past agricultural systems. Southern Iraq in the first half of the 20th century offered a range of agricultural systems from which to draw 'facts' but they should not be used out of context, e.g. by mixing up incompatible practices, or selecting techniques simply because they appear to match a cuneiform description. Comparison of a small farm-owner's cropping practice with that of a large-scale, centrally controlled, temple-run system of Sumerian times would have no more relevance than comparing the same farmer with a large land owner employing the latest equipment in modern Iraq. Similarly the nature of the equipment and new techniques would mean that large land owners of today and the temple lands of Sumerian times would have no more in common other than, perhaps the size of land holding and the employment of workers to carry out the farming.

Many of the practices have been explained with reference to the local soil and climatic conditions, although there are still some, such as the high level of weed contamination (of seed/crop fields/harvested crop), that are difficult to understand other than as a response to external pressures from landowners, or to the fact that much of the winter cereal crop was grown to provide food for the livestock rather than for the human population.

It is necessary to compare like with like, and failing that to attempt to understand how the soil and the crops grown on it respond to different practices and different tools. From this predictions can be made about the nature of Sumerian agriculture and its impact on the lowland alluvial plain of Mesopotamia.

The agricultural practices described below are those employed in the irrigation agricultural systems of southern Iraq for the cultivation of winter crops, as witnessed in the earlier parts of this century. Pertinent information concerning summer cultivation and other arid regions, are included to explain the Iraqi situation. This includes discussion of alternative types of cultivation observed in southern Iraq, together with an assessment of the different systems with reference to their impact on the soils.

The significance, archaeological and archaeobotanical, of these systems, i.e. whether they could be detected, and, if found, interpreted, are also considered.

3.2 Extensive farming: winter field crops

3.2.1 Pre-sowing tillage

> "The need and justification for numerous tillage operations had been grossly exaggerated in the past" Arnon (1972 p. 418).

Soil tillage can be used to improve soil structure and fertility by working in organic material and loosening compacted soils as well as preparing the seed bed and helping in weed control. Its purpose will vary from area to area in accordance with the condition and composition of the soil.

The most common form of tillage traditionally practised in Iraq was ploughing. It has several functions:

i. soil conditioning, which breaks up the surface crust produced by rain and irrigation and loosens the soil after compaction by trampling, other tillage practices, or the effects of water,

ii. seed bed preparation and seed coverage,

iii. the control of winter weeds - a side effect occurring when weeds germinate prior to ploughing due to rainfall, or an early irrigation.

The techniques used and the reasoning behind them have been described in detail by Russel (1957 p. 3-21) and are summarised below.

The plough used was 'shovel pointed,' pulled in most cases by a single animal. It was light, easily manoeuvered and did not penetrate the soil deeply or turn it over. Instead it just broke the soil surface, leaving a narrow furrow only a few centimetre deep 5-10(-15 cm) (Poyck 1960 p. 45) and ca. 45 cms apart (West 1958 p. 24).

The first ploughing was at right angles to the old furrows and irrigation borders and left a rough, cloddy seed bed, with lumps of soil up to 10 cms diameter, on to which the seeds were broadcast. The reasoning behind these rough seed beds is discussed above (2.6.2). The second ploughing, at right angles to the first, covered the seeds.

Ploughing did not usually commence until the first rains or until very humid conditions had softened the soil; ploughing while the soil was still moist could help to improve its structure (West 1958 p. 24).

There was a tendency, however, for the ploughing to begin while the soil was still waterlogged causing the soil to become 'puddled', i.e. badly compacted, when it dried out. If the soil was very uneven or ridged at the end of the summer then hoes, mattocks or spades were used to break up the soil surface sufficiently to allow ploughing (Naval Intelligence 1944 p. 450).

Small earth dykes were constructed, using spades, once the soil had been ploughed and the seed sown. They regulated the flow of irrigation water (see Section 2.5.1 for tillage practices associated with irrigation).

Paterson (1927 p. 11) records that 0.4 ha/day can be ploughed by two mules and one person in a day (to a depth of 10 cms) while H.T.S. (1958 p. 224) give figures of 0.25 ha/7 hours. The animals used to pull the plough were donkeys, mules, horses, oxen and cattle (Naval Intelligence 1944 p. 450 and Poyck 1962 p. 45).

3.2.2 Sowing to harvest

3.2.2.1 Sowing

Seed-bed preparation and sowing activities were co-ordinated to meet the optimal conditions for seedling germination and the early stages of seedling development. These conditions were described by Arnon (1972a p. 430):

i. close contact between the seed and soil particles to ensure rapid water movement, but not so compact as to prevent the root penetrating the soil,
ii. good soil aeration, to provide oxygen for seed germination,
iii. sufficient soil cover to protect the seed(ling) from drying out and from other climatic extremes while being shallow enough to allow rapid seedling emergence.

The type of seed bed commonly seen in southern Iraq, which allowed for some soil collapse, presented some problems with regard to sowing, principally that the seed might be sown too shallow or too deep resulting in an uneven crop cover (MacDonald 1959 p. 115).

Cereal crops were typically broadcast sown in Iraq, the amount of care taken to ensure an even spread of seed being very variable. Russel (1957 p. 12) observed fields being divided up into approximately 6-metre squares, each square receiving a known quantity of grain; on still days the sower would walk down the middle of the square, throwing seeds evenly to the left and right; these practices gave as good a coverage as was needed.

Four sow/plough regimes have been described for southern Iraq;

i. plough/broadcast sow/cross plough to cover seed,
ii. plough/cross plough/broadcast sow/drag to cover seed (H.T.S. 1958 p. 224),

iii. broadcast sow/plough (more commonly done with tractors perhaps because the ground was still hard at this time),
iv. seed broadcast directly on to unploughed field with no subsequent covering.

The majority of winter crops needed to be sown early in the autumn e.g. October, in order to obtain maximum yields, but this optimal period was often missed and the sowing of winter cereals was delayed until December or even January (H.T.S 1958 p. 225). The delay was caused by the lateness of autumn rains, the unavailability of irrigation water, or the deliberate avoidance of an early irrigation to allow ploughing for fear of waterlogging. This had a serious effect on crop yields, as illustrated by Guest (1930 p. 3) who records that the delay of sowing linseed until December can halve the amount of seed harvested from an autumn-sown crop. The use of a pre-sowing irrigation to ensure early sowing is noted where the crop was to be used as a green fodder, e.g. barley (H.T.S. 1958 p. 225).

As the advantages of an early sowing have been stressed by several writers it is surprising that a pre-sowing irrigation to moisten and soften the soil and thus guarantee that sowing is on time, was not used more frequently. Russel (1957 p. 15) gives four reasons why this might be the case;
i. after an irrigation the soil is slow to dry and because ploughing should not be done until it is reasonably dry there is a strong danger that rainfall will keep the soil waterlogged, delaying sowing for even longer,
ii. before irrigating some earth borders are needed which would require some working of hard baked soil.
iii. if the irrigation is light, so that the soil does not take too long to dry, then a second irrigation to ensure good seed germination is required, but if this

"is a heavy irrigation it will give the plants a setback. If it is not heavy it will not properly leach the salts downward into the subsoil",

iv. this initial irrigation would take place under very hot, dry conditions which means that the rate of evaporation from the moist soil leaving salts on the surface, will be very high.

He adds that farmers with low salinity-good textured soils are the first to use a pre-sowing irrigation, "All others hesitate, and they only irrigate before ploughing as a last resort as soil continues hard and the planting season gets late" (Russel 1957 p. 16).

The timing of the sowing was, therefore, usually dependent on the arrival of the first rains or more humid conditions and only in a few cases was a pre-ploughing irrigation used; for though it appears to offer greater control over the sowing date the attendant problems may delay sowing even further.

By increasing the amount of seed sown various deficiencies of the seed-bed preparation, soil conditions and the high levels of weed contamination frequent in Iraqi agriculture could be partly compensated. But it was found that the amounts were low in comparison with the other arid regions (Charles 1985, 1987) and only tillering i.e. vegetative reproduction in cereals, rectified the patchiness of the plant cover (H.T.S 1958 p. 224).

Seed amounts of 48-72 kgs/ha for wheat, 50-80 for barley have been recorded by H.T.S (1958 p. 224) in the lower Diyala Region compared with 80-100 for wheat and 100-128 for barley in the Hillah-Diwaniya region (Poyck 1962 p. 50). One man can sow approximately 24 ha/day, with cereals (Paterson 1929, p. 12).

3.2.2.2 Irrigation

The principal types of irrigation used in southern Iraq have already been discussed above (sections 2.4.2 and 2.5) of concern here is the timing of irrigation relative to ploughing and the crops' development.

After sowing and the construction of irrigation boundaries the soil was liberally irrigated to provide adequate moisture for germination and early seedling growth as well as flushing salts out of the rooting zone. This first irrigation was of 6-10 cms depth plus ca. 5 cms for the leaching. Barley received between four and eight irrigations during the growing season at approximately three to four weekly intervals, the timing and frequency being determined by rainfall and the availability of irrigation water.

The watering requirement of the other main winter crops were similar to those of barley. Wheat was described as needing lighter but more frequent irrigations than barley (Poyck 1962 p. 45), while Guest (1930 p. 6) notes that linseed needed four to six irrigations in a normal season. The amount of water applied was varied according to the soil salinity levels with the number of irrigations being increased from four to five per growing season on non-saline land (ca. 25 cms/irrigation) to 12 or more on saline soils. The increased watering washed salts out of the rooting zone.

The water requirement or consumptive use is a measure of evapo-transpiration from the crop and soil surface (Dielman 1977 p. 69). To this may be added the amount of water required at the beginning of the growing season to raise the soil moisture content to the minimum level for the crop to obtain water (Nedeco 1959 p. 171). The consumptive use for winter crops in southern Iraq was between 335-380 mm (Nedeco 1959 p. 173), and if the irrigation was to include leaching then the total amount required was 445 mm. The actual amounts applied were ca. 480 mm (ie 6 x 80 mm waterings), the excess application being a result of more water being available than was needed for the land under cultivation and the need to keep the canal running at full capacity. It was also seen that in some cases the system was organised in such a way that watering had to take place at specific times virtually irrespective of whether the water was needed at that moment or not (H.T.S. 1958 p. 226).

Experiments to establish the consumptive use of crops, carried out at the Dujailah experimental farm (near Kut, southern Iraq) revealed the interactions between crops, irrigation and rainfall in the years 1956-1958 (Boumans 1977 p. 69-81). The level of irrigation water applied was seen to vary according to the amount of rainfall and the need to leach salts from the upper soil layers.

3.2.2.3 Manuring

Buringh quotes Keen (1946) as saying;

> "in arid and hot regions the organic manure disappears in a short time due to rapid oxidation and therefore the soils obtain no benefit from it. This is particularly true if the soils are saline." (1960, p. 253).

The conclusion should perhaps be modified to say that there is no long-term change because there is evidence that, in the short term at least, the addition of manure can increase soil fertility (Halstead 1987). The further claim that saline soils benefit even less is apparently contradicted by Hulsbos who, commenting on crop yield on Iraqi soils in response to fertilizers and salt level, says;

> "It follows from these experiments that if the soils have been leached to a certain salinity level (approx. ECe=8) more benefit may be expected from fertilizer application than from further leaching." (1977 p. 66).

In experiments on so called 'strong' and 'weak' soils (see Section 2.7.2.2) it was found that high nitrate levels gave a yield increase in all the crops tested, including legumes on non-saline and moderately saline soils alike. It was thought that the nitrate reduced the influence of the salinity (Nedeco 1959 p. 113-123). It was observed that well manured vegetable growing land gave higher yields when it was returned to winter cereal cropping (H.T.S. 1958 p. 248).

From the evidence available it seems that widespread application of manure, on a large enough scale, to enhance the yield of winter cereal crops was not a part of traditional southern Iraqi farming practice, though yield could be increased in the short term. It is certainly the case that much, if not "all manure, particularly in central and southern Iraq, is used as fuel" Buringh (1960 p. 252).

It has also been suggested (MacDonald 1959, p. 114) that dung from animals grazing on the young cereal plants or on weeds in fallow fields will have some beneficial effect on the soil fertility.

The value of manure as fertilizer depends largely on the speed with which it becomes incorporated into the soil rather than being dried on the surface, and for that reason manuring is best done in the winter months when temperatures are lower and humidity levels are higher. The usefulness, for example, of dung from grazing animals will be greater therefore in the winter months than during the grazing of the harvested crop stubble.

3.2.2.4 Weeds and weeding

There was little or no attempt at weeding the winter cereal crops. The seed sown was often highly contaminated and the crop stands were frequently seen to contain more weeds than crop plants. The major weed problem was caused by annuals, especially grasses, whose flowering and fruiting coincided with that of the winter crops, e.g. Avena sp., Lolium sp. and Cardaria sp. The perennial bulb plants complete their life-cycle before the crop matures, but the late developing thistles could hinder harvesting considerably.

The only weeding mentioned by Poyck (1962 p. 45) is the removal of bushes of Alhagi sp. and Prosopis sp. from wheat and barley crops, which aided harvest rather than reducing the competition between weed and crop. The tool used for this weeding was a FASS, which resembles an ADZE (it is primarily used for cutting fuel plants, such as Prosopis sp. and Alhagi sp.). West (1958 p. 25) and H.T.S. (1958, p. 156) both suggest that the pre-irrigation of fields prior to ploughing would encourage the germination of weed seeds which could then be ploughed into the soil, but it does not appear that this was carried out at that time, H.T.S. conclude;

> "such a method of control has hardly been feasible up to now on land being planted to winter crops because of the very limited quantities of irrigation water normally available in late summer; but in future with ample summer water made available it should be possible to adopt such a method" (1958 p. 156).

The only check to weed numbers in the southern Iraqi system seems to have been the inclusion of a fallow period during which, presumably, animal grazing prevents the weeds reseeding. Russel implies that one of the reasons a lightweight non-inverting plough was used was to avoid killing off some weeds.

> "Iraq has weeds but they are predominately useful leguminous weeds that fix atmospheric nitrogen and thereby replenish nitrogen annually to the soil. Some are perennial leguminous weeds which would be starved out if persistently cut off deeply below the surface with the sharp share that goes with a turning plow. Others are small seeded spring annuals which would be obliterated in the course of time if their seeds were continually inverted deeply" (1957 p. 6).

He was puzzled that no intertillage of row crops was carried out after sowing despite the work done to prepare the land, etc.;

> "They pull a few weeds and they clip grasses to an extent with hand sickles. They do not use hand hoes, or wheat hoes, or any type of animal drawn cultivators. They will argue heatedly that it is not good to kill the weeds" (1957 p. 21),

and he suggests that the reluctance to destroy the weeds is due to the belief that shade from the weeds reduces evaporation and thus inhibits the rise of salts into the root zone. "One observation that corroborates this is that people are considerably more diligent at weed elimination wherever the salinity is absent" (1957 p. 21).

The system, therefore, appears to have encouraged weeds rather than eradicating them; apparently for the purpose of maintaining soil fertility/structure in addition to providing livestock grazing.

3.2.2.5 Harvest

Once the winter cereal crops had dried sufficiently they were harvested with hand-held sickles which had serrated edges. The process involved all the members of a family. The plants were cut fairly low down on the stem, ca 10-15 cm from the ground, and there was little apparent effort to avoid the weeds, except for the spinier plants, such as thistles and the young _Prosopis_ and Camelthorn (_Alhagi_ sp.) bushes. The cut sheaves were laid flat in circular heaps with the ears in the centre and the stalks radiating outwards like wheel spokes ca. 1.5-2.0 m in diameter and were left in the field to continue drying (H.T.S. 1958 p. 228).

According to Paterson (1928 p. 12) one person could cut an eighth of an acre per day, i.e. ca. 0.07 ha/day, including the collection of sheaves into small heaps. It has been calculated, by Wright, that one hectare would require;

> "2 man-days of labour during the height of harvest activity, a period of about 12 days, thus a single laborer can cultivated and harvest up to 6.0 hectares" (1969 p. 22).

This was based on figures presented by Adams (1965) and originally derived from H.T.S.' research in the Diyala region (1958 p. 113).

The harvest of the winter cereals occurred between April and June depending on the growing season conditions and water availability. The barley crop ripened first and was generally harvested two weeks before the wheat, i.e. barley cut from mid April through to May, whereas the wheat crop was ready from early May onwards, and the harvest might continue into June. Wright (1969 p. 22) notes that the farmers and their families sometimes occupied huts located near the crop fields during the harvest period so that the harvesting could continue from dawn to dusk.

3.2.3 Post harvest events

The harvested crop was transported to the threshing area on the backs of donkeys, horses or camels, after drying in the fields for 1-2 weeks. In the Hillah-Diwaniyah region some of the transporting was done by Bedouin camels, usually in return for grazing rights on the idle and fallow lands (Poyck 1962 p. 50-51). As H.T.S (1958 p. 228) pointed out, "the use of a simple cart would certainly reduce the great amount of time and labour devoted to this operation", but carts were rarely seen. It took several weeks to move all the crop and the operation could continue into September.

No mention is made of the preparation of special threshing areas, simply that the cereals were placed in large, round stacks ca. 1.5 m high and 15 m wide, on to which the animals were walked, up one side of the stack which was gently sloped, (H.T.S 1958 p. 228). Poyck describes a different process, "the animals thresh the barley by treading over a thin layer of sheaves spread out around the heap [of whole harvest]" (1962 p. 45).

Fernea observed that threshing was often done cooperatively on a common threshing area, the grain being divided up later by a neutral party (1970). Threshing occurred from July to October. The process was very time consuming: "limited amounts of grain are threshed out by hand, using palm fronds, to meet any immediate requirements for food or feed." (H.T.S. 1958 p. 228).

Cows, donkeys and horses were sometimes observed trampling the crop and in some cases pulling rollers or flint studded threshing sledges (called a HULLWA in southern Iraq, Naval Intelligence p. 450). In the Hillah-Diwaniya area it was usual for somebody to be paid to thresh the crop with a team of donkeys (five or six) or sometimes the animals of the village would be brought together to do the work (Poyck 1962 p. 50). On occasion the animals were tied by bridle to a peg in the ground and driven around, thus trampling the crop scattered in their path, (Naval Intelligence 1944 p. 450).

The threshed crop was winnowed using long, wooden 5-pronged forks, or shovels to separate the grain, straw and chaff. "The straw is transported to the farms by women or donkeys and ensilaged in pits in the ground and the grain is transported to the farm by (hired) camels." (Poyck 1962 p. 45). Alternatively, the straw was left near the threshing ground and covered with earth to protect it, being used later for mud bricks, plastering and dung cakes.

The finer chaff (awns, rachis internodes, lemmas, paleas, etc.) was used in wall plaster, pottery (as temper), or was fed to the livestock (as was barley bran of first quality).

In the lower Diyala region the crop not sold was set aside;

> "either in sacks or in earthenware pots, or in grain pits or grain stacks covered with soil. The straw is also carefully stored in stacks completely covered with soil, and is then used throughout the winter and spring for feeding to livestock." (H.T.S. 1958 p. 231).

There are no descriptions of processing the harvested crop to remove chaff, weed seeds and other impurities, or of what was done to the waste products of these processes.

3.2.4 Summer field crops

Little mention is made of the methods of cultivation employed for the summer field crops and certainly the area used was restricted by water availability and was much less than that under winter crops. Sesame was seen to be sown on fallow land in the spring (March-April) or on winter cropped land among the harvested crop stubble;

> "sometimes the barley or linseed stubble is ploughed, while on occasions the barley stubble may be heavily grazed by sheep to break up the soil and produce the necessary seed bed." (H.T.S. 1958 p. 247).

It was cultivated with a minimum of attention after the crops established.

Other types grown as extensive field crops include greengram, millet, and sorghum (rice and cotton were probably late introductions). The frequency of water applications was altered to suit the crops and there could be upward of 10-20 irrigations per growing season. Poyck notes that;

> "The cultivation of summer crops is largely dependant on the quantity of water available. Therefore in the northern part of the area a relatively high percentage of land under rice and vegetables is found, whereas in the southern part at the tail of the irrigation system millet, sorghum and greengram, being more drought resistant, can be found", (1962 p. 40).

3.3 More intensive crop growing practices

3.3.1 Semi-intensive cultivation

Vegetables were grown as row crops in fields with "no ploughing, weeding or manuring", though ridges for their planting were constructed (Poyck 1962 p. 46). Crops grown in this way included water melons, tomatoes, egg plants, onions and garlic, and the cultivation techniques used did not appear to differ significantly from that used on the cereals and pulses.

3.3.2 Intensive cultivation

Details of the cultivation of a range of vegetables (and fruits) e.g. the size of ridges, planting distances etc have been given elsewhere (Charles 1987 p. 1-21). It is worth considering the chief ways in which the system differed from that of the cereals and pulses, as outlined by Poyck (1962 p. 46) describing the farming practices of farmowners near a large town. The whole process was labour intensive, the crops were weeded often, the soil regularly manured and frequently irrigated. A brief description is given below for comparison with the winter cereal crops. Some of the crops were also cultivated in a semi-intensive way, as mentioned above.

Vegetables were often grown on the better quality soils, e.g. the light soils of river or canal banks (which may have been kept separate from the winter cropped land). The fields were ploughed with the lightweight parting plough to loosen the soil and to break the surface crust. Poyck (1962 p. 46) noted that the fields were "divided into blocks of 7 by 1.5 metres or rows at 1 metre intervals" by small ridges, or irrigation ditches were dug to produce ridges or raised beds. The distance between the ditches varied according to the crop to be grown and the soil salinity level (Section 2.5.1.4).

Well rotted farmyard manure was worked into the edges of these ridges, in the area of planting, prior to the seeds being placed into holes dug along the sides of the ditch/ridge. Alternatively the manure was applied as a top dressing or a mulch, or some was placed with each seed in the sowing hole.

The irrigation ditches were filled to the level of the planting holes once the seeds or seedlings had been planted and the water was kept at this level to drive salts into the centre of the ridge or down into the ground water, producing a salt-free rooting zone. Thereafter irrigation followed at regular intervals at a rate proportional to the climate (and consumptive use). In December-January the rate was 1 per 14 days, in May-September every 4 or 5 days and "for the rest of the year once a week" (Poyck 1962 p. 46), the total amount of water applied being as much as 2000 mm (Nedeco 1959 p. 272).

Where the land was only used for vegetable growing the same ditches and furrows were used each season though there was generally a year, or at least a seasons' fallow, between growing times. Manure was applied regularly. A second crop, such as barley was sometimes planted along the centre of the ridge (bed) when the soil was salt-free. The silt deposited along the bottom of the irrigation ditches was dug out at intervals and in some cases was placed around the growing plants to increase the amount of salt-free soil available (Russel 1957 p. 20).

Weeding occurred regularly especially when the vegetables were grown for sale. Chakravarty states;

> "The land for water melon cultivation should be free of weed as far as practicable and weeds if grow later must all be removed by harrowing before the seeds are sown. This is important as weeding is difficult when the vines spread all around" (1966 p. 45).

There were three overlapping vegetable growing periods, and some species were grown in more than one season.

3.3.2.1 Winter Crops

Winter crops, such as garlic, onion (grown from seed) and early sown cucumbers were planted in the autumn or early winter months (October-January) and harvested at approximately the same time as the winter cereals and pulses Elaborate care was taken with the cucumbers to protect the plants from frost: palm frond covers were put over them each night and wind screens erected around the growing areas to ensure fruit development by the spring when they could be sold for high prices. This system of cultivation, described by Chakravarty (1966, p. 42-43), contrasts strongly with the extensive, minimum tillage-minimum labour systems used for winter cereal and pulse growing.

3.3.2.2 Spring crops

Planted in March and April, i.e. before the harvest of the winter crops and therefore on fallow land, spring crops included early water melons, tomatoes, late cucumbers, onions (seed), aubergine and okra, radishes, turnips and beet. Most of these crops reached maturity and were harvested in June and July. They were grown on ridges in rows, the seeds sown directly where they were to grow and not in nurseries. The crops were irrigated about once a week until May when the frequency was increased to meet the warmer conditions. This growing period coincided with the highest river level, and the threat of flooding was probably greater than that of water shortage (Section 2.3).

3.3.2.3 Summer Crops

Planted from May to July in the winter-cultivated fields or on specially prepared land the summer crops included water melons, onions and long cucumbers. They were generally cultivated in fields, although it was also possible to grow many of them in orchards as an under-storey crop or in small garden plots (this also applied to barley). Where this was the case the cultivation e.g. the frequency of watering or weeding, was probably somewhat altered to accommodate the new circumstances.

The description below is based on date palm orchards, often called gardens, which was the most common alternative to field cropping.

3.4 Alternatives to field based cultivation

3.4.1 Date palm orchards

Orchards accounted for some 2.0% of the total Hillah-Diwaniya area, 4.2% of the cultivated land, the principal fruit tree being the date palm. The date palm orchards were situated on the higher river banks on the coarser, sandy soils which provide favourable drainage conditions. Within the study area the orchards were concentrated near the main town of Hillah and were cultivated by farm owners or by tenant farmers. Table 3.2 gives the percentage of farmland devoted to various crop types. On the date palm orchards farm owners had almost 90% of their land under orchard compared with 41% for the tenant farmers. The percentage of waste and idle land was low in both cases, reflecting the high intensity of use and the good soil conditions that pertain in the orchards. There was some interplanting of barley, other winter crops and summer vegetables under the date palms.

As mentioned in Section 2.6.3 river-levee soils are excellent for crop growing and, where they were cropped regularly, non-saline. Moving from the levee into the river basin;

" there is always a gradual transition from the levee to the basin soils, which can be well observed in the date gardens, as height, diameter and quality of the date trees decrease towards the basins" (Buringh 1960 p. 149).

There are numerous advantages to inter-cropping within the date palm orchards, with the date palms shading the lower storeys and the soil, keeping temperatures lower and reducing the amount of water transpired from the plants because the humidity is higher (a combination of lower air temperature and slower moving air). Cultivation and manuring of the topsoil benefits all the plants, and presumably the manure has longer term effects in this environment as the rate of oxidation is lower. Buringh also mentions that;

> "soil biological activity is relatively high and intensive, soils do not have crusted surface layers and there is a constant homogenization of at least the upper metre of the soil." (1960 p. 149).

Not all the date palm orchards had such ideal conditions and on more saline soils the diversity of crops was reduced to the more salt-tolerant ones. Buringh (1960 p. 273-279) classified the soils of the date gardens in relation to the crops grown in them, starting with excellent soils (D1) on which citrus, pomegranates, grapes, figs (middle-level crops) and various vegetables, water melons etc (low-level crop) all grew. The cropping in these gardens was virtually continuous with at least three crops coming off the same land annually. On poor soils (D4), where the date trees were of poor quality, there was only occasionally a low-level crop e.g. alfalfa which is fairly salt tolerant. On soils of class D7 even the date trees, which are quite strongly salt-tolerant were unable to grow.

3.4.1.1 Date palm cultivation

Side shoots growing at the base of suitable high yielding trees were cut with a large chisel and planted in manured ground either in a nursery or directly in the garden or field where they were to grow. The planting distance varied depending on whether inter-cropping was to be carried out or not.

During the first few years of growth barley was sown among the trees and regularly irrigated. The young trees required little protection except against frost in the first year and against animals for 8-10 years. The trees start producing fruit after 4-5 years, and the yields increased rapidly after the seventh year to reach a maximum from years 12-15. They continued to fruit for another 40-50 years but were usually cut down when they were 30-40 years old and the yield started to decrease.

The level of cultivation the mature trees received varied considerably. Regular weeding and the 'spading' of the top soil were recommended, to keep a top layer of loose soil. In cases where inter-cropping was carried out the soils received more regular cultivation and irrigation. Cultivating the soil after each irrigation was often sufficient to keep down the weeds, and when basic irrigation was used a straw mulch in the basins helped to prevent weed growth.

The types of fertilizer applied to these crops included;

i. dung - from cattle, sheep, goats birds or humans,
ii. plant material - green manure crops or palm fonds, leaf litter etc.,
iii. any other organic material or nutrient-rich substances, e.g. fish heads or mound soil.

Poppenoe (1973) lists several ways in which mature date palms were fertilized by applying a top dressing of manure and digging in with hoes, spades, etc., taking care not to damage the roots. Alternatively trenches or ditches were dug under the trees and filled with manure which was left to decompose. Crops sown under the trees also benefited under this system. Green manure, e.g. legumes was also used to fertilize fruit trees and was ploughed into the soil before the legumes reached maturity. One final variation was to tie a buffalo to each tree for four days at a time!

Manuring was usually carried out in the cooler, wetter winter months so that the material could become incorporated into the soil before the summer when it rapidly dried up.

Irrigation was more likely to be limited by the amount of water available than as a result of overwatering, for, as was recorded in the Shatt al-Arab area, date palms can be flooded with water twice a day every day providing the soil drains freely in between times to allow some soil aeration. The efficiency of water use is much higher in garden/orchard cultivation, and in addition the cooler, more humid conditions reduce evaporation.

The plants used as ground-level crops must be suitable for this type of cultivation, i.e.;

i. tolerant to the amounts of irrigation water applied,

ii. replenish the soil nutrients levels,

iii. in the early years of date palm establishment they must be very shallowly rooted (some crops were considered too deep rooting for the mature trees e.g. alfalfa),

iv. have cultivation requirements that fitted in with those of the date palms.

At some stage, not specified, after the date palms were sufficiently established, other fruit trees were introduced to form the middle storey in the gardens on good soils:

> "A really good fruit garden has a combination of various fruit trees (dates, oranges, pomegranates, grapes, figs) and various kinds of vegetables (water melons, egg plants etc.). Cultivation is permanent and relatively intensive with several harvests per

year!" (Buringh 1960 p. 149).

The orchards provided a suitable setting for the growing of a broad range of crops and though they did not represent the 'true' nature of southern Iraqi agriculture because they accounted for a comparatively small percentage of the agricultural land (Wirthe 1972) they did offer an alternative cultivation system which may have had a larger role in the past.

There may have been some problems in providing sufficient irrigation water to date palm orchards high on the river levees: the deep rooting trees may be able to utilise seepage from the river, and certainly small-scale irrigation operations involving human- or animal-driven equipment have been recorded (Smith 1957 p. 4 Naval Intelligence 1944 p. 440-441).

3.5 The cultivation of seasonally exposed soils

3.5.1 River and canal banks

Foreland soils (between the stream/river water level and the bank top) are covered by the high-water levels of the flood season, the river banks and small islands being exposed from late May to the winter when river levels start rising again. The lower soils do not need irrigating as they remain moist from capillary water. The foreland soils need artificial irrigation (Buringh 1960 p. 130). The soil conditions are good and the salinity level low. The crops grown on these soils include watermelons, cucumbers and other summer vegetables, planted in rows and cut by hand. Once established the crops receive little other attention.

3.5.2 Cultivation of marsh edges

Rice (Oryza sativa) is believed to have been introduced to

Mesopotamia by the first century B.C. (van Zeist 1984 p. 15), and the intensive, continuous flooding techniques involved in its cultivation are considered too specific to be of relevance to any of the crops grown in Mesopotamia in the Early Dynastic period. The practice of growing rice and sorghum on soils uncovered at the edge of marshes as the water retreats during the summer may, however, have some relevance to the past agriculture of lower Mesopotamia.

Salim (1962 p. 85) makes a distinction between rice and sorghum (great millet) growing on the basis of the level of irrigation and cultivation required by the two; rice needed frequent irrigation while sorghum seemed to be able to survive on very little water.

The seedlings were planted on the good quality, e.g. fertile and well draining soils, as the flood waters receded in June. In the winter the land was usually covered in bulrushes and these were cut either in April before the floods or in June just prior to planting. The land was occasionally ploughed or dug over with a long-handled spade, but was usually untilled. Irrigation water for the rice crop was provided in the tidal areas by the natural cycle of high water levels, but further north the water was carried to the crop in shallow clay-lined baskets. The crop was irrigated about once a week for four or five weeks. Apparently the sorghum requires no irrigation preferring or at least thriving in dry conditions.

The crops were harvested with a 'curved-handled' sickle. The threshing and winnowing of rice seems similar to the technique used for the winter cereals. A threshing floor was specially prepared for sorghum processing by clearing a small area of ground and beating it flat. The ripe ears were spread on the floor and threshed by animals or, as was preferred, with the long mid-ribs of date palm frond.

The work was done by teams of two or three people sitting and beating the crop, thus producing a 'cleaner' grain, although it was easier to use animals 80% was done by hand .

This form of cultivation could only take place if the water receded early, i.e. June to August, and this may only occur in 10 out of every 20 years, Thesiger (1964 p. 174) mentions that if the floods remain high after May, weeds came up on the cleared ground, "choking it". Also the level of flooding was important in determining which areas were to be cultivated. High floods would suit farmers who used the water for irrigation on the higher areas, while the lower lands remained under water.

3.6 <u>Other aspects of traditional southern Iraqi farming</u>

3.6.1 <u>Fallow</u>

The use of fallow was an integral part of the agricultural system of southern Mesopotamia. It was essential for restoring soil fertility and structure where there was no regular programme of manuring to replace the benefits of fallow on alluvial soils that are prone to becoming saline.

The beneficial features of fallow include:

a. Improvement or restoration of soil fertility, achieved by:
    i. leguminous weeds, annual or perennial which fix nitrogen from the atmosphere, and increase the amount available to crops (Russel 1957 p. 6),
    ii. dung deposited by animals as they graze the weeds/pasture (MacDonald 1959 p. 114),
    iii. breakdown of minerals present in the soil to produce nutrients in a form usable by plants.

b. Improvement or restoration of soil structure by:

i. the drying of the soil to quite considerable depths often with deep cracks that allow the penetration of plant residues, water, soil particles, and air (Arnon 1972 p. 344),

ii. the growth of deep rooting plants, especially grasses and legumes, which bind the soil particles together.

c. Lowering of the water table, which was of special relevance in southern Iraq where the water table was close to the surface.

The growth of deep rooting summer perennial legumes helped to dry the top few metres of soil allowing soil leaching (Section 2.7.3).

d. Breaking the link between plant and diseases that were established in continuous cropping.

3.6.1.1 Fallow and soil fertility

> "In a fallow period the natural fertility of the soils increases considerably but the fertility deteriorates again rather rapidly where irrigation is applied even within the Niren system. Restored soils taken into rotation after a long fallow period are unanimously described as 'strong' land by the farmers, and land which has been cropped for a long period as 'weak'" (Nedeco 1959 p. 144).

There is no suggestion that the fallow period was used to conserve soil moisture. Conversely, the farmers required the top layers to be dried out to facilitate leaching in the next crop growing season (c f. Halstead 1987 p. 81-82). Bare fallow, where weeds were eradicated, was rarely practiced in southern Iraq, because the principal reason for doing so, the preservation of soil moisture for the next season's crop, was of no advantage in this area.

In southern Iraq the fallow period normally lasted one year and was a weed fallow. The main period of weed growth was early winter through to the spring coinciding with the rainfall. The weeds were allowed to grow unchecked, rather than being ploughed in, to provide animal grazing. The advantages of this were considered sufficient to outweigh those of ploughing the fallow land in March, which would make possible an early start to the following autumn's ploughing on the loosened soils. Delaying the sowing until the autumn meant that the soils remained untreated for ca. 20 months and were consequently very hard.

3.6.2 Pasture, grazing and fodder

> "Animal husbandry is an important source of income, for the sharecropper as well as for the small landowner. The 'fallow' lands are used for grazing ground. The rainfall is of great importance. When there is no rain in spring, irrigation water is used for part of the 'fallow' land, to be able to feed the cattle". (Nedeco 1959 p. 14-15).

