An Archaeobotanical Study from the Excavation at Vadnagar for the Field Season 2019-22

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Abstract: *This summary report is based on the results of an archaeobotanical analysis of plant remains retrieved through the flotation method from excavations at Vadnagar, District Mehsana, during the 2019-22 field season. The study has been compiled and combined with a photographic catalogue of ancient plant remains a detailed note on taphonomic preservation aspects, and other supporting writings. Most of the grain samples investigated came from the stratigraphic context of Trench No. A1/33/63 from the lowest layers (water-logged deposits) to layer 1, and from the subsequent periods, which show plant exploitation for over 2000 years.*

Keywords: Archaeo-botanical Findings, Preservation, Grains, Medieval Warm Period, Roman Warm Period, Little Ice Age, Dark Age Cold Period

Introduction

The excavation was carried out over the field season 2019-22 with the specific aim to create an Experiential Museum at the site. The site was selected in the northeastern corner of the fortified town. The excavation encompassed a total area of 3200 square meters, including the long stretch of the fortification wall. Trench A1/33/63 was selected from a total of 24 trenches for the specific purpose of carrying out an archaeo-botanical investigation (Figures 1 and 2). Right from the beginning of the excavation, we gathered soil samples weighing between 200 kg and 300 kg from each 10 cm interval. By performing flotation techniques on these samples, which encompass deposits from

Period I to Period VII. The botanical samples collected by the flotation technique were analysed in the Botany department of the M.S. University Baroda. In addition to excavating this trench, a few botanical specimens were gathered from the lower stratum of Trench A1/33/94. The archaeobotanical samples that have been studied are addressed in the following paragraphs.

Figure 1: Deep cutting at Trench A1/33/63

General Remarks on Preservation Aspects of Materials

The archaeobotanical materials from recent excavations carried out by a team of the Archaeological Survey of India have yielded carbonized and semi-carbonized, phosphatized remains of plants from seven cultural horizons recovered through manual hand-picking as well as dry & wet sieving (floatation technique). The preservation of the material is uniquely interesting. Well-preserved samples are relatively few making final identification a bit challenging and tricky. Most of the samples have been affected by harsh taphonomic processes, some grains are broken into fragments, often appearing un-diagnosable to the botanists or at times even to the specialists. Some grains appear to be battered or pitted, and many grains have partially lost the waxy shining epidermis. Since the upper cuticular surface is eroded, grains appear dull - monotonous as if unimpressively photographed. Some grains show vesicles much of the materials are poorly preserved, fragmented, and abraded. Artefacts of carbonisation are prominently seen giving rise to pseudo-morphological features further adding to the difficulties in correct diagnosis up to species level. Some of the grains show vesicles formed in the exposed kernel, indicating the release of gas while carbonisation was happening. No wonder, morphotypes are more than the actual diagnosable species. This is one of the toughest materials examined by the senior author & hence this special note has been specially added by him. This has been amply compensated by taking into consideration of assemblage approach wherein different gradations of preservations are taken into account for diagnosis rather than individual samples. Thus, a tentative diagnosis of even the broken fragments could be attempted. Basic (raw) data is documented here (Tables 1 and 2).

Table 1: Material remains and its cultural association

Lab Serial No.	**Depth (in cm)**	**Thickness of the layer (in cm)**	**Layer**	**Period**	**The Thickness of the Cultural Deposit (in m)**	**Cultural Association**	**Broad Geological/ Environmental Zonation**
	+ 91 to 0	91 cm	1	VII	1 m	Gaekwad (17^{th}/18^{th} Century to 20^{th} Century CE)	Post-Medieval Warm Period (PWP/LIA- Little Ice Age)
	0-11	11 cm	2	VI	2 m	Sultanate-Mughal, 14^{th} Century to 17^{th} Century CE)	
1	11 to 70	59 cm	3				
2A 2B 2C 2D	70 to 112	42 cm	4				
3A 3B 3C 3D 3E 3F 3G 3H	112 to 201	89 cm	5				

3I							
4A 4B	201 to 249	48 cm	6	V	3.5 m	Solanki (10^{th} Century to 13^{th} Century CE)	Medieval Warm Period (MWP)
5A 5B 5C	249 to 296	47 cm	7				
6A 6B 6C	296 to 347	51 cm	8				
7A 7B 7C 7D	347 to 416	69 cm	9				
8A 8B	416 to 453	37 cm	10				
9A 9B 9C 9D	453 to 510	57 cm	11				
10A 10B	510 to 546	36 cm	12				
11A 11B 11C 11D 11E 11F	546 to 630	84 cm	13	IV	5 m	Post Kshatrapa (5^{th} Century to 9^{th}/10^{th} Century CE)	Dark Age Cold Period (DACP)
12A 12B 12C	630 to 670	40 cm	14				
13A 13B 13C 13D 13E	670 to 740	70 cm	15				
14A 14B 14C	740 to 780	40 cm	16				
15A 15B	780 to	38 cm					

15C	818		17				
16A 16B 16C 16D 16E	818 to 871	91 cm	18				
17A 17B 17C	871 to 923	52 cm	19				
18A 18B 18C 18D 18E	923 to 977	54 cm	20				
19A 19B 19C	977 to 1062	85 cm	21				
20A 20B 20C 20D	1062 to 1136	74 cm	22	III	4.25 m	Kshatrapa (1st Century CE to 4th Century CE)	Roman Warm Period (RWP)
21A	1136 to 1175	39 cm	23				
22A 22B 22C 22D	1175 to 1235	60 cm	24				
23A	1135 to 1272	37 cm	25				
24A 24B 24C 24D	1272 to 1332	60 cm	26				
25A 25B	1332 to 1372	40 cm	27				
26A 26B	1372 to 1411	39 cm	28				
27A 27B	1411 to	42 cm	29				

	1453					
28A 28B 28C	1453 to 1485	32 cm	30			
	1485 to 1556	71 cm	31	II	1.5 m	Rampart (2nd Century BCE to 1st Century CE)
	1556 to 1613	57 cm	32			
	1613 to 1641	28 cm	33			
	1641 to 1668	27 cm	34	I		Pre-Rampart (Pre 2nd Century BCE)
29A 29B	1668 to 1845	Water logging deposit				

Some plant remains (grains) were also obtained from Trench No. A1/33/83, which is associated with Period III-Kshatrapa levels. This is only relevant to a small portion of the entire cultural sequence and therefore it was not given much attention. Additional samples were collected from the Anaj Godown site; however, no grains were found, only a small amount of charcoal fragments. Additionally, a few charcoal fragments and small grains were obtained from samples collected from Ambaghat, specifically from layers corresponding to the upper Periods (Sultanate-Mughal and Gaekwad).

The archaeobotanical findings from Trench No. A1/33/63 and A1/33/94 have been provided with appropriate lab serial numbers for adequate recording. All of these laboratory samples were photographed and presented in the figures (Figure 3-22). The materials have been poorly preserved in many samples and hence a challenging job indeed.

The Table of Ubiquity shows that RWP was congenial for agricultural operations during both summer and winter seasons, Rice was a major and most dominant crop during RWP which continues up to the medieval warm period (MWP). Water could have been made available for the production of rice with artificial tanks around the site. LIA was uncongenial for agricultural crop production because of drought-prone years. There is an overall reduction in counts in general. This indicates the occurrence of drought-prone years and, a decline in agricultural activities.