Within the crop/fallow system of southern Iraq there were two periods of grazing. During the first, in July or August after the harvest of the winter crops, livestock were allowed into the crop fields to eat the stubble, fallen grain and the summer weeds. The grazing animals may then have been removed to allow the growth of winter weeds, and the land was irrigated to encourage weed growth. The livestock was allowed back into the fields for the second period from January or February and continued to graze until April or May, by which time the best of the plant growth had been removed (there is little weed growth in the summer) (Russel 1957 p. 13-14).

The livestock also grazed the young plants of winter cereals, primarily barley, being allowed on to the field in January or February (when the plants are 45-60 days old). This reduced the final grain yield by ca. 10%, but was considered an important part of the agricultural system. It was noted previously (Section 3.2.2.1) that sowing rates were sometimes increased, where grazing was to take place, to reduce the loss of harvested grain. In some cases livestock were allowed to graze the fully mature crop, e.g. when the crop failed for lack of water, but it was more usual for the livestock to be removed from the fields after a few weeks (10-20) days so that the crop could continue developing (Poyck 1962 p. 51).

Poyck further noted that barley 100-120 days old was grazed completely and that the growth was particularly dense because of the high sowing rates used. Plants 90-120 days old were also cut, "The purpose is again feed for the animals and the prevention of lodging. In this case a harvest is as yet (still) obtained." (p. 52).

3.6.3 Cereal grain as fodder

The feeding of barley grain (dry) to horses, sheep and goats was common in the Hillah-Diwaniya region during the winter months, when insufficient fallow land was available for grazing. The amount animals received depended on the activity and physical condition of the animal as well as on the amount of grazing, and:

> "It was repeatedly reported that horses receive 400-600 kilos of barley per year if, in addition to ploughing, they are also used for working water lifting devices. Sheep and goats receive 30-50 kilos of barley per animal in winter.",
>
> "Cows seldom receive barley and only pregnant cows or weak calves are given supplementary feeding. The straw is given chiefly to horses and cows.
>
> It is estimated that 16.4% of the total barley yield is given to livestock." (Poyck 1960 p. 53).

In the date palm growing areas where there was little pasturage 52% of the barley grain was fed to the animals.

Other sources of fodder or grazing included:

a. Land - watered in a process termed 'haphazard irrigation', where excess irrigation water is allowed to flood the fallow lands.

Approximately 4-5% of the farmland was flooded in this way to produce pasture (Poyck 1960 p. 52). Wright mentions that through the summer sheep and goats, "eat straw and the dried weeds and stubble on specially irrigated fallow and waste land or on canal and pond beds." (1969 p. 14).

b. Uncultivated desert land, grazed after the winter rains.

Wright (1969 p. 15) describes two systems for doing this;

i. small herds of 20-40 animals grazed near the cultivated land by children,

ii. Larger flocks supervised by specialist herders who take the animals;

> "south into the desert with the first rain and return to summer homes and campsites during March and April. During the summer these graze in flooded fallow and waste areas",

iii. canal banks, irrigation ditches and waste land near canals which receive seepage from raised canals and other marshy areas were frequently grazed. Small herds of animals were taken out each day from the village along routes which change as the areas were 'grazed out'. The richest areas of weed growth, e.g. canal banks, field edges, etc. were often visited by the women of the village who cut the green weeds and carried them on donkeys, or their backs, to the village (the weeds were cut with the sickle used for cereal harvesting),

iv. forage crops - rarely seen perhaps due to a "lack of interest on the part of the landowners, and shortage of irrigation water" (Poyck 1960 p. 53).

Table 3.1 Land use in the Hilla - Diwaniya area; percentages of crops (after Poyck 1962)

	Winter	Summer	(Gross area as 100%)
Waste and idle lands	50.2	50.2	
Fallow	20.4	43.6	
cereals (wheat, barley)	23.9	2.5 (rice, millet, sorghum)	
pulses (broad beans, lentils)	0.1	0.1 (greengram)	
vegetables	0.5	0.7	
others (cotton)	0.2	0.2 (cotton)	
pasture	2.2	0.1	
orchards (dates)	2.1	2.1	
oil plants	/	0.6	
crops under date palms			
barley	0.3	/	
vegetables	0.1	/	

Table 3.2 Crop growing and land use in the Hilla - Diwaniya area; for the different types of land ownership (after Poyck 1962)

	types of land ownership/management (% of gross area)					
land use	1 (T)	2 (T)	3 (F)	4 (F)	5 (F)	6 (T)
waste and idle land	52.4	49.0	56.5	41.4	1.5	11.1
farmland	47.6	51.0	43.5	58.6	98.5	88.9
Winter use as percentage of total farmland						
fallow	49.1	39.0	31.2	36.3	1.1	20.4
wheat	14.2	14.9	9.9	25.2	(21.0)	3.7
barley	30.2	38.2	47.1	32.8	8.8	30.1(6.8)
other	1.7	1.4	2.7	0.5	2.0(3.3)	4.6(6.5)
pasture	4.4	5.5	4.7	3.9	/	/
orchards (dates)	0.4	1.0	4.4	1.0	88.1	41.2
Summer crops as a percentage of total farmland						
fallow	93.3	87.4	85.1	90.2	9.3	54.2
rice	3.6	5.9	8.5	4.2	/	/
vegetables	0.3	1.6	0.6	0.9	1.7(3.3)	2.6(2.8)
others	1.4	4.1	1.4	2.7	0.9	2.0
orchards (dates)	0.4	1.0	4.4	1.0	88.1	42.1
rotation factor	0.58	0.74	0.84	0.74	1.02	0.84

Chapter 4 Abu Salabikh; site, sampling and plant recovery

4.1 The Site of Abu Salabikh

4.1.1 Location

The site is situated on the Lowland Mesopotamian Plain, midway between the rivers Tigris and Euphrates. The nearest modern towns are Hillah and Diwaniya, both on the banks of the Euphrates, the river that supplies the water to the present-day village of Abu Salabikh, which sits on the southern edge of the tell.

Abu Salabikh;

> "lies on the eastern fringes of cultivation, which relies on the waters of the Daghghara branch of the Euphrates. Only a kilometre to the east begin the sand-dunes of the desert which still separates Euphrates from Tigris and in which stands the major Islamic site of Zibliyyat, with its brick tower making an imposing landmark visible from Abu Salabikh in all but the thickest dust-storms. Despite its sand and sunshine Abu Salabikh is hardly a place one would choose for a holiday, with its sandflies in hot weather, and amazingly slippery mud when the surface salts are wet from the winter rains. Once, though, it must have been very different: a branch of the Euphrates, or at least a canal, must have flowed by the houses, and there was no doubt a belt of date-palms and pomegranates along the river banks, and outside these, fed by its waters, wheat and barley fields perhaps only beginning to suffer the effects of salinization which is the plague of all agriculture in southern Iraq." (Postgate 1985 p. 48).

During the Uruk and Early Dynastic periods, the periods of study in this dissertation, the site is thought to have been on a branch of a major water-course that branched off the Euphrates some 100 kilometres to the north, above the ancient cities off Sippar and Tell ed-Der. The water course continued to the east of Abu Salabikh southwards through Nippur, Uruk and on to Eridu (Fig. 4.1 from Postgate 1985).

4.1.2 Climate

The area currently receives about 120 mm of rain a year, mainly between November and May, (Poyck 1960 p. 28), and lies between the 100 and 150 mm rainfall isohyets (Guest 1966 p. 12, Fig 1.1). The air humidity is low, especially in the summer, and the water evaporation rate is very high. It does not seem likely that the area was able to support rain-fed cultivation of the winter crops at the time under consideration.

4.1.3 Soils

Abu Salabikh is at the boundary of the Euphrates flood and delta plain soils (Guest 1966 p. 10), both of which are gypsiferous alluvial deposits, now generally saline. The level of soil fertility is low (Poyck 1962 p. 28) and;

> "On the whole the flat area slopes to the south and south east and shows here and there elevations, which came into being naturally or artificially, namely sand and clay dunes, 'Argubs' i.e. sediments excavated regularly from the canal bottoms which cause the formation of large banks along canals, and 'Tells' i.e. hills formed as a result of long periods of continuous habitation. The average slope of the area is 12 cm/km, providing a favourable topographical situation for irrigation and drainage. Poyck (1962 p. 28).

4.1.4 Archaeology

The site is most famous for the 500 clay tablets ('Old Sumerian') that were found in 1963-5 by an American expedition, and showed that the site was once perhaps the capital of a small city-state, connected with areas as far away as Ebla (in Syria).

The site comprises a series of low mounds, only reaching four or five metres above the plain, spread over an area of some 50 hectares. The mounds represent the changing areas of city occupation at different times in the past, and each one may comprise several occupation periods. The site appears to have been occupied from the Late Uruk, through the Early Dynastic I, II and III periods and on to Akkadian times (3200-2300 B.C.).

The site was chosen as it offered the opportunity "of investigating a significant proportion of the (Early Dynastic) city" (Postgate 1985 p. 50) much of which is on or close to the surface of several of the mounds including the main one, unlike other sites where the remains are covered by later deposits. To increase the amount of the city plan recovered, surface clearance, which "consisted of clearing the topsoil to a depth of 10-20 cm and then examining the surface for walls and other features" Postgate (1978 p. 81), was adopted in addition to standard excavation techniques. The features revealed could then be "planned quite as accurately as after actual excavation, and very much faster" (Postgate 1985 p. 59). By these means it was hoped that the area of the site examined could reach 10% compared with the figure of 2% that would have been possible with normal excavation practice.

4.1.4.1 Date of the material

The dates of the soil samples largely reflect the areas and periods of the site excavated when archaeobotanists were present, in the seasons since 1978. Some attempts were made to resample parts of the site excavated previously, which it was thought might be of particular interest, but these samples proved to be unproductive, perhaps because the areas had been exposed for several years, promoting the break up of any charred plant material.

Most of the samples are from the main mound (Fig. 4.2) and date principally to the E.D. III period, with some E.D. I and II deposits also sampled (Table 4.1). The west mound provided samples (from a deep sounding and some open area excavation) dating to the Uruk and E.D. I periods.

4.2 Archaeobotanical sampling at Abu Salabikh

4.2.1 Introduction

The recovery of charred plant remains was begun in 1978 by Dr R. Ellison, when clearly stratified layers in an ashtip were sampled and treated with bucket flotation. The process produced very little plant material (Postgate 1980 p. 91), probably due to a combination of the comparatively small size of sample taken, e.g. 21 litres, and the low frequency of charred material in the site as a whole, particularly in areas of the ash tip. Two other samples taken in the same season as they had visible charred material, came from Room 119 of an E.D. III building and were rich in grain and chaff (2433 and 2464) showing that the methods of recovery were not at fault.

In the 1981 and 1983 seasons sampling was increased (by the author) again using bucket flotation (hand flotation) but the amounts of plant material recovered were still small. Bucket flotation by one person limited the size (average sample size 3-9 litres) and number of samples which could be processed during the excavation season. This unduly restricted the amount of plant remains that could be recovered, so in 1985 a flotation machine was built made it possible to process much larger amounts of soil. The average volume of soil floated per context in 1985 was 45 litres.

4.2.2 Contexts sampled

Although it was hoped that features would be uncovered with obvious concentrations of material, few such features were discovered, and samples were taken from a wide range of context types to ensure that material was not being overlooked (Table 4.2).

One context type repeatedly examined was that of so-called fire installations (Postgate 1981 footnote p. 105). These were excavated as features of rooms and buildings in the course of normal digging, but as they were often visible on the mound as large rings (ca. 2-3 m in diameter) of orange or brown colouration they were sometimes investigated in isolation from the surrounding structures. The types of fire installations, as can be seen from Postgate's description, ranged from small domestic ovens or hearths, presumably used for food preparation, to the larger 'industrial' scale structures capable of pottery or brick baking. It was expected that the former, at least, would provide suitable deposits for archaeobotanical investigation, especially as the fills were often dark black ashy with apparently many charcoal flecks. These were often disappointing, however, containing modern beetle cases rather than ancient charred seeds. The close proximity of these features to the surface and the exposure to the wetting-drying and freezing-baking conditions may well have caused the disintegration of identifiable plant material as well as affording access for insect invasion.

The only samples, other than the two from Room 119, to have relatively high densities of charred plant remains were the layers of an ash pit, consisting of a series of ashy layers in a narrow baulk (c. 1.5-2 metres wide) that had been left by excavation several years before (samples 3308-3323), and a street fill sample (8304) , which seemed, in its plant remains and its colour (pale grey) and texture (light, soft ashy), to represent the ashy material cleared out from a small oven. Such material is seen in dumps around modern dung burning TANNOURS. The only feature common to these more productive samples seems to be their relative height above the present level of the plain, which means that they are less prone to contact with the highly saline ground water and subsequent wetting and drying processes that may have produced the degradation of plant material elsewhere.

4.2.3 Method of flotation

The design of the flotation machine was similar to the S.M.A.P. flotation rig described by Watson (1976) although the similarity is a case of convergent evolution as those designs were not seen until after the machine was constructed in Iraq.

The machine consisted of a metal oil drum which had two pipes welded onto it, an inlet and an outlet, some dexion angle iron outside the drum to support the flot sieves and two metal rods, at right angles to each other, welded inside the drum approximately 40 cms from the top. These rods were to support a square wooden box or insert that was placed inside the drum into which the soil was placed. The wooden box had metal window-screen mesh (ca. 1.5 mm diameter holes) secured across the bottom, and a metal funnel, beaten from a large tin can, protruding from a cut away section of the box and through a matching cut away in the barrel. The funnel overhangs the sieves, of mesh size 1 mm and 250 mm, that catch the flot. The wooden box had handles and could be picked up and shaken or turned sideways and lifted out of the barrel, to tip out the non floating residue.

The sequence of processing was as follows;

i. 7-10 litres of soil were poured into the box with the funnel at right angles to the cut-out section of the barrel to prevent floating soil particles from flowing into the flot sieves,

ii. once all the soil was soaked the box was turned and lowered into the cutout so that the water carrying charred items in suspension, overflowed into the sieves. This ensures that only material from the box gets into the sieves,

iii. the soil was allowed to soak for 5-10 minutes, with only the water pressure from the pump (which is low) agitating the soil and thus lifting the less dense material to float and flow over into the sieve,

iv. the soil was then stirred gently by hand, the stirring gradually becoming more vigorous, until eventually all the soil lumps were broken up. The box was also picked up at intervals during this process which was found to release more charred material from the soil.

. . . .

Once this process was complete and only the coarser mineral material was left on the mesh (the fine soil particles having sunk through the screen), the residue, termed the wet-sieve residue, was tipped onto another sieve ready to be processed for animal remains etc. The wet-sieve residue from 10 litres of each sample was kept to be checked for seeds and other plant material that had not floated.

Between 100 and 200 litres of soil were kept from each context that was being sampled, where available. A minimum of 50 litres were then floated and, depending on the amount of material recovered in the flot sieves more of the sample could be processed in order to generate sufficient quantities of remains for analysis.

In accordance with the procedures described by van der Veen & Fieller (1982) and Jones (1983) the retrieval of a minimum of 100 seeds per sample was aimed for, and where practical the 400-500 seeds needed for more or less infinite target populations (541 seeds = 98% confidence limit with an infinite population, van der Veen 1982).

In practice this involved estimating the number of identifiable items which were visible (to the naked eye) in the flot from the first 50 litres of soil floated, and then calculating the extra volume of soil that would have to be processed to produce a minimum of 100 or, ideally, the larger target of 384-541 seeds.

If the extra volume of soil needed to produce these numbers of seeds was greater than the remaining store of soil then no more would be floated. Again, if the first 50 litres of soil produced more than 384-541 seeds then no more soil needed to be processed, although samples of this sort were very rare at Abu Salabikh.

4.2.4 Sample sorting

The only 'on site' sorting that was undertaken was the examination of the wet sieve residue (>1·5mm) of 10 litres or more soil, per sample, for plant remains which had not floated. It was found to be too time consuming to sort all the wet sieve residue, as was done at Assiros (Jones 1983), perhaps as a result of keeping all the mineral residue (>1 mm rather than that >3 mm as was the case at Assiros).

The amount of plant material found in the residues was very small indeed (less than 5% of the total amount of the total plant remains), and much less than the amounts found at Assiros, (Jones 1983 p. 31). This could have been due to the different methods of flotation used at the site, the low concentrations of remains at Abu Salabikh, or some physical difference in the plant material or the soils.

Approximately 300 samples were floated in the seasons from 1978-1986 and 106 were sorted and scored. Of these samples only 54 had more than 100 identifiable items, and were included in further analysis. Species occurring in less than 4 samples (i.e. 7.5%) were excluded, which reduced the number of non-cultivated seed types from 76 to 31.

4.3 The Abu Salabikh plant remains

4.3.1 Preservation

The Abu Salabikh plant remains were not on the whole very good. In many cases the outer layers were missing or badly corroded and could not be used for the identification of the types to the species level. The loss of seed surface may have been caused by the action of salts which are abundant in the soils of the Abu Salabikh mound, and throughout much of southern Iraq today. The surface of the mound has a thin salt crust on top of a soft powdery soil layer several centimetres deep. Within a few hours salt crystals start to form on any new area of the site opened up by surface scraping or excavation.

The effect of the salt is clearly visible in the modern baked bricks left on the ground for a few months. Although these appear sound they will frequently disintegrate on contact. The same effect is sometimes seen in pot sherds recovered from the top 20-30 cms of the mound. It is likely that the salt would have a similar effect on charred plant material, the growth of salt crystal within the charred seeds causing them to break up. The problem may well be exacerbated by the opening up of quite large areas of the site during surface scraping with excavation sometimes not following for several years.

The surface of the mound is also subjected to extreme climatic conditions during the year. The high temperatures and evaporation of the summer months can cause the surface layers to dry and crack, decreasing the chances of preservation of the charred remains. There is minimal damage to the plant remains by root growth as the site has a sparse covering of plants restricted to salt-tolerant plants in small depressions and <u>Prosopis</u> and camel thorn scrub on the mound edges.

Well preserved material has been found at the site, e.g. the two contexts from Room 119 sampled in 1978. These black ashy contexts were still visible in the baulk in 1983 and they were resampled. This time, however, they failed to yield much in the way of identifiable plant remains, presumably as a result of soil drying and salt crystallisation.

4.3.2 Identification

The identification of the remains was made with reference to modern plant collected from around the site of Abu Salabikh. Other seed collections used for comparative purposes include that of Gordon Hillman, from Turkey, and that at the Department of Human Environment (Institute of Archaeology, London).

The identification of the specimens collected near Abu Salabikh were checked by the staff of the National Herbarium of Iraq. "The Flora of Iraq" and "The Flora of Lowland Iraq" were the principal sources of plant names used in the dissertation.

Much effort has been made to name each type to species level but this was not always possible and where this is the case the genera or group of genera to which the specimens have been assigned are discussed within the restrictions imposed by this lack of precision. In some cases the failure to identify a type to species level does not have a very detrimental effect as the other members of the genus share similar characteristics of habitat preference, growth cycle and potential uses.

4.3.3 Identification criteria

4.3.3.1 Cultivated plants

Hordeum sativum (2-and 6-Row) Hulled Barley.

The identification of the types of barley and their relative proportion at a site have been discussed by Jones (1983 p. 39). In 6-row barley each rachis bears three grains, two twisted laterals and one straight medial (i.e. 2:1 twisted:straight grain) in 2 row the lateral florets are sterile and there are only straight grains. When only grain is present in the samples the relative proportions of the two types of barley are determined on the ratio of the straight to twisted grains. If all the grains are straight then the crop is assumed to have been purely 2-row, if there is a 2:1 twisted to straight grain ratio the crop was probably 6-row. In a 50:50 mixture of the two crops there would be a 1:1 ratio of straight to twisted grain; equivalent ratios can be worked out for various proportions of the two forms of the crop.

In much of the Abu Salabikh material it was not possible to distinguish between straight and twisted grain due to distortion and poor preservation, and in these cases the grains had to be assigned to an indeterminate category.

Individual rachis internodes possess diagnostic features and can be identified to variety level. At Abu Salabikh four types of rachis were recognised;

a. 2-row type.

Face view comparatively narrow, straight sided, looking down on the grain attachment surface the rachis tended to be a narrow oblong and the glume bases only protrude outwards slightly.

b. 6 row type.

Broader, and wider at the top; from above, the rachis is broader and oval rather than oblong, the glume bases protrude more noticeably from the grain-attachment surface.

c. Basal rachis segments (often two or three joined together and sometimes a small length of stem present).

The basal rachis internodes are much shorter than the medial ones and tend to be much thickened with pronounced venation and a lip on the outer face. It was not often possible to positively identify these to a type.

d. Indeterminant type.

Insufficient features for identification.

The proportions of 2- and 6-row at Abu Salabikh are discussed below (section 4.3.3.1).

<u>Triticum monococcum/T. dicoccum</u> (glume wheats)

<u>Grain</u>

In the few Abu Salabikh samples with any quantity of wheat grain there was a range of grain forms, identified as <u>T. monococcum</u>, T. <u>dicoccum</u> and an indeterminate type <u>T. monococcum/dicoccum</u>. For these two species there were 1-grained, 2-grained and indeterminate 1/2-grained forms. Many of the grains had to be assigned to the indeterminate categories due to poor preservation. There were, however, sufficient numbers of well preserved specimens to confirm the presence of the two species at the site.

In the remainder of the samples there were few well preserved grains and it was not always possible to identify these past the glume wheat level. For the purpose of the analysis the numbers of the two glume wheats have been combined.

One of the difficulties, in the identification, was found to be the separation of grain into 1- and 2-grained forms, <u>T. monococcum</u> (einkorn) has 1- and 2-grained forms, the former being the more common. In the 1-grained form the single caryopsis swells to fill the spikelet as it develops, giving it a characteristic rounded surface. In the 2-grained form the caryopses press against each other producing flattened ventral surfaces A typical 2-grained form of _T. monococcum_ has a flattened, often slightly irregular, ventral surface; the grain is more or less parallel-sided in side view with only a slightly curving dorsal surface.

One-seeded spikelets only occur in _T.dicoccum_ (emmer) at the base and apex of the ear, the majority of the spikelets being 2-grained. There is however, a possibility that 2-grained forms of _T. dicoccum_ charred free of the spikelet and thus not constricted along the ventral surface have a more rounded surface than when charred in the spikelet and can be mistaken for 1-grained forms.

From experiments carried out on modern _T. monococcum_, _T. dicoccum_ and _T. dicoccoides_ it was seen that the grain shape did vary according to whether they were charred within the spikelet or as free grain.

a. An evenly curved ventral surface being characteristic of 1-grained forms; einkorn and emmer were distinguished on the basis of;

- i. the apex is pointed in einkorn, broader in emmer,
- ii. the embryo angle is steeper in emmer,
- iii. einkorn grains are more asymmetrical.

b. 2-grained forms had flattened ventral surfaces; emmer and einkorn were separated on;

- i. in lateral (side) view the dorsal surface of emmer has its high point just behind the embryo; in einkorn the high point is in the middle of the dorsal surface,
- ii. in dorsal view the emmer grains are broader with blunt apices compared with the pointed ones in einkorn.

Spikelet material

Most of the spikelet material consisted of glume bases and it was often difficult to assign a positive identification. There were examples of both einkorn and emmer, the latter being the more abundant, and a large percentage that had to be put in an indeterminant category T. monococcum/T. dicoccum.

In the modern material examined the separation of emmer and einkorn spikelet forks was achieved on a number characteristics (see Hillman forthcoming for explanation of terms used).

a. Scar width (attachment point for next spikelet).
Einkorn spikelet forks tend to have a wide scar relative to the spikelet width at that point, while that of emmer is narrow.
b. Angle between glumes.
The angle between the glumes is typically narrower in einkorn than emmer.
c. The position of glume insertion.
The glumes are inserted level with the scar in einkorn whereas in emmer insertion tends to be below the scar.
d. The angle of the glume faces in transverse section.
In einkorn the outer faces of the glumes are almost parallel, while in emmer the glumes are closer at the back of the fork (away from the scar) than at the front.
e. The second nerve or dorsal keel.
The dorsal keel is pronounced in einkorn but less obvious in emmer.

When applied to archaeological material the separation was found to be much more difficult, with much of the material being classified as T. monococcum/dicoccum. Some of spikelet forks met the majority of conditions listed above for einkorn except in one regard, a flap of tissue protruding from the primary (ventral) nerve. In einkorn this flap points forwards, i.e. at ca. 180° to the face of the glume whereas in emmer it tends to point out sideways, at an angle closer to 90°, (Glynis Jones pers. comm.). In the archaeological material identified as einkorn in other respects the angle was more like that of emmer. For this reason all the material was grouped together for the analysis.

Ficus carica (Moraceae)
The seeds of fig are ovate, slightly laterally compressed with a 'ridged beak' which often has a small circular aperture below. The seed coat is smooth.

Lens culinaris (Leguminosae)
The seeds of this species were identified on the basis of the characteristic lenticular shape.

Linum usitatissimum (Linaceae)
Linseed/Flax seeds are distinctive; flattened laterally and roughly oblong or obovate in outline with a notch at the narrower end, the hilum. The dimensions of the Abu Salabikh seeds fall within the range of the cultivated species (van Zeist and Bakker-Heeres 1975).

Sesamum indicum (Pedaliaceae)
The seeds identified to this species were pear drop shaped (obovate), laterally compressed and transversely elliptic in cross section. The outer layer of the seed was often missing and when present the surface was badly eroded and the surface pattern was not clearly discernible. The cotyledon surface had characterisic wavy, irregular walled cells (Plate 4.2 Fig. 4) which resemble those on modern specimens of Sesamum indicum (Plate 4.1 Fig. 4). The seeds are within the size range of modern sesame seeds.

4.3.3.2 Non-cultivated plants

Amaranthus sp. (Amaranthaceae)
The fruits were circular and flattened (lenticular) with a ridge around the margin, the embryo. The ridge was slightly notched at one point giving a characteristic

shape to the seed. The surface was smooth. The specimens found in the Abu Salabikh samples were smaller than the European species examined. The closest resemblance was to A. albus.

Arenaria sp. (Caryophyllaceae)
The seeds were very small with a reniform shape to Silene sp. but with a smoother surface and a cell pattern more like that of Arenaria sp. e.g. A serpyllifolia illustrated in Berggren (1981 p. 198). The only species found in Iraq today is Arenaria leptoclados which has not been seen.

Atriplex sp. (Chenopodiaceae)
Round flattened seeds with a radicle that runs round the circumference of the seed and protrudes at the tip, making the seed somewhat comma shaped. In cross section it is almost angular. The surface is patterned and not radially aligned. The specimens did not correspond exactly with any of the N. European or Turkish species. The Iraqi members of the Atriplex genus share similar habitat preferences and growth periods, so for the purpose of this analysis the failure to identify to species was not considered sufficient to exclude the seeds.

Chenopodium sp. (Chenopodiaceae)
Lenticular seeds, with the embryo visible in places. Little of the surface intact. In size these seeds are slightly smaller (ca. 1.0 x 0.8 x 0.4 mm) than both C. album and C. murale as given in Berggren (1981) but match the dimensions listed by van Zeist & Bakker-Heeres (1984b p. 181) for Mureybit.

Cyperus sp. (Cyperaceae)
The fruits of this genus are oval with a fairly prominent ridge running between the two pointed ends. The surface is otherwise smooth. The identification of Cyperaceae fruits on European sites of the Cyperaceae is very problematic given the number of overlapping genera. In Iraq, however,

genera such as Carex are restricted to high altitudes (above 750 m). The seeds can be assigned reasonably confidently to the genus Cyperus, though more accurate identification is not possible. The majority of the more common species share the same habitat preferences, though some have a markedly different seasonality, as is discussed below in Section 4.5. The tubers of Cyperus rotundus have a distinctive appearance, with strong ridges along the long axis and circular patches of vascular strands (Hillman 1989). Their identification was confirmed by J. Hather of the Institute of Archaeology.

The seeds identified as Cyperus are not thought to be C. rotundus.

Galium sp. (Rubiaceae)
The seeds (mericarps) are hemispherical with a large hole on the flat surface, marking the point of hilum attachment. The surface of the seed is quite rough. The Abu Salabikh mericarps are small in comparison with many of those looked at in the comparative collections, even smaller than G. aparine. Several species with mericarps similar in size to the Abu Salabikh specimens are mentioned in the Flora of Iraq but reference material was not available.

Hordeum sp. non-cultivated types (Gramineae)
a. Hordeum spontaneum
The separation of barley fruits (caryopsis) seeds into H. spontaneum (wild barley) and H. sativum on the basis of caryopsis or rachis morphology is not completely straightforward and from charring experiments conducted by the author seems to depend to a large degree to the charring regime experienced by the ancient material. In fresh material the caryopses of H. spontaneum can be distinguished by their more or less parallel sides in dorsal or ventral view. In cross section the dorsal

surfaces tend to slope concavely down from the central ridge whereas in H. sativum this dorsal face is often flat or rounded (convex). Overall the seed of H.spontaneum is more angular and flattened. W. van Zeist (1984 p. 203-4) also pointed out that it "is particularly clear in lateral view, (that) wild barley grains are very thin at the apex", and that;

> "Although modern grains of both barley species are not difficult to separate, in carbonized, sub fossil specimens the distinction is often less clear. This may to a high degree be due to a puffing of the grains and other kinds of deformation through carbonization."

The puffing up of the grain can be extreme under certain charring conditions, e.g. dry roasting the grain in a pan, and H. spontaneum grains can be made to resemble H. sativum. Treating H. sativum grain in the same way produces almost spherical grains, similar to 'puffed wheat'.

In the identification of the grain only those specimens exhibiting several of the features described above are identified as H. spontaneum.

None of the barley rachis material looked at could be confidently assigned to the H. spontaneum group.

b. Other non-cultivated Hordeum species

Two types of 'weed' Hordeum species were distinguished at Abu Salabikh principally separated on the grounds of size.

i. fruits with an average size 3.4 x 1.2 x 1.0 mm. These are similar to fruits illustrated by van Zeist & Baker-Heeres (1984 p. 220). Parallel-sided like H. spontaneum but not as flattened, they are rather round in cross section and quite thick at the apex and in lateral view. They resemble modern specimens of H. geniculatum and H. marinum,

ii. Larger fruits 5.2 x 2.5 x 1.6 mm. These have the same basic shape as those described above, again lacking the prominent angularity seen in <u>H. spontaneum</u>, but are consistently larger. Their surfaces are often very cracked with lines running at right angles to the long axis of the grain. In size the fruits most resemble species such as <u>H. bulbosum</u> or <u>H. leporinum</u>.

<u>Lolium</u> sp. (Gramineae)
This genus has dorso-ventrally flattened caryopses more or less oblong in ventral view with parallel or slightly convex sides. In longitudinal section the ends can be pointed or quite blunt. The ventral surface has prominent lines running along its length. The actual surface of the caryopses is smooth but quite often patches of lemma and palea adhere to the surface and these have a distinctive papillionate texture.

The measurements of the Abu Salabikh material are within the range 2.9-3.5 x 0.9-1.3 x 0.8-1.2 mm which fits into the range for <u>L. rigidum</u> and <u>L. persicum</u> which themselves show considerable overlap in their appearance (the latter is rare in S. Iraq).

Seeds of certain species of <u>Festuca</u> are often confused with <u>Lolium</u> but the genus is rare in Iraq and restricted to the upper reaches of the mountain zone (>500-750 m).

<u>Malva</u> sp. (Malvaceae)
Malva seeds have a fat horse-shoe shape, one arm of which is sometimes prolonged. In side view they are wedge-shaped.

<u>Malva</u> seeds can be confused with <u>Althaea</u> sp. and <u>Laverta</u> sp. but there is only one species of <u>Althaea</u> in Iraq and it very rarely occurs below 500 m. The seeds do not resemble those found at Abu Salabikh. The <u>Lavatera</u> sp. present in Iraq has seeds very different from those of <u>Malva</u>. Among the species occurring in southern Iraq, the Abu Salabikh specimens most closely resemble

M.nicaensis/aegyptiaca in size, but in the absence of the surface patterns firm identification was not possible.

Salsola sp. (Chenopodiaceae)
Circular flattened seeds with a conspicuous spiralled embryo (2.5 or 3 full turns). Where the outer layers of the fruit are present the shape is hemispherical. Identification to species was not possible as not all the species were available for comparison.

Phalaris sp. (Gramineae)
These were several small 'Phalaris types' present, the most common was;

Phalaris sp. 1; a laterally compressed caryopsis, ovate or oval in side view, and a narrow pointed oval in dorsal or ventral view. This type compared favourably with P. minor in shape and size.

Of the remaining types one other was common enough to be described and included in the analysis.

Phalaris sp. 2; this was longer, with less rounded caryopsis, in side view, similar to P. paradoxa.

Polygonum sp. (Polygonaceae)

Polygonum corrigioloides
The seeds of this species are smaller than the other members of the genus Polygonum (1.0 x 0.7 x 0.6 mm). They are oval with three well defined angles at one end (less pronounced at the other). Whereas most trigonous Polygonum species have show concave surfaces between the ridges, P. corrigioloides is more or less spherical in cross section. The embryo runs along one of the angles as is typical for Polygonum sp. (c.w. Rumex sp.).

Polygonum sp.
Two other types of Polygonum were distinguished.

a. Polygonum 1.

A tiny trigonous seed lacking pronounced angles. The surface is usually minutely wrinkled, the wrinkles at right angles to the long axis of the seed. None of the Polygonum species looked at was as small as this, though several of the Iraqi species were not available for examination.

b. Polygonum sp.

The seeds of this type are very small (1.2 x 1.0 x 0.9 mm) in comparison to other Polygonum species. They are rounded in cross section. The seeds are angled but here the angles continue along the entire length of the seeds. The only species that has seeds as small as this is P. aviculare ssp. aequale.

Prosopis farcta (Leguminosae)

A large distinctive seed, with an ovate flattened shape, elliptic in cross section. The surface is smooth and the outer layer of the seed coat is thick and bears a horseshoe-shaped line on one flat face. Fragments of the seed coat and the cotyledons can also be recognised.

P. farcta is the only native species of Prosopis in the Near East.

Rumex sp. (Polygonaceae)

In cross section the seeds are triangular with small ridges at the angles. In outline the shape is broadly elliptical, slightly wider towards the base reducing to a sharp pointed apex and a squarer base. The embryo runs along the centre of one of the seed faces. The seed surface is smooth and shiny.

Of the commonly occurring Iraqi species the Abu Salabikh seeds most resembled R. conglomeratus in shape and size.

Scirpus sp. (Cyperaceae)
The fruits are obovate, tapering to a fairly narrow truncate base. The seeds are somewhat compressed, dorso-ventrally, and in cross section are hemispherical (a depressed ovate). The curved surface has a blunt ridge. The fruit surface is smooth. Measurements of modern *S. maritimus* population given by van Zeist & Bakker-Heeres (1984 p. 217) coincide with those of the Abu Salabikh specimens (2.1 x 1.6 x 1.0 mm). Positive identification was not possible as certain species from S. Iraq had not been seen, including some common ones (Townsend & Guest 1985). The kernel of this fruit was often present on its own and was counted with the whole fruits.