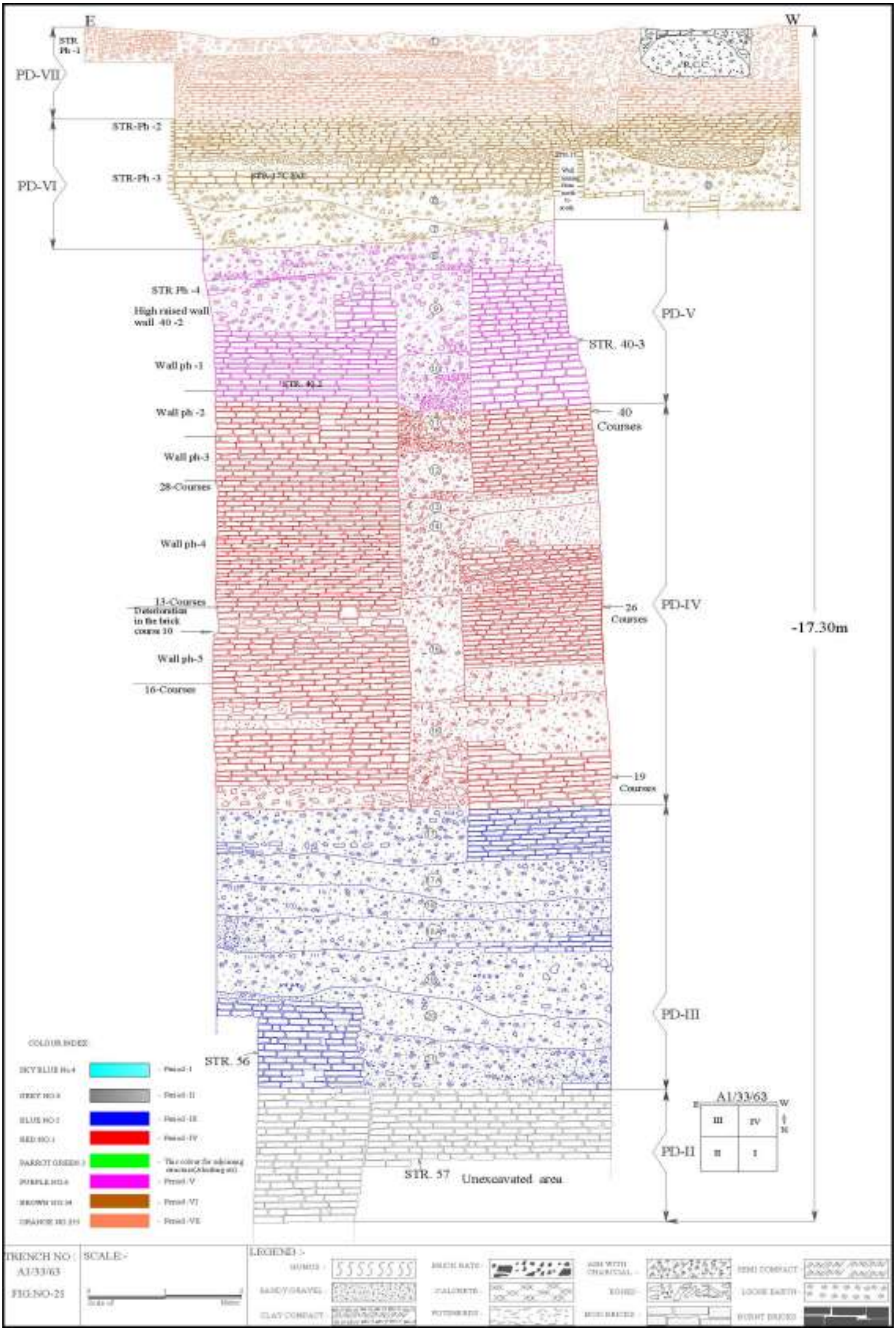


Figure 2: Ambaghat 2019-2022, Section facing north, Trench A1.33.63

Table 2: Ubiquity of various archaeobotanical findings

Phase	**Roman Warm Period**			**Dark Age Cold Period**			**Medieval Warm Period**			**Little Ice Age**			
Total Samples	25			36			20			14			
Taxa	Absolute count	Present in samples	Ubiquity	Absolute count	Present in samples	Ubiquity	Absolute count	Present in samples	Ubiquity	Absolute count	Present in samples	Ubiquity	**Total Grains**
Major Cereals													
Oryza sativa (Rice)	933	24	0.96	127	11	0.3	28	5	0.25	4	4	0.28	1092
Oryza minuta				4	2	0.05	2	1	0.05				6
Hordeum vulgare var hexastichum (Barely)	36	10	0.4	51	8	0.22	76	6	0.3	7	1	0.07	170
Triticum sps	8	2	0.08	2	1	0.02	9	5	0.25				19
Triticum sphaerococcum/ compactum	10	6	0.24	4	4	0.11	1	1	0.05				15
Triticum durum/vulgare							1	1	0.05				1
Triticum durum /aestivum	1	1	0.04										1
Triticum cf diccocum	1	1	0.04				1	1	0.05				2
Minor Cereals/ Millets													
Sorghum sp. (Jowar)				2	1	0.02	3	1	0.05	18	3	0.21	23
Panicum sumatrenses							1	1	0.05				1
Paspalum sps (Kodo millet)	26	1	0.04	1	1	0.02	4	3	0.15				31
Settaria sp.	1	1	0.04	1	1	0.02							2
Eleusine sp. cf corocana (Ragi)	2	2	0.08	3	1	0.02							5
Pulses													
Vigna radiata (Green gram)	129	8	0.32	133	17	0.47	26	6	0.3	19	7	0.5	307

Vigna cf aconitifolius (Moth bean)	1	1	0.04				6	4	0.2	1	1	0.07	8
Vigna cf Mungo (Black gram)				13	2	0.05							13
Vigna cf catjang (Cow pea)				1	1	0.02	2	1	0.05	1	1	0.07	4
Macrotyloma uniflorus (Horse gram)	5	3	0.12				11	4	0.2	1	1	0.07	17
Lablab purpureus (Hyacinth bean)	7	3	0.12	3	1	0.02	12	3	0.15	2	2	0.14	24
Cicer cf arietinum							10	3	0.15	4	2	0.14	14
Pisum sativum (Pea)	1	1	0.04										1
Pisum cf arvense (Pea)	1	1	0.04				1	1	0.05				2
Wild legume cf Vicia	7	1	0.04										7
lentil/lens				1	1	0.02	2	1	0.05				3
Cajanus cf cajan (Pigeon pea)				1	1	0.02	1	1	0.05	1	1	0.07	3
Legume cf Astragalus	1	1	0.04				1	1	0.05				2
Dolichos sp. cf										1	1		1
Oil Seeds													
Carthemus cf	2	2	0.08										2
Gossipium sp.							2	1	0.05				2
Trigonella sp.	1	1	0.04										1
Trees													
Ziziphus mauratiana	11	4	0.16							11	5	0.35	22
Tamarindus indica	2	2	0.08	1	1	0.02							3
Acacia nilotica (L) Del. Ssp. Indica Brenan (Babul)							1	1					1
Tubers													
Cyperus	1	1	0.04							1	1	0.07	2

Tuber												
Idents												
Idents												
Convolvulated indent grain												
Indet Portulacaceae/ Aizoaceae												
Indet legume												
Miscellaneous Type												
Weed seeds												
Hairy *Malvaceae* type												
Internode												
Abelmoschus cf (Wild bhindi)	9	3	0.12	2	2	0.05	3	2	0.1			14
Legume weed												
Boraginaceae weed												
Weeds												
Node internode												
Malvaceae type												
Wild semi-carbonised grass seed												
Grass seed												
Portulacaceae weed												
Bone fragment												
Weeds												
Abutilon sp. cf							1	1	0.05			1
Plantago cf Plantagenaceae							1	1	0.05			1

The agricultural activities are showing the occurrence of major cereals, millets, legumes, trees, and some crop weeds albeit in reduced proportions as compared to previous RWP, DACP and MWP. People might have survived and continued to inhabit because of other commercial activities without a break in occupation.

Overview

Comparative statistical data of various important grains and statistical tables of measurements of individual categories of crop species like Major Cereals, Millets, Pulses, Trees, and Oil crops have been given.