Suaeda sp. (1.0 x 0.7 x 0.6 mm) (Chenopodiaceae)
A round comma shaped seed with a small hilum scar visible in the notch at the margin on the protruding radicle tip and a smooth surface. In cross section the seed is transversely rhombic or elliptical; in side view it is ovate. It was not possible to identify the Abu Salabikh material to species.

Triticum boeoticum (Gramineae)
A long slender seed with more or less parallel sides in outline, viewed ventrally and laterally. There is some lateral compression and a pronounced dorsal ridge. The Abu Salabikh material appears to be of the 2-seeded type as the ventral and dorsal surfaces are not strongly laterally compressed. In the 1-grained form the dorsal and ventral edges are very concave rather than like the almost flat ones seen in the Abu Salabikh grain.

Vicia/Lathyrus sp. (Leguminosae)
Large angular seeds (ca. 5.0 x 5.0 x 3.5 mm), wedge-shaped in side view with poorly preserved hilum and evidence of the cotyledon joining the seeds. They resemble *Lathyrus sativus/cicera* but the lack of well preserved specimens precluded the accurate identification of this type. There

is considerable overlap between members of these two genera so they were grouped together for this analysis.

Small legume group (Leguminosae)
This is the most abundant group of seeds found on the site with a great range of forms, and while some of the types are distinctive and can be identified to a genus with reasonable confidence, identification to the species level is rarely possible. This is due to the large number of species of some genera the lack of modern comparative material, and the types may have to be grouped together to varying degrees.

The genera tentatively identified at Abu Salabikh are Astragalus spp. of which there are 116 in Iraq, Medicago spp. (17), Melilotus spp. (4), Trifolium spp. (33) and Trigonella spp. (18).

Astragalus sp.
Laterally compressed seeds typically transversely elliptical in cross section. They were described as "obliquely quadrangular in outline. Most characteristic is the hilar notch, the identification with the hilum, on one of the long sides" by van Zeist & Bakker-Heeres (1984 p. 223-4). Some of the specimens are more rounded and could overlap with Melilotus or Trifolium species.

Medicago sp.
Seeds again laterally compressed, often crescent shaped with a slender protruding "finger" running up one long side of the seed, usually pressed against the surface, the radicle.

Melilotus sp.
Elliptical seeds, laterally compressed, with a conspicuous radicle tip running along two thirds of the seed and a marginal notch. In cross section transversely broadly elliptical. Small Melilotus species tend to overlap with

Trifolium species and there is an intermediate category for these seeds *Melilotus/Trifolium* sp.

Trifolium sp.
A group of broadly obovate seeds with a marginal notch on the narrowest part of the seed and an inconspicuous radicle. The seeds ranged in size from larger than 2.5 mm to those with a greatest dimension of less than 1 mm. There was also considerable variation in the texture of the seed coat. Some testas were smooth, others covered in a 'crazy paving' pattern. There were also types tinted orange or yellow, although the cause of this is unknown.

Trigonella sp.
More or less oblong seeds with the marginal notch two thirds of the way down one of the long faces. The seeds are also angular, oblong (transversely narrowly) in cross section. The seed surfaces of the specimens were smooth.

4.4 Non-cultivated plants at Abu Salabikh

4.4.1 'Modes of arrival'

The means by which seeds and other "identifiable units" of plant material are brought on to a site have been considered by several authors. Miller and Smart (1984 p. 15) have summarised these as;

i. prehistoric seed rain - natural seed dispersal,
ii. direct resource utilization - seed itself used,
iii. indirect resource utilization - another part of plant used,
iv. incidental inclusion with utilized resources e.g. crop weed seeds.

In addition they suggested another process, the inclusion of the seed in animal dung that is "intentionally burned as fuel" (p. 16).

Hillman (1984) devised a system for the "classification of each species by the probable mode of arrival of its seeds on the site". Pointing out that "Different sites will clearly require different systems of classification, depending on which species are represented in the remains" (1984 p. 19). At Abu Salabikh the classification of the plant remains had to take account of the seasonality of the plants, relative to the winter crop types. In addition to the seeds there were culm nodes, tubers etc. which had to be considered.

When assessing the means by which the material came on to the site at Abu Salabikh the principal concern was to distinguish those plants that were growing in the winter crop fields, whose seeds were put through the crop processing stages with the cereal grain and thus reflect on the origin of the sample and on the conditions in the crop field. This was of particular importance at Abu Salabikh as there are no samples that could be positively identified as a primary, uncontaminated stored crop or where the association of crop and wild plant can be more of less guaranteed (cf. Jones 1983 p. 179-180).

Before attempting the classification of the Abu Salabikh material the problems of classifying a species on the basis of information gathered from various sources, including personal observation, are illustrated for the genus Malva.

In Iraq Malva parviflora is;

> "Common in fields and gardens, in ditches, by roadsides and in depressions on waste land. Feb.-Apr. The leaves are collected, cooked and eaten as a vegetable by the people; the plant also affords good grazing for livestock." (Guest 1933 p. 60),
>
> "Watt (1891) states that the seeds are used as a demulcent for curing coughs and to alleviate ulcers and bladder complaints in India where peasant women use the root to cleanse their hare and woollen cloth is also washed with it;" (Townsend & Guest 1980 p. 240).

The following was noted about the closely related species of Malva sylvestris;

> "The leaves, young shoots and even sometimes the roots form an ingredient of mixed salads and the fresh unripe fruit are considered a delicacy by children. A dye can be extracted from the flowers." (Townsend & Guest 1980 p. 235).

So for this genus classification as a crop weed, fodder plant, food plant and medicinal plant are all possible. These methods of plant utilisation do not, however, all involve the collection of the seed, which is the part of the plant identified in the charred remains at Abu Salabikh. It seems that the dried seeds were avoided, though they could have been brought in along with the immature fruits. In view of the number of mature or partly dried seeds arriving at the site and the chances of the material being burnt, then the major source of Malva seeds would seem to be harvested crops or animal dung.

For each identifiable category of plant material there are several possible modes of arrival, all of which have to be considered prior to interpretation of assemblages. For example, Hillman (1984 p. 20) lists the multiple classifications given to some of the species found at the site of Cefn Graeanog in Wales. Yet, in a situation where decisions have to be made regarding the most likely way in which the material became incorporated with the site's plant remains, then it is necessary to classify each species as narrowly as possible.

Classifying non-cultivated plant material on the basis of its most likely mode of arrival is a task fraught with difficulties, especially if there is no help from the sample composition e.g. if the samples appear to be of mixed origin.

If the samples being dealt with consist of, "primary contexts, notably an extensive destruction deposit resulting from a catastrophic fire in a grain storeroom complex" (Jones 1987a p. 312), then the likelihood of the non-cultivated plant seeds found in the samples having arrived by means other than as crop weeds is relatively small.

When the samples are of a more uncertain origin and the probability of contamination either by deposit or product/by-product mixing is high, then the origin of a type of plant material and its relationship to the crop becomes very much more difficult to establish with any certainty.

To use these likely modes of arrival to assess whether the samples have been contaminated, i.e. contain material not present in the crop fields, risks employing a circular manner of argument. Thus a non-cultivated plant which is both a potential food plant and a regular crop weed could be used to argue that the sample was a product/by-product of crop processing or equally that the sample was of mixed origin and that the species had been collected as a food and accidentally charred.

The Abu Salabikh non cultivated seeds were considered from three viewpoints;

i. seasonality,
ii. distribution or habitat preference,
iii. principal uses of the plant as recorded in Iraq.

4.5 Seasonality

Before using weed seeds in the study it is important to determine which of the non-cultivated species represented at the site were present in the fields and were harvested with the crops. The inclusion of species from other habitats will only confuse the identification of the crop processing stages that produced the residues.

One conspicuous feature of agriculture in southern Iraq is the number of plants, usually perennials, that appear after the winter wheat or barley crop has been harvested, and which do not fruit until the early autumn (September-October) e.g. Prosopis farcta and Alhagi graecorum. It is unlikely that their seeds would be harvested with the winter crop.

This seasonality reflects the strong differences between the winter and summer climate of the area (Section 1.2) and manifests itself as annual plants flowering and fruiting in March-May and perennials with deep rooting systems that utilise the stored ground water which appear in spring and produce seeds in the early autumn.

There is some overlap of the growing period of the summer and winter weeds, the summer weeds often germinating in the spring and some winter crop weeds continuing through into the early summer. The likelihood of the seeds of summer flowering species being harvested with the winter crop or vice versa is small.

This differentiation has to be taken into consideration when dealing with the non-cultivated seeds found in the Abu Salabikh samples. In order to do this the flowering and fruiting periods of the weed species were determined from the Flora of Iraq and other studies conducted in Lowland Mesopotamia (MacDonald 1959, Hassaway et. al. 1958), concentrating, where possible, on the fruiting dates, observation of the weed infestation of crop fields, and the weed seed contaminants of the harvested crop or seed stores (table 4.3). There are also several descriptions of the weeds associated with winter and summer crops, e.g. in Guest (1966 p. 93) and MacDonald (1959 p. 260).

When the dates of flowering and fruiting for the various weed groups were assembled it was seen that not all types could be assigned unequivocally to one season's crop, some dates encompassing both. Based solely on flowering and fruiting dates the following three categories of weeds were constructed.

a. Winter-spring: April-May (-June)
Arenaria sp., Galium sp., Lolium sp., Medicago sp., Melilotus sp., Phalaris sp., Rumex sp., Trifolium sp., Trigonella sp., Vicia/Lathyrus sp., Malva sp., Hordeum sp. weed and Hordeum spontaneum.
b. Early summer: (May-) June-July (-August)
Polygonum sp., Salsola sp., Cyperus sp., Scirpus sp., Suaeda sp.
c. Summer: July-October (-December)
Amaranthus sp., Atriplex sp., Setaria sp., Prosopis farcta

Wheat and barley are harvested from mid April to late May, sometimes carrying through to the second week of June, but rarely any later. Summer crops may be sown on fallow land from March onwards or may be grown on the winter cropped fields after harvest.

Of the Abu Salabikh genera Guest (1966 p. 93) lists the following species as being common in the fields of winter crops: Phalaris brachystachys, Hordeum geniculatum, Lolium temulentum, Melilotus indicus, Medicago polymorpha, Lathyrus sativus/Vicia sativa, and Malva parviflora. Common summer crop weeds are members of the Polygonum genus, while the perennial Cyperus rotundus is associated with permanently irrigated gardens. Hassaway et. al. (1958 p. 245) mention the following species as "weeds which infest wheat and barley with their seeds": Lathyrus annuus, Lolium rigidum, Malva rotundifolia, Medicago hispida, Melilotus indicus, Phalaris minor, Trifolium procumbens, Vicia calcarata (p. 246). Weeds "encountered in rice fields and along irrigation ditches of rice areas" are Cyperus odoratus and Scirpus littoralis (rice is a summer growing crop).

The winter and summer categories are quite distinct but there is a problem in deciding how to treat the early summer plants in terms of how likely their seeds are to be a contaminant of the harvested grain. Table 4.4 gives the flowering and fruiting information collected for each one.

All these early summer plants, with the exception of Suaeda, are mentioned as weeds of summer crops. Cyperus and Scirpus were observed in winter crops, but as the precise dates of fruiting, rather than the period covering flowering and fruiting, are not known and both have been described as being common summer crop weeds (Guest 1966 p. 93, Hassaway et. al. 1959 p. 245) they are considered as such here. The seeds of these genera, Cyperus, Salsola, and Scirpus, would seem more likely to appear in the harvest of summer crops than in a winter one (though the latter cannot be ruled out) and more precise information on the fruiting date of a range of plants and the contaminants of the major (traditional) crops is needed.

Suaeda sp. are not generally seen in crop fields of present-day southern Iraq occurring rather in waste places, old canals, abandoned fields, derelict gardens, etc. which are frequently saline (Guest 1933, p. 97, Guest 1966 p. 93). So despite the overlap of its fairly narrow flowering and fruiting period with the end of the winter cropping season it has been left with the group of early summer weeds and thus not included in the present analysis.

The division of weed seed types into winter and summer groups and the exclusion of the latter from the analysis of the winter crops at Abu Salabikh is occasioned by the particular set of environmental conditions of Lowland Mesopotamia and is presumably unnecessary in Northern European countries where the summers are wetter and the distinction of winter and summer field crops is not so pronounced.

The distinction does not appear to have been made at the other Mesopotamian sites and yet it seems to be important, when trying to establish information about crop growing conditions, to separate the weeds present in the crop fields during their growing period (whose seeds will end up in the harvested crop) from plants which, even if they grow in the crop fields, have a life cycle that precludes their seeds from being harvested with the crop, but which can become mixed with the harvested crop at a later stage. While it may be dangerous to pre-judge the plant material to too great an extent before analysis, e.g. by excluding species whose ecological range does not include crop weeds, because field conditions and the species present may well have changed, it still seems necessary to distinguish the plants according to their seasonality. The chief problem in this approach is in deciding which species were actually in fruit at the time of crop harvest, i.e. species synchronized to the crop's life cycle, especially for the intermediate species (early summer groups). It is also these plants that would have been most affected by any changes in climatic conditions, methods of crop husbandry, or crop varieties cultivated in the past. In Iraq today there is an approximate 2-week discrepancy in the harvest times of wheat and barley crops (Section 3.2.2.5).

Before looking more closely at the various types of non-cultivated plant use the natural vegetation of the alluvial plain of Lowland Mesopotamia is briefly described to explain the significance of the native plant habitats and the effect artificial watering has had on the flora of the area.

4.6 Habitat preference and plant distribution

> "There is far less change in the hygrophilous vegetation of our country, from south to north or from west to east, than in the vegetation of the primary habitats. Hygrophilous plants tend to be less affected by climatic change than

> other types, and some of the species found in our lakes, ponds and canals are almost cosmopolitan in distribution" (Guest 1966 p. 91).

These words also describe the effect of irrigation on the distribution of non-cultivated plants throughout the Lowland Mesopotamian Plain. The artificial watering of the land for the growing of crops also creates conditions suitable for plants to thrive that would not normally be able to survive the desert/sub-desert conditions. These plants are mainly crop weeds of the wetter upland regions of Mesopotamia, though some of the endemic sub-desert species are also able to colonise the new habitats.

Little is known of the endemic flora of the region as so much of the area has been cultivated or exploited in other ways by humans (animal grazing, fuel gathering etc.);

> "In some parts of the plain there are large numbers of small strips and patches of vegetation which may appear natural but are in reality of secondary origin" (Guest 1966 p. 66),
>
> "The typical natural vegetation of the sub-desert consists of more or less scattered shrublets practically nowhere completely closed and often very open and including barren tracts of edaphic desert and secondary desert. In spring the open spaces between the bushes are generally occupied by a relatively sparse crop of annuals." (Guest 1966 p. 71).

It is common to find that a species found growing wild in the lower forest and moist steppe zones only occurs in habitats associated with irrigation on the lower alluvial plain e.g. Hordeum geniculatum, Lolium rigidum, Melilotus indica, and Cardaria draba. Rarely these plants are found in non irrigated habitats which receive run off water.

The majority of the common weeds of winter crops in Lowland Mesopotamia appear to have come from the upland regions, the natural vegetation of the alluvial plain contributing comparatively few species to the weed flora of the fields. The types of habitat encountered in Lowland

Mesopotamia can be divided into two basic zones;

a. Dry-land habitats (desertic).

Land receiving only rainfall, which in Lowland Mesopotamia is on average less than 150 mm (and thus insufficient to support crop growing). Within this zone there are some habitats where the amount of water available is slightly higher as a result of runoff concentrating the water.

b. Wet-land habitats.

Where the soil receives water in addition to rainfall;

i. naturally watered areas where the supplementary water is from the rivers, i.e. river beds, banks, levees and marsh areas,

ii. artificially watered areas-irrigated crop fields, and areas around the irrigation works, including the canal banks and beds, fallow fields and any area within the seepage zone of the canals, etc.

An example of a habitat kept moist by canal seepage was seen between the mounds of Abu Salabikh and the canal that runs alongside today. The soil in this 40-50 m strip has a high water table due to seepage from the unlined canal and in addition receives runoff water from the site itself. Despite the fairly high salinity of the area it supports a luxuriant growth of plants in the spring, and retains some cover, mainly of grasses and perennial shrubs, throughout most of the year. The species thriving here in the spring include the legumes, Melilotus indica, Medicago polymorpha, Trifolium resupinatum, Trigonella stellata etc, and the grasses, Cynodon dactylon, Phalaris minor, Hordeum geniculatum, Lolium persicum etc. and they provide grazing for the herds of cows from the nearby village.

4.6.2.1 Winter plants

Only 2 species H. spontaneum and Triticum boeticum can be confidently described as segetals as they do not occur in Lowland Mesopotamia at all today and it can only be assumed that they were brought in as contaminants of the crop seed used for growing, unless some ecological feature of the area was very different.

Today wild wheat and barley are common in northern Iraq in the lower mountain pastures and forest. H. spontaneum extends out onto the steppic plain, down to 100 m but is not reported in the sub desert zone.

Most of the remaining genera occur in irrigation or water associated habitats but are not exclusive to the crop fields. While most of the Abu Salabikh species show a propensity for the wetter habitats there are a few that can also tolerate more desertic conditions, ie Hordeum marinum, Malva parviflora, Astragalus spinosa, Phalaris minor and Trigonella stellata. Medicago spp. are abundant in the sub-desert during the wet spring months.

4.6.2.2 Early summer plants

Suaeda sp. seeds are very common at Abu Salabikh and are apparently restricted to desertic habitats. Several of the other genera have marked preferences for wetter conditions and are often found in marshes, along canal banks and in permanently irrigated places, i.e. Cyperus, Salsola, Scirpus spp.

4.6.2.3 Summer growing plants

Within this group are two genera regarded as segetals in summer crops, Amaranthus and Setaria, and one truly desertic plant, Atriplex. The final species, Prosopis farcta, is found in a large range of habitats, excluding true desert, but is unlikely to be a contaminant of the harvested crop seed.

4.7 The uses of non-cultivated plants

Information on the uses of the plant species and genera found at Abu Salbikh was obtained from the Flora of Iraq, and also from literature dealing particularly with Mesopotamia (Hooper & Field 1937, Hassaway et. al. 1968, and Guest 1933). Each type was scored for its suitability for each method of utilisation and was only positively included or excluded from a given group if, for example, the mature seed was poisonous or actively avoided by humans or animals for certain reasons or it was observed that the mature fruits were eaten by livestock (in some cases the dried fruits were used as a concentrated fodder).

An explanation of the categories into which the Abu Salabikh plants were divided is given below and the types placed in each category are shown on Table 4.5.

4.7.1 Crop weeds

This includes plants found regularly in crop fields, those which are restricted to crop fields in Lower Mesopotamia such as *T. boeticum* and *H. spontaneum* as well as plants such as *Galium* spp., weed *Hordeum* spp., *H. spontaneum* and *Lolium* spp. which are avoided as they are coarse textured, and could damage the livestock's tender mouth parts. Other plants are not cut for fodder as they poisonous or thought to taint the milk but may presumably be eaten by the livestock.

Hillman (1984 p. 4-6) has indicated the points where the by products of crop processing and thus the crop weed seeds would be exposed to fire.

4.7.2 Plants collected as human food plants

There are numerous wild plants described in the Flora of Iraq as famine foods or as foods of the poor. There are many problems related to determining the accuracy and use of such descriptions in the interpretation of archaeological plant remains. These difficulties concern the identification of the plant being used and the value that can be given to occasional accounts of the plant being eaten.

Of chief concern here is whether the plant is actively sought for some property such as its taste or nutritional value etc. and whether it is in fruit or bears the identifiable organs, as observed in the plant remains, at the time of collection. Also pertinent is whether the seed (or other organ) is directly used and if any treatment by fire is involved in the preparation of the seed (or organ) for consumption.

4.7.3 Plants used in manufacture and furnishings

Plants used for bedding, matting, thatching and for the manufacture of equipment e.g. containers etc. The only category of plant remains in the Abu Salabikh plant remains put in this group are the Phalaris/Arundo culm nodes (no seeds found). The use of reeds in Iraqi villages is ubiquitous and the chances of burning, accidental and deliberate (to dispose of waste and old material) are very high.

Other plants, e.g. sedges and rushes whose seeds were found were also used in this way but the seeds were more likely to have arrived by other means.

4.7.4 Miscellaneous uses of plants

Such as the use of wild plants as medicines, dyes, tanning agents etc.

4.7.5 Fodder species; grazing potential

Plants regularly occurring outside the crop fields which are mentioned as being particularly good as fodder when in seed e.g. Trifolium sp, Medicago sp, Trigonella, or are absent from crop fields.

In the case of Medicago polymorpha the 'burrs' ie the mature fruits, "provide a valuable concentrated fodder for animals in winter; they are more readily eaten after softening by rain" (Townsend & Guest 1974 p. 131).

The seeds of crop weeds are eaten by livestock grazing with the mature barley plants (Poyck 1962 p. 52), when the livestock are allowed on to the crop stubble after harvesting or when residues of crop processing are given to supplement the diet. In addition to animal grazing, wild plants from a range of habitats including crop fields were often collected to feed the animals.

Most animal grazing of non-cultivated species is of the young vegetative parts of the plant, and even when these plants are dried and the seeds are mature, the bulk of the dung matrix comprises non-seed material. In southern Iraq the species of plants grazed though the year would have shown a marked seasonality, which might be visible in the dung providing there was no mixing.

The determination of whether a species was included in the animal dung is dependent upon assessment of the relative suitability, perceived or otherwise, of the species as a fodder plant. Several species are deliberately avoided by animals due to their taste, older plants may be too coarse for consumption whereas others are selected for livestock feeding.

4.7.5.1 Winter plants

Some species, e.g. Triticum boeoticum, are not mentioned in relation to grazing. Phalaris, Medicago and Trifolium, together with Suaeda (an early summer plant) are described as fodder plants some of which were cut for livestock feed, while the other small legume species, Astragalus and Trigonella are also known to be grazed. Phalaris and small legumes are the two largest groups of winter growing species in the Abu Salabikh samples and in order to allow for the possibility that these are dung contaminants some of the later analyses were carried out without them.

Of the other winter growing species Malva, Rumex, Polygonum and Vicia/Lathyrus are all grazed but are not so highly recommended as fodder; Lolium spp., Galium spp., and Hordeum spp. species are all relatively unpalatable when older, i.e. when in fruit, thus reducing the likelihood of the seeds of these plants becoming incorporated in animal dung.

4.7.5.2 Early summer plants

Suaeda sp. "are valuable for camel grazing and also to some extent for sheep" (Guest 1933 p. 97) it occurs rarely in cultivated fields. Salsola, Cyperus and Scirpus spp. are all grazed. Salsola sp. is also used as a fuel, the tubers of certain Cyperus species e.g. C. rotundus are used medicinally or occasionally as a food (Guest 1933). Horses and water buffalo eat Scirpus sp. but it is not stated whether this occurs often when the plant is in fruit as by this stage the plants are quite tough and have rough edges that could deter browsing.

4.7.5.3 Summer plants

Setaria sp. and Amaranthus sp. are excellent fodder plants, though Setaria sp. may become quite coarse as it matures. _Atriplex_ sp., a mainly desert dwelling genus, is eaten by "sheep and other animals" Guest (1933).

Prosopis farcta is a common plant on the alluvial plain and it was noted that "where subterranean water is available this species is the dominant plant over very large expanses of bare fallow and abandoned land, as well as on fields actually bearing crops" Guest (1966 p. 92). "It lies dormant and leafless in winter" and "does not shoot again and grow away until the early summer after winter crops have been harvested";

> "it is of the utmost importance to the shepherd since it covers immense tracts of barren land throughout the summer after the annual herbs have died down and when grazing is very scarce. The pods are eaten by sheep [and camels] the seeds pass through them undamaged and germinate readily at the coming of the winter rains" (Guest 1933 p. 78).

The pods are also eaten by humans as a famine food though as Aitchison (1888) points out they "are usually infested with insects" (in Townsend & Guest 1974 p. 41). The plant is also collected for fuel.

Atriplex sp. and _Prosopis_ sp. have been considered here as dung contaminants while _Setaria_ sp. and _Amaranthus_ sp. have stronger association with summer crop fields.

4.7.5.4 Crop weeds and fodder

Plants found in a range of habitats including crop fields, which are eaten by livestock but are thought to be of low feeding value or are avoided. _Phalaris_ sp. becomes coarse when mature and some plants are avoided because of their strong taste e.g. _Melilotus_ sp, known as "Bitter Meliot", which has a high content of coumarin and is sometimes refused by livestock (Townsend & Guest p. 149).

Given the nature of this evidence, in particular specific mention of the mature fruits being eaten, it is not easy to discount the possibility of the seed arriving in animal dung or as a crop weed so the types have been left in this intermediate group.

4.7.5.5 Fodder and fuel plants

This group includes plants which are grazed and are also used as fuel. The fact that the plants are burnt when mature (dry) increases the chance of the seed being charred.

Prosopis sp. (summer growing) *Salsola* sp. and *Suaeda* spp. (spring growing) were included in this category, but there were no representatives in the Abu Salabikh winter plants. By the time *Prosopis* sp. bushes are cut for burning the majority of the seed pods have been removed by the grazing sheep and goats.

4.8 Weed seed categories

The Abu Salabikh weeds seeds were classified on three characteristics considered most relevant to crop processing: seed size, headedness and their aerodynamic properties (Table 4.6), following the procedure described by Jones (1983 p. 134-135). These characteristics affect how the seed behaves during crop processing i.e. sieving, winnowing etc. As the features are not entirely independent the;

> "weed seeds were grouped into categories such as big, heavy and headed (BHH); small free and light (SFL) and so on, so as to take account of all three characteristics simultaneously" (Jones 1984 p. 55).

In most cases it was possible to use field observations to provide details of the stage of maturity reached by each species at the time of winter crop but in some cases this information was not available either because certain seeds could not be identified to species or the species were not encountered during field work in Iraq and there were no references, in the literature, to their behaviour in relation to winter crops. In these cases extrapolations from closely related species have been made.

4.8.1 Seed size

Direct measurements were made of the ancient seeds and classified according to the average size of 10 specimens (where available) compared to the estimated fine sieve size of 1.5 mm. The size of the seed affects its fate in relation to the sieving. In the processing of free-threshing cereals there are two sieving stages, one with a coarse sieve which separates the grain from larger contaminants e.g. straw nodes, and the second, using a fine sieve which retains the grain but not the smaller weed seeds.

One difficulty encountered is in deciding the size of the original fruit when it was harvested, where the species has not been determined, e.g. with Galium sp., Jones (1983, table 4.11) assigns two species of Galium, G. aparine and G. verrucosum to the Big Free Heavy (BFH) category, where the mericarps of G. aparine are 3-5mm long and "always densely setose with hooked setae" (Townsend & Guest 1980 p. 606). The archaeological specimens of Galium sp. from Abu Salabikh have not been identified to species, and the average seed size of 1.5 x 2 x 1.8 mm which puts them in the small size category but with hairs, hooks, etc., could be sufficient for them to be caught up in the fine sieve. In addition the fruit of Galium sp. "consist of two seeded mericarps" (Hickey & King 1980 p. 400), so a slightly immature fruit harvested with the crop would have a minimum dimension of approximately twice that of an individual mericarp. For the moment Galium sp. has been assigned to the small-seed category on the basis of the seed size.

4.8.2 Headedness

The term 'headedness' refers to whether the seeds retained in a head, the fruit etc., or are freely dispersed when they reach maturity. Without first hand experience of a species in southern Iraq in relation to winter crops it was sometimes difficult to determine the 'headedness' of the seed at the time of harvest.

4.8.3 Aero-dynamics

This includes "density, shape and presence or absence of features such as wings or hairs and this is most relevant to the process of winnowing" (Jones 1983 p. 135).

4.8.4 The effect of glume wheat processing on weed seeds

Glume wheat processing involves an additional series of steps, including the pounding of the spikelets, which is required to free the grains from the spikelets; the pounding also breaks up weed heads, thus freeing the seeds (Hillman 1984 p. 5 step 9).

The 'headedness' of the seed is important at the coarse sieving stage, seeds held in heads larger than the cereal grains remaining in the sieve, regardless of the seed size.

In glume wheat processing weed heads of approximately the same size as or smaller than the spikelets which have passed through the coarse sieve (or riddle, step 6) will enter the rest of the processing sequence, where their progress is determined by size and aerodynamic qualities rather than headedness.

The aerodynamics of a seed may also be altered by pounding e.g. by the loss of wings and other protrusions. Hillman observed that the majority of the seeds reaching the second winnowing stage, and which go into the fine sieving stages, "derive from immature weed heads broken up during pounding (step 9). Many of these seeds are therefore immature to varying degrees" (Hillman 1984 p. 5 footnotes).

Thus the weed-seed species reaching the fine sieving stage will be different for free-threshing cereals and glume wheats. In the former weed heads bigger than the grain are sieved off while in the latter only those heads larger than the spikelets are removed. Therefore the size of the weed head becomes as important as the degree of headedness of the species.

At Kolofana (Jones 1983) the samples are from free threshing crops i.e. <u>T. aestivum</u>, <u>T. durum</u>, <u>Hordeum vulgare</u>, <u>Pisum sativum</u> and <u>Lens culinaris</u> and these provide a clear picture of the behaviour of weed types in the processing sequence of free-threshing crops. There is no equivalent body of data available for glume wheat processing, and instead it is necessary to look at archaeological remains, such as the samples from Assiros where glume wheats were grown and for which the types of crop processing have been established, to give the required data.

At Assiros, where many of the cereal samples are dominated by glume wheats, the behaviour of the weed seed categories appears very similar to that of the free-threshing Kolofana samples (Table 4.7), e.g. the fine sieve by-products are dominated by SFH seeds and the product by BFH as expected, there is also little difference in the relative proportion of SHH at the two sites though at Assiros it might be expected that as a result of weed heads being broken up there would be a higher percentage of SHH than at Kolofana. The quite high percentage (ca. 35%) of the SHH seeds in the Kolofana samples reach the fine sieving stage in a free-threshing crop suggesting that there is some freeing of the seeds even in the processing of free-threshing cereals.

Spikelet pounding will also affect the other, headed, seeds that reach this stage (i.e. heads smaller than or the same size as the spikelets) so that SHL seeds will be winnowed off as SFL (Hillman 1984 p. 5 stage 10) while BHH seeds would presumably behave like BFH seeds and pass into the (fine-sieve) product.

When the Abu Salabikh weed seeds are classified into weed seed categories SHH seeds are seen to be the most frequent, making up just over 60% of all the winter weeds (being the most abundant form in 39 of the 54 samples), while the others have individual values of less than 20%, with BFH being the next most frequent.

4.9 Miscellaneous non-seed material

4.9.1 Reed culm-node fragments

There are fragments of reed culm node in approximately one third of the Abu Salabikh's samples, though not in very large quantities and never exceeding 5% of the total material. It was not possible to distinguish between *Phragmites* sp. and *Arundo* sp. so the discussion is based on both of the genera.

They are abundant on the lowland alluvial plain of Iraq today and in marshes, along irrigation and drainage channels and in any wet places.

Phragmites sp. are eaten by livestock but only when young as they are "too coarse to be of much value as a fodder plant except when young"; to encourage regeneration "the marsh Arabs are accustomed to burn down large areas of reed every year so as to encourage the fresh young growth", "The young shoots which spring up after the burning are grazed by water buffalo and cattle and even in herd seasons by horses" Guest (1933 p. 73).

The young reeds are cut, with a saw-edged sickle, and used as fodder for buffalo (Thesiger 1964 p. 45). The use of reeds as fodder is not as important as the many other uses to which they are put, including the making of matting, screens, baskets etc. The uses of reeds (and rushes) in ancient and modern Iraq are discussed fully by Postgate (1980 p. 99-112).

It is not possible from the literature to establish precisely how long the plants can be grazed, but the culm nodes found are frequently of large diameter suggesting the plants were mature and therefore quite coarse textured. The abundance of reed material brought on to the site for a multiplicity of purposes, and the regular appearance of burnt reed matting during the course of excavation, point towards this rather than dung as a major contributor of reed material to the site.

4.9.2 Cyperus rotundus tubers

Whole tubers or fragments are found in 23 samples (43%) and in two of them they make up 20% of the total remains (8336 and 8337).

Cyperus rotundus is common in moister areas of Lowland Mesopotamia, e.g. by irrigation channels and marshy areas, as well as being a weed of summer crops.

The young plants are eaten by livestock though they are considered to be of "low feeding value" (Townsend & Guest 1985 p. 340) and they may become too coarse to be eaten when older. There is no mention of whether the tuber is ever eaten by animals but they are not poisonous. Guest (1933 p. 28) notes that the tubers are eaten in India "in time of famine".

The tubers could be eaten by livestock when they are exposed, e.g. when the soil around them is washed away, or when they are ploughed up in crop fields (Townsend & Guest 1985 p. 340) but there are no records of this taking place.

4.9.3 Culm nodes and non cereal grasses

It is not possible to identify these nodes beyond the level of Gramineae and no references were found to this type of material in other sites on the alluvial plain. While they may have been brought to the site deliberately there is no real reason why they should not for the moment be considered as being part of the dung material given that grasses often form the bulk of the animal fodder.

4.9.4 Animal dung material

This is mainly in the form of sheep or goat pellets and occasionally fragments of coprolites from larger animals such as cow or donkey. The sheep/goat pellets are usually burnt to a grey ash and in the fragments there is little recognizable except finely chopped grass stems. Dung material was present in 18 samples (33%). In one sample (7920), dung makes up 25% of the sample.

The recognition of large fragments of sheep/goat pellets was relatively straightforward, and smaller fragments could also be identified if some surface was preserved. It did not prove possible to identify the material from larger animals to any one group.

The modern dung cakes examined contained little cereal material, mainly culm nodes. Dung cakes made of material collected from animals fed on barley grain were not available for charring experiments. No investigations have been possible of the effect of the digestive systems of various animals on seeds. The topic of dung material and identification is discussed in more detail below (Section 5.8.3).

4.10 Cultivated plants; (non-cereal)

This was the smallest group at Abu Salabikh comprising under 2.5% of total remains; they constitute more than 10% of the total in only one sample.

Lentil and flax/linseed are winter growing field crops with similar growing periods to the winter cereals. Lentils are harvested from April to early June, flax/linseed in May, they occur in only four samples.

Sesame is a summer growing field crop sown in February or March on fallow land, in April-June if it is following a winter crop; it is harvested in September or October. Sesame is present in one third of samples albeit at fairly low levels. The presence of summer growing field crops and their weeds, such as sesame, in the Abu Salabikh samples has to be remembered when interpreting the plant remains. The presence of fig does not contribute any information concerning crop production.

Table 4.1 Breakdown of periods sampled at Abu Salabikh

Periods sampled	number of samples included in analysis
Uruk	6
Uruk/E.D.I	1
E.D. I	5
E.D. II	3
E.D. II/III	1
E.D. III	38

Table 4.2 Breakdown of context types sampled at Abu Salabikh

context type	no. of samples included		
Ash pit	9	Jar	2
Ash tip	6	Pit	5
Brick	1	Room fill	4
Drain	1	Street fill	1
Fill	3	Tip line	1
F.I.	12	Other	1
Floor	8		

Table 4.3 Flowering and fruiting dates of the Abu Salabikh winter and (?) summer plant types

winter	early summer	summer	
March - May (-June)	May - July	July - November	(Date of flowering and fruiting)
Vicia/Lathyrus	Salsola sp.	Amaranthus sp.	
H. spontaneum	Cyperus sp.	Setaria sp.	
Galium sp.	Scirpus sp.	Prosopis farcta	
Rumex sp.	Suaeda	Atriplex	
T. boeoticum			
Lolium sp.			
Hordeum sp. 'weed'			
Arenaria sp			
Malva sp.			
Phalaris sp.			
small legumes			

Table 4.4 Flowering and fruiting dates of the Early summer species

species/ type	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cyperus sp.			-	-	-	-	------	----
Salsola sp.			------	------	------	------	------	----
Scirpus sp.		-	------	------	------	----	-	-
Suaeda sp.			------	------	----			

\- single dash means rare occurrences

\--- continuous line typical flowering / fruit

Table 4.5 Potential plant use and mode of arrival

Most likely mode of arrival	Plant type
Crop weed	
winter	Galium sp., weed Hordeum, H.spontaneum, Lolium sp., T.boeoticum.
early summer	Amaranthus sp., Setaria sp.,
other	small Gramineae (culm nodes), reed culm nodes
Weeds and fodder	
winter	Malva sp., Melilotus sp., Phalaris sp., Polygonum sp., Rumex sp., Vicia/Lathyrus sp.
early summer	Cyperus sp. (seed)
summer	Atriplex sp., Prosopis sp.
Fodder (in seed)	
winter	Medicago sp., Trifolium sp., Trigonella sp.,
early summer	Scirpus sp.
Fodder and fuel	
winter	(Astragalus sp.),
early summer	Salsola sp.,
summer	Prosopis sp.
Furnishings	
	Phragmites / Arundo sp.
Food	
	Cyperus rotundus (tuber)

Table 4.6 Weed seed categories

weed seed categories				
BHH	BFH	SFH	SHL	SHH
big	big	small	small	small
headed	free	free	headed	headed
heavy	heavy	heavy	light	heavy
winter plants				
Malva sp	Vicia/ Lathyrus H. spontaneum T. boeoticum Hordeum (lrg)	Rumex sp. Chenopodium sp Galium sp. Polygonum sp.	Lolium sp. Hordeum (sml)	Arenaria sp. Phalaris sp. small legume
early summer species				
		Salsola sp.		Cyperus sp. Scirpus sp. Suaeda sp.
summer plants				
Prosopis farcta		Amarantus sp. Setaria sp. Atriplex sp.		

Table 4.7 Percentage breakdown of weed seed categories occurring in the product and by-product samples at Kolofana

Crop processing stages	BFH	SFH	SHL	SHH	SFL	BHH (%'s)
winnowing by-product	2.6	25.8	57.4	8.1	3.1	2.9
coarse sieving by-product	0.7	7.2	61.7	25.9	1.0	3.6
fine sieving by-product	9.0	64.8	10.7	15.4	0.1	0.03
fine sieving product	42.9	39.5	11.6	4.7	0.1	1.2

Table 4.8 Percentage breakdown of weed seed categories occurring in the product and by-product samples at Assiros

Crop processing stages	BFH	SFH	SHL	SHH	SFL	BHH (%'s)
fine sieving by-product	15.9	69.6	1.2	13.2	0	0
fine sieving product	64.8	21.4	1.3	2.7	9.6	0.2

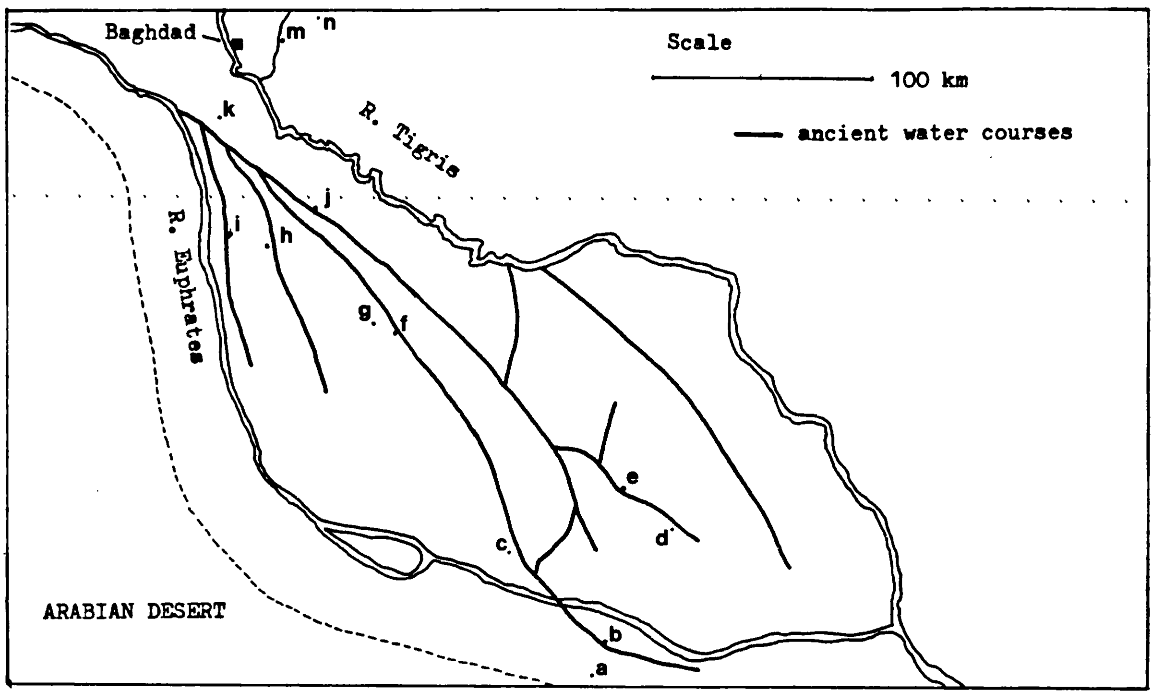


Figure 4.1 Sumer showing principal water courses and sites in the 3rd millenium (after Postgate 1977 p. 68)

Key

a. Eridu
b. Ur
c. Uruk
d. Lagash
e. Girsu
f. Nippur
g. Abu Salabikh
h. Kish
i. Babylon
j. Jemdet Nasr
k. Tel ed-Der
m. Khafajah
n. Eshnunna

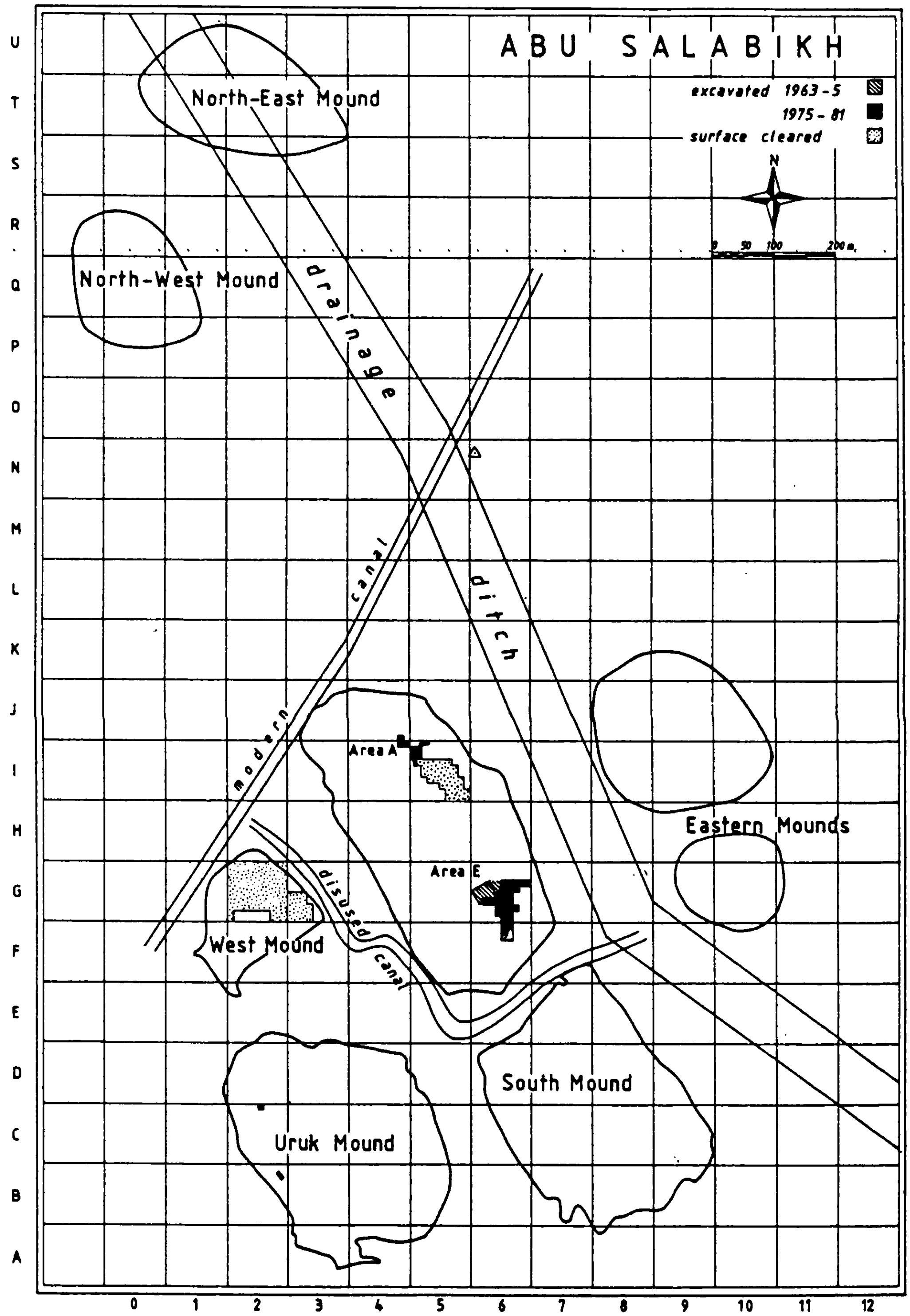


Figure 4.2 The mounds making up the site of Abu Salabikh (after Postgate 1982 p.58)

Plate 4.1 <u>Modern Sesamum indicum seeds under the Scanning Electron Microscope (S.E.M.)</u>

Figure 1 Whole seed (x 69), part of seed coat (testa) removed to show cotyledon surface

Figure 2 Close up of seed coat (x 790)

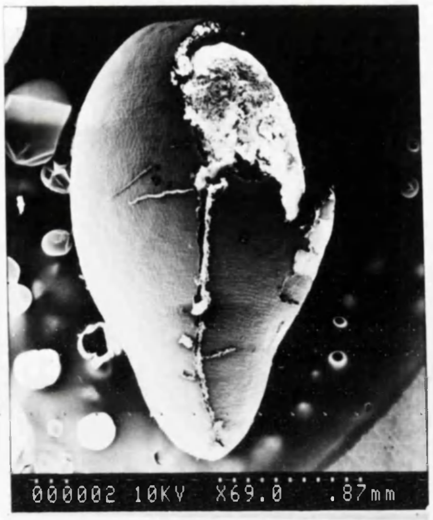
Figure 3 Close up of cotyledon surface (x 800)

Figure 4 Close up of cotyledon surface (x 690)
Scale bar = 0.87mm

Figure 5 View of narrow end of seed, testa removed (x 80)

Figure 6 Transverse section of seed (x 200) with close up of cotyledon and testa (x 2000)

1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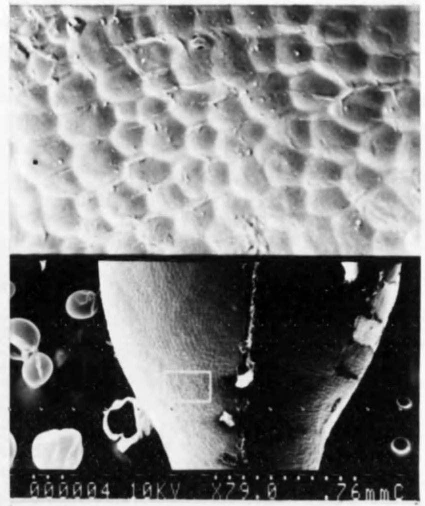
2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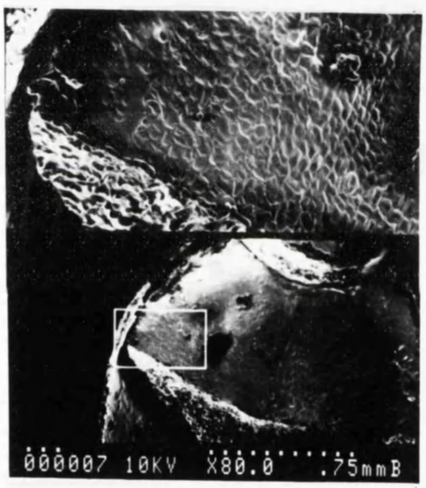
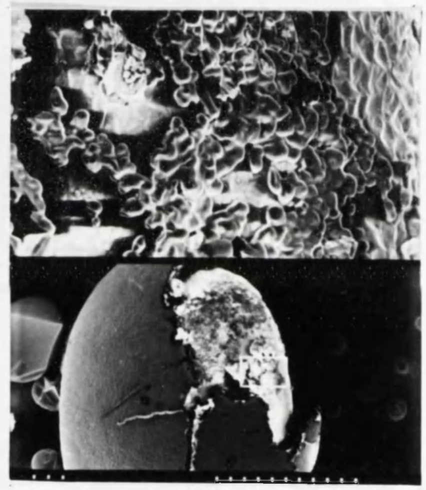
3


000007 10KV X80.0 .75mmB

4



5


000005 10KV X80.0 .75mm

6

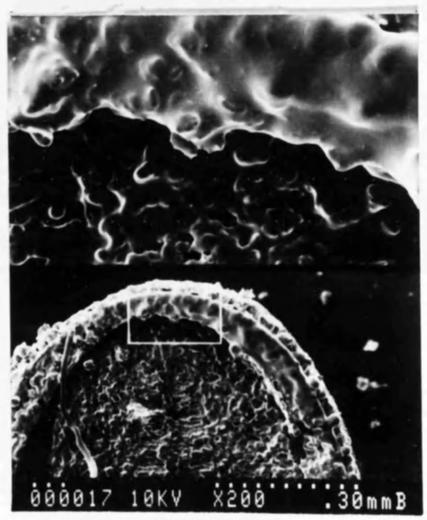

000017 10KV X200 .30mmB

Plate 4.2 <u>Ancient Sesamum indicum seeds under the Scanning Electron Microscope (S.E.M.)</u>

Figure 1 Whole seed (x 80), testa and part of one cotyledon absent

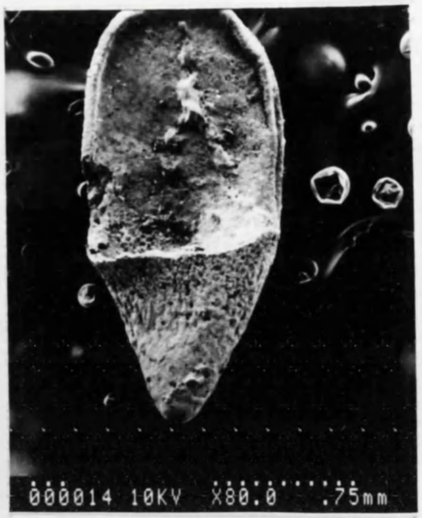
Figure 2 Close up of cotyledon surface (x 1035)
Scale bar = 0.58mm

Figure 3 View of narrow end of seed, testa absent

Figure 4 View of narrow end of seed, with close up of cotyledon surface (x 1090)

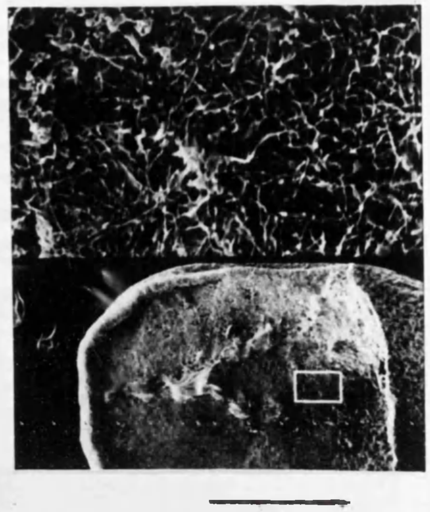
Figure 5 Cotyledon surface, badly eroded (x 1980)

Figure 6 Whole surface, testa and part of one cotyledon absent


000014 10KV X80.0 .75mm

1

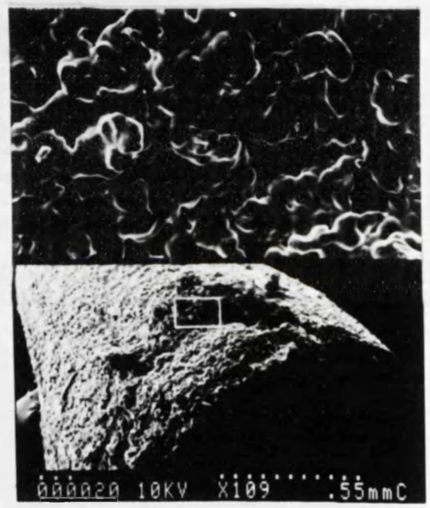
2




000019 10KV X100 .60mm

3

4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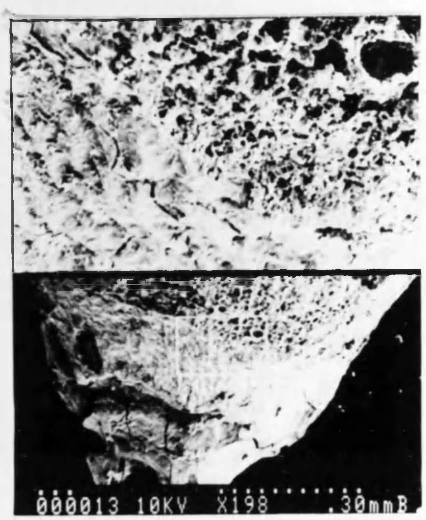

000013 10KV X198 .30mmB

5

6


000012 10KV X80.0 .75mm

Chapter 5 Analysis of the Abu Salabikh plant remains

5.1 Preliminary comments on the cereal remains

Cereal remains were the single most abundant group of charred material at Abu Salabikh (see Table 5.6), constituting just over 50% of the total remains recovered, compared with winter weeds (c.25%) and early summer weeds (14.4%). In 32 of the 54 samples used in the study cereal remains make up more than half of the total remains, and in 40 samples they are the single largest category.

5.1.1 Barley (Hordeum sativum)

The Barley material, grain and rachis, outnumbers wheat, grain glume and spikelet by about 1.5:1 over all the samples and comprises grain, straight and twisted, and rachis material, of 2- and 6-row forms. The grain was the most frequent category of material at Abu Salabikh, present in all 54 samples and the dominant cereal in 29 of them, while rachis internodes were found in 33 samples and were the most abundant in six. The relative proportions of the grain and chaff within the samples give some idea of what treatment the crop received after harvesting. The expected ratios of grain to chaff depend, to some extent, on whether the crop grown at Abu Salabikh was 2-row, 6-row or a mixture of the two crops (see Section 4.3.3.1).

For the samples where both straight and twisted grain were recognised the ratio of twisted to straight grain averages 1.59 (Table 5.1) approximately the same as that calculated for all identifiable grain (1.61). A ratio of 1.6 twisted to straight grain would result from a 4:1 mix of the 6-row and 2-row crops (Table 5.1), although the difficulty in identifying the grain accurately to straight or twisted categories could affect the figures.

Where both types of rachis were identified in a sample the ratio of 6-row to 2-row was 7.5:1 and for all samples 17:1 On the basis of the grain and rachis proportion it seems that the majority of the barley crop was 6-row with a small amount of the 2-row form present (up to 10-20%), and in a few cases the proportions are closer to 1:1.

So that the barley material in the samples could be identified as the products or by-products (or unprocessed crop) on the basis of the grain to chaff ratio, a range of 'expected' values was calculated. In a harvested but unprocessed 2-row crop, the grain to rachis ratio would be approximately 1:1 (ignoring sterile basal and upper spikelets), while in a 6-row crop the ratio would be about 3:1.

To allow for the possibility that the crop was a mixture of 2- and 6-row forms, which would affect the ratios, and to allow a margin of error for indeterminant grains etc., the upper range of the 'expected' values was doubled, i.e. 6:1, and the lower limits halved, i.e. 0.5:1.

A sample would only be considered to have had rachis internodes removed if the ratio was greater than 6:1, and would then be tentatively identified as a crop processing product. If, however, the ratio was less than 0.5:1 then the sample would be regarded as a by-product, i.e. some of the grain had been removed. The ratios of barley grain to chaff for the Abu Salabikh samples were then compared with those of the three major processing stages in the modern samples (cereal samples only) collected at Kolofana (Table 5.2).

The figures from Kolofana show that it is not just the various products of processing that can have more grain than chaff, as the fine sieving by-product has appreciably more grain than rachis internodes. Jones (1983) has pointed out that the cereal remains are not as good as the weed seed categories in identifying the products and by-products of crop processing and the ratios given here agree with this view.

The archaeological samples at Assiros (Table 5.3) showed a high grain to internode ratio in the fine sieving product of 93.3, and there were no rachis internodes in the fine sieved by-product. The proportions in the original crop were also calculated from the by-product and product values as 1.89.

The Abu Salabikh samples divided into three groups on the basis of the barley grain to chaff ratios (Table 5.5);

a. Samples with a greater than predicted ratio of grain to chaff.

There were eight samples with some rachis material. The highest ratio was 30.2, and the average value 14.6. In 21 of the samples there were no barley rachis internodes. Evidence from more than half the samples, then, indicates the removal of rachis internodes presumably as a result of crop processing rather than preferential survival of grain.

Judged purely on the basis of the barley remains these samples, with rachis internodes, most resemble the by-product of fine sieving. Where barley rachis internodes are absent the samples could be characterised as fine sieving products.

b. Samples with a lower than predicted grain to chaff ratio.

Only five of the samples fall into this category. A ratio of lower than 0.5:1 ratio is only seen in the Kolofana samples in the by-products of winnowing or coarse sieving.

c. In the 12 remaining samples the grain : chaff ratio is within that predicted for an unprocessed crop, i.e. the harvested crop prior to threshing.

5.1.2 Wheat Material

While grain is the most common barley category, in the glume wheat material chaff, in particular glume bases, constitutes the dominant category (Table 5.5).

Wheat chaff was present in all but one of the samples compared with grain in 35 of the 54 samples and generally at a low frequency. The relative proportion of glume bases to grain for all samples is ca. 10:1. Glume bases were the second most abundant type of plant material in all the Abu Salabikh samples (Table 5.5).

Calculations based on modern T. monococcum (einkorn) and T. dicoccum (emmer) have produced an expected range of between 0.75 and 1.00 for grain:glume base in an unprocessed crop. As was done in the case of barley, the upper limit was doubled and the lower halved to allow for any differential preservation features, the range used for discussion of the Abu Salabikh glume wheat material being 0.38-2.0.

No glume wheats were grown at Kolofana so there is no modern material available for direct comparison of crop processing residues, as there is for barley. In the samples assigned to fine sieve products and by products at Assiros values of 1.6 and 7.3 respectively were estimated for glume wheat grain:chaff (glume bases and spikelet forks).

From Hillman (1984 p. 5-6) it appears that glume bases and rachis internodes, together with the tail grain and small weeds (the 'Cleanings' store equivalent to Jones' fine sieve by-product), are separated from the prime grain by the wheat sieve. The spikelet forks are retained in the sieve and are incorporated in the 'Bulk Grain' store before being removed from the grain by hand sorting and thrown into the fire or added to the 'Cleanings' store.

The ratio of wheat grain to glume bases and spikelet forks (converted into glume bases for the analysis) for all Abu Salabikh samples is 0.27, which is below the lower limit set for an unprocessed crop, i.e. there were ca. four glume bases for every grain.

At Assiros the archaeological samples identified as the product of fine sieving had comparatively high numbers of spikelet forks (and glume bases) which is probably attributable to the different levels of cleaning performed, because as was pointed out;

> "some of the products do, in fact, seem to have been quite thoroughly cleaned before storage. It is quite possible, then, that we are dealing with a range of products some of which have been thoroughly sieved and others of which have been poorly sieved or not fine sieved at all before storage" (Jones 1983 p. 156).

The Abu Salabikh samples were placed into groups on the basis of the glume wheat material;

a. Grain to chaff ratio below that predicted for a harvested crop.

This occurred in 24 of the 54 samples, in 10 of which the amount of chaff was more than 10 times that predicted; and in 19 there was no wheat grain. The most likely origin of these samples, given the low numbers of wheat grains and the high number of glume bases, the fine sieving by-product.

In the Assiros samples classified as fine sieve by-products, in which it might be anticipated that there would be a high percentage of chaff fragments, there were actually far more grains than either glume bases or spikelet forks. The great excess of glume bases compared with grain seen in the Abu Salabikh samples was a phenomenon not found at Assiros even in the fine sieve by-products.

In the 19 samples lacking glume-wheat grain the amount of chaff material was high, averaging 45% of all the cereal components, and in 10 samples glume wheats were the most abundant cereal category. In three of the samples chaff amounted to less than 10% of all cereal components. As was the case with the barley material, it is reasonably safe to assume that the absence of a cereal category, i.e. glume wheat grain, is a result of crop processing rather than a quirk of preservation and therefore it is possible to group these samples with those that had a lower than expected grain : chaff ratio, but where some grains were present.

b. Samples with more wheat grain than chaff.
Only three samples fell into this category (2464, 7090 and 7918) and in one case (7920) there was no chaff present at all. The amount of grain in these samples is high, averaging 27.7%, and in sample number 2464 wheat grain is the dominant cereal category. So we may conclude that some processing had been carried out to remove some of the chaff, e.g. a partial (rough) fine sieving after the spikelets had been broken up by pounding.

The glume wheat remains in the majority of samples appear to represent some form of fine sieving by-product, and in a few other cases we may have the product of the same process.

5.1.3 The cereal remains as a whole

When considering the Abu Salabikh samples on the composition of just the wheat or barley remains it is possible to assign them, albeit tentatively, into crop processing groups. When, however, all the cereal material is considered it is apparent that, in many cases, there is an inverse relationship between the two crop types, with regard to the grain : chaff ratio. For barley, grain is more common than rachis and it can be concluded that there had been treatment of the harvested barley crop which had removed rachises, leaving a product, e.g. of winnowing.

Conversely for the wheat remains, grain was infrequent and most of the samples have a high percentage of chaff material, predominantly glume bases. This pattern more resembles a by-product than a product, e.g. a fine sieving by product.

There are possible explanations for these apparently contradictory relationships;

a. The growing of a mixed wheat and barley crop.
This is a fairly common practice around the Mediterranean, e.g. on Amorgos (Jones 1983 p. 67) though it was not mentioned for southern Iraq in this century, perhaps due to the different salt and drought tolerance levels of the two crops, as well as the differences in fruiting time. In the instances described, the wheats involved are always free-threshing not glumed types (barley is free-threshing also). If wheat and barley were grown together at Abu Salabikh it seems improbable that the sorts of ratios seen would have resulted from processing as a single crop, unless the glume-wheat spikelets could somehow be separated from the free-threshing grain e.g. by sieving, the processing residues would then have been mixed together at a later stage.

b. Growing wheat and barley as separate crops.
If two crops were grown and processed separately then the residues of different processing stages (roughly assigned to winnowing and fine sieving) could be brought together,

i. by the mixing of accidentally charred material e.g. during disposal,
ii. when feeding animals,
iii. in the manufacture of fuel cakes from animal dung (bearing barley grain) and by-products of crop processing containing chaff e.g. the cleanings store from fine sieving (Hillman 1984 p. 5),
iv. contamination from previously processed crops ie sieves or threshing floor, etc.

Given the large quantities of barley grain involved, the relative consistency of dominance by barley grain and wheat glumes, and the known use of wheat chaff as animal feed (Hillman 1984 p. 5), then the use of these crop residues to feed livestock (a frequently cited practice in cuneiform tablets of the time) seems a strong possibility.

Hillman refers to hummelling of the barley grain to remove the awn base left by threshing which could injure livestock if eaten, a practice that is particularly important in 6-rowed varieties as they have very rigid awns. The process is carried out after threshing (Hillman 1984 p. 5 step 3) and is followed by "winnowing and/or sifting" and "is generally done with a mortar and pestle (or mallet)" (Hillman 1984 p. 20). The product of hummelling and winnowing would contain barley grain and chaff in proportions similar to those observed in the Abu Salabikh charred remains.

5.2 Introduction to the computer aided analysis of the Abu Salabikh plant remains; internal and external analysis

To try to make sense of the interactions of plant types in the Abu Salabikh samples a number of statistical tests were carried out, to examine the material internally and an external analysis to compare the samples with modern samples of known origin, (cf. Jones 1987a p. 311).

5.2.1 Internal analysis

These were carried out using multivariate statistical techniques to group similar samples together and to find what features (variables) of the samples were most important in forming these groups. The techniques enable large numbers of measurements of a set of objects (samples) to be represented in an interpretable, two-dimensional fashion. The techniques used were principal components analysis and cluster analysis.

5.2.1.1 Principal Components Analysis (P.C.A.)

This takes a set of multivariate data, which has not been ordered in any way, finds axes (principal components) which account for as much of the data variability as possible, and gives the relative contribution made to the axes by each variable (in this case the plant type). In the discussion of P.C.A. the percentage variance of the principal components (P.C.'s) shows how much of the total sample variance is accounted for by each P.C., a high proportion of the variation being accounted for by the first two or three P.C.'s thus indicating a 'strong' data structure which makes interpretation of the components easier.

The other set of values often mentioned in the text are the standardised score of the correlation of variables and the P.C.'s which are a measure of the relative contribution the variables make to each P.C. Strongly positive (+ve) or negative (-ve) figures show which variables make the greatest contribution and are thus the strongest features in determining the relationship of the samples to each other, as illustrated in the plots of the transformed variables.

Running the Abu Salabikh data without scaling down the richer samples produced a very high first P.C. of ca. 90%, and the variables contributing to this were the most abundant plant types. The plot of the first two P.C.'s showed the samples clustered around the first P.C. or axes, the rich samples at one end, the poor at the other. This reveals little about the actual composition of the samples and the data were then transformed by various methods to remove any bias due solely to the size of the sample.

5.2.1.2 Cluster Analysis (using the KMNS method)

This was used to group together samples with a similar composition. The technique works by finding the most different samples and then matching the 'closest' samples to them. The technique tries every sample in every cluster until the greatest 'measure of fit' i.e. the internal homogeneity of the clusters, is attained (up to the specified number). The best clustering arrangement is indicated by the percentage total sum of squares for each group, which can be plotted out to find the cluster level where the improvement of fit starts to drop, a so-called 'elbow' on the graph. In kmns analysis each sample is assessed individually at each clustering solution, unlike other techniques where samples put together at the first level remain together throughout the analysis.

5.2.2 External analysis

The Abu Salabikh samples were compared with the modern ethnographic ones from Kolofana on the Greek island of Amorgos (Jones 1983). The 4 crop processing stages from which material was collected were run against the Abu Salabikh samples, the fifth group, using a form of discriminant analysis to see how the Abu Salabikh samples were classified relative to the Kolofana ones.

5.2.2.1 Discriminant Analysis (using Canonical Variates Analysis)

The technique tries to separate the assigned groups as much as possible along axes, the variate components (V.C.'s), and the 'success' of each component is recorded as the percentage of the variance accounted for, the higher the better. The contribution of each variable to these components is given in the way described for P.C.A.

Having done this the analysis then allocates the samples into the best groups, the ones that give the smallest overall variance, and the fate of any re-allocated samples is displayed, i.e. which group the samples (units) move from and which they move into.

The analysis was originally carried out on the Kolofana data alone to ensure that the technique was functioning in a similar way to the form of Discriminant Analysis (D.A.) used by Jones (1983 Ch. 4). Despite the technical differences between the two, the results gave a close match, so the C.V.A. method could be employed with some confidence that any problems were not a result of the techniques being used.

5.3 <u>Cereal material</u>

5.3.1 <u>Percentage square root</u> (Statistical analysis of the nine cereal types).

Jones (1983, p. 121-123) found the most suitable form of standardising sample size was to take percentage values of each plant type; and that the most suitable way of transforming data, to make the variables more normally distributed, was to use the square roots of the percentage figures.

The samples were analysed internally using PCA and KMNS on the nine cereal types, including unidentified cereal grain, and cereal culm nodes (Table 5.7 Fig. 5.1). The first P.C., which accounts for 38% of the total sample variance has high loading variables which make a large contribution to the component, and which load in both positive and negative directions: <u>Hordeum sativum</u> grains (HSAW) +0.73 and <u>Triticum</u> (glume type) glume bases (TRTG) -0.97. This means that the first component, or axis, separates samples with relatively high frequency of HSAG and a low TRTG frequency from those with a relatively high frequency of TRTG and few HSAW.

The remaining variables are much more neutral, i.e. make a smaller contribution, with regard to the first P.C. *H.sativum* rachis internodes (HSAR) +0.45 and cereal indeterminant grains (CERW) +0.42 and *Triticum* (glume type) grain (+0.26) in the same direction loading towards HSAW while the remaining wheat categories load negatively (TRTS =spikelet forks, TRTR =rachis internodes).

The second P.C. (27%) has HSAR (+0.88) and HSAW (-0.48) at opposite ends, TRTW (-0.32) loads with HSAW and CERW (-0.20); TRTS (+0.45) and Cereal indet. culm node (CERK), +0.36, load in the same direction as HSAR. The most strongly loading variable on the third P.C., which accounts for 12% of the total variance, is TRTW which loads negatively (-0.80), the most positive loading variable is CERW (+0.44).

The cluster analysis (KMNS) did not find a 'best fit', i.e. a number of clusters after which the there is little reduction in the amount of variability that exists within the clusters. The best established groups appear to occur at the 3-cluster level, i.e. the groups formed at this level hold together well at further cluster levels, the new groups that form being sub-divisions of only one of the existing groups and involving little movement of samples from the other two groups or between groups.

These groups (Fig. 5.1) can be tentatively classified as follows;

a. Wheat by-product.

Samples with a high percentage of TRTG and little other *Triticum* sp. material (TRIT) or HSAR material.

b. Unprocessed barley.

HSAR and HSAW levels more or less equal; there may be quite high levels of HSAW, even higher than HSAR, but the ratio is still lower than usual.

c. Barley product.

Samples rich in HSAW, little HSAR or TRTG. At the 4 cluster level the barley product group splits into two in one of the new groups there are samples with a fairly high frequency of wheat material and a low or negative H. sativum (HSAT):TRIT ratio which are likely to be of a mixed origin. In the other are those with a high HSAT:TRIT and HSAW:HSAR ratio which would still be classified as 'true' barley samples.

The groups remain relatively unchanged until the 7-cluster level when the barley product group splits into samples with some HSAR and those with none (3323, 7918, 7920, 8318, 8512). The absence of the rachis material appears to be the result of crop processing rather than a feature of differential preservation etc. as there is TRTG material in all but one of the samples.

The plot of this run (Fig. 5.1) shows a high degree of sample separation along the first two components.

On the first P.C. highly negatively loading samples rich in TRTG and little HSAW are at one end; at the other are those with a high percentage of HSAW but comparatively little TRTG. The main separation on the second P.C. is of samples with a comparatively high percentage of HSAR (low ratio of HSAW:HSAR) though the amount of HSAW may be up to twice the amount of HSAR from samples with a very high percentage of HSAW and no, or little, HSAR.