Table 3: Comparative statistical data of various important grains

Lab Sr. No.	Layer	Locus	Lot No.	Depth	Cultural Period	Result
1	3	A1/33/63	6	61 to 70 cm	VI	One-Mung, One-immature Mung? *Zizyphus* tiny fragments. Indet. grain Fragments. One longish well-preserved grain - TP One rice grain poorly preserved and eroded.
2A	4	A1/33/63	7	70 to 81 cm	VI	One millet (*Panicum sp.*) - TP, Indet. grains, roundish flat 3 grains - TP, Insect sample.
2B	4	A1/33/63	8	81 to 93 cm	VI	Barley grain - TP, One Mung - TP, Millet, Insect fragments, Insect material.
2C	4	A1/33/63	9	93 to 102 cm	VI	Grain fragment, one Mung grain, Insect.
2C	4	A1/33/63	11	102 to 118 cm	VI	Millet + Indet. grain + weed - TP, One *Dolichos*?
3A	5	A1/33/63	13	118 to 135 cm	VI	Barley fragment + (Indet. fragment + Mung split - TP)
3B	5	A1/33/63	14	135 to 152 cm	VI	Barley grain + *Phaseolus spp.* + Indet. grain - TP, Grain Fragment + *Zizyphus* fragment
3C	5	A1/33/63	15	152 to 163 cm	VI	All grains - TP
3D	5	A1/33/63	16	163 to 170 cm	VI	Legume + Malvaceae grain - TP, Indet. fragment
3E	5	A1/33/63	19	190 to 200 cm	VI	*Sorghum* + Mung + Indet. grain - TP,

						fragments
3F	5	A1/33/63	17	170 to 177 cm	VI	Suspected jowar (TP), Barley, tiny grass TP, Cajanaus? (TP), *Vigna cf catafan* (TP), urad type? *Dolichos biflorus* type, cotyledon, *Vigna catfan* eroded, Mung cotyledon eroded, broken pulses fragments
3G	5	A1/33/63	18	177 to 190 cm	VI	Well-preserved *Sorghum*, slightly eroded sorghum, grain fragments, tiny millet, Cyperus tuber, internode, rice
3H	5	A1/33/63	20	200 to 213 cm	VI/V	*Vigna Mungo*? (TP), VMP, circular weed (TP), *Dolichos* type?, (Well preserved), lablab, Mung, Zizyphus, Vigna sp. Indet?, legume broken fragment, branch fragment, rice fragments
3I	5	A1/33/63	21	213 to 227 cm	V	Rice, cajanus (TP/TM)
4A	6	A1/33/63	22	227 to 235 cm	V	Rice + *Phaseolus* + grain + Malvaceae + *Phaseolus spp* + Indet. grain + weed + *Dolichos*?? + Node/internode + grass, *Sorghum*??- all TP
4B	6	A1/33/63	23	235 to 253 cm	V	Legume + Legume (Tiny) - TP, Rice fragment + Wheat - TP, Malvaceae (Cotton) - TP, Malvaceae - TP, Lentil + Horse gram grain -

						TP, *Phaseolus spp.* - TP, Rice, Ant, Isabgol? - TP + grass - TP, fragment
5A	7	A1/33/63	25	253 - 270 cm	V	Gram + Horse gram grain + Internode-node + wheat fragment + Sorghum (3) + *Phaseolus spp.* - All TP, *Zizyphus* fragments, Rice fragment.
5B	7	A1/33/63	27	270 to 288 cm	V	Grass (TM), Horse gram grain (TP, TM), Barley? (TP), Wheat? (TP), Horse gram grain (TP, TM), Indet. grain (TP), Indent legume (TP), Rice fragment, *Phaseolus* (TP, TM), Fragments.
5C	7	A1/33/63	29	288 to 298 cm	V	*Zizyphus* (TP, TM), horse gram grain (TP, TM), Malvaceae, *Sorghum*, Rice, *Phaseolus* - (TP, TM), Millet (TP), gram, stem fragment
6A	8	A1/33/63	31	298 to 311 cm	V	Broken grain, Mung TP, *Zizyphus* fragments, Rice + *Acaccia*? (TP, TM), Indet. fragment (TP), Indet. (TP, TM), *Sorghum*? poorly preserved (TP)
6B	8	A1/33/63	33	311 to 327 cm	V	Broken fragment, rice, *Zizyphus, Phaseolus* cotyledon (TP, TM), Indet. Brassicaceae? (TP, TM)

6C	8	A1/33/63	34	327 to 344 cm	V	Indent + *Phaseolus* (TP), broken rice, indent (TP), Indet. (TP), horse gram grain? Millet *Panicum*? (TP), *Phaseolus* (Mung) TP, rice intact (TP), indeterminate weed (TP), tuber (TP), broken fragment, *Zizyphus* fragment, barley broken (TP).
7A	9	A1/33/63	36	344 to 358 cm	V	Grass weed (TP), Broken fragment, Barley (TP), insect, horse gram grain (TP, TM), rice (TM), tuber (TP), *Phaseolus* (TP-optional), *Panicum* type (TP)
7B	9	A1/33/63	37	358 to 370 cm	V	Mung, broken grain cotyledon (TP), *Panicum*, (millet) TP, poorly preserved barley (TP), barley intact (TP, TM), Kodo millet (TP), broken fragment lablab beans (TP), wheat? (TP), rice intact
7C	9	A1/33/63	38	370 to 390 cm	V	Barley intact (TP), lablab (TP), Kodo millet (TP), barley broken, Indet. imp, broken fragment, Mung (TP), rice, *Panicum* type (TP)
7D	9	A1/33/63	41	358 to 394 cm	V	*Vigna*? (TP), barley intact (TP), Mung (TP), wheat (TP), Kodo millet (TP), Indet. (TP), *Zizyphus*, plant product (TP),

						broken barley (TP), lablab (TP), rice intact
8A	10	A1/33/63	40	430 to 444 cm	V	Suspected coprolite, lablab (TP), broken barley grain fragment (TP), wheat (TP), barley intact (TP), Indet. (TP)
8B	10	A1/33/63	42	394 to 444 cm	V	Lablab (TP), rice intact, Mung cotyledon (TP), tiny millet (TP), indeterminate product (TP), Broken Barley
9A	11	A1/33/63	43	444 to 468 cm	V	Indet., Barley (TP), Wheat (TP), Mung (TP), Feacalremnent (TP), Tiny grass seed (TP)
9B	11	A1/33/63	44	468 to 480 cm	V	Mung, Barley, Indents
9C	11	A1/33/63	45	480 to 495 cm	V	Lablab, Barley, Rice, Mung, *Zizyphus* Indet. (TP)
9D	11	A1/33/63	46	495 to 510 cm	V	Indet. (TP), *Zizyphus* (Seed) TP, Rice broken, Malvaceae (TP)
10A	12	A1/33/63	47	510 to 530 cm	V	Internode node (TP), Indet. (TP)
10B	12	A1/33/63	48	530 to 550 cm	V	Internode (TP), Rice (TP), Mung (TP), *Zizyphus*
11A	13	A1/33/63	49	550 to 555 cm	IV	Barley (TP/TM), Indet.
11B	13	A1/33/63	52	552 to 585 cm	IV	Malvaceae (TP)? Rice (TM), Mung (TP), Bean? (TP), *Zizyphus* (Broken), grass seed
11C	13	A1/33/63	51	555 to 585 cm	IV	*Zizyphus*, Lenticel, Mung, Wild pulses (TP), Indet, Rice

11D	13	A1/33/63	53	585 to 597 cm	IV	Semi carbonious Indent (TP), Indet, Barley, *Zizyphus*, Malvaceae, Rice
11E	13	A1/33/63	54	597 to 610 cm	IV	Mung, Lablab, *Zizyphus*, Rice, Chenopodiaceae (Weed) (TP/TM), wild grass type
11F	13	A1/33/63	55	610 to 624 cm	IV	*Zizyphus*, Rice (TP), Indet.
12A	14	A1/33/63	56	624 to 636 cm	IV	*Zizyphus*, Rice - TM
12B	14	A1/33/63	57	636 to 648 cm	IV	*Zizyphus* (?)
12C	14	A1/33/63	58	648 to 662 cm	IV	--
13A	15	A1/33/63	59	662 to 680 cm	IV	Indet. (TP), poorly preserved grass, Indet. pulse/Mung
13B	15	A1/33/63	60	680to 695 cm	IV	*Zizyphus* seed, Rice TM
13C	15	A1/33/63	61	695 to707 cm	IV	Wheat TP, Malvaceae (TP), *Zizyphus*, Indet. pulse (TP), Rice TM
13D	15	A1/33/63	62	707 to724 cm	IV	Rice TM, Mung (?), Indet. (TP/TM) *Zizyphus*
13E	15	A1/33/63	63	724 to734 cm	IV	Malvaceae, Indet.
14A	16	A1/33/63	64	734 to 750 cm	IV	Rice, Mung bean, *Zizyphus*
14B	16	A1/33/63	67	750 to 762 cm	IV	Rice, Mung (TM), Horse gram (TP), Indet.
14C	16	A1/33/63	68	762 to 778 cm	IV	Legume? Kidney bean?? (TP/TM), Rice TM, Indet., Mung bean
15A	17	A1/33/63	69	778 to 790 cm	IV	Mung (TP/TM), Broken cotyledon, *Zizyphus*, Broken Barley, Rice (TM/TP)
15B	17	A1/33/63	70	790 to 803 cm	IV	Rice (TP/TM), Mung (TM/TP), Wheat TP/TM, Indet.

15C	17	A1/33/63	71	803 to 815 cm	IV	Mung TP/TM, Rice TP/TM, Indet.
16A	18	A1/33/63	72	815 to 826 cm	IV	Rice TP/TM, Wheat TP/TM, Malvaceae, Broken Barley, *Zizyphus*, Mung TM/TP
16B	18	A1/33/63	73	826 to 836 cm	IV	Indet. TP/TM, *Zizyphus*, Mung TP/TM, Rice TP/TM
16C	18	A1/33/63	74	836 to 850 cm	IV	Wheat TP/TM, Broken Barley, *Zizyphus* seed TP, *Zizyphus*, Rice TP/TM, Mung TP/TM
16D	18	A1/33/63	75	850 to 863 cm	IV	Barley TP/TM, Rice TP/TM, Mung TP/TM, Indet. TP, *Zizyphus* frag.
16E	18	A1/33/63	76	863 to 875 cm	IV	Mung, Indent
17A	19	A1/33/63	77	875 to 883 cm	IV	*Zizyphus*, Indet., Mung (TP/TM)
17B	19	A1/33/63	79	895 to 906 cm	IV	Indeterminant food? (TP), Barley, Indet., Indet. (TP), Mung, Rice, *Zizyphus*
17C	19	A1/33/63	80	906 to 917 cm	IV	Wheat TP, Barley, Indet. (TP), Mung (TP/TM), Rice (TP/TM), Fragment
18A	20	A1/33/63	81	917 to 931 cm	IV	Rice, Barley, Indet. (TP), Zizyphus
18B	20	A1/33/63	82	931 to 945 cm	IV	Rice, Mung, Barley, Indet., *Zizyphus*
18C	20	A1/33/63	83	946 to 956 cm	IV	Indet. TP, Indet. TP, Barley, Mung, (TP/TM), Rice
18D	20	A1/33/63	86	956 to 963 cm	IV	*Zizyphus* (TP/TM), Jowar (TP), Ragi? (TP), Barley, Mung, Wheat (TP), Millets? TP, Indet., Rice
18E	20	A1/33/63	87	963 to 980 cm	IV	Indet., Mung, Barley

19A	21	A1/33/63	88	980 to 991 cm	IV	*Phaseolus aconitifolius*? (TP), Rice, Mung (TP/TM), Indet. (TP), Barley (TP/TM), Indet. (TP)
19B	21	A1/33/63	89	991 to 1010 cm	IV	Spaerococcoid Wheat (TP/TM), Rice (TP/TM), Broken Barley, *Dolichos* (TP), animal skeleton (TP), Indet. (TP), Mung
19C	21	A1/33/63	90	1010 to 1022 cm	IV	*Vigna* (cajan) TP, Rice (TP/TM), Mung type (TP/TM), *Zizyphus*, Barley, Indet., Indet. (TP/TM), Wheat (TP/TM)
20A	22	A1/33/63	106	1057 to 1075 cm	IV/III	*Dolichos* (TP), Indent (TP), Zizyphus, Mung, Rice (TP/TM), Barley, Indet. (TP)
20B	22	A1/33/63	107	1075 to 1088 cm	III	*Carthamus*? (TP) OR Malvaceae type, *Astragalus* (TP), Barley (TP), Rice (TP), Mung, Methi? (TP), *Dolichos*, Indet.
20C	22	A1/33/63	108	1088 to 1100 cm	III	Wild legume (TP), *Zizyphus* seed (TP), *Zizyphus*, Mung, Rice, Malvaceae type (TP), split cotyledon
20D	22	A1/33/63	109	1100 to 1125 cm	III	Rice (TP/TM), Barley (TP/TM), Mung, *Zizyphus* (TP/TM), Malvaceae (TP), Indet. (TP)
21A	23	A1/33/63	110	1125 to 1153 cm	III	Methi? (TP), Suspected jowar? (TP), wild legume (TP), wild grass (TP), Malvaceae (TP), Indet. cotyledon, Mung, Rice

22A	24	A1/33/63	111	1153 to 1202 cm	III	Tamarind? Malvaceae type, *Dolichos*? (TP), Barley, *Zizyphus* wild seed (vivia?) TP, Indet., Rice (TP), Mung (TP)
22B	24	A1/33/63	112	1202 to 1217 cm	III	Indet., weed (TP), Mung, rice, *Zizyphus* (TP), Malvaceae, lablab, *Phaseolus* type (TP), wild legume weed (TP), circular margin weed (TP), Intermediates.
22C	24	A1/33/63	116	1217 to 1227 cm	III	Rice, *Zizyphus*, Barley, Mung, wheat (TP), Malvaceae, wild weed (TP)
22D	24	A1/33/63	117	1227 to 1239 cm	III	Tiny wheat (TP/TM). Rice, *Zizyphus*, *Phaseolus*, Mung, tiny grass seed, Indet.
23A	25	A1/33/63	118	1239 to 1261 cm	III	Tiny grass (TP), Barley, Indet. weed, lablab bean TM, leguminous cotyledon, *Zizyphus* fragments (TP/TM), rice TM, Mung types TM
24A	26	A1/33/63	119	1261 to 1285 cm	III	Barley, rice, Mung type, wheat (Spaerococcoid) (TP/TM), lablab, horse gram? Indet., broken fragments
24B	26	A1/33/63	120	1285 to 1300 cm	III	Zizyphus, Indet. cereals, rice, Malvaceae type, lablab bean, Mung type
24C	26	A1/33/63	126	1300 to 1315 cm	III	Wheat (TP/TM), Barley (tm), Mung

						type, TM, Malvaceae type (TP), pea (*Pisum*?) *Zizyphus* TM, rice TM, Indet., Indet. cotyledon
24D	26	A1/33/63	127	1315 to 1332 cm	III	*Zizyphus*, rice (TM), Barley, Mung type, wheat (Spaerococcoid) (TP/TM), *Carthemus*? (TP)
25A	27	A1/33/63	128	1332 to 1347 cm	III	Rice TM, Mung TM, Wheat (hexaploid), indent legume, oil seed? tiny fragments
25B	27	A1/33/63	124	1347 to 1362 cm	III	Mung type, Indet., wheat (TP/TM), rice (TP/TM), *Zizyphus* (TP/TM)
26A	28	A1/33/63	131	1369 to 1388 cm	III	*Zizyphus*, wheat fragment, Indet. (TP), Indet. legume (TP), Oil seed? Ragi? weed seed, Indet. *Dolichos biflorus* type? Malvaceae type (oil seed type), *Mung*, rice (TM) rice with husk (TP)
26B	28	A1/33/63	132	1388 to 1412 cm	III	Indet. fragment, *Zizyphus* (TP, epi., mesocarp), Malvaceae type, rice (TP/TM), indet. pulse, weed grass, wheat, barley, Indet., Mung
27A	29	A1/33/63	133	1412 to 1429 cm	III	Mung, rice (TP), Indet. wheat, *Zizyphus*
27B	29	A1/33/63	134	1429 to 1447 cm	III	Tubers (TP) (TM), convulated wheat (TP), *Zizyphus*, Indet. fragment, rice (empty) (TP), Mung TM, rice