5.3.2 Unidentified cereal items removed

5.3.2.1 Wheat and barley remains examined jointly (percentage square root transformation)

The analysis was repeated without the indeterminant cereal grains and culm nodes as they could not be assigned to a wheat or barley species (or other cereal type) and their inclusion might affect the interpretation of the sample groups. The few upper fragments of glume were excluded as they might cause some overestimation of the amount of wheat chaff (Table 5.8 Fig. 5.2).

The proportion of sample variance accounted for by the first two P.C.'s increased by 5% in each case which is not surprising as there are fewer variables over which the variance is spread. The component loadings, the plot and groups generated are virtually identical to those of the nine cereal groups, from which we can conclude that the CERW, CERK and TRTU had little effect on the analysis. In the KMNS analysis there are shallow 'elbows' on the plot at 2- and 3- cluster stage which are represent the most secure groups.

Only two samples are put in different groups, apparently on the basis of the removal of the CERW category, and the samples fit these new groups more closely than those they were previously in, e.g. 6801 has a high HSAW:HSAR ratio but was in the barley unprocessed group due to its high CERW value, whereas 5801 was not included in the unprocessed barley group because, unlike the others, it had no CERW grain even though its HSAW:HSAR ratio is low (2.96).

The removal of the variables, CERW, CERK and TRTU does not alter the results drastically but appears to clarify the grouping to some degree.

5.3.2.2 Wheat and barley remains examined separately

As it was suspected from the composition of the cereal remains that the samples contained a mixture of wheat and barley product and by-product material it was decided to look at the wheat and barley types separately to see if any of the crop processing stages represented could be identified. To avoid producing a straight line plot between just HSAR and HSAW, the CERK type was added to both sets of analyses. It was also hoped that this would reveal something of the origin of the culm nodes.

a. Wheat categories and cereal culm nodes (Table 5.9 Fig. 5.3).

The first P.C. has almost 50% of the variance and separates samples on the basis of their relative amounts of TRTG (-0.87) and TRTW (+0.97), while the second (28%) has TRTS (-0.98) and TRTG (+0.33) at opposite ends of the axes. When plotted the samples are separated into those where TRTG is the most frequent type and there is little or no TRTW, and those with more or less equal amounts of TRTW and TRTG.

There is no best cluster solution generated by KMNS but two groups can be seen on the plot in addition to the TRTG-rich group, one dividing it into those samples with little TRTS and the second where the proportion is equal or greater than TRTG. Both these groups, which include the majority of the Abu Salabikh samples (72%), have high levels of wheat chaff in comparison with grain and are most likely to represent a by-product of wheat processing. In some cases the amount of wheat in the whole sample is small and in these the absence of wheat grains may be a feature of preservation rather than one resulting from processing.

Four samples split off from the TRTW 'rich' group, and these have TRTW as the dominant type. They are the only potential wheat-product samples. The remaining 11 samples have very little TRTW and would be classified as wheat by-product solely on the basis of the wheat remains.

The relationship between spikelet forks and glume bases is one of degree of fragmentation. The break up of a spikelet fork into two glume bases may occur before or after deposition, and while a spikelet fork may become two glume bases, the latter can never become the former (except on an archaeobotanist's score sheet). The behaviour of the two types is expected to be broadly the same though there may be a tendency for TRTS to end with the prime grain and TRTG in the fine sieve residue due to size differences, and whether they are caught in the sieve or not. But there is not a strong relationship between TRTW- and TRTS-rich samples at Abu Salabikh and therefore no indication that this is the case here. Whether greater fragmentation in some samples is due to context type or post-depositional compaction is not yet known. Flotation could account for at least some of the break up of the spikelet forks.

The removal of CERK had very little effect, the P.C.s increased slightly, the groups created by KMNS were virtually identical, and there is no pronounced best clustering solution.

b. Barley categories and cereal culm nodes (Table 5.10 Fig. 5.4).

The 2 cluster solution gives the 'best fit', backed up by the very high values of the first P.C. which accounts for 88% of all the sample variance and separates samples with high numbers of HSAR from those consisting of mainly HSAW. Samples with no CERK have only two variables to be plotted, producing a straight-line plot, and those with CERK are scattered around this line. The HSAW rich group contains those samples with no HSAR as well as ones with low numbers and these all fall into the potential barley product category (group 1). The samples identified as having relatively high numbers of HSAR are divided into those with HSAR > HSAW (c.1.5-3.0:1) where the ratio is higher but not so great as to rule out the possibility of differential survival rather than the remains being by-products of barley processing (group 2), there are eight samples in this group and seven of them have more HSAR than HSAW at ratios within the range predicted for an unprocessed crop (group 3).

Comparison of these groups with the nine cereal categories analysed previously gives the following results for the groups recognised here;

Group 1: barley product, just under 50% were previously in the wheat by-product group i.e. have more wheat than barley, while the remainder were originally classified as barley product samples.

Group 2: barley by-product (tentative identification), one sample was classed as a wheat by-product, the rest as unprocessed barley.

Group 3 unprocessed barley, two samples were originally classed as wheat product, seven of the 20 as unprocessed barley and the remaining 11 as barley product.

5.3.3 Conclusions concerning the cereal remains

By separating the wheat and barley it has been possible to investigate the stages of crop processing that the Abu Salabikh samples represent. In most of the samples the wheat remains are dominated by chaff components (wheat grain is the dominant type in only four samples), mainly glume bases, which implies that they are by-products of crop processing. There are three stages recognizable in the barley remains: barley product, by-product and a group representing apparently unprocessed material. This latter group also tends to have higher levels of CERK, though the relationship is not absolute.

When all the cereal remains are analysed together the barley product and unprocessed groups are still recognizable, together with a group dominated by wheat by-product, while the barley by-product samples are included with the barley unprocessed samples. The four samples in which wheat grains outnumber the chaff material are all included in the barley product group, though in the case of sample 2464 the amount of wheat is over 70% of the total amount of cereal remains and is the closest to an uncontaminated cleaned wheat product seen at Abu Salabikh.

5.4 Weeds

5.4.1 Winter weeds (all species)

5.4.1.1 Abu Salabikh samples

The weed species were amalgamated into categories as described above (see Section 4.8) and the percentage square root values were used in PCA and KMNS analysis (Table 5.11 Fig. 5.5).

The first P.C. (39%) separates samples with a high percentage of SHH (-0.92) from those rich in BFH (+0.61), BHH loads weakly in the same direction as the SHH while the other two categories are moderately positive. On the second P.C. (19%) SFH loads strongly positively (+0.80) and BHH is the most -ve (-0.53). There is no strongly 'preferred' number of clusters. At the 2 cluster level there is a large group (39 samples) which have a relatively high SHH level and a group of 13 with low SHH values (two of the samples have no weed seeds and are excluded from further analysis).

At the 3 cluster level the main group of SHH rich samples splits into those with more than 80% SHH category weeds. The three main groups formed at the 3 cluster stage are:

i. samples with high SHH levels (>80%), little other material,
ii. samples with a smaller, not always dominant, SHH content, SFH <70%, SHL <25%,
iii. samples with a comparatively small SHH content (<35%), BFH medium (<50%), and a small to medium SHL and SFH (<67%).

The whole analysis is dominated by SHH seeds, which could imply that:

i. the proportion of SHH seed bearing plants in the Abu Salabikh fields was high,

ii. the remains are derived from material, rich in SHH seeds, which was brought to the site by some means other than as crop weeds, e.g. as animal dung or fuel,

iii. some other factors not yet defined, such as mixing, post depositional activity, produced these concentrations of SHH seeds.

If the crop was purely free-threshing then the first group (SHH-rich) could be classified as a by-product of coarse sieving. The second has elements which could be classified as fine sieving by-products, but even here the SHH category is the most frequent seed type dominating the analyses. In the third group where the samples have lower SHH levels the dominant seed type is BFH, followed by SFH and SHL, and there are few BHH seeds. These proportions most resemble those of fine sieved products (Table 5.12). If the crop was predominantly made up of glume wheats, then the two SHH-rich groups could be considered as representing fine sieved by-products.

5.4.1.2 Comparison with the Kolofana processing groups

Canonical Variates Analysis was used to compare the Abu Salabikh samples with the four cereal crop processing groups from Kolofana. The pulse samples were not included to minimise any differences and to keep the data matrices at a reasonable size. A square root transformation was carried out on the weed seed percentage values for each sample prior to amalgamation into the weed seed categories.

When the Kolofana samples were analysed on their own (Table 5.13, Fig. 5.6) the first Canonical Variate (C.V.)

which accounted for 53% of the total variation separated samples rich in BFH and SFH, i.e. the fine sieve product and by-product from those dominated by SHL and SHH. The second C.V. (23%) split the fine sieve group into the product, rich in BFH seeds, and the by-product, with high SFH levels. The by-products of winnowing and coarse sieving are separated on the third C.V., the winnowing by-products being dominated by SFL and SHL seeds while in coarse sieve residues there is a high proportion of SHH and BHH seeds. The reallocation procedures of D.A. moved nine samples into new groups (8%), six from the coarse sieving to the winnowing by-product, one in the reverse direction and two samples moved within the fine sieving groups.

The addition of the Abu Salabikh samples leaves the plot of the first two C.V.'s more or less unchanged (Table 5.14 Fig. 5.7) and there is little overlap between the material from the two sites. The first canonical variate (C.V.) accounted for some 37% of the sample variation, the most strongly loading variable being BFH (0.61). SFH also loads +vely (0.61), while SHl (-0.59) was the most strongly negative category followed by SHH (-0.31), SFL (-0.15), and BHH (-0.14). Thirty-five samples were reallocated, 29 moving within the Kolofana groups, mainly between the fine sieving groups, and two samples move into the Abu Salabikh groups from the coarse sieving residue. Of the six Abu Salabikh samples that are moved into the Kolofana groups three are put in the fine sieve product, two in to the by-product and one to the coarse sieve by-product.

The separation of the Abu Salabikh sample from the Kolofana groups is due to the high proportions of SHH seeds (and to a lesser extent BHH) which are not encountered in the modern samples. This emphasises the very high levels of SHH seeds in the AbS samples and the suspicion that they are from a source other than crop weeds. In order to investigate the samples without the influence of the possibly dung derived elements, the run was repeated without the small legume and Phalaris species (which are SHH seeds previously classified as likely animal fodder plants).

5.4.2 Winter weeds without the potential dung species

5.4.2.1 Abu Salabikh samples (Table 5.15 Fig. 5.8)

Once the likely 'fodder' types (fodder is used here to denote plants preferred or selected for animal feeding, whether or not they were deliberately collected and fed to stalled animals or grazed from fields, etc.) are removed the SFH weeds (+0.91) become the most strongly loading category on the first P.C. (30%) with BFH at the other extreme (-0.49), while the other categories are more or less neutral. The SHL (+0.70) and BHH (-0.71) categories are at opposite ends of the second P.C. (26%) with SHH loading weakly with BHH (-0.25) and BFH (0.42) with SHL.

There is no strongly preferred cluster solution, but there are reasonably stable groups at the four cluster level. These comprise;

i. samples with high BHH level (>95%),
ii. samples rich in SFH weeds and medium numbers of SHL,
iii. samples dominated by SHL seeds (c.50%) with quite high BFH levels,
iv. samples with only one category of weeds, e.g. BFH seeds.

These groups are still difficult to interpret as it is not known whether they have come from the field of a free-threshing or glumed cereal and this affects the way in which the weed categories might be expected to behave, e.g. when processed with a glume wheat SHH will behave differently than in a free-threshing barley crop.
In the SHL-'rich' group, samples with a high level of barley (>70%), the proportion of SHL is relatively low,

ca. 30%, while in those samples where the dominant type of cereal is wheat (>70%) the average SHL value is 72%, and it is possible that the pounding to break up the glume wheat spikelets also broke up the SHL weed heads.

5.4.2.2 Abu Salabikh and Kolofana samples (Table 5.16 Fig. 5.9)

The effect of removing the potential fodder plants was to increase the negative loading on SHH (-0.61) and SHL (-0.78) categories, BFH (0.46) and SFH (0.13) both load positively but not strongly. On the second C.V. BHH loads +vely (0.33) while SFH is strongly -ve (-0.84). The plot of the transformed values shows the Abu Salabikh samples occupying the +ve quarter, with the samples having high BHH, BFH and, occasionally, SFH values. There is more mixing of the modern and ancient samples mainly in the fine sieve products, also observed in the reallocation of samples by C.V.A., with 21 samples moving, 11 within the Kolofana groups (mainly between winnowing and coarse sieving by-products), 10 from Abu Salabikh to Kolofana groups, eight to the fine sieving product, one to the by-product and 1 to the winnowing by-product group.

The main feature apparently separating the 2 bodies of material is the high level of BHH seeds seen in the Abu Salabikh samples.

5.4.3 Conclusions

Comparison of the full complement of Abu Salabikh winter plant types with the Kolofana weed categories highlights the dominant role played by the SHH category in the Abu Salabikh samples, but the removal of the bulk of the types in this category has comparatively little impact on the interpretation of the Abu Salabikh material as only a few samples are placed within the Kolofana groups. The reclassified Abu Salabikh samples are associated with the fine sieving stages, mainly the product, and tend to have high levels of barley material, but they were classified both as barley product and by-product in the cereal only analyses.

Whether these differences between the sets of material are purely those resulting from the mixed or contaminated nature of the Abu Salabikh samples or are in part related to the presence of glume wheat crops at the site was not proved satisfactorily. The fact that the archaeological samples from Assiros, which also contained glume wheat material, were shown to correspond well with those from Kolofana does suggest that the mixing of the Abu Salabikh material is the chief factor in the observed discrepancies.

5.5 Winter weeds and cereal groups (Table 5.8 Fig. 5.2)

The identified cereal remains are the only types of material whose derivation from crop fields can be ascertained with confidence, even if the manner of their arrival in the Abu Salabikh samples is not yet fully understood.

The Abu Salabikh samples were analysed on the basis of six cereal groups alone. For the principal groups produced by the cluster analysis the average total of each of the weed seed categories was calculated (Table 5.12).

Five groups were recognised;

i. Triticum dominated samples, with a very high TRTG:TRTW ratio (118.2) which was identified as a by-product of glume wheat processing e.g. the fine sieving by-product,
ii. Hordeum dominated samples (HSAT:TRIT = 2.1) with a more or less equal HSAR:HSAW ratio (1.36), which are tentatively identified as an unprocessed barley crop (after Kolofana),

iii. Hordeum dominated (5.1) with a HSAR:HSAW ratio (0.27) just outside that expected for an unprocessed barley crop (0.33) but still within the safety margin that has been assumed. There are five samples which are outside this extended range namely 3 (0.06), 10 (0.13), 18 (0.10) 50 (0.12), and 52 (0.15),

iv. Hordeum dominated (4.4) with a very low HSAR:HSAW ratio (0.01) which are identified as barley processing residues (product or by-product), e.g. coarse sieving product or fine sieving by-product,

v. Samples with a more or less equal barley:wheat ratio (0.87). The barley material in these samples shows, on average, a 0.07 HSAR:HSAW ratio suggesting that some rachis material has been selectively removed. The wheat material, conversely, has a TRTG:TRTW ratio of 1.67 i.e. the number of grains is less than expected perhaps as a result of crop processing, in which case this could be a by-product from an early stage of glume wheat processing. The wheat and barley remains may be considered as the mixing of processing residues of two separate crops rather than a single cultivation of two crops.

5.5.1 Cluster Analysis groups and the winter weeds (Table 5.17)

SHH seeds account for 56.6% of all the seeds in the analysis and are the single most abundant species in every group, 'drowning out' the influence of the other categories. Their level of frequency is greatly in excess of SHH seeds in the Kolofana samples, and possible reasons for this high level have already been discussed.

In order to test the relationship between the cereal and the other weeds the same analysis was performed after the 'fodder' species were removed.

5.5.2 Cluster Analysis groups and the winter weeds minus potential dung species (Table 5.1)

Removing the small legumes and Phalaris species leaves little SHH material, and none of the other categories dominate the analyses as the SHH did previously. The unprocessed barley (group 2), should give the best indication of the weed flora of the crop and in these samples there was a prevalence of SFH and BFH seeds (49 and 31% respectively) with SHH and BHH at about the 10% level. A similar pattern is seen in group 3 where there may also have been no processing.

In the processed barley crop samples (group 5), there is a preponderance of BFH seeds (55%) while the proportion of SFH is reduced to 13%. Such a level of BFH seeds would be expected in fine sieving products. The BFH category is also the most common in group 4 which comprises samples with roughly equal proportions of wheat and barley. The level of wheat grain in this group is the largest of any group, equivalent to the chaff.

The wheat dominated group (no.1) have a relatively high SHL content (35%) with the other categories all about 20%. SHL seeds are principally removed by winnowing or coarse sieving in free-threshing cereal processing but may behave differently with a glume wheat cereal. The cereal remains of this group were identified as possible fine sieving by-products, in which case the dominant weed seed category would be expected to be SFH (Table 5.1).

5.6 Non-statistical analysis

5.6.1 Cereal groups based on wheat and barley levels and the frequency of winter weeds (minus potential dung species)

Even after identifying and excluding certain likely dung species there is still the problem of deciding whether the samples represent a single crop of, one or two cereal types, or material from two separate crops, product or by-product, that have become amalgamated.

In addition to these possibilities there will, inevitably, be some contamination from sieves, threshing floors, etc. which in samples of such mixed nature as at Abu Salabikh it might be difficult to detect.

It was therefore assumed that where one cereal species outnumbers the other by more than 2:1, i.e. at the 70% level, it represents a single crop. The samples were then grouped according to the proportion of the cereal genera and the average value for each weed seed category in these groups was calculated as a percentage of the total number of weed seeds (rather than as a percentage of all the remains as the quantity of cereals is much larger than that of the weed, Table 5.18).

5.6.2 Triticum dominated samples

a. Samples with a high glume base to grain ratio (>5.0). There are eight samples in this group and they have an average glume : grain ratio of 163. According to Hillman's work (1984 p. 10), this might be expected in a fine sieving by-product though in the archaeological samples from Assiros it was rare for the number of glume bases to exceed the number of grains even in the samples identified as fine sieving by-products. There is no glume wheat at Kolofana, but by analogy with rachis material, assuming that the glumes behave in a broadly similar way (Hillman 1984), it is seen that rachis internodes are found in the winnowing and coarse sieving by-products. In the fine sieve by-product the amount of grain always exceeds that of rachis (by c.20:1 for wheat and by c.28:1 for barley).

The weed seeds are dominated by the SHL and SFH categories, SHL is likely to be most frequent in the (second grain) winnowing, following spikelet pounding in glume wheat processing though the effect of pounding the weed heads is not known precisely. High SFH levels in conjunction with SHL are typical of the free threshing crops after winnowing (reconstructed, Table 5.12).

b. TRTG:TRTW 0.2-0.4
Only one sample, which was not discussed

5.6.3 Barley dominated samples

a. HSAR:HSAW <0.16. Barley product (by-product).
The average ratio of chaff to grain for these samples is 0.05 (ie 19:1 grain:chaff). A high grain to chaff ratio is found in the products of the later stages of free threshing cereal processing, i.e. the coarse sieving and fine sieving product. The fine sieving by-product also has a comparatively high ratio and it is not possible to conclude whether this represents a product or by-product purely on the basis of the cereal remains, though in five of the 12 samples there are no HSAR. The proportions of the weed categories in these samples, BFH accounting for some 40% of the weed material, most closely resembles those of the fine sieving product group of Kolofana, though the dominance of BFH is not as clear as that seen in Assiros fine sieved products.

On balance this group would be (tentatively) identified as a fine sieved product of a barley crop.

b. HSAR:HSAW 0.17-0.60. Barley unprocessed (?).

All of the samples in this group have some HSAR. The average ratio for the seven samples is 0.34 which is within the predicted range for an unprocessed, or one only partly processed, 6-row barley crop. In the Kolofana material this most closely resembles the winnowing product (reconstructed) which has a ratio of 0.24. The weed seeds, however, are more like those of fine sieved product.

c. HSAR:HSAW 0.61-2.0 + >2.0. Barley by-product (average ratio 1.3).

As most of the Abu Salabikh barley appears to be 6-row these two groups have been amalgamated even though one has samples that fall within the range used previously for the maximum expected values of a 2-row crop. These samples have less grain than expected and are closest to the coarse sieving by-product of Kolofana (average 2.6). None of the samples has values as high as those seen in the winnowing by-product (7.2), even allowing for some 2-row mixing. The weeds, however, are very clearly biased towards the samples being fine sieving by-products, or even the product of coarse sieving (reconstructed).

5.6.4 Mixed wheat and barley samples

This group illustrates the phenomenon described at the beginning of this chapter, namely the opposing nature of the wheat and barley remains in terms of the proportions of grain and chaff, which is typical of Abu Salabikh samples. The barley remains fall within the range for a more or less unprocessed crop while the wheat remains more resemble a by-product of processing with some grain removed.

The weed material levels are similar to those found in fine sieving products at Kolofana, e.g. BFH (39.5%) and SFH (29.4%), here, perhaps, reflecting the high levels of these categories are from the flora of the crop fields.

5.6.5 Conclusions

Calculating the weed category values for the groups created by the KMNS cluster analysis revealed some apparent correlations between some of the weed groups and cereal types, especially after the 'fodder' species were removed, although these associations were at best tenuous. Thus there seems to be some relationship between samples with high numbers of barley grains relative to rachis internodes and BFH seeds, a composition which would be predicted in the later stages of crop processing, namely in the fine sieving product. There are high levels of BFH seeds in the samples tentatively identified as unprocessed barley which could be interpreted as indicating that the number of BFH seeds in the original crop fields was also high.

The creation of sample groups based on the relative abundance of the cereal types rather than those generated by statistical analysis does not produce weed category values that are more easily interpretable. This result is disappointing but not completely unforseen given the conclusions reached by Jones (1983, p. 147) that the cereal remains did not give as clear a picture of crop processing events (in free-threshing crops) as the weed seeds. Whereas the proportion of the various weed seed categories are quite distinct after each processing stage the proportions of the cereal remains from different stages may resemble one another, e.g. the ratio of barley grain to rachis internodes in the fine sieving averages 28:1 compared with the figures of 65:1 (reconstructed, see Table 5.2) for the coarse sieved product.

5.7 Statistical analysis of the cereal and winter weeds

5.7.1 Cereal and full 'weed' complement (Table 5.19 Fig. 5.10)

The strongest separation results from the relative amounts of TRTG and SHH in the samples, the cereal types loading in one direction and the weed seed categories in the other. The main group produced comprises samples with high percentages of barley, grain and chaff, and of SHH seeds.

The other groups discernible tend to be dominated by a single category. One is characterised by high SHH levels, in some samples more than 90% of all the plant remains, and in another TRTG is dominant. The fourth group contains samples rich in HSAW, and although certain trends can be perceived the frequency of the SHH category makes interpretation very difficult.

5.7.2 Cereals and the reduced weed set (Table 5.20 Fig. 5.11).

The groups produced by the cluster analysis are, for the main part, determined by the cereal remains, the weed categories playing only a small role (not loading strongly). As such the groups resemble those described in the cereal only analysis above (Section 5.3);

a. Unprocessed barley.

In the unprocessed barley samples <1> SFH is the most frequent weed seed category (c.48%) and this may reflect the proportions of the original weed flora.

b. Wheat by-product (fine sieving?).

In the wheat by-product group SFH is again the most common weed category but at a reduced level (38%) even though it would be expected to be high in a fine sieving by-product. The weed seeds are in closer agreement with the predicted proportion as the BFH category (54%) is more than three times the next most abundant category.

c. Barley product.
BFH is the most abundant weed category.

d. Samples dominated by a single weed category.
This group was not seen in the previous analysis, and comprises only four samples in this group.

One problem that arises from running the cereal and weed categories together is that the contribution made by the two groups to the analysis are very unequal: 5.5:1 cereal to weed remains, and thus greater weight may be given to the cereal remains. A comparison of the cereal:weed ratio of the Abu Salabikh groups with those calculated for Assiros and Kolofana (Tables 5.2 & 5.3) shows that it is unlikely that any of the Abu Salabikh samples represent fine sieved products, at least not ones as carefully cleaned of weed seeds as those found in Kolofana or Assiros, where the cereal:weed ratio is very high (>100).

5.7.3 Non winter material

In order to further understand the relationship of the various wild plant species and other categories of plant and non plant material at the site of Abu Salabikh the various sets of data were compared with the cereal and winter plant types.

5.7.3.1 Non winter groups totals

The totals of early summer and summer plants' weeds were added, together with the group of miscellaneous remains, to the nine winter cereal groups and the five winter weed seed categories. The percentages were then calculated for each type in each sample and then finally a square root transformation was performed on the data, before using the values in the analysis.

The cereal types and BFH load positively on the first P.C. while SHH loads strongly -ve. On the second P.C. there is a separation of samples into those with high TRTG levels and those rich in HSAW.

The early summer (ESUM) group loads strongly with the HSAW rich group, the summer (SUMM) variable loads towards the SHH category, while the miscellaneous group (MISC) is neutral.

The individual types present in these groups were then considered separately.

5.7.3.2 Early summer fruiting plants

The individual early summer species were run against the winter cereals and weeds in the way described above. Within the ESUM group Scirpus sp makes a very large contribution to the first and second P.C.s loading with the cereals, in particular HSAW. The other ESUM species behave like the winter weeds, other than SHH, and are generally neutral throughout the analysis.

There is no apparent correlation with the SHH category which might have been expected if the ESUM plants were grazed, as has been proposed.

5.7.3.3 Summer fruiting plants

The SUMM types are all very neutral in their contribution to the P.C.s, the strongest loading being by Prosopis towards TRTG dominated samples and away from those rich in HSAW. They behave most like the winter weed species and given that they are almost certainly not from crop fields supports the inference that the samples of very mixed origin.

5.7.3.4 Miscellaneous types of plant remains

This groups includes animal dung mainly in the form of sheep/goat pellets (DUNG), culm nodes of reed (REEDK) and small (non cereal) gramineae (SGRMK), and the tubers of Cyperus rotundus (TUBR). The first three P.C.s are only responsible for 37% of samples variance, and on the first one the HSAT remains, TRTG, SHH and BHH load away from the TUBR, SGRMK and REEDK types. Dung is neutral on this P.C., as it is on all the first three P.C.'s.

On the second P.C. the major cereal types are fairly neutral while the REEDK and SGRMK again load strongly, this time away from BFH, TRTS and TRTW.

The separation of the animal dung material from the other members of this group agrees with the earlier discussion of the latter's mode of arrival on the site, the reed material as furnishings, the tubers of Cyperus as a potential food/medicine, and with the assumption that the culm and culm nodes of the small unidentified grasses would have been charred in dung burning.

Despite, or perhaps because of the central role attributed to animal dung in this study the behaviour of the dung material itself (in relation to cereal and weed categories) does not offer much assistance in the elucidation of the factors producing the combinations of plant material at Abu Salabikh Its loading through this analysis is neutral, the only signs of life being exhibited on the first P.C. where it reaches a value of 0.23 which is in the same direction as the HSAT, TRTG, SHH and BHH categories, and away from the other types put in the miscellaneous group.

5.8.1 The use of animal dung as fuel

The use of animal dung as manure was discussed in (Section 3.2.2.3. In the following sections the use of animal dung as a fuel and the types of plant material which are likely to find their way on to the site by this means are considered.

The types of animal feeding common in the Hillah-Diwaniya region of southern Iraq were described in some detail in Chapter Three and, as with other aspects of the traditional agricultural system, comprised a mixture of what could be called intensive and extensive techniques. While herds of animals were driven to and from areas of natural grazing, other areas were deliberately irrigated to encourage weed growth for animal feed, and barley was grown as fodder, and fed to the animals green or as a dried mature crop.

A range of cultivated plant material can become incorporated into the dung in various ways, in addition to the non-cultivated plants already discussed (see Section 4.7.5).

5.8.2 The feeding of livestock

5.8.2.1 Cultivated plants and animal dung

In southern Iraq the young cereal plants, usually barley, were grazed but the stems would not be identifiable archaeologically to genus. The dry, mature plants, either the post harvest stubble, straw and fallen grain, or the crop processing residues and the partly or fully processed grain were often eaten either grazed or as fodder fed to stalled animals and a high percentage of the this material will be archaeologically recognizable and identifiable to genus or species level.

Crop processing residues such as straw, chaff and crop weeds, were used, deliberately, in the making of dung cakes and could also become incorporated accidentally when the dung from stalled animals is collected together with any bedding material, e.g. straw, that has been put down for the animals.

5.8.2.2 Selection of crops for animal fodder

The crop least favoured for human consumption is usually the one used for animal feed and thus in southern Iraq in the 1950's free threshing wheat was reserved for humans while a high percentage of the barley was fed to the livestock (Poyck 1962 p. 53). Barley also seems to have been the cereal most commonly fed to livestock in Early Dynastic Mesopotamia (Maekawa 1983 p. 81) whereas wheat, probably T. dicoccum, was eaten by humans and there is no mention was made to it being used for animal feed.

Percival (1921 pp. 171 and 188) mentions that T. monococcum and T. dicoccum, two crops found at Abu Salabikh, were grown in areas of Europe as a replacement for oats and barley as feed for livestock so this possibility should not be ruled out automatically for Lower Mesopotamia. These glume wheats were fed to livestock in the husked form and there is no mention of any special processing of the crop prior to feeding (Percival 1974 p. 171).

Four crop processing residue types of glume wheats that are used for fodder are listed by Hillman (1984a p. 144-145) (cf. for free threshing cereals, Hillman 1985 p. 213):

i. stores of broken straw - bulk of the coarsest straw,
ii. light chaff store - lemmas, paleas and some awn fragments,
iii. 'cleanings' store - consisting of straw nodes, large and small weed seeds, glume bas es and tail grain,

iv. bran store - i.e. bran peeled from grain kernels.

The daily diet of full grown buffaloes as recorded by Poyck (1962 p. 54) was;

> "alfalfa 50 kilos, cotton seed 2 kilos, sesame buds 3 kilos, barley chaff 5 kilos, barley bran first quality 5 kilos, second quality 4 kilos, rice chaff 4 kilos, rice bran 3 kilos and straw 5 kilos".

Where the importance of livestock in the economy is comparatively large and a high percentage of at least some of the crops grown is devoted to animal feeding it is possible that the methods of crop husbandry, harvesting and subsequent processing will all differ from that carried out on crops intended for human consumption. For example (see Section 3.6.2) the sowing rate of barley crops which are to be grazed can be increased to compensate for yield reduction, a fairly elaborate mixed cropping system of barley and broad beans to produce fodder is quite common, and additional processing stages were often included to produce a suitable type of feed (presumably other features such as the need for careful weeding etc. could also be varied depending on the intended fate of the crop which in turn could affect the weed composition of the field crop).

5.8.2.3 Non-cultivated plants - grazing and fodder

Cuneiform information concerning the feeding of livestock suggests that a small proportion of animals, including sheep, goats and cattle, were kept for part of the time in the "sheep pen of the palace" and were provided with barley and other kinds of fodder during the time that they were penned (Maekawa 1983 p. 83). What these other types of fodder were is not described but could presumably have included non-domesticated plants cut for fodder (whether these plants were deliberately cultivated for livestock feeding is not known). Maekawa also mentions that the flocks of sheep and goats were "most likely pastured on grass land or fallow land in the daytime in the favourable seasons" (p. 83).

5.8.3 The Effect of animal digestion and subsequent burning on plant material

> "S. Bottema and E. Neef (pers. comm.) have demonstrated that some barley grains pass out of the digestive tract of animals undamaged; it was found that the same applies to wheat that is fed to cattle and goats." Van Zeist & Bakker-Heeres (1985 p. 275-8).

> "Seeds were present in nearly all the dung samples from the mammals tested in these experiments. However, the numbers of seeds recovered varied from one species of seed to another and from one test animal to another (both between and within animal species). The amount of time that had elapsed since the ingestion of the seeds also affected the number of seeds recovered" (Miller & Smart 1984 p. 17).

The animals tested included cattle, sheep, chickens, hogs and horses and it was observed that "seeds were found to be present in cattle dung for at least 10 days after they were ingested" (Miller & Smart 1984 p. 17).

The ancient sheep/goat dung pellets recovered from Abu Salabikh were broken up and examined and did not contain any seeds or other identifiable plant material.

In most cases the preserved pellets were a pale grey colour, probably indicating that they had been exposed to high temperatures and had burnt completely, causing oxidation of the dung material.

Relatively modern material taken from the middens adjoining a recently abandoned TANUR oven was rich in charred sheep/goat pellets many of which were charred rather than completely oxidised. Some seeds, including barley grains, were found in these modern samples which were collected by Miller from the village of Malyan in Southwestern Iran and which contained charred dung with, in some cases, charred seeds embedded in it as well as 'free' seeds presumed to have come from dung (Miller & Smart 1984 p. 17-18).

5.8.4 Dung cake production

In southern Iraq "The fresh or moistened manure is mixed with straw and dried in the sun. It is often a commercial product" (Buringh 1960 p. 252).

The dung and straw mixture is wetted and kneaded to produce large flat cakes 15-25 cms in diameter. Once dry they are often stored beside the houses in piles forming small domes. The principal type of dung used is provided by cattle, although a single cake may be made from sheep, goat, cow and donkey dung, and sometimes no straw is added.

Fenton (1985 p. 96-111) gives a fascinating account of the use of manure as a fuel in Northern Scotland:

> "Where sheep were continually penned, their dung was pressed into a solid layer by the animals feet; at time of fuel shortage, people cut this up, dried it and used it in their fires" (p. 105).

There the dung was moulded into cakes and dried on the sides of the buildings, but there is no specific mention of the deliberate inclusion of straw, which was considered; "less efficient as a fuel than cow-dung" (Fenton 1985 p. 106), and in another example: "care was taken to keep it free of straw in the byre, so that the dung should be as pure as possible" (Fenton 1985 p. 106).

It was also pointed out that different types of dung burn in different ways, e.g. some smoulder others are more likely to flare up etc. and where possible the most suitable type is chosen. A single fire may contain two or three types of dung plus dried plant material to produce the correct temperature.

5.8.5 The effect of dung contamination on the interpretation of plant remains

Miller and Smart (1984 p. 20) proposed;

> "that the use of dung as fuel be considered as one possible interpretation of an archaeological charred seed assemblage when the following conditions are met: (1) the site occurs in an environment where wood for fuel might have been scarce; (2) suitable dung-producing animals were present in the area; (3) the assemblage of charred material contains burned dung and/or seeds from plants that could have been eaten by dung-producing animals; and (4) the archaeological secondary dumping of hearth contents".

This check list was used on two groups of archaeological samples and in both cases the criteria indicating that the material was derived from derived were met, although other interpretations could have been made. A similar approach for the Abu Salabikh samples is outlined below;

i. the supply of wood as a fuel could have come from a number of sources including the date palm orchards, the natural riverine vegetation, the shrubs of the sub desert areas behind the river watered zone, however, there are no extensive areas of woodland and an arid area such as this is easily depleted of its trees as has been the case in this century,

ii. large numbers of sheep, goats, cattle, pigs and species of Equus were all present in Lowland Mesopotamia in Early Dynastic times,

iii. charred dung material was present in samples, and there was a large number of seeds of plants that could have been eaten by livestock. What is perhaps of more relevance to Lowland Mesopotamia is the presence in the Abu Salabikh samples of the species that would not have been present in the winter crop fields or on irrigated crop land, e.g. the desert type plants,

iv. the archaeological contexts examined included several hearth type deposits as well as features containing the waste product of the hearths. Another negative feature of the samples was that they do not contain material that can be confidently identified as a primary storage context with an uncontaminated crop sample of the sort found at Assiros which had;

> "good preservation, little distortion, low ratios of weed to crop seeds, large quantities of big, free, heavy weed seeds and small quantities of small, heavy weed seeds" (Jones 1983 p. 163),

or of the type 1 samples from Bulgaria described by Dennell (1974 p. 276) which consist;

> "almost entirely of the seeds or grains of one species of cultigen. There were very few weed seeds, comprising a very limited range of weed species. There were no spikelet fragments.".

Without samples of an uncontaminated nature it is not possible to ascertain positively what weeds were growing in the crop field.

The samples from Abu Salabikh would on this basis be considered contaminated by dung. What then are the consequences of this in the interpretation of the plant remains? The aim of identifying samples as the products or by products of particular crop processing stages is; "to filter out variation due to crop processing before using archaeobotanical evidence to answer more important questions" on the basis of the weed seeds from comparable stages of processing (Jones 1987a p. 321). The presence of non-cultivated plant seeds of unknown origin which cannot be separated reliably from the crop weed seeds renders the samples unusable for other interpretive purposes. No satisfactory method has been found in this study to reliably separate these two types of material.

In addition to confusing the interpretation of the non-cultivated plant seeds, the inclusion of cultivated plant material from animal dung may also have a significant effect on the representation of the crop plants in the charred plant remains at a site. If a crop is selected for animal feeding and the dung of these animals is used for fuel then the frequency with which that species is represented in the charred remains of the site are markedly increased over species not so used. In Lowland Mesopotamia the increasing frequency of barley, relative to wheat, observed in the plant remains has been used as evidence for an increase in soil salinity of the area. It could, however, be associated with changes in livestock feeding practice; e.g. an increase in the number of livestock, or a shift from wheat as animal feed.

Table 5.1 Barley grain : rachis ratios in Abu Salabikh samples and in mixed 2 and 6 row crops

a. Numbers of 2 row and 6 row grain and rachis components in the Abu Salabikh samples

samples included	2 row		6 row	
	grain	rachis	grain	rachis
for all samples	64	15	103	255

b. Ratios of 2 row and 6 row components in the Abu Salabikh samples

	rachis	grain
samples included	6 row : 2 row	twisted : straight
overall	17.0	1.6
samples with both types present	5.7	1.5

c. Proportions of grain and chaff in 2 row, 6 row and mixed crops

crop type	grain	rachis	grain type twisted	straight
6 row crop	3	1	2	1
2 row crop	1	1	0	1
1:1 mix	2	1	1	1
4:1 (6 row: 2 row)	2.6	1	1.	1

Table 5.2 The ratios of barley grain to rachis internodes for the 3 major processing stages at Kolofana (after Jones 1983)

crop processing stage	by-product	product	
original crop	/	1.89	(reconstructed)
winnowing	0.14	4.17	"
coarse sieving	0.39	64.9	"
fine sieving	27.9	579.0	"

(average figures for all the cereal samples in each group)

Table 5.3 <u>The proportions of wheat and barley remains in the archaeological samples from Assiros: fine sieving product and by-product (from Jones 1983)</u>

a. Glume wheat

	grain	spikelet forks	glume bases	grain : chaff
f/sieve by-product	66	8.7	0.3	7.3
f/sieve product	44	14	13	1.6

b. Barley

	grain	rachis	grain : rachis
f/sieve by-product	24.5	0	/
f/sieve product	28.0	0.3	93.3

Table 5.4 <u>The relative proportions of grain and chaff components in glume wheat processing stages (from Hillman 1984 p. 10)</u>

stage no.	crop processing stage	spikelet fork	glume bases	rachis	grain prime	tail
4	coarse sieving (>prime grain)	/	/	/	/	/
5	fine sieving (<prime grain)	xx	xxx	xxx	/	xx
6	semi clean grain in bulk storage	x	x	xxx	x	
7	cleanings from hand sorting	x	x	(-)	/	/

/ = none = rare
x = few xx = some xxx =lots

Table 5.5 The proportions of the major categories of cereal remains in the Abu Salabikh samples (percentage values)

cont	hsar	hsaw	trtg	trtr	trts	trtw (%'s)
1162	0.0	56.1	43.9	0.0	0.0	0.0
1164	0.0	68.9	31.2	0.0	0.0	0.0
1183	4.7	79.1	16.3	0.0	0.0	0.0
2139	18.0	71.4	10.1	0.0	0.0	0.5
2140	0.0	32.6	64.4	0.0	0.0	3.0
2141	4.6	77.5	14.5	0.0	0.0	3.4
2433	2.5	73.8	17.8	0.0	3.1	2.9
2464	1.5	19.4	18.8	0.5	10.0	49.8
2682	31.9	56.2	11.9	0.0	0.0	0.0
2683	9.4	70.6	15.3	0.0	0.0	4.7
3308	64.8	18.1	13.2	0.0	2.2	1.8
3310	54.1	34.7	10.7	0.0	0.0	0.5
3312	52.1	23.9	18.2	0.5	2.1	3.1
3313	49.9	18.3	28.0	0.0	3.6	0.2
3314	18.3	44.6	33.2	0.0	3.7	0.3
3315	39.7	26.1	22.0	1.3	8.6	2.2
3316	25.9	27.0	41.0	0.0	6.1	0.0
3317	8.3	81.4	8.3	0.0	0.0	2.1
3323	0.0	86.4	9.7	0.0	0.0	3.8
4314	22.1	44.5	11.2	0.0	22.1	0.0
4315	14.1	27.5	41.4	0.0	13.3	3.7
4704	15.0	27.6	56.0	0.0	1.4	0.0
5381	0.0	39.9	60.1	0.0	0.0	0.0
5412	0.0	12.5	87.5	0.0	0.0	0.0
5413	0.0	3.17	93.7	0.0	3.2	0.0
5431	0.0	45.2	32.9	11.0	0.0	11.0
5443	0.0	58.5	32.7	0.0	5.9	3.0
5525	0.0	18.7	72.0	0.0	7.0	2.3
5535	0.0	22.7	77.4	0.0	0.0	0.0
5602	0.0	38.0	41.4	0.0	0.0	20.6
5607	0.0	36.4	54.5	0.0	7.8	1.3
5612	0.0	8.7	91.3	0.0	0.0	0.0
5801	23.3	68.9	4.7	0.0	0.0	3.2
5804	15.6	67.5	11.8	0.0	0.0	5.2
6401	27.8	49.1	13.9	0.0	0.0	9.3
6413	11.5	63.6	24.7	0.0	0.0	0.2
6416	30.2	61.0	8.6	0.0	0.0	0.2
6417	21.8	62.0	16.2	0.0	0.0	0.0
6801	6.0	36.6	40.3	0.0	10.8	6.3
7090	0.0	53.7	9.6	0.0	3.9	32.8
7228	15.3	3.3	67.8	0.0	13.7	0.0
7406	0.0	36.6	63.4	0.0	0.0	0.0
7918	0.0	76.4	6.0	0.0	0.0	17.7
7920	0.0	71.6	0.0	0.0	0.0	28.4
8122	11.5	47.9	23.4	0.0	5.8	11.5
8304	1.9	6.5	81.2	0.2	8.6	1.7
8316	28.3	43.9	27.1	0.0	0.0	0.6
8318	0.0	91.7	8.3	0.0	0.0	0.0
8336	0.0	16.7	79.8	0.0	3.5	0.0
8337	7.3	63.6	9.7	0.0	19.4	0.0
8512	0.0	89.1	6.5	0.0	0.0	4.4
8614	12.0	81.9	6.1	0.0	0.0	0.0
8667	47.1	20.5	14.6	0.0	14.8	3.0
8670	4.6	49.7	27.4	4.6	9.2	4.6
	13.0	46.5	32.1	0.3	3.5	4.6 average %

cont = context number   hsar = Hordeum sativum rachis internodes
hsaw = barley grain   trtg = glume wheat glume bases
trtr = glume wheat rachis internodes
trts = glume wheat spikelet forks   trtw = glume wheat grains

Table 5.6 Proportions of the 8 major groups of plant remains in the Abu Salabikh samples (numbers of items / 10 litres of soil floated)

cont	cer9	wnt	slg	cult	dung	esum	summ	rmg	total
1162	54.17	16.67	3.33	0.00	3.33	13.33	8.07	3.33	102.23
1164	6.42	54.66	194.66	0.00	1.50	0.00	41.16	5.33	303.73
1183	23.50	11.25	0.00	0.00	0.00	5.50	0.00	0.00	40.25
2139	185.94	56.25	35.00	5.00	0.00	30.00	0.00	0.00	312.19
2140	15.90	1.67	0.00	0.00	0.21	2.92	0.88	0.21	21.79
2141	149.47	18.05	5.00	0.21	0.00	11.67	0.00	0.83	185.23
2433	557.49	172.09	156.66	3.33	0.00	47.49	36.88	23.33	997.27
2464	1514.77	181.67	50.00	83.33	0.42	61.67	6.67	14.99	1913.52
2682	3.58	2.43	0.34	0.41	0.19	1.01	0.20	0.34	8.50
2683	9.31	7.45	1.40	1.33	0.00	1.28	0.00	0.40	21.17
3308	26.34	4.85	1.21	0.00	0.33	3.34	0.33	0.06	36.46
3310	12.42	3.79	0.86	0.17	0.01	4.22	0.00	2.24	23.71
3312	23.04	3.63	0.11	0.00	1.38	0.95	0.11	0.00	29.22
3313	57.83	7.63	1.63	0.42	1.91	6.16	0.19	0.56	76.33
3314	30.41	7.17	4.25	0.71	1.00	3.40	0.23	1.42	48.59
3315	44.94	2.46	0.72	0.57	5.53	0.55	0.23	0.55	55.55
3316	33.58	1.98	1.67	0.28	0.95	2.74	1.23	1.07	43.50
3317	26.61	6.92	3.70	1.05	0.30	3.96	4.46	4.74	51.74
3323	11.74	5.17	0.00	0.97	0.04	2.27	0.97	0.65	21.81
4314	3.85	3.33	3.33	0.00	0.63	24.27	0.00	0.00	35.41
4315	58.04	15.00	1.67	0.00	0.84	108.34	0.07	3.33	187.29
4704	38.62	3.13	2.00	71.06	0.25	1.00	0.60	0.00	116.66
5381	129.38	446.67	1350.01	2.92	2.08	20.00	103.06	16.67	2070.79
5412	59.22	15.00	162.50	0.00	0.16	17.50	12.50	2.50	269.38
5413	106.87	10.00	3.33	0.00	0.00	3.33	3.33	3.33	130.19
5431	10.76	1.11	0.00	0.00	0.28	50.27	0.05	0.00	62.47
5443	77.91	55.00	2.22	0.00	0.00	56.66	11.11	0.00	202.90
5525	147.50	9.99	3.33	0.00	0.00	9.99	0.07	0.00	170.88
5535	22.70	42.50	6.66	0.00	4.17	106.67	0.00	0.00	182.70
5602	12.56	4.99	87.27	0.00	0.53	1.21	6.92	0.00	113.48
5607	30.72	6.04	0.00	1.27	1.89	1.88	0.75	2.64	45.19
5612	39.58	223.33	6.67	0.00	0.21	3.75	9.74	0.00	283.28
5801	5.37	2.72	0.64	0.00	0.00	3.91	0.00	0.17	12.81
5804	8.31	6.64	0.16	0.16	0.00	3.74	0.00	0.16	19.17
6401	13.25	0.00	3.00	2.00	0.44	0.00	0.00	2.25	20.94
6413	15.16	3.39	0.00	1.50	1.72	1.00	1.60	0.88	25.25
6416	6.07	1.88	1.10	0.00	0.32	1.63	0.00	1.00	12.00
6417	6.66	4.04	2.00	0.92	0.64	3.41	0.74	0.83	19.24
6801	7.95	0.75	0.00	0.00	0.23	0.34	0.00	0.00	9.27
7090	14.75	0.73	0.00	0.00	0.00	0.84	0.00	0.42	16.74
7228	3.07	0.00	0.00	0.00	0.00	0.42	6.81	0.00	10.30
7406	73.13	17.50	0.00	6.25	0.00	10.00	0.00	0.00	106.88
7918	4.70	7.36	0.47	0.24	0.00	15.80	1.18	1.65	31.40
7920	0.82	0.40	0.00	0.00	0.92	1.00	0.01	0.00	3.15
8122	3.06	0.15	0.77	0.00	0.01	0.76	0.00	0.00	4.75
8304	111.77	10.39	2.64	0.67	0.15	2.64	0.39	0.66	129.31
8316	5.63	1.03	0.46	0.00	0.25	2.87	0.01	0.23	10.48
8318	5.44	0.00	0.00	0.00	0.00	0.50	0.01	0.00	5.95
8336	10.29	0.45	1.43	1.43	6.41	2.14	0.01	0.00	22.16
8337	7.60	4.18	3.28	0.00	4.37	2.95	0.00	0.90	23.28
8512	9.62	0.85	1.70	0.03	0.19	1.60	0.00	0.00	13.99
8614	12.12	18.13	2.50	1.66	4.14	6.25	20.13	2.50	67.43
8667	6.92	2.82	0.00	0.04	0.00	1.41	0.00	0.00	11.19
8670	4.57	1.62	1.05	0.00	0.00	0.94	0.00	0.21	8.39
total	5972.2	1587.3	2110.7	187.9	47.9	671.5	280.7	100.4	10958.6

cont = context number
cer9 = winter cereals
wnt = winter wild plants
slg = small legumes
cult = cultivated plants (non cereal)
dung = various non seed material
esum = early summer wild plants
summ = summer wild plants
remg = indet seeds

Table 5.7 (Standardised) Loadings of principal components: 9 Abu Salabikh cereal categories

variable	principal components			
	1	2	3	4
	(38.4)	(27.0)	(12.0)	(10.3) (%'s)
cereal culms	0.18	0.36	-0.17	-0.01
cereal grains	0.42	-0.29	0.44	-0.73
barley internodes	0.45	0.88	0.07	0.01
barley grains	0.73	-0.48	0.08	0.42
wheat glume bases	-0.97	0.08	0.13	0.03
wheat internodes	-0.06	-0.02	-0.33	0.03
wheat spikelets	-0.27	0.45	-0.49	-0.20
wheat grains	0.26	-0.32	-0.80	-0.30

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.8 (Standardised) Loadings of principal components: 6 major Abu Salabikh cereal categories

variable	principal components			
	1	2	3	4
	(44.0)	(32.5)	(14.2)	(10.3) (%'s)
barley internodes	0.49	0.86	-0.04	-0.09
barley grains	0.76	-0.54	-0.25	0.17
wheat glume bases	-0.97	0.11	-0.13	-0.05
wheat internodes	-0.04	-0.03	0.28	-0.08
wheat spikelets	-0.24	0.44	0.57	0.65
wheat grains	0.25	-0.35	0.84	-0.30

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.9 (Standardised) Loadings of principal components: Abu Salabikh wheat categories (and cereal culm nodes)

variable	principal components			
	1	2	3	4
	(46.5)	(28.1)	(14.3)	(4.5) %'s
cereal culms	0.04	-0.23	0.97	0.00
wheat glume bases	-0.87	0.33	-0.09	0.15
wheat internodes	0.15	-0.10	-0.08	-0.12
wheat spikelets	0.02	-0.98	-0.16	0.06
wheat upper glumes	0.14	-0.01	-0.14	-0.91
wheat grains	0.97	0.17	-0.05	0.09

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.10 (Standardised) Loadings of principal components: Abu Salabikh barley categories (and cereal culm nodes)

variable	principal components		
	1	2	3
	(87.7)	(10.0)	(2.3)
cereal culms	-0.36	0.93	-0.13
barley internodes	-0.99	-0.09	-0.07
barley grains	0.94	-0.14	-0.30

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.11 (Standardised) Loadings of principal components: Abu Salabikh weed seed categories

variable	principal components			
	1	2	3	4
	(38.6)	(18.8)	(17.0)	(15.4)
big, free, heavy seeds	0.61	-0.03	0.35	0.70
small, free, heavy seeds	0.30	0.80	-0.49	0.13
small, headed, light seeds	0.41	0.37	0.56	-0.49
small, headed, heavy	-0.92	0.24	0.18	0.20
big, headed, heavy seeds	-0.02	-0.43	-0.53	0.03

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.12

The proportions of the weed seed categories in the products and by-products of crop processing at Kolofana.

	BFH	SFH	SHL	SHH	SFL	BHH
original crop (r)	13.8	34.3	35.4	13.5	1.1	2.0
winnowing						
by-product	2.6	25.8	57.4	8.1	3.1	2.9
product (r)	17.6	37.2	28.0	15.3	0.4	1.6
coarse sieving						
by-product	0.7	7.2	61.7	25.9	1.0	3.6
product (r)	26.0	52.2	11.12	10.0	0.1	0.6
fine sieving						
by-product	9.0	64.8	10.7	15.4	0.1	0.1
product	42.9	39.5	11.6	4.7	0.1	1.2

Table 5.13 (Standardised) Loadings of canonical variates: Kolofana weed seed categories

variables	canonical variates 1 (52.9)	2 (22.5)	3 (7.6)	4 (5.7)
big, free, heavy seeds	0.62	0.62	-0.15	0.55
small, free, heavy seeds	0.55	-0.63	-0.24	0.47
small, headed, light seeds	-0.50	0.08	-0.43	0.85
small, headed, heavy seeds	-0.43	0.08	0.54	0.76
small, free, light seeds	-0.12	0.06	-0.65	-0.11
big, headed, heavy seeds	-0.18	0.37	0.26	-0.002

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.14 (Standardised) Loadings of canonical variates: Kolofana and Abu Salabikh weed seed categories

variables	canonical variates 1 (37.1)	2 (25.9)	3 (16.8)	4 (7.1)
big, free, heavy seeds	0.61	0.08	-0.71	0.09
small, free, heavy seeds	0.44	-0.75	0.39	0.09
small, headed, light seeds	-0.59	-0.55	-0.47	0.38
small, headed, heavy seeds	-0.31	0.31	0.11	0.21
small, free, light seeds	-0.15	-0.12	-0.20	-0.94
big, headed, heavy seeds	-0.14	0.18	-0.18	0.06

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.15 (Standardised) Loadings of principal components: Abu Salabikh weed seed categories (minus 'dung' species)

variables	principal components 1 (30.3)	2 (25.6)	3 (23.3)	4 (16.2)
big, free, heavy seeds	-0.49	0.42	0.74	0.17
small, free, heavy seeds	0.91	0.04	0.41	0.10
small, headed, light seeds	0.13	0.70	-0.47	0.52
small, headed, heavy seeds	0.01	-0.25	0.20	0.07
big, headed, heavy seeds	-0.14	-0.71	0.06	0.68

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.16 (Standardised) Loadings of canonical variates: Kolofana and Abu Salabikh weed seed categories (minus 'dung' plants)

variables	canonical variates			
	1	2	3	4
	(41.6)	(19.8)	(14.5)	(9.4)
big, free, heavy seeds	0.46	-0.16	-0.87	0.02
small, free, heavy seeds	0.13	-0.84	0.20	-0.31
small, headed, light seeds	-0.78	-0.10	-0.50	-0.14
small, headed, heavy seeds	-0.61	-0.36	-0.28	0.63
small, free, light seeds	-0.20	0.04	-0.18	-0.66
big, headed, heavy seeds	-0.05	0.33	0.01	0.06

loadings >0.7 underlined

Values in ()'s are the percentage contribution of each p.c. to total variation

Table 5.17 Proportions of weed seed and cereal categories in groups based on cereal frequencies (Abu Salabikh samples)

	Cereal components (%)						Weed seed categories (%) including 'dung'				
	HSAR	HSAW	TRTG	TRTR	TRTS	TRTW	BFH	SFH	SHL	SHH	BHH
group 1	2.3	23.0	70.9	0.01	3.2	0.6	9.2	9.1	11.6	65.5	4.7
group 2	38.8	28.5	23.4	0.2	7.7	1.5	16.7	24.4	5.7	48.7	4.6
group 3	17.9	65.7	13.2	0	1.4	1.9	9.0	9.7	4.7	72.1	4.3
group 4	3.0	43.6	28.3	2.0	4.6	17.5	25.2	11.8	19.5	42.3	1.3
group 5	0.9	79.4	11.8	0	0.4	7.6	29.4	7.4	4.3	54.6	4.4

	Weed seed categories (%) minus 'dung' species				
	BFH	SFH	SHL	SHH	BHH
group 1	21.8	18.8	32.6	2.2	24.5
group 2	31.2	49.6	10.6	0.3	8.3
group 3	34.1	36.1	14.2	2.1	13.5
group 4	54.5	13.2	21.4	2.4	8.5
group 5	46.0	14.1	11.5	12.2	16.0

group 1 = samples dominated by Triticum remains (by-product of fine sieving ?)
group 2 = samples dominated by Hordeum remains (unprocessed ?)
group 3 = samples dominated by Hordeum remains (processed ?)
group 4 = samples with equal proportions of Triticum and Hordeum
group 5 = samples dominated by Hordeum remains (coarse sieving product ?)

Table 5.18 Proportions of cereal remains and weed seed categories calculated from the sample groups basedon cereal dominance in the Abu Salabikh samples

	HSAR	HSAW	TRTG	TRTR	TRTS	TRTW	BFH	SFH	SHL	SHH	BHH
Triticum > 70%											
group 1 (8 samples)	2.2	11.5	81.3	0.03	4.5	0.5	18.6	28.8	43.2	0	9.4
group 2	/										
group 3 (1 sample)	1.5	19.4	18.8	0.5	10.0	49.8	31.8	0	68.2	0	0
Hordeum > 75%											
group 1 (12 samples)	4.1	78.6	9.9	0	1.9	5.6	39.7	24.0	17.8	1.0	17.6
group 2 (7 samples)	21.8	64.4	12.6	0	0	1.3	45.0	33.1	7.8	3.9	10.2
group 3 (5 samples)	45.4	33.9	16.6	0	0.5	2.9	16.9	60.8	10.6	0.8	10.9
Others (22 samples)	14.5	38.5	36.6	0.8	5.7	4.2	39.5	29.4	12.6	3.3	15.2

Table 5.19 (Standardised) Loadings of principal components: principal Abu Salabikh cereal and weed seeds categories

variables	principal components			
	1	2	3	4
	(29.2)	(20.9)	(17.4)	(10.7)
barley internodes	0.03	-0.30	<u>-0.94</u>	-0.11
barley grains	0.24	<u>-0.75</u>	0.23	-0.41
wheat glume bases	<u>0.72</u>	0.63	-0.10	-0.11
wheat grains	0.33	-0.47	0.34	0.19
big, free, heavy seeds	-0.05	-0.53	0.19	0.21
small, free, heavy seeds	-0.22	-0.20	-0.29	<u>0.72</u>
small, headed, light seeds	-0.05	0.09	0.06	0.65
small, headed, heavy seeds	<u>-0.92</u>	0.26	0.00	-0.20
big, headed, heavy seeds	-0.45	0.10	0.03	-0.01

loadings >0.7 underlined

values in ()'s are the percentage contribution of each p.c. to total variation

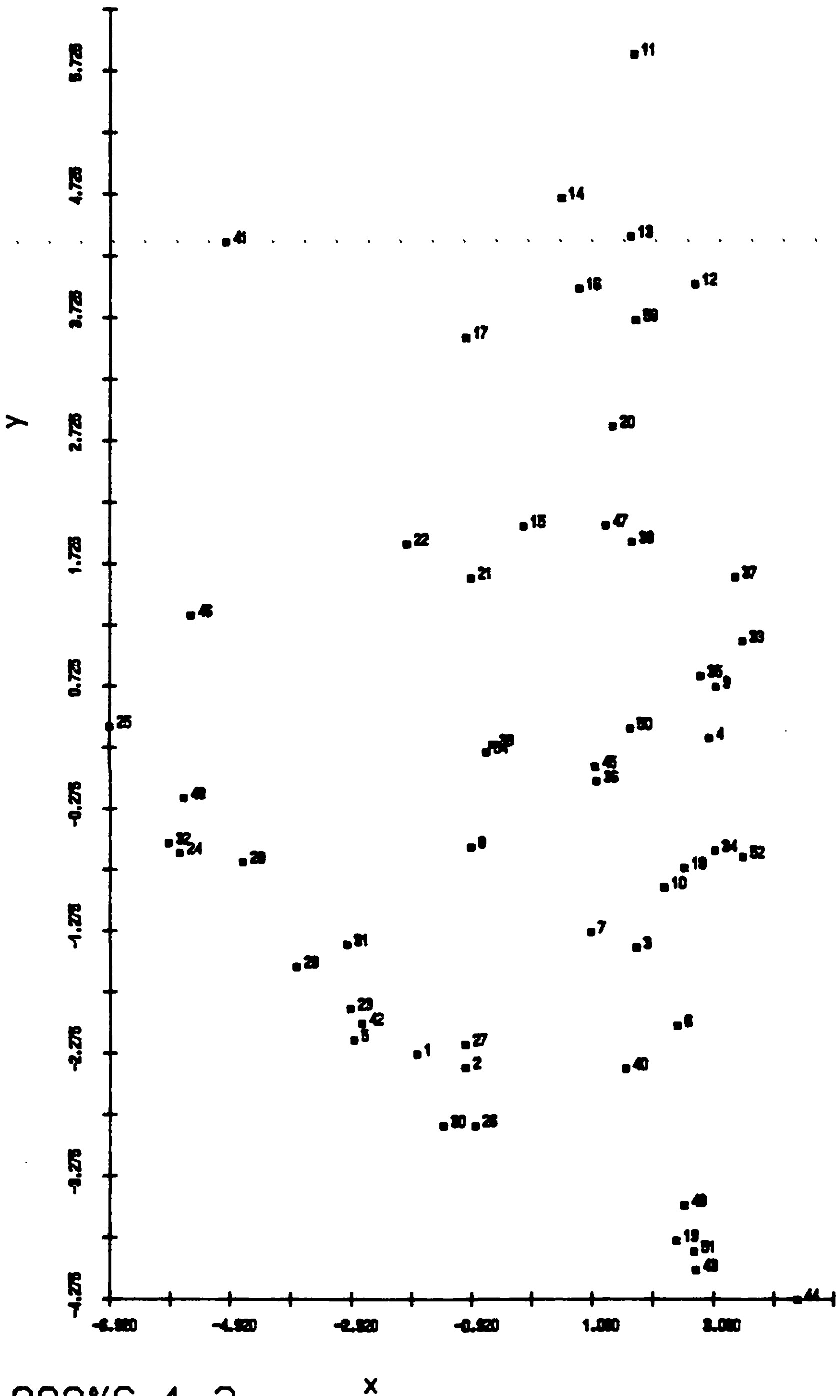
Table 5.20 (Standardised) Loadings of principal components: principal Abu Salabikh cereal and weed seeds categories (minus 'dung' plants)

variables	principal component 1 (26.9)	2 (20.4)	3 (16.8)	4 (10.9)
barley internodes	0.46	-0.87	0.02	0.13
barley grains	0.64	0.24	0.60	-0.08
wheat glume bases	-0.90	-0.26	0.25	0.02
wheat grains	0.20	0.38	0.30	-0.14
big, free, heavy seeds	0.43	0.38	-0.13	0.26
small, free, heavy seeds	0.31	-0.15	-0.65	-0.39
small, headed, light seeds	-0.06	0.08	-0.50	-0.64
small, headed, heavy seeds	0.11	0.22	-0.40	0.35
big, headed, heavy seeds	-0.03	0.26	-0.53	0.67

loadings >0.7 underlined

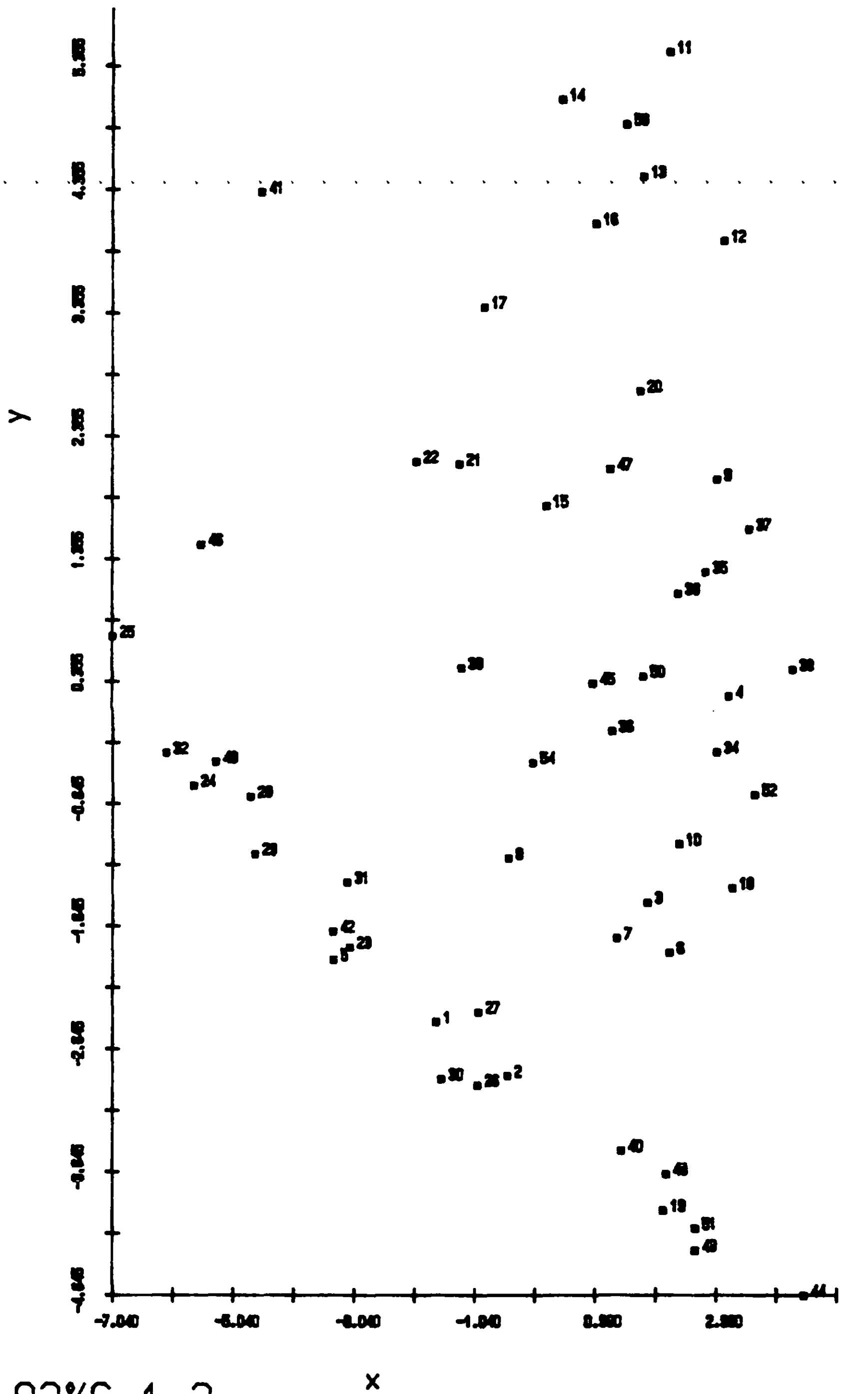
values in ()'s are the percentage contribution of each p.c. to total variation

Figure 5.1 Plot of Abu Salabikh samples in relation to the first two Principal Components: 9 cereal categories



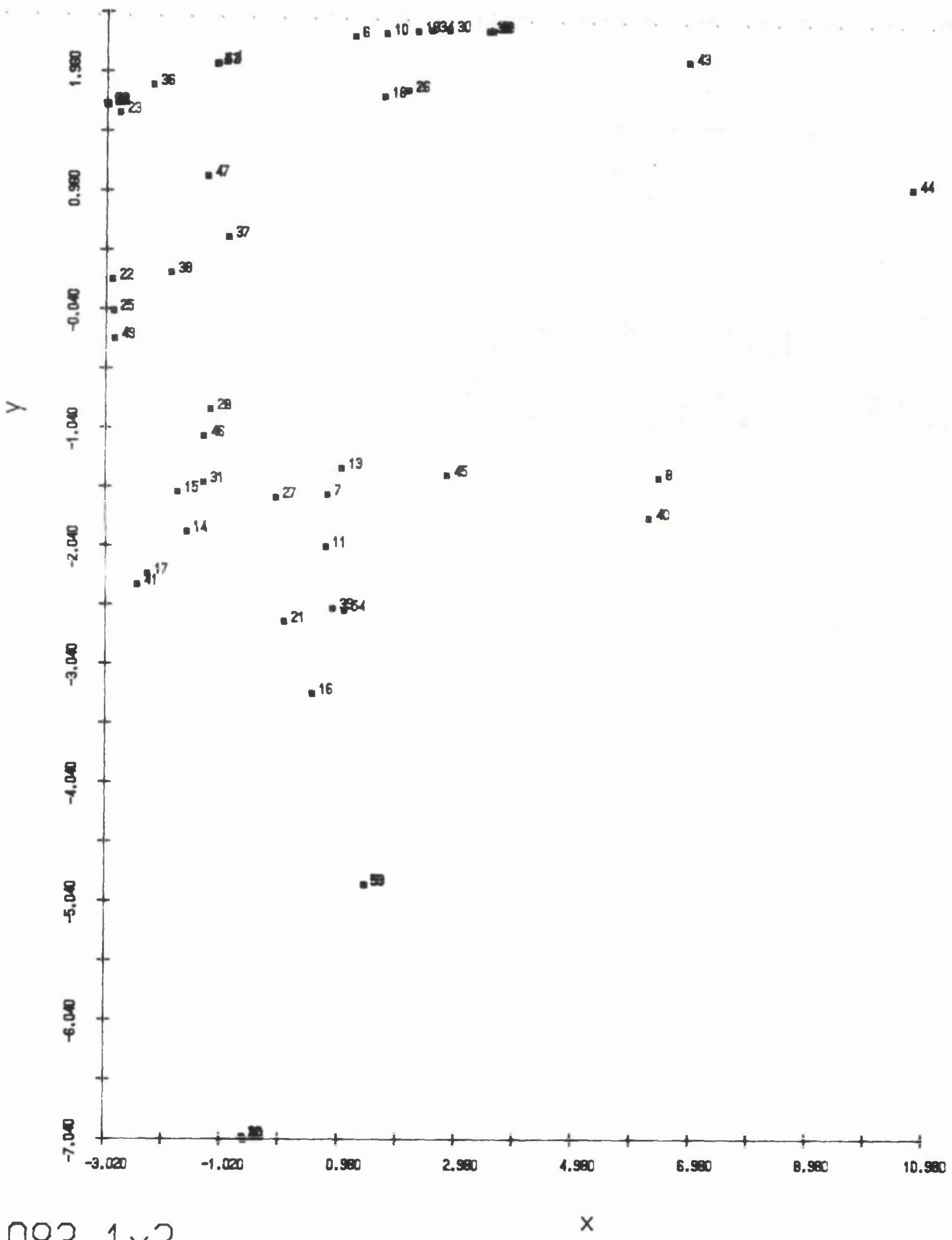
080%S.1x2

Figure 5.2 <u>Plot of Abu Salabikh samples in relation to the first two Principal Components: 6 major cereal categories</u>