						TM
28A	30	A1/33/63	135	1447 to 1460 cm	III	Tiny weed (TP), convulated grain, barley, legume weed seed (TP), Malvaceae type? Indet. TP, pea? Mung type, rice, Indet.
28B	30	A1/33/63	136	1460 to 1480 cm	III	Malvaceae, eroded barley, well-preserved Mung, eroded Mung, rice, leguminous weeds
28C	30	A1/33/63	137	1480 to 1484 cm	III	*Zizyphus*, rice, Mung, eroded Indets.
The sample was not retrieved from Layers 31 to 34						
29A	35	A1/33/63	145	1740 to 1782 cm	I	Rice TM, Indet., uncarbonized, barley, tamarind? (TP), *Zizyphus*, rice fragments, Millets (TP) (Suspected Paspalum, Panicum, suspected cotton (TP), Mung, fragments
29B	35	A1/33/63	147	1820 to 1845 cm	I	*Sisyphus* well preserved (TP0, *Zizyphus* fragments, Indet. seed (TP/TM), gram? cotyledon, Indet. (TP), legume cotyledon fragments, barley fragments, Mung, rice, uncarbon-ised millets, uncarbo-nised, Indet. (TP), Indet. (TP), insect, tiny grass. Broken millet type, Panicum type, millet, Indet. weed (TP), fragment, Ragi??, Setaria type

Abbreviations: *Indet–Indeterminate: Cf–Comparable form: Frags–Fragments: Sp.–Species not decided: Sps. –More than one Species*

Figure 3: Archaeobotanical remains from Vadnagar

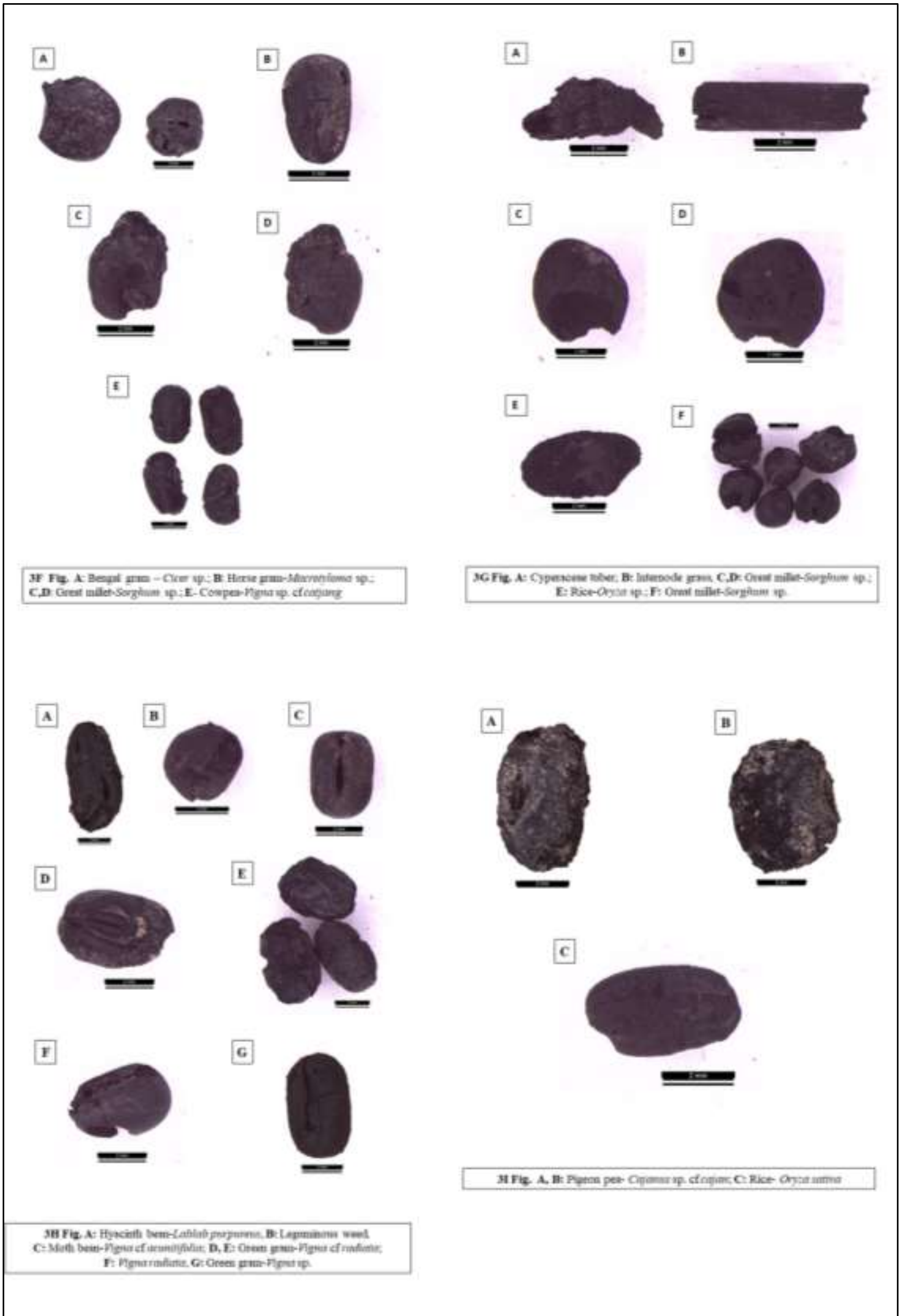


Figure 4: Archaeobotanical remains from Vadnagar

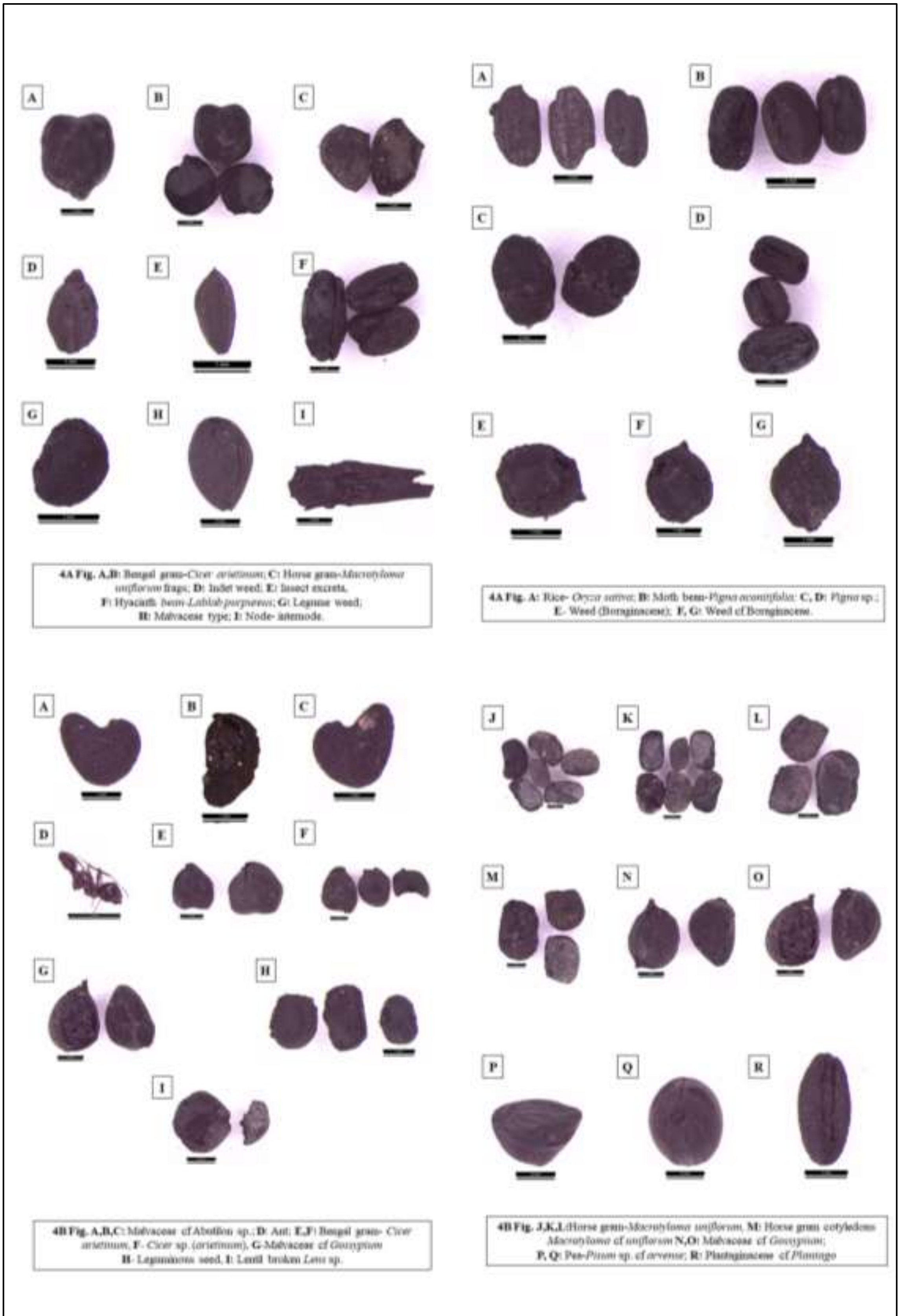


Figure 5: Archaeobotanical remains from Vadnagar

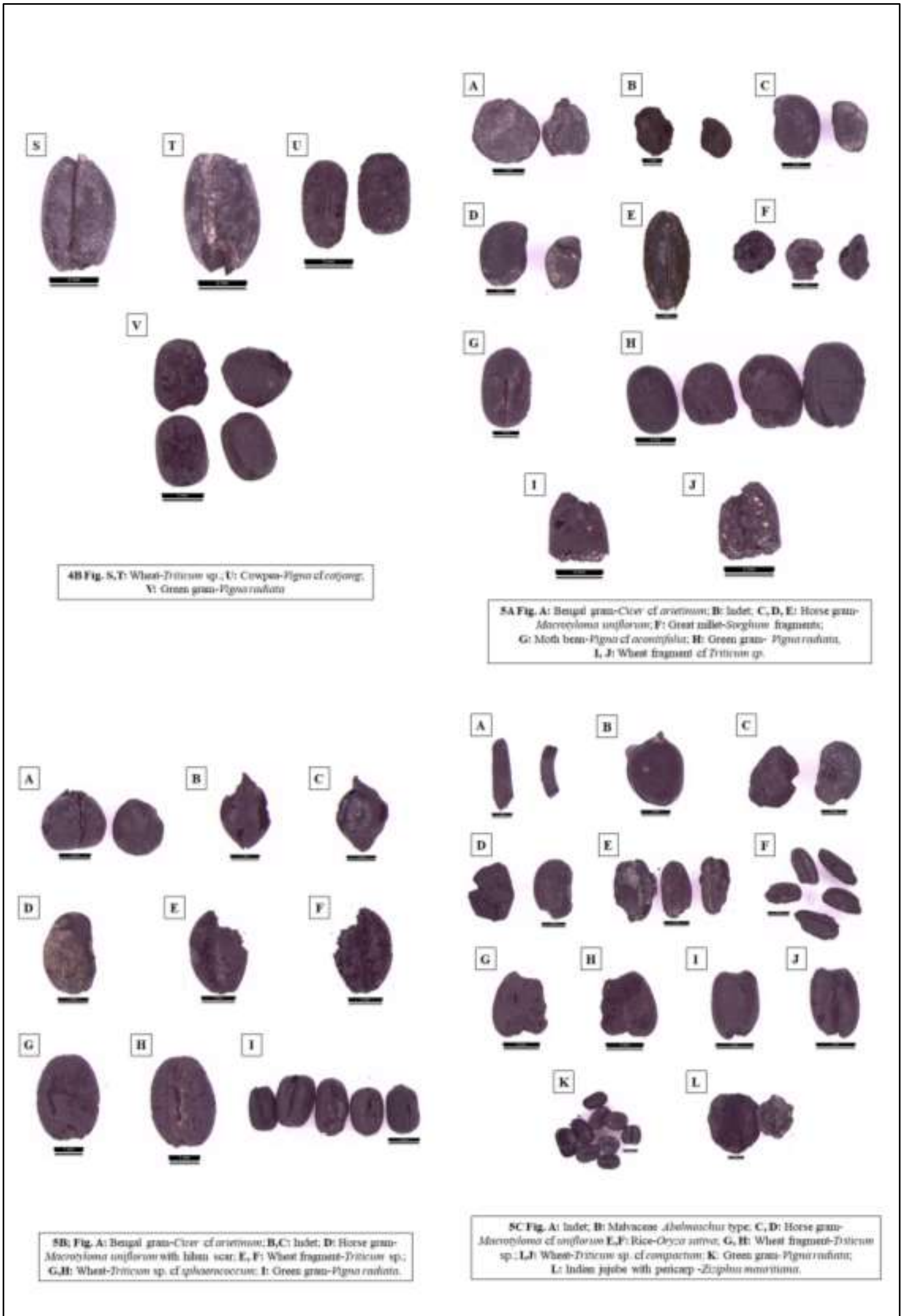