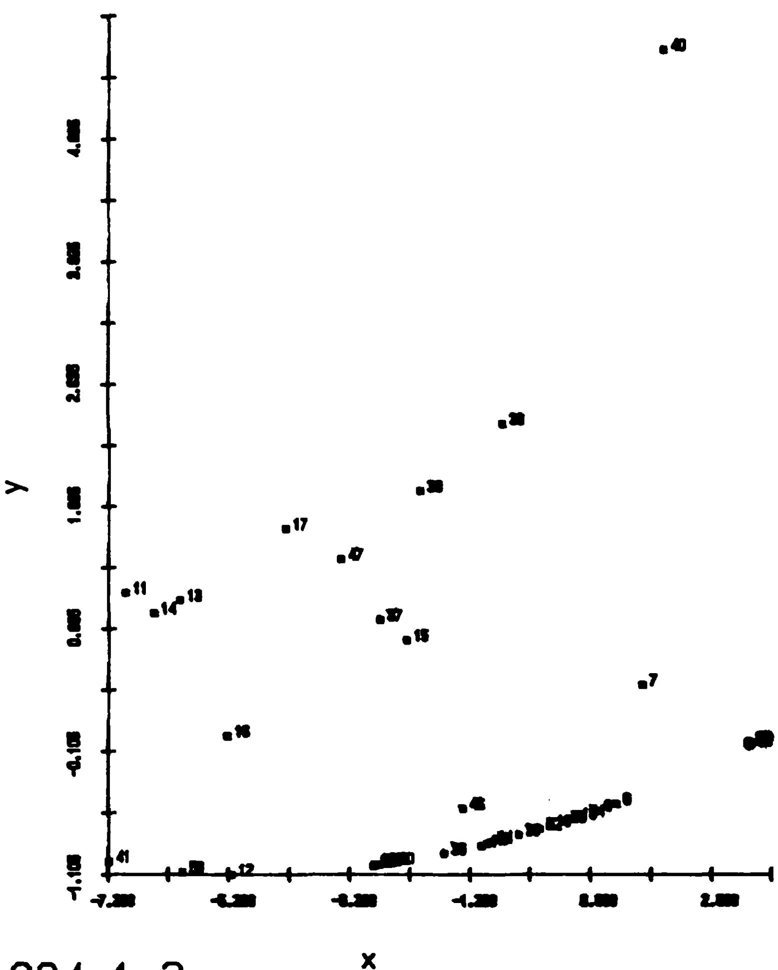
93%S.1x2

Figure 5.3 Plot of Abu Salabikh samples in relation to the first two Principal Components: wheat categories (and cereal culm nodes)



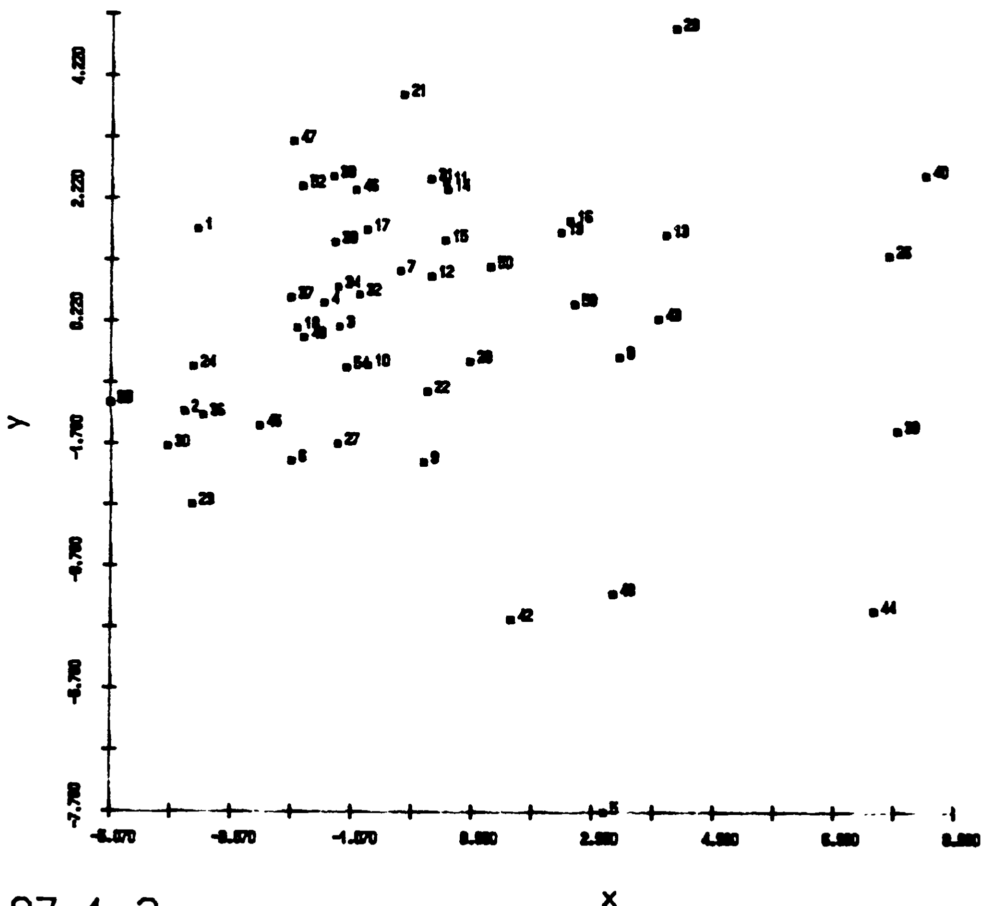
083.1x2

Figure 5.4 <u>Plot of Abu Salabikh samples in relation to the first two Principal Components: barley categories (and cereal culm nodes)</u>



084.1x2

Figure 5.5 Plot of Abu Salabikh samples in relation to the first two Principal Components: weed seed categories



97.1x2

Figure 5.6 Plot of Kolofana samples in relation to the first two Canonical Variates : weed seed categories

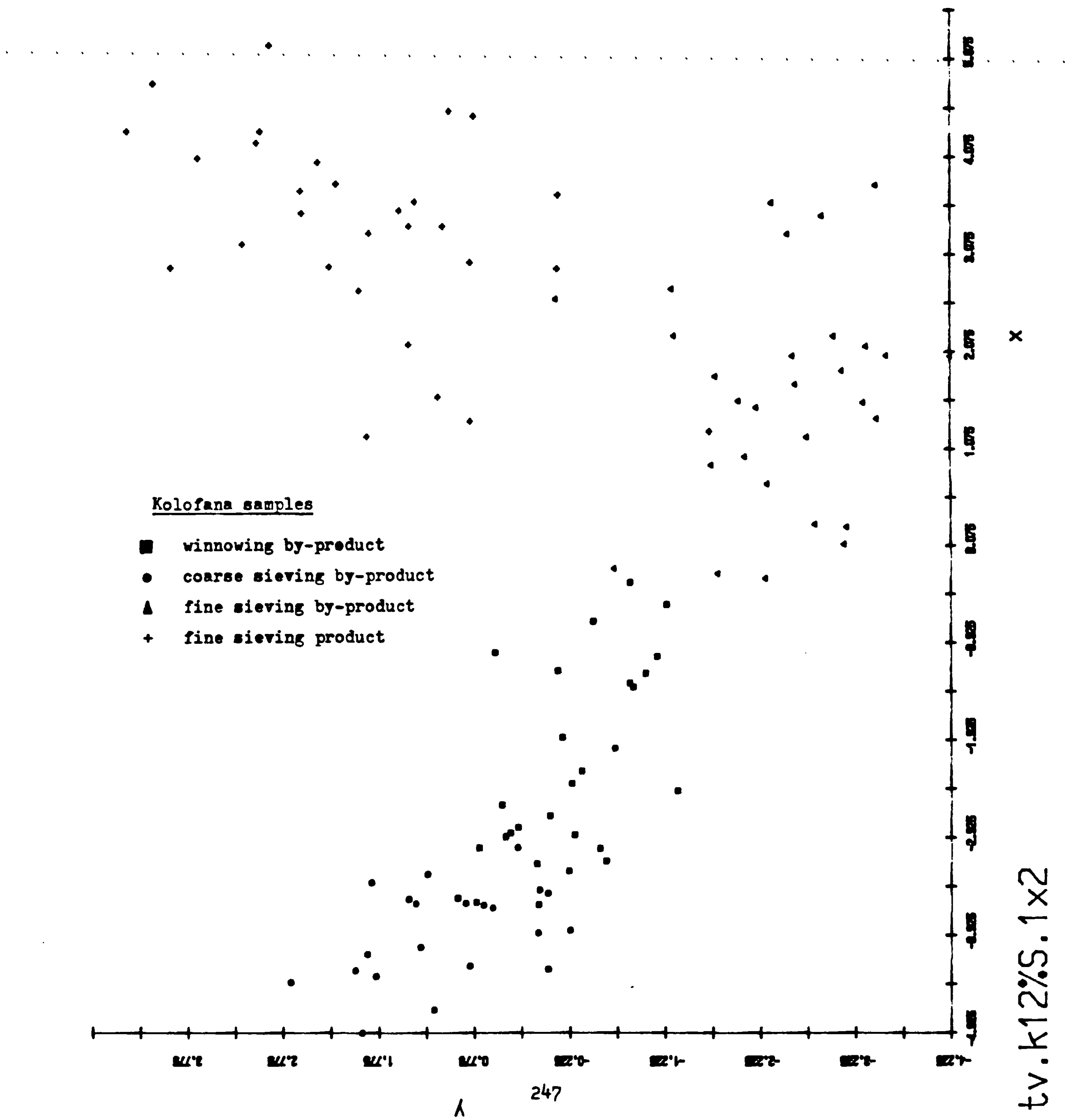
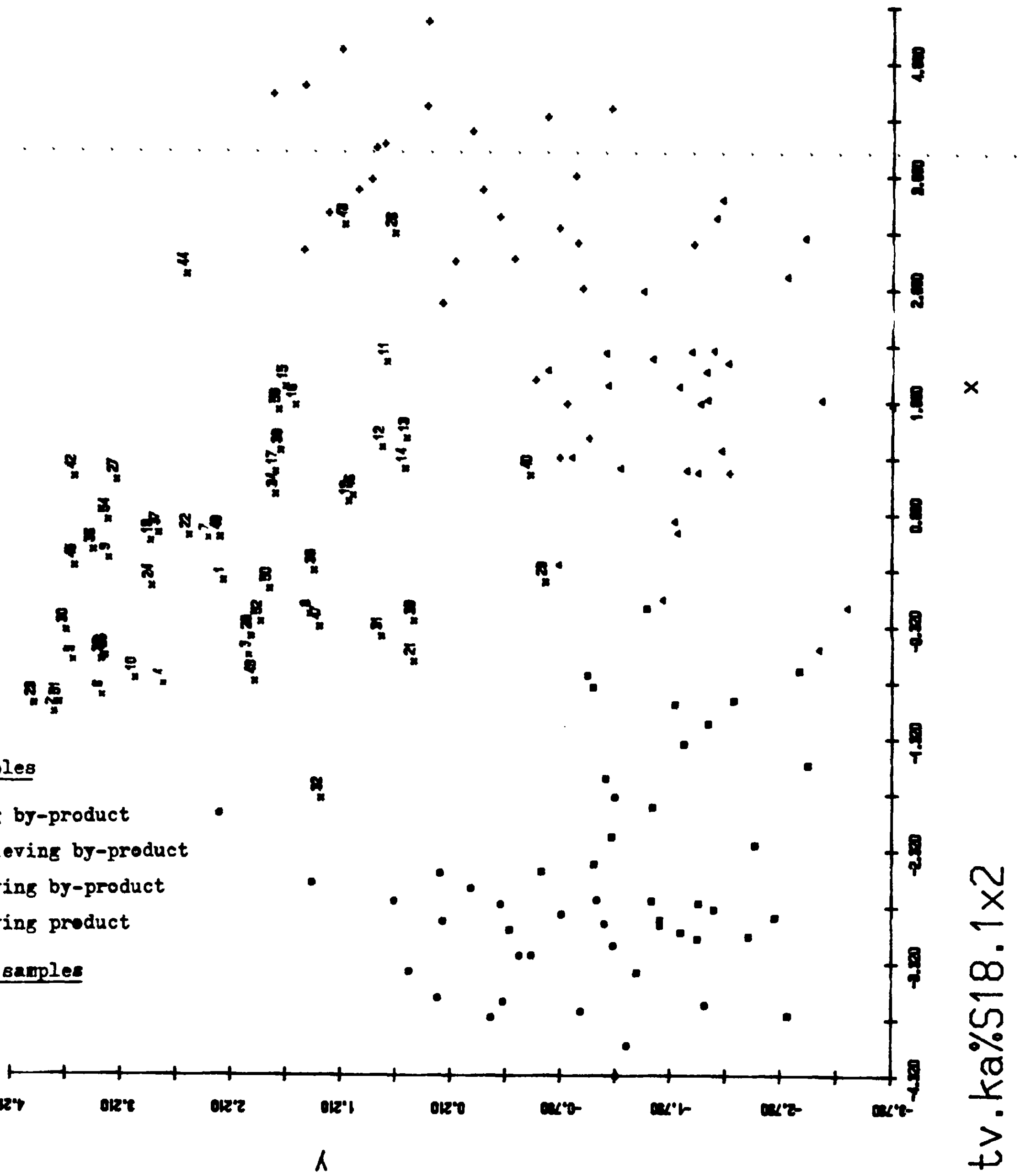


Figure 5.7 Plot of Kolofana and Abu Salabikh samples in relation to the first two Canonical Variates weed seed categories



Kolofana samples

■ winnowing by-product

● coarse sieving by-product

▲ fine sieving by-product

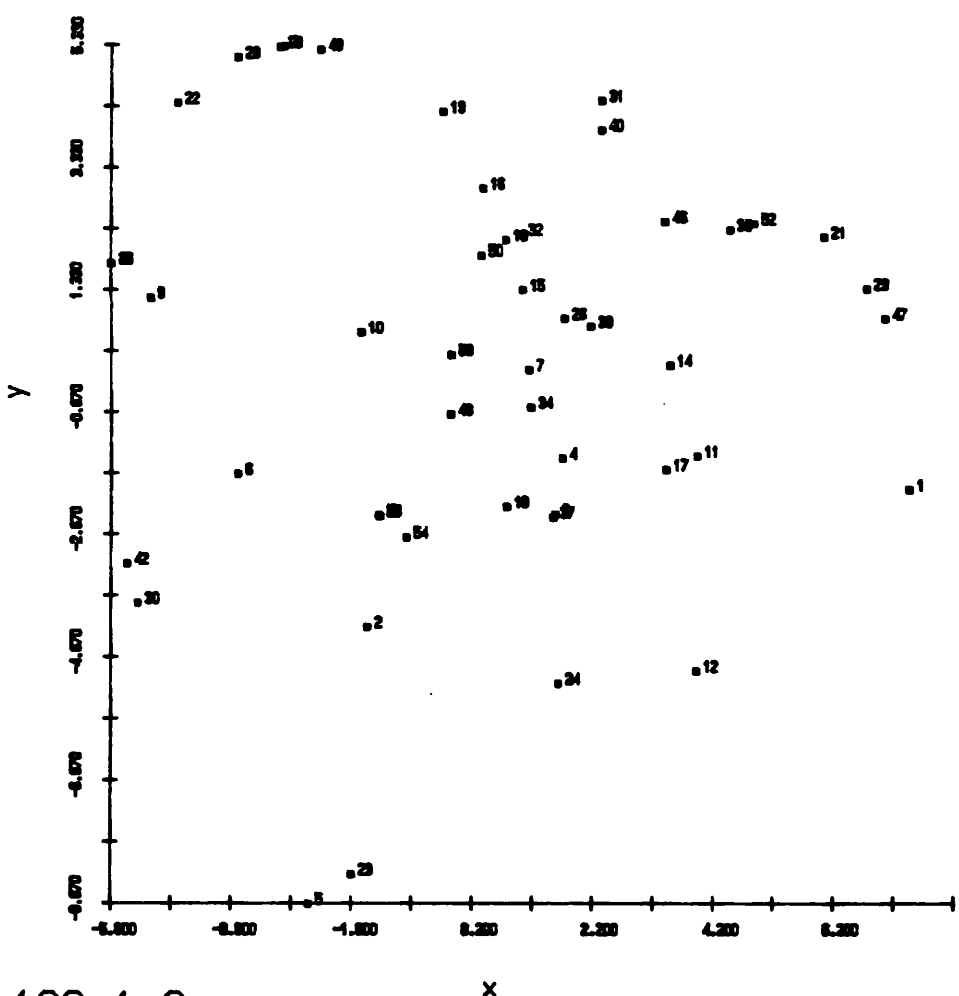
+ fine sieving product

Abu Salabikh samples

x (number)

tv.ka%S18.1x2

Figure 5.8 <u>Plot of Abu Salabikh samples in relation to the first two Principal Components: weed seed categories</u> (minus 'dung' plants)



102.1x2

Figure 5.9 Plot of Kolofana and Abu Salabikh samples in relation to the first two Canonical Variates: weed seed categories

(minus 'dung' plants)

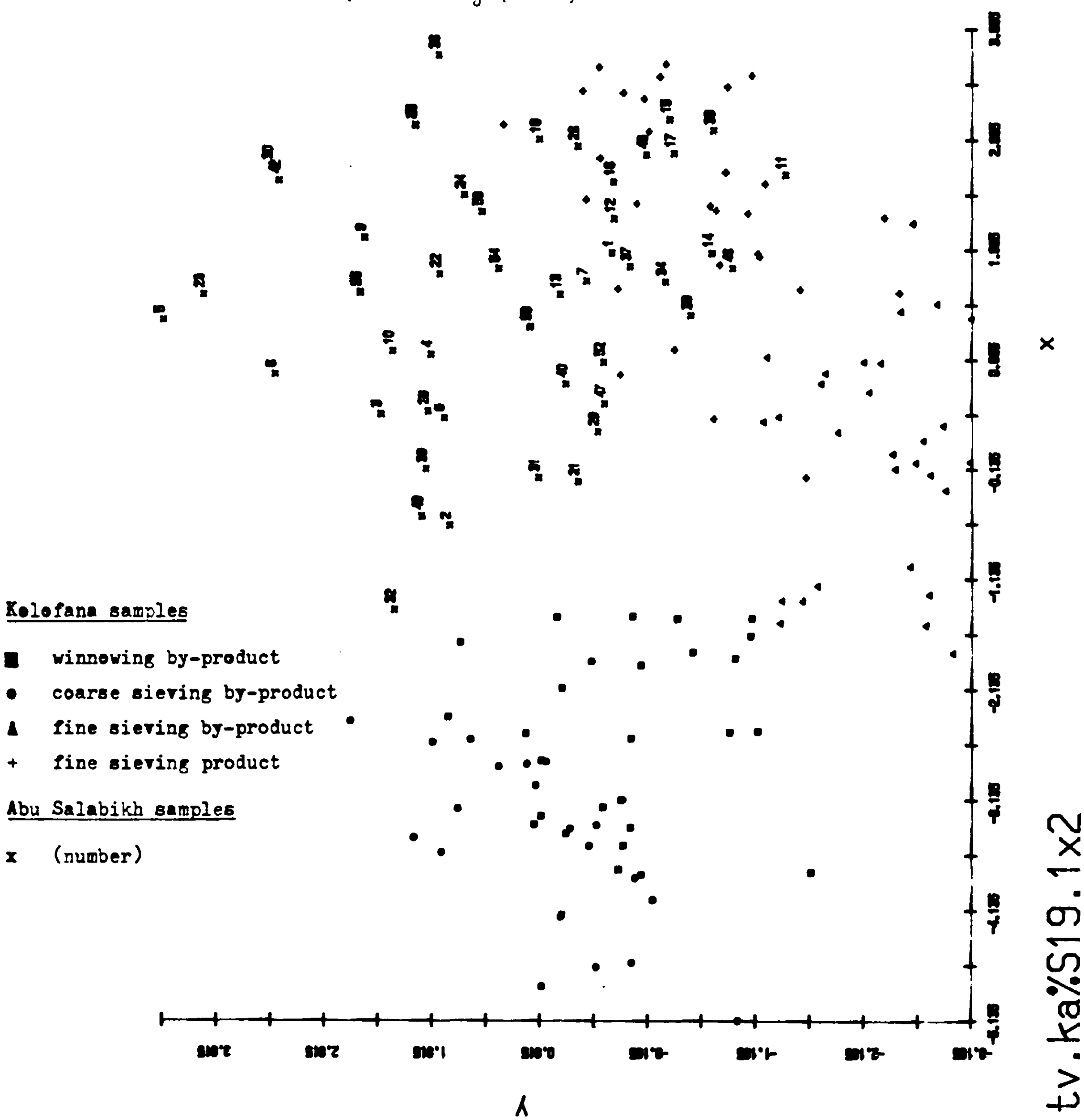
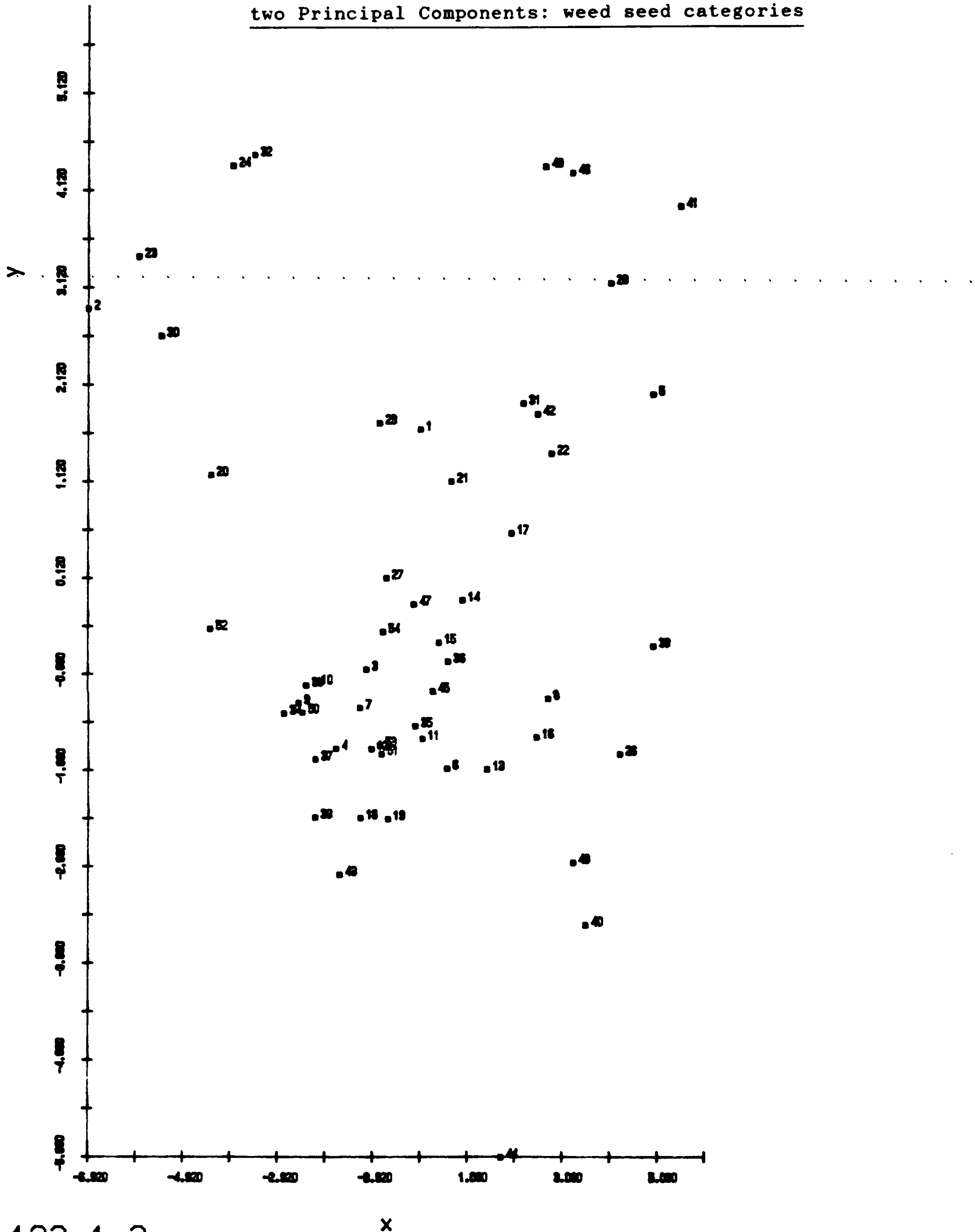
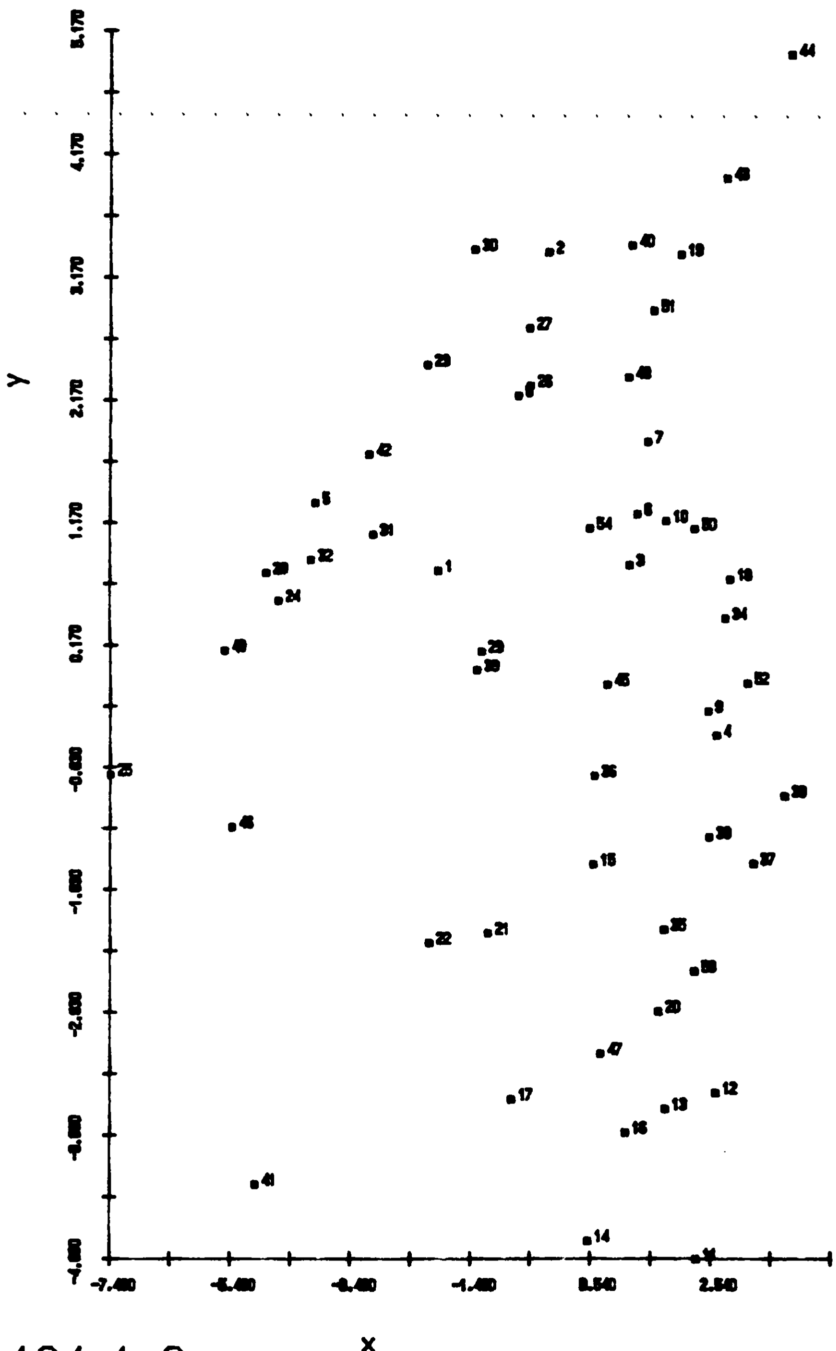


Figure 5.10 Plot of Abu Salabikh samples in relation to the first two Principal Components: weed seed categories



103.1x2

Figure 5.11 Plot of Abu Salabikh samples in relation to the first two Principal Components: weed seed categories (minus 'dung' plants)



104.1x2

Chapter 6 Conclusions

6.1 Introduction

The aims of the dissertation as stated in the first chapter were to investigate the agricultural regime of Lowland Mesopotamia in the late fourth and early third millennia B.C.

The present day agricultural system of the area is generally highly mechanised and of little relevance to traditional practice and thus, presumably, to that of the Sumerian's. A survey of literature dealing with agriculture of the earlier part of this century (Chapters Two & Three) provided information about a traditional agricultural system based on the cultivation of winter staple crops; the area of summer cultivation was less being restricted by a shortage of water. Within this traditional system were types of more intensive cultivation which it was proposed could have been a closer approximation to that employed by the Sumerian's.

The essential issues raised by Chapters Two and Three, relating to Sumerian agriculture, included:

i. the role of livestock in the agricultural system and methods of livestock feeding (cultivated crops, fodder and grazing),

ii. the identity of the crop types and the seasonality of cultivation,

iii. the use of non-domesticated plants,

iv. the intensity of cultivation employed (manuring, weeding, land preparation), the potential role of garden/orchard rather than field cropping and the area of land farmed,

v. the scale of cultivation,

vi. the use and methods of irrigation,

vii. the addition of salt and silt to the soils of lowland Mesopotamia, the life expectancy of the land under irrigation, the types of soil present and the way in which they were exploited,i.e. the inter-relationship of soils and crop types.

6.2 Comparison of Abu Salabikh material with modern ethnological samples

To analyse the ancient samples successfully it was vital to ascertain the origin of the plant component. To this end the Abu Salabikh samples with sufficient quantities of identifiable items for statistical analysis were compared with modern ethnographic samples collected from the Greek island of Kolofana using several computer-based statistical techniques (Chapter 5).

The seeds of wild plants were grouped into weed seed categories according to the method described by Jones, (1983 Chapter 4) based on morphological characteristics which dictate seed behaviour during crop-processing and, therefore, preclude the necessity for the species used in the analyses to be identical.

6.3 Agriculture in Lowland Mesopotamia 3000-2500 B.C.

At Abu Salabikh the predominant type of plant material recovered was concluded to have derived from animal dung. This contrasts with the three categories of evidence for the utilization of plants identified in the archaeological samples from Assiros which comprised;

> "Firstly, product samples, and especially the rich array of products from the phase 9 storerooms, allow a certain range of crops to be identified with considerable confidence. Secondly, the "straw" sample and the contaminated residues provide evidence for the collection of certain other types of plant material. Thirdly, a range of cultigens and useful wild plants, which occur in residues and as minor contaminants of products, could possibly have been grown or cultivated deliberately" Jones (1983 p. 180).

The Abu Salabikh material was identified as being animal dung on the basis of:

i. the presence of large quantities of seeds of wild plants which have markedly different seasonality and habitat preferences from those found in the winter crop fields,

ii. the grain to chaff ratios of the principal crop types.

It was assumed that animal dung was a major source of fuel at the site and thus contributed the bulk of the site's charred plant remains.

Animal dung can contain plants, domesticated or wild, from both crop fields and uncultivated areas, and with this degree of uncertainty as to the origin of the material the Abu Salabikh samples could not be used to directly address the questions concerning crop husbandry, irrigation, salinity and soil type as outlined above but they do reveal details of other agricultural practices occurring at the site.

6.3.1 Plant exploitation at Abu Salabikh

6.3.1.1 Livestock feeding

The Abu Salabikh material gave information concerning the type of food the livestock were feeding on. The cereals, i.e. the grain, chaff and straw component, seem to have made up the bulk of the material fed to the livestock, chiefly in the form of barley grain and glume wheat chaff (glume bases) together with relatively small quantities of barley chaff and wheat grains (glume wheat type). It was suggested that this represented animal feed consisting of an unprocessed or only partly processed barley crop mixed with a by-product of glume wheat processing, e.g. the fine sieving by-product. Combining this information with that in the cuneiform texts it seems likely that at least some of the barley crop was grown expressly for feeding to the livestock, while the wheat was predominantly intended for human consumption (Chapter 5).

It was suggested that the straw in the samples, represented by the straw culm nodes, was probably barley (after consumption by the livestock) though it could also have been incorporated with the animal dung in dung cake manufacture.

The most common of the non-cultivated plants were winter growing small-seeded legumes, grasses (e.g. Lolium sp. Phalaris sp.) and Malva sp., the spring/summer growing Scirpus sp., Suaeda sp. and the summer growing Prosopis farcta. In some samples the frequency of some plants or groups of plants was so great that it might suggest that they were collected, in fruit, and given to the penned animals. In many of the samples, however, the presence of wild plants with different ecological preferences would imply that the animals were grazing in a range of habitat types.

The reports from the analyses of cuneiform texts (Chapter 5), that the penned animals were also taken out to graze on pasture land, seems to confirm this view and means that the accurate establishment of livestock feeding methods from archaeobotanical samples would be very difficult given the mixing of plants from cultivated and wild areas.

Whether the other cultivated plants found in the samples, namely lentil, linseed/flax, sesame, fig, cultivated Lathyrus/Vicia spp., were from animal dung or accidentally charred human food (e.g. during cooking or seeds thrown into the fire) remains a matter of conjecture.

6.3.1.2 Cultivated plants in Lowland Mesopotamia (and the seasonality of cultivation)

Due to the absence of uncontaminated crop product samples little could be said about the relative economic importance of the cultivated plant species and any changes in their presence through time. The apparent mixing of crop product and by-product also precluded any conclusions being reached regarding the manner of crop growing, e.g. single or mixed crops field/garden or orchard cultivation, but some tentative suggestions were made about the seasonality of cultivation.

a. Winter crops.

Einkorn, Emmer, bread wheat, barley, lentil, large-seeded Lathyrus, and flax/linseed have all been found at other sites on the alluvial plain. The lentils recovered at Abu Salabikh are the earliest record of that species in the Lowland but they are present in only a few samples at low frequency.

b. Summer crops.

Sesame, is the second summer growing species to be found in the region in the third millennium and the Abu Salabikh seeds represent the first specimens to be found in charred remains (the other type is Panicum sp. found as an impression in pottery (Helbaek in Jacobsen 1982). The presence of small numbers of sesame seeds in such mixed samples means that the research was not able to determine conclusively that summer cultivation was carried out at Abu Salabikh but the fact that they occur in several samples and are not restricted to storage deposits might well suggest that such cultivation did take place.

If summer cultivation (a matter of some debate, cf. Oates and Oates 1976 p. 117) was confirmed then it suggests that a greater degree of water management existed than had previously been supposed. It would also bring a number of other crops into consideration for cultivation in Lowland Mesopotamia at this time, for which evidence has not yet been found, and which had previously been ruled out on the grounds of their summer seasonality. One of the major, and as yet unresolved, questions concerning summer cultivation is whether any staple crop, e.g. millet or sorghum, was grown in the summer to provide resources additional to the winter staples.

The fruit trees identified are fig, present in 15 samples, and a single occurrence of grape.

6.3.1.3 Non-cultivated plants (potentially utilisable wild plants)

Several of the wild plant species represented by seeds at Abu Salabikh could have been used as foods or medicines, but in most cases the balance of the evidence at the site was not considered sufficient to indicate that these plants were deliberately collected for these purposes (Chapter 4).