Figure 6: Archaeobotanical remains from Vadnagar

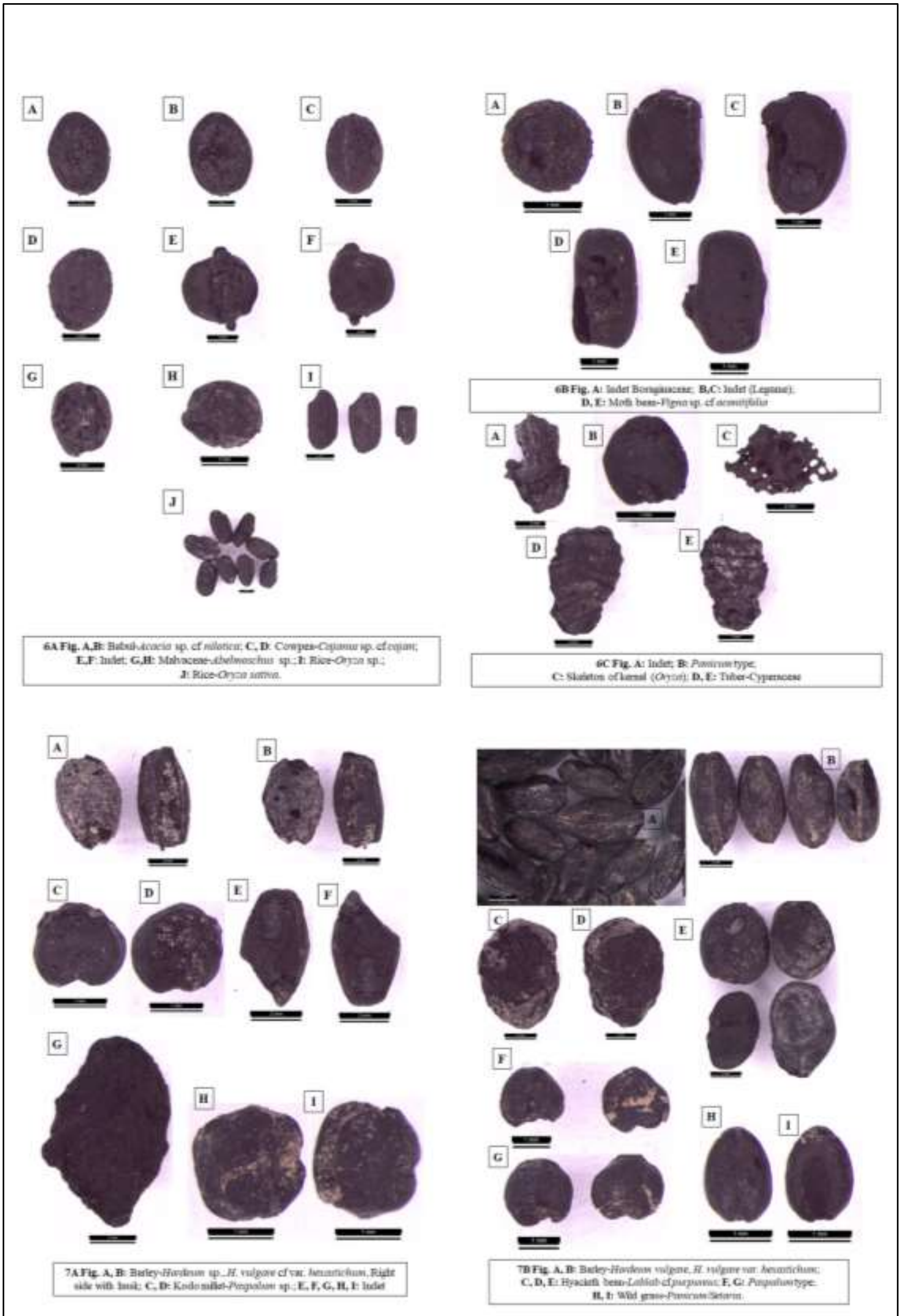


Figure 7: Archaeobotanical remains from Vadnagar

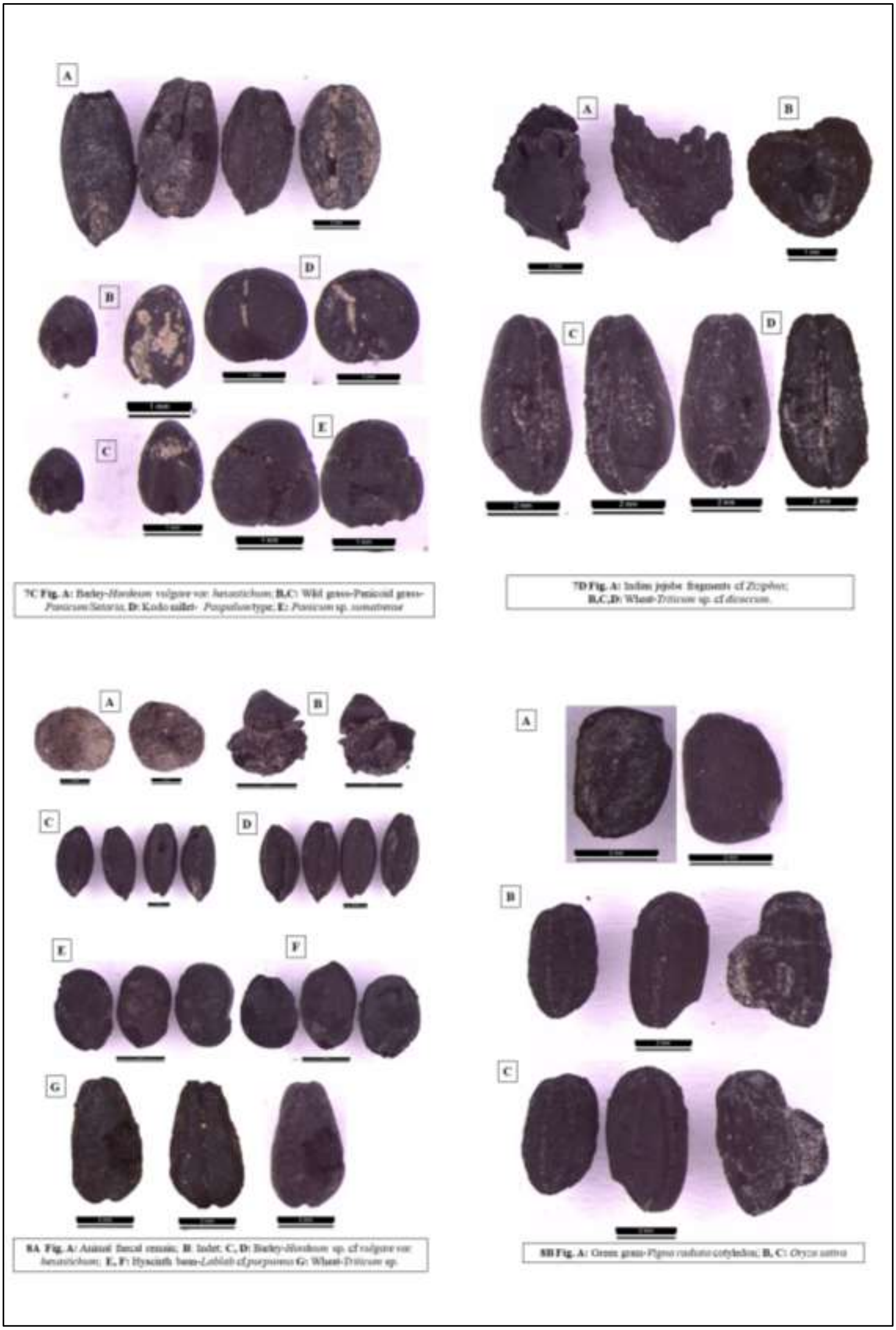


Figure 8: Archaeobotanical remains from Vadnagar