There did seem, however, a greater likelihood that the *Cyperus rotundus* tubers present could have been intended for use as a human food even though, as has been mentioned (Section 4.9.2) they could also have been grazed by livestock. Hillman (1989 p. 215) suggests that if tuber or root remains are found together with other more obvious food plants it is probable that they were also being consumed; such a concurrence was seen at Tell ed-Der, where *C.rotundus* tubers were found in a sample with barley grains and some date stones. At Abu Salabikh they were present in samples with several other types of plant material including cereal grain and chaff as well as the seeds of wild plants, but the inclusion of these tubers with cereal remains was not regarded as conclusive proof of their use as human food plants as in this case the cereals were most likely consumed by livestock.

6.3.1.4 The intensity and scale of cultivation

It was proposed that up to this time little consideration had been given to the possibility that the agriculture practised by the Sumerians differed significantly from the extensive winter crop/fallow system (niren-niren) observed in southern Iraq in the earlier part of this century. There may have been differences in the manner or the intensity of cultivation, i.e. the frequency of cultivating, weeding, manuring, etc, (which have developed to meet the particular conditions prevalent on the Lowland Mesopotamian Plain in the recent past) and which affect crop yields, crop types, the likelihood of salinisation, crop water requirements, the area of land cultivable and ultimately the length of time an area could support cultivation.

An assessment of the agricultural limitations of the southern Iraqi land and how farming techniques have evolved to meet them was considered to be of importance in determining the physical and social environment in which the Sumerian's lived.

Poyck's study of the Hillah-Diwaniya area (1962) has shown that within a fairly small area a whole range of farming systems had developed, differing in the relative importance given to livestock and to crops for human consumption, the types of crops grown, the use of fallow and even the amount of land cultivated per person, sowing rates etc. These differences arose in response to the physical environment and the social organisation.

If Poyck's study is to be used to model past practices then the processes involved in their development, and what can be inferred from them about the agricultural potential and limitations of Lowland Mesopotamia, need first to be understood and the distinct systems present recognised and examined separately.

a. The intensity of cultivation.

In this context intensity refers to the level of labour put into crop cultivation, e.g. soil tillage, weeding, manuring, etc. In broad terms the scale or intensity of cultivation has been divided into two categories 'Garden' cultivation (small scale, labour intensive with considerable soil conditioning) and 'Field' cultivation (large scale, less intensive with minimal soil tillage).

The topic of cultivation intensity is of central interest in the study of Sumerian agriculture and although the textual sources provide some information regarding agricultural practices there are still many aspects for which there is no information. Study of the weeds of the Sumerian crop fields would give some insight into how closely farmers obeyed the instructions included in the so called 'Farmer's Almanac' or 'Georgica' (Salonen, 1968 p. 202) regarding weeding, general soil preparation and the seed sowing practice (distance between rows and distance between sowing holes).

Jones (1987 p. 121) has suggested that aspects of crop husbandry, e.g. the frequency of weeding, the level of hoeing, the use of manure as fertilizer, and perhaps even the amount of shade cast by the crops, and thus the relative intensity of cultivation, could be recognised in the weed seed assemblages. Jones (1987 p. 122) has also pointed out that:

> "Intensive garden type cultivation of cereals is quite unlike anything practised in Greece today. Its existence in prehistory would have important implications, therefore, for current debate concerning the part played in the development of hierarchical socio-political systems by control of scarce arable land or of capital items such as plough-teams. Theories which depend on the competition for land or the need for plough animals would not be applicable to societies practising small-scale garden cultivation. It becomes vitally important, then, to know when the change-over from intensive to extensive land-use occurred.".

Though this did not prove possible for the Abu Salabikh material such an evaluation of the Sumerian sites would provide valuable information on the social and political environment during the period of occupation.

b. The area of land under cultivation.
The determination of the amount of land cultivated around each settlement, e.g. "A 'corona ' of irrigation agriculture around each town" (Adams 1981 p. 142 referring to Oppenheim), is more the preserve of archaeological or textual research. The amount of charred material at a site does not supply information regarding the area of land cultivated at any one time, though the size of grain reserves and the methods of crop storage carried out at the site can be assessed from suitable assemblages of material, e.g. the store rooms of Assiros (Jones 1987 p. 119)

6.3.1.5 Irrigation and agriculture

The need of irrigation for the reliable cultivation of the staple winter crops, wheat and barley, in Lowland Mesopotamian agriculture has been generally accepted. Evidence of irrigation works exists in the archaeological and cuneiform records (Bulletin of Sumerian Agriculture 1988), Helbaek (1966) also described the way in which seed size might be affected by irrigation and could thus be used to verify the use of regular irrigation on the crops of the Early Dynastic fields.

None of this would, however, provide a means of assessing the levels of irrigation, whether through time or over the range of cultivated crop fields, which in turn could indicate an increased reliability of water supply. A study of weed species in relation to irrigation levels, carried out in northern Spain (Jones et al. in prep.), has shown that considerable variation existed in the weed floras of fields in areas receiving different levels of irrigation. A less detailed study carried out around the site of Abu

Salabikh found that the weed floras of the fields at the end of the irrigation run differed from those of the fields closer to the beginning, and that these differences were apparently related to the amount of water supplied rather than to soil conditions. This latter study was limited by the amount of time available (and the inexperience of the researcher) and the data cannot be analysed statistically although the information does provide some insight into the relative behaviour of weed species in response to differing levels of irrigation in southern Iraq. The results of this could be compared with archaeobotanical material comprising relatively unmixed samples of crop products or by-products in order to determine the level of irrigation.

6.3.1.6 Soil salinity: the impact of irrigation on Lowland Mesopotamian soils

> "The theory that progressive salinisation of the soil undermined the economy of ancient Sumer and resulted in its ultimate political and cultural eclipse was first adumbrated by Thorkild Jacobsen and Robert McC Adams" (Powell 1985 p. 7).

Powell in a critique that considered the textual, archaeobotanical and modern agricultural basis of this theory concluded that;

> "The critique finds the arguments and evidence as a whole inadequate to sustain the theory. It [the critique] accepts the premise that salinisation of the soil constituted a problem for Sumerian agriculture, but it also calls attention to evidence in the material adduced by SALINITY [*] which suggests that the Sumerians understood this problem and coped with it effectively in time of peace" (Powell 1985 p. 38). [* SALINITY refers to Jacobsen 1982]

The risk of soil salinity reaching a level where the types of crop grown and crop yields are decreased has frequently been discussed in studies of the irrigation agriculture of early civilisations in Mesopotamia. It is a topic on which archaeology is more or less mute, for though excavations may reveal that specific sites and areas were abandoned in the past the artefactual evidence would not necessarily allow inferences to be drawn about the causes of these movements.

The only direct archaeological evidence for this phenomenon would be the presence of drainage systems and it would be very difficult to distinguish archaeologically between drainage and irrigation channels. Records of salinisation in the cuneiform sources, from the late second millennium, were mentioned by Jacobsen (1982) but there is some disagreement as to the interpretation of the terms (Powell 1985 p. 37).

Information produced by archaeobotanical investigations on the degree of salinity of the crop fields would thus be helpful in determining the development of saline conditions in the various regions of Lowland Mesopotamia, in particular how serious a problem salinity was at any point in time. The strong relationship between soil salt content and plants, in particular perennials, seems well established (FAO 1973 chapter 9) with certain 'indicator species' giving relatively unambiguous information of the soil and ground water conditions:

> "In arid zones water and salts are the main environmental factors influencing plant growth. Under natural conditions the vegetation reflects accurately the conditions of soil, water and ground water and of intensity and type of salinity" (p. 258)

6.4 The implications of the Abu Salabikh plant remains for the study of Sumerian agriculture

Two sites were picked out in the first chapter (section 1.4.2) as they had produced samples containing a broad range of plant types, contrasting with the archaeobotanical material reported from the majority of sites in the area. At Tell ed-Der (the 'Archive' samples) and at Tell Yelkhi the plant remains represented stored crop products and their associated weed seeds. They did not contain the categories of material which have here been considered to imply the presence of animal dung contamination and which were so common in the Abu Salabikh samples.

At both sites samples were taken from deposits with conspicuous concentrations of charred material, the volume processed was not large, and yet they yielded a large quantity of identifiable plant remains. Such deposits were rare at Abu Salabikh and plant remains were generally only recovered in adequate numbers by floating comparatively large volumes of soil. This method has generated charred plant remains in sufficient quantity to allow statistical investigation, but the material was of such uncertain origin as a result of pre- and post-depositional mixing, that it precluded meaningful comparison with the material recovered from sites such as Tell ed-Der and Tell Yelkhi.

The dichotomy is emphasised by comparison of the Tell ed-Der 'Archive' samples, rich in cultivated plants, some of which appear to have been imported, with those found in the rooms not associated with that building. Samples from Sounding A contained a few poorly preserved Hordeum fruits and rachis internodes, three Prosopis seeds, one seed of Cyperus sp. plus a few straw/reed stem fragments, some Hordeum awn silica skeletons, and some non-charred remains believed to be Cyperus stems (van Zeist 1984 p. 2-4). This latter group of samples, similar to the Abu Salabikh remains, was taken from ashy layers, inside an oven and a tomb.

The origin and composition of the individual samples is, therefore, of crucial importance in determining their value for studying plant utilisation, crop husbandry and local environmental conditions (i.e. of soil and climate) during the occupation of the site. The sample types described above can be classified as:

i. cleaned crop products with associated weeds (grown locally),

ii. cleaned crop products with associated weeds (imported),

iii. background noise - highly mixed samples containing crops, weeds and wild plants brought together by one product of animal feed.

Each of these groups offers different types of information on the utilisation of plants at the site, provided that it can be isolated from other material, but it is not necessarily possible, or desirable, to use this information to tackle areas outside the immediate remit of the sample type. Thus plant material from animal dung will yield details of livestock feeding, but should not be used to draw up lists of plants for human consumption.
Unless the different types of material can be identified and separated from the crops and their field weeds the samples are rendered useless for the purpose of establishing details of plant utilization. The recovery of plant remains by large-scale flotation from deposits with relatively low concentrations of charred items may produce more material, but this does not necessarily compensate for the 'quality' of the samples for archaeobotanical interpretation. At Abu Salabikh the lack of primary deposits of crop products or animal dung means that even the determination of livestock feeding patterns are difficult.

6.5 Concluding remarks

Jones (1983 Chapter 6) discusses in detail the way in which human agricultural activity can be studied "through a knowledge of weed ecology" and comments that;

> "The potential of archaeological weed studies stretches beyond the identification of soil types, however, as the techniques farmers used for cultivating the soil and the treatments applied to the growing crop all have an effect on the weed species which grow in arable fields. Factors such as time of sowing, fallowing, rotation, irrigation, and

> manuring are all potentially identifiable from archaeological weed assemblages." (Jones 1987 p. 121).

In this dissertation an attempt was made to investigate these factors and thus the details of Sumerian agriculture using recently developed techniques of archaeobotanical analysis. Due to the nature of the samples from Abu Salabikh some of the original research intentions were not attainable, and to some extent, the dissertation became methodological. Though the remains could not be used in the manner described by Jones they did, instead, provide information on another aspect of Sumerian agriculture, namely, the feeding of livestock and the relative importance that livestock had within the agricultural system.

In order to realise the full potential of the archaeobotanical material, data from relevant modern studies of weed floras, such as those carried out at Kolofana (Greece) and Borja (Spain), and of the taphonomy of animal dung, are needed from Near Eastern areas, that are still farmed in an essentially traditional way, for comparison with suitable archaeological weed assemblages. To be of maximum use these studies need to generate a statistically valid database and to have separated and assessed the various factors of soil and climate that have influenced the development of the plant associations.

Thus the analysis of this set of data from lowland Mesopotamia has yielded some significant results, despite the initial problems arising from the confusing make-up of the material, and it has highlighted the fact that archaeobotanical research still has much to contribute to the study of Sumerian agriculture and its impact on the landscape of the Mesopotamian lowlands. It has also emphasised that the recovery of large quantities of plant remains is not the only factor to be considered in devising a successful archaeobotanical sampling strategy.

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composition of the Abu Salabikh archaeological samples used in the analysis (number of items/10 litres of soil floated)

species		1 *1162	2 *1164	3 *1183	4 2139	5 2140	6 2141	7 2433	8 2464
		samples							
Cereal culm nodes		0	0	0	0	0	0	3.33	0
Cereal indet. grain		1.04	0	202.0	12.5	1.67	40.21	10	0
Hordeum sativum internodes		0	0	1	31.25	0	5	13.33	20.83
Hordeum sativum grain		29.8	4.42	17	123.8	4.64	84.68	401.7	270.8
Glume wheat glume bases	*	23.33	2	3.5	17.5	9.17	15.83	96.67	263.3
Glume wheat internodes		0	0	0	0	0	0	0	6.66
Glume wheat spikelet forks		0	0	0	0	0	0	16.66	140.0
Glume wheat upper glume frg		0	0	0	0	0	0	0	116.7
Glume wheat grain		0	0	0	0.94	0.42	3.75	15.83	696.5
Ficus carica seeds		0	0	0	5	0	0	0	3.33
Lens culinaris		0	0	0	0	0	0	3.33	0
Linum usitatissimum		0	0	0	0	0	0	0	0
Sesamum indicum		0	0	0	0	0	0.21	0	80
Arenaria sp.		0	34.67	0	0	0	0	6.67	0
Chenopodium sp.	*	0	0	0	0	0	0	10	0
small Galium sp.		0	1.33	1	0	0	0	0	0
large Hordeum sp.	*	0	0	0.25	0	0	0	13.33	40
small Hordeum sp.	*	0	0	0	0	0	0	0	0
Hordeum spontaneum		0	0	0	5	0	0.83	26.67	10
Lolium rigidum et al		0	1.33	1	5	0	1.67	20	121.7
Malva sp.	*	0	13.33	21	0	1.67	3.33	21.67	0
Phalaris minor		16.67	0	71	5	0	3.33	60	0
Phalaris cf. paradoxa		0	0	0	21.25	0	8.33	3.33	3.33
Rumex cf. conglomeratus		0	0	0	0	0	0	0	0
Triticum boeoticum		0	0	0	0	0	0	10	6.67
large Vicia/Lathyrus sp.		0	4	0	0	0	0.56	0.42	0
Polygonum corrigioloides		0	0	0	10	0	0	40	0
cf. Polygonum (tiny)		3.33	0	0	0	0	0	0	0
Polygonum cf. avicul.	*	0	0	0	0	0	0	0	0
Astragalus sp.		0	9.33	0	5	0	0	0	0
Medicago sp.		0	1.33	0	0	0	0	10	0
Melilotus sp.		3.33	1.33	0	0	0	0	10	0
Melilotus/Trifolium sp.		0	90.67	0	0	0	0	6.66	0
Trifolium sp.		0	90.67	0	25	0	0	0	33.33
Trigonella sp.		0	1.33	0	0	0	0	10	6.67
tiny Trifolium sp.		0	0	0	5	0	5	120	10
Cyperus indet sp.		0	0	0	5	0	0	0	0
Cyperus sp. 1		0	0	1	0	0	0	0	0
Salsola sp.		0	0	0	0	0	0	4.16	3.33
Scirpus cf. maritimus		0	0	1.5	10	2.09	11.67	3.33	41.67
Suaeda sp.		10	0	3	5	0.83	0	0	16.67
Amaranthus sp.		0	33.33	0	0	0	0	0	6.67
Atriplex sp.		0	2.67	0	0	0.83	0	36.67	0
Prosopis farcta sp.		8.07	5.16	0	0	0.05	0	0.21	0
Setaria sp.		0	0	0	0	0	0	0	0
Dung (sheep/goat/cow)		3.33	1.5	0	0	0	0	0	0
Reed culm nodes	*	0	0	0	0	0	0	0	0.42
small Gramineae culm nodes		0	0	0	0	0	0	0	0
Cyperus rotundus tubers		0	0	0	0	0.21	0	0	0

		10	11	12	13	14	15	16	17
	2682	2683	3308	3310	3312	3313	3314	3315	3316
Cere,c	0	0	1.11	0	0.84	1.63	0.62	0.37	1.43
Cere,w	1.48	0.8	0.07	0.32	1.39	5.17	0.77	2.40	0.69
Hsat,r	0.67	0.8	16.3	6.55	10.85	25.47	5.31	16.47	8.14
Hsat,w	1.18	6.01	4.55	4.2	4.98	9.33	12.93	10.83	8.5
Trtc,g	0.25	1.3	3.31	1.29	3.79	14.27	9.64	9.12	12.91
Trtc,r	0	0	0	0	0.11	0	0	0.55	0
Trtc,s	0	0	0.55	0	0.43	1.84	1.06	3.58	1.91
Trtc,u	0	0	0	0	0	0	0	0.73	0
Trtc,w	0	0.4	0.45	0.06	0.65	0.12	0.08	0.89	0
fica,w	0	0	0	0.17	0	0	0.71	0.28	0.24
lecu,w	0	0	0	0	0	0	0	0.11	0
lium,w	0	0	0	0	0	0	0	0	0
sesa,w	2.50	1.33	0	0	0	0.42	0	0.18	0.04
aren,w	0	0	0.11	0	0	0	0	0	0
chen,w	0	0	0.33	0	0	0.11	0	0	0
galm,w	0	0.2	0.22	0.69	0	0.63	1.24	0.55	0.24
hrdl,w	0.71	0.65	0.44	0	1.37	0.09	1.06	0.88	0
hrds,w	0.17	0	0	0	0.84	0.58	0.18	0	0
hspo,w	0	0.4	0.33	0.17	0.16	1	1.59	0.39	0.42
lolm,w	0	1	0	0	0	0	0	0.18	0
malv,w	0.17	0.8	0.11	1.38	0.21	0.47	0.09	0	0.12
pha1,w	1.04	3.2	0.33	1.38	0.84	3.79	2.12	0.46	1.07
pha2,w	0.17	1.2	1.32	0	0	0	0	0	0
rumx,w	0	0	1.66	0.17	0.21	0.95	0.71	0	0.12
tboe,w	0	0	0	0	0	0	0	0	0.01
vila,w	0.17	0	0	0	0	0.01	0.18	0	0
poco,w	0	0	0.44	0.17	0.84	1.53	0.18	0.09	0.83
pol1,w	0	0	0	0	0	0	0	0	0
pol2,w	0	0	0	1.38	0	0	0	0	0
astr,w	0	0	0	0	0	0	0	0.18	0
medc,w	0	0.4	0.66	0	0	0.05	1.06	0.18	0.24
melt,w	0.17	0.4	0	0.69	0	0.21	1.42	0.18	0.83
mltf,w	0.17	0.2	0.44	0.17	0.11	0.42	0	0.09	0.36
trif,w	0	0	0.11	0	0	0.84	1.77	0.09	0.24
trig,w	0	0.2	0	0	0	0.11	0	0	0
ttrf,w	0	0.2	0	0	0	0	0	0	0
cypi,w	0	0	0	0.86	0	0.05	0.35	0	0
cyp1,w	0.17	0.2	0.11	0	0	0	0.35	0	0
sals,w	0.17	0.8	2.13	1.38	0	3.63	0.75	0.09	1.43
scir,w	0	0.08	0.44	0.43	0.11	0.95	1.06	0.28	0
suad,w	0.67	0.2	0.22	0	0	0	0.71	0.09	0.48
amar,w	0	0	0	0	0	0	0	0	0
atrp,w	0	0	0.33	0	0.11	0	0	0	0.24
prfa,w	0.2	0	0	0	0	0.19	0.23	0.23	0.99
seta,w	0	0	0	0	0	0	0	0	0
dung,p	0	0	0	0	0	0.12	0.19	0.07	0.17
reed,c	0	0	0	0	0.84	0.95	0.60	1.83	0.28
sgrm,c	0.18	0	0.33	0	0.53	0.84	0	3.49	0.48
cype,t	0.01	0	0	0.01	0.01	0	0.21	0.14	0.02

	18	19	20	21	22	23	24	25	26
	3317	3323	4314	4315	4704	5381	5412	5413	5431
Cere,c	0.00	0	0	0	0	0	0	0	0
Cere,w	0.07	3.41	0.1	7.71	2.03	6.88	0.63	1.88	0.63
Hsat,r	2.11	0	0.83	7.09	5.5	0	0	0	0
Hsat,w	20.74	7.2	1.67	13.86	10.09	47.5	7.34	3.33	4.58
Trtc,g	2.11	0.81	0.42	20.83	20.5	71.67	51.25	98.33	3.33
Trtc,r	0	0	0	0	0	0	0	0	1.11
Trtc,s	0	0	0.83	6.67	0.5	0	0	3.33	0
Trtc,u	1.05	0	0	0	0	3.33	0	0	0
Trtc,w	0.53	0.32	0	1.88	0	0	0	0	1.11
fica,w	0	0.65	0	0	71	0	0	0	0
lecu,w	0	0	0	0	0	0	0	0	0
lium,w	1.05	0.32	0	0	0	2.5	0	0	0
sesa,w	0	0	0	0	0.06	0.42	0	0	0
aren,w	0	0	0	0	0	0	0	0	0
chen,w	0	0	0	0	0	0	0	0	0
galm,w	0.53	0	0	0	0	0	0	0	0
hrdl,w	0	1.94	0	0	1.5	1.67	1.25	0	0
hrds,w	0	0.97	0	0	0.5	0	0	0	0
hspo,w	1.05	0	0	0	0.13	1.67	1.25	0	1.11
lolm,w	0	0	0	5	0	0	0	0	0
malv,w	0.53	0	0	0	0	430	10	0	0
pha1,w	4.74	2.26	3.33	10	1	13.33	2.5	10	0
pha2,w	0	0	0	0	0	0	0	0	0
rumx,w	0	0	0	0	0	0	0	0	0
tboe,w	0	0	0	0	0	0	0	0	0
vila,w	0.07	0	0	0	0	0	0	0	0
poco,w	0	0	0	0	0	6.67	0	0	0
pol1,w	0	0.65	0	6.67	0	0	2.5	0	1.11
pol2,w	0.53	0	0	0	0	0	5	0	0
astr,w	0	0	0	0	0	193.34	2.5	0	0
medc,w	0.53	0	0	1.67	0	13.34	2.5	0	0
melt,w	0.53	0	0	0	0	0	0	0	0
mltf,w	2.11	0	0	0	0	1060	0	0	0
trif,w	0.53	0	3.33	0	2	73.33	157.5	3.33	0
trig,w	0	0	0	0	0	10	0	0	0
ttrf,w	0	0	0	0	0	0	0	0	0
cypi,w	0	0	0	0	0	0	0	0	0
cyp1,w	0	0.65	10	6.67	0	0	0	0	0
sals,w	0.53	0	0	0	1	0	7.5	0	0
scir,w	1.32	0.97	14.27	95	0	0	0	0	49.16
suad,w	1.58	0	0	0	0	13.33	2.5	3.33	0
amar,w	0	0	0	0	0	6.67	2.50	0	0
atrp,w	0	0	0	0	0	73.33	10.00	0	0
prfa,w	4.46	0	0	0.07	0.60	23.06	0	0	0.05
seta,w	0	0.97	0	0	0	0	0	0	0
dung,p	0	0	0	0	0	2.08	0	0	0.14
reed,c	0.3	0.04	0	0.21	0	0	0.16	0	0
sgrm,c	0	0	0	0	0	0	0	0	0
cype,t	0	0	0.63	0.63	0.25	0	0	0	0.14

	5443	5525	5535	5602	5607	5612	5801	5804	6401
Cere,c	0	0	0	0	0	0	0	0	0
Cere,w	3.06	3.96	3.33	0.83	1.65	1.25	0	2.1	2.44
Hsat,r	0	0	0	0	0	0	1.25	0.97	3
Hsat,w	43.75	26.88	4.37	4.46	10.58	3.33	3.7	4.19	5.31
Trtc,g	24.44	103.33	15	4.85	15.85	35	0.25	0.73	1.5
Trtc,r	0	0	0	0	0	0	0	0	0
Trtc,s	4.44	10	0	0	2.26	0	0	0	0
Trtc,u	0	0	0	0	0	0	0	0	0
Trtc,w	2.22	3.33	0	2.42	0.38	0	0.17	0.32	1
fica,w	0	0	0	0	0.75	0	0	0	2
lecu,w	0	0	0	0	0	0	0	0	0
lium,w	0	0	0	0	0	0	0	0	0
sesa,w	0	0	0	0	0.52	0	0	0.16	0
aren,w	0	0	0	0	0	0	0	0.16	0
chen,w	0	0	0	0	0	0	0	0	0
galm,w	0	0	0	0	0	3.33	0	0	0
hrdl,w	17.220	0	0	0.38	0	0	0.32	0	0
hrds,w	0	0	0	0	1.89	0	0	0.16	0
hspo,w	0	3.33	0	2.42	0	0	0	0.48	0
lolm,w	0	3.33	39.170	0	93.330.17		0	0	0
malv,w	0	0	0	2.42	0	6.67	0	0.32	0
pha1,w	37.783.33		3.33	0	3.77	120	1.87	4.72	0
pha2,w	0	0	0	0	0	0	0.17	0.32	0
rumx,w	0	0	0	0	0	0	0.34	0.16	0
tboe,w	0	0	0	0	0	0	0.17	0	0
vila,w	0	0	0	0.15	0	0	0	0	0
poco,w	0	0	0	0	0	0	0	0.02	0
pol1,w	0	0	106.67	0	0.75	0	0.34	0.32	0
pol2,w	0	0	0	0	0	0	0	0.32	0
astr,w	0	0	0	7.27	0	0	0	0	0
medc,w	0	0	0	0	0	0	0	0	0
melt,w	2.22	0	0	0	0	0	0.51	0.16	1
mltf,w	0	0	3.33	0	0	0	0.13	0	0
trif,w	0	3.33	3.33	71.52	0	0	0	0	2
trig,w	0	0	0	8.48	0	0	0	0	0
ttrf,w	0	0	0	0	0	6.67	0	0	0
cypi,w	0	0	0	0	0	0	0.51	0.48	0
cypl,w	0	0	0	0	0	0	0.34	0.16	0
sals,w	0	3.33	0	0	0	0	0.51	0.16	0
scir,w	1.11	3.33	0	0	0.75	0.42	1.87	1.8	0
suad,w	55.55	3.33	0	1.21	0.38	3.33	0.34	0.48	0
amar,w	0	0	0	0	0	0	0	0	0
atrp,w	11.11	0	0	6.06	0.75	0	0	0	0
prfa,w	0	0.07	0	0.86	0	9.74	0	0	0
seta,w	0	0	0	0	0	0	0	0	0
dung,p	0	0	4.17	0.53	1.84	0	0	0	0.31
reed,c	0	0	0	0	0	0	0	0	0
sgrm,c	0	0	0	0	0	0	0	0	0
cype,t	0	0	0	0	0.05	0.21	0	0	0.13

					40	41	42	43	44
	6413	6416	6417	6801	7090	7228	7406	7918	7920
Cere,c	0	0.2	0.5	0.33	2.65	0	0	0	0
Cere,w	1	0.64	0	1.42	1.25	0	10	0.68	0.08
Hsat,r	1.63	1.58	1.34	0.37	0	0.47	0	0	0
Hsat,w	9	3.19	3.82	2.27	5.83	0.1	23.13	3.07	0.53
Trtc,g	3.5	0.45	1	2.5	1.04	2.08	40	0.24	0
Trtc,r	0	0	0	0	0	0	0	0	0
Trtc,s	0	0	0	0.67	0.42	0.42	0	0	0
Trtc,u	0	0	0	0	0	0	0	0	0
Trtc,w	0.03	0.01	0	0.39	3.56	0	0	0.71	0.21
fica,w	1	0	0	0	0	0	5	0.24	0
lecu,w	0	0	0	0	0	0	1.25	0	0
lium,w	0	0	0.25	0	0	0	0	0	0
sesa,w	0.5	0	0.67	0	0	0	0	0	0
aren,w	0	0.2	0	0	0	0	0	0.47	0
chen,w	0	0	0	0	0	0	0	0.71	0
galm,w	0	0	0.17	0	0	0	0	0	0
hrdl,w		0.18	0.83	0.25	0.31	0	0	4	0
hrds,w	0	0	0	0.5	0.42	0	0	0	0
hspo,w	0.13	0.1	0	0	0	0	7.5	1	0.4
lolm,w		0	0	0	0	0	0	0	0
malv,w	0	0.1	0	0	0	0	5	0.47	0
pha1,w	2	0.7	2.21	0	0	0	5	0.71	0
pha2,w	1.13	0.6	0.33	0	0	0	0	0	0
rumx,w	0	0	0.5	0	0	0	0	0	0
tboe,w	0.13	0	0	0	0	0	0	0	0
vila,w	0	0	0	0	0	0	0	0	0
poco,w	0	0.3	0.33	0	0	0	0	0	0
pol1,w	0	0.1	0	0	0	0	0	1.18	0
pol2,w	0	0	0	0	0.42	0	0	0.71	0
astr,w	0	0	0	0	0	0	0	0	0
medc,w	0	0	0	0	0	0	0	0	0
melt,w	0	1	2	0	0	0	0	0.47	0
mltf,w	0	0	0	0	0	0	0	0	0
trif,w	0	0.1	0	0	0	0	0	0	0
trig,w	0	0	0	0	0	0	0	0	0
ttrf,w	0	0	0	0	0	0	0	0	0
cypi,w	0	0.1	0.17	0	0	0	5	0	0
cyp1,w	0	0	0	0	0	0	0	0	0
sals,w	0.5	0.4	0.33	0	0.42	0	0	0.47	0
scir,w	0.5	0.23	0.25	0.17	0	0.42	5	7.79	1
suad,w	0	0.5	2.33	0.17	0	0	0	5.65	0
amar,w	1	0	0.04	0	0	0	0	0.71	0
atrp,w	0	0	0	0	0	0	0	0	0
prfa,w	0.60	0	0.20	0	0	0	0	0	0.01
seta,w	0	0	0.50	0	0	0	0	0.47	0
dung,p	1.72	0.21	0	0.02	0	0	0	0	0.8
reed,c	0	0.11	0.23	0	0	0	0	0	0.01
sgrm,c	0	0	0.17	0	0	0	0	0	0
cype,t	0	0.24	0.21	0	0	0	0	0.11	0.01

	45	46	47	48	49	50	51	52
	8122	8304	8316	8318	8336	8337	8512	8614
Cere,c	0	0.01	0	0	0	0	0	0
Cere,w	0.45	1.45	0.52	2.44	0	0.59	1.43	1.72
Hsat,r	0.3	1.98	1.38	0	0	0.51	0	1.25
Hsat,w	1.25	6.88	2.14	2.75	1.72	4.46	7.3	8.52
Trtc,g	0.61	86.57	1.32	0.25	8.21	0.68	0.53	0.63
Trtc,r	0	0.25	0	0	0	0	0	0
Trtc,s	0.15	9.18	0	0	0.36	1.36	0	0
Trtc,u	0	3.64	0	0	0	0	0	0
Trtc,w	0.3	1.81	0.03	0	0	0	0.36	0
fica,w	0	0.08	0	0	1.43	0	0	0
lecu,w	0	0.38	0	0	0	0	0	0
lium,w	0	0	0	0	0	0	0	0
sesa,w	0	0.21	0	0	0	0	0.03	1.66
aren,w	0	0	0	0	0	0	0	0
chen,w	0	0	0	0	0	0	0	0
galm,w	0	0	0	0	0	0	0	0
hrdl,w	0.15	0.91	0	0	0	0.79	0	0
hrds,w	0	0.33	0	0	0	1.36	0	1.25
hspo,w	0	0.08	0	0	0.09	0.68	0	0.63
lolm,w	0	0.17	0.11	0	0.36	0	0	0
malv,w	0	0	0	0	0	0.45	0	0
pha1,w	0	6.94	0.92	0	0	0.45	0.85	15
pha2,w	0	0	0	0	0	0	0	1.25
rumx,w	0	1.76	0	0	0	0.45	0	0
tboe,w	0	0	0	0	0	0	0	0
vila,w	0	0.2	0	0	0	0	0	0
poco,w	0	0.41	0.46	0	0	0.45	0	3.75
pol1,w	0	0	0	0	0	0	0	0
pol2,w	0	0.25	0	0	0	0	0	0
astr,w	0	0	0	0	0	0.45	0	0
medc,w	0.31	2.23	0	0	0	0.45	0	1.25
melt,w	0	0.41	0	0	0	0.45	0.43	1.25
mltf,w	0.31	0	0	0	0	0.57	0.21	0
trif,w	0	0	0	0	1.43	1.36	1.06	0
trig,w	0	0	0	0	0	0	0	0
ttrf,w	0.15	0	0.46	0	0	0	0	0
cypi,w	0	0.66	0	0	0	0	0	0
cypl,w	0.15	0	0	0	0	0	1.28	0
sals,w	0	0	0.46	0	0	1.82	0	0
scir,w	0.61	0.99	1.49	0.5	2.14	0.23	0.32	0
suad,w	0	0.33	0.46	0	0	0.45	0	2.5
amar,w	0	0	0	0	0	0	0	0
atrp,w	0	0	0	0	0	0	0	0
prfa,w	0	0.39	0.01	0.01	0.01	0	0	20.13
seta,w	0	0	0	0	0	0	0	0
dung,p	0	0.01	0	0	0.36	0	0.19	0
reed,c	0	0.01	0.01	0	0	0.03	0	0
sgrm,c	0	0	0.11	0	0.36	0	0	0
cype,t	0.1	0.13	0.13	0	5.69	4.34	0	4.14

	53	54
	8667	8670
Cere,c	0	0
Cere,w	1.59	0
Hsat,r	2.51	0.21
Hsat,w	1.09	2.27
Trtc,g	0.78	1.25
Trtc,r	0	0.21
Trtc,s	0.79	0.42
Trtc,u	0	0
Trtc,w	0.16	0.21
fica,w	0	0
lecu,w	0	0
lium,w	0	0
sesa,w	0.04	0
aren,w	0	0.21
chen,w	0	0
galm,w	0	0
hrdl,w	1.09	0.05
hrds,w	0.16	0
hspo,w	0.16	0.42
lolm,w	0	0
malv,w	0.31	0.21
pha1,w	1.1	0.52
pha2,w	0	0
rumx,w	0	0.21
tboe,w	0	0
vila,w	0	0
poco,w	0	0
pol1,w	0	0
pol2,w	0.63	0
astr,w	0	0.21
medc,w	0	0
melt,w	0	0.84
mltf,w	0	0
trif,w	0	0
trig,w	0	0
ttrf,w	0	0
cypi,w	0	0
cypl,w	0	0.21
sals,w	0.31	0.42
scir,w	0.16	0.1
suad,w	0.31	0.21
amar,w	0	0
atrp,w	0	0
prfa,w	0	0
seta,w	0	0
dung,p	0	0
reed,c	0	0
sgrm,c	0	0
cype,t	0	0

all the material referred to is seed unless stated

* Glume wheat = Triticum monococcum/dicoccum
* Chenopodium sp. = Chenopodium cf. album/murale
* large/small Hordeum sp. = Hordeum non sativum/spontaneum sp.
* Malva sp. = Malva cf. nicaensis/aegyptiaca
* Polygonum cf. avicul. = Polygonum cf. aviculare ssp. aequale
* Reed culm nodes = Phalaris/Arundo reed culm nodes

* 1162 = context 3G 81
* 1164 = 5379
* 1183 = 5I 46-47

r = rachis internodes	w = whole grain/seed
c = culm node	s = spikelet forks
g = glume bases	u = upper glume fragments
p = pellet (dung)	t = tuber