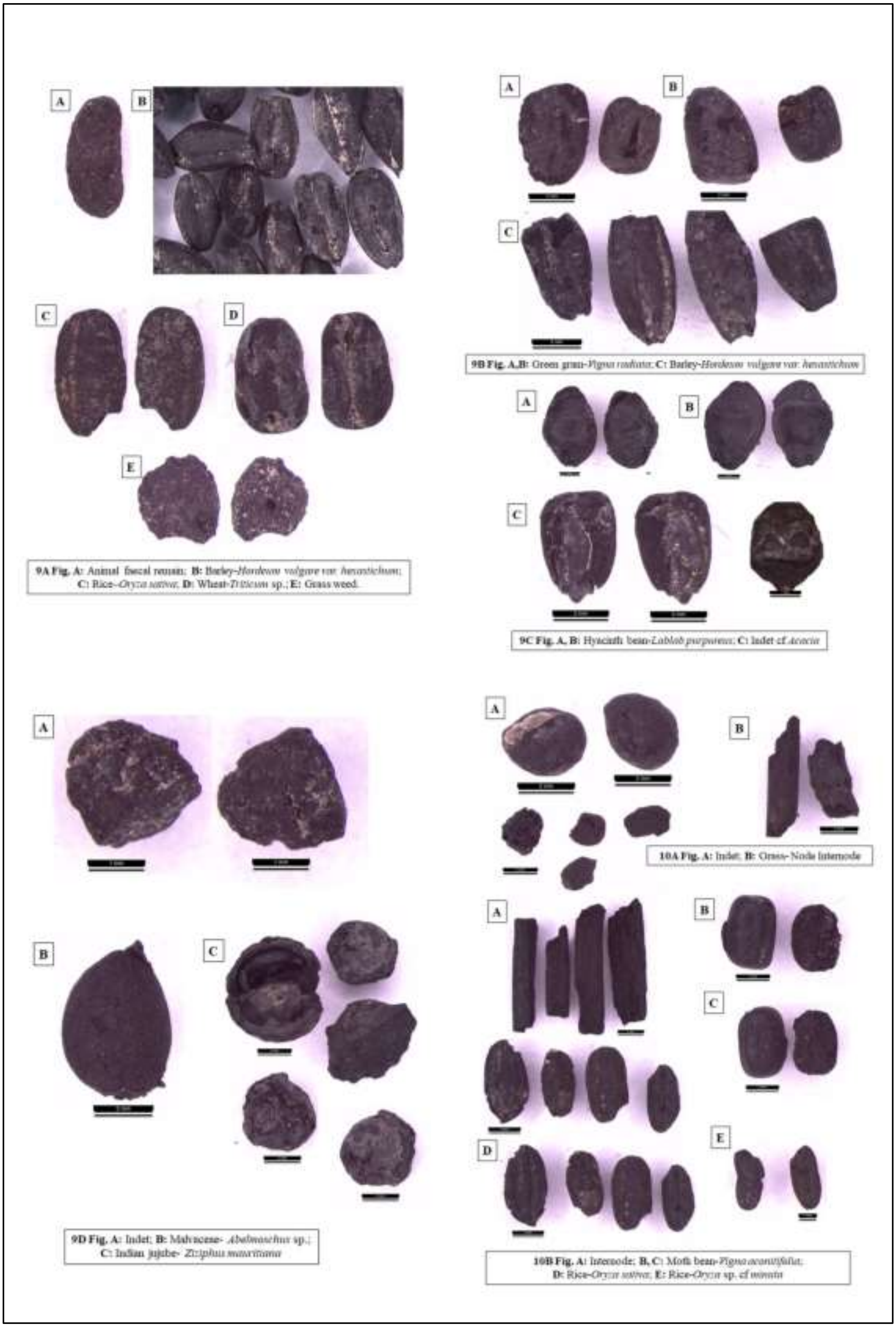


Figure 9: Archaeobotanical remains from Vadnagar

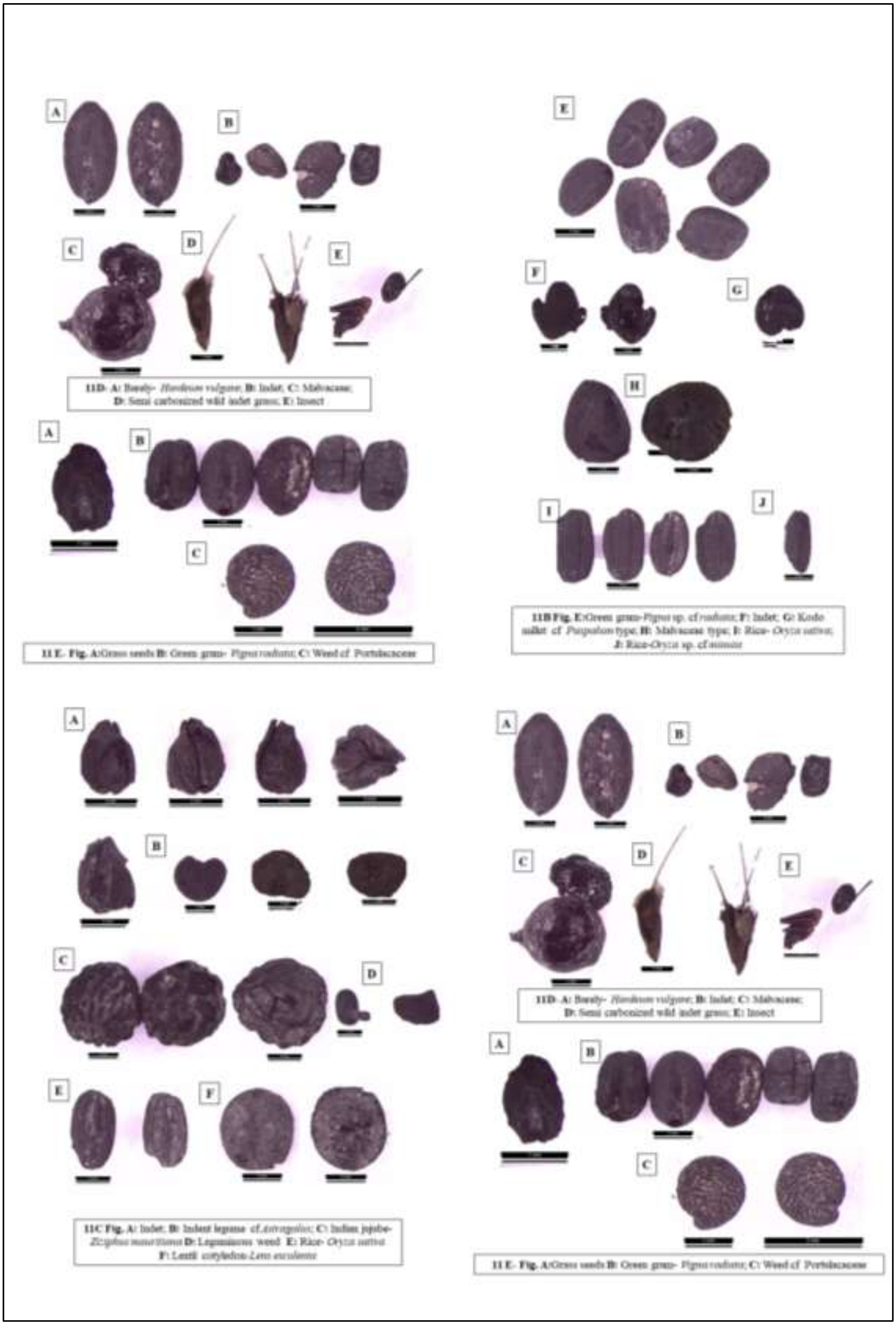


Figure 10: Archaeobotanical remains from Vadnagar

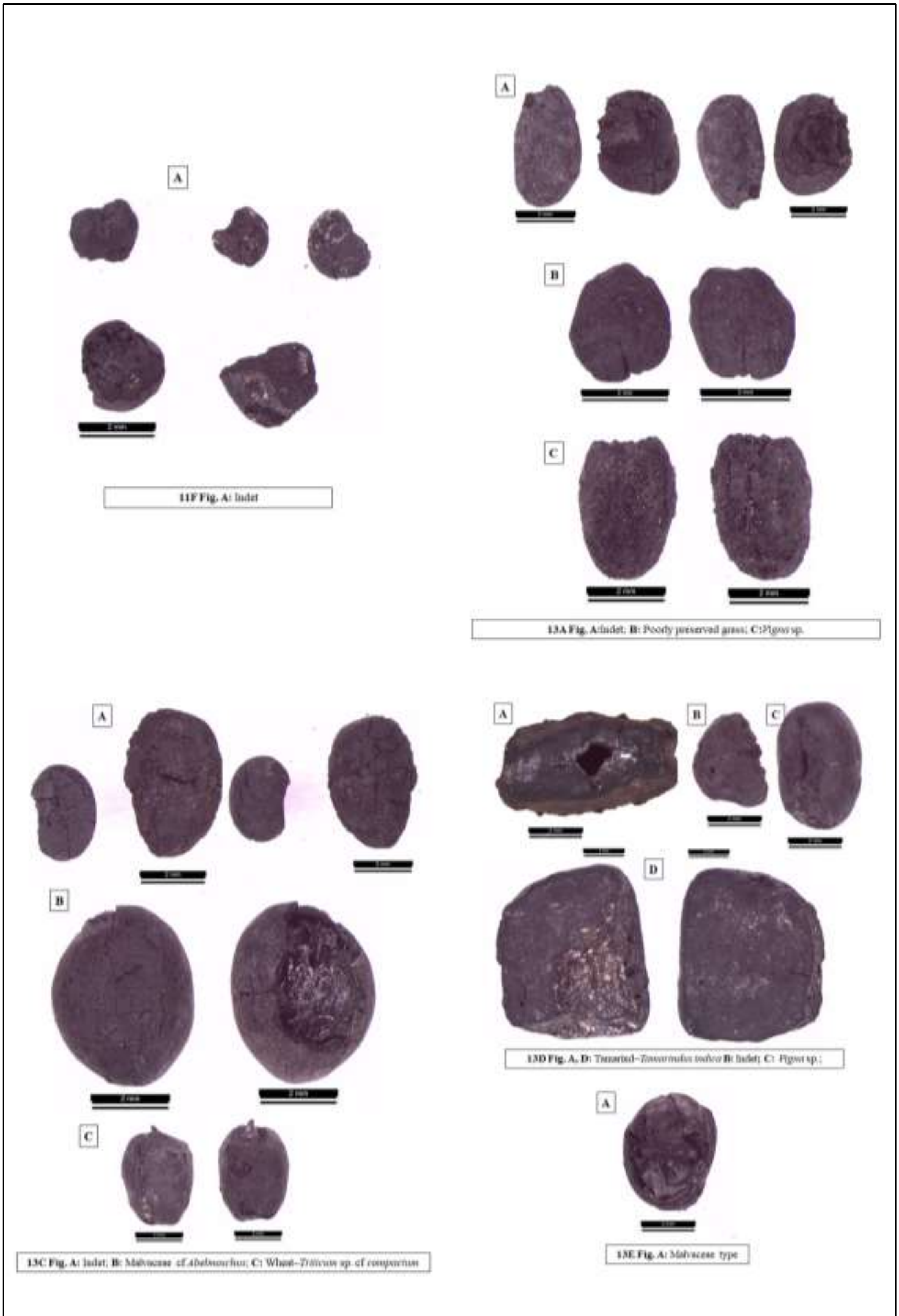


Figure 11: Archaeobotanical remains from Vadnagar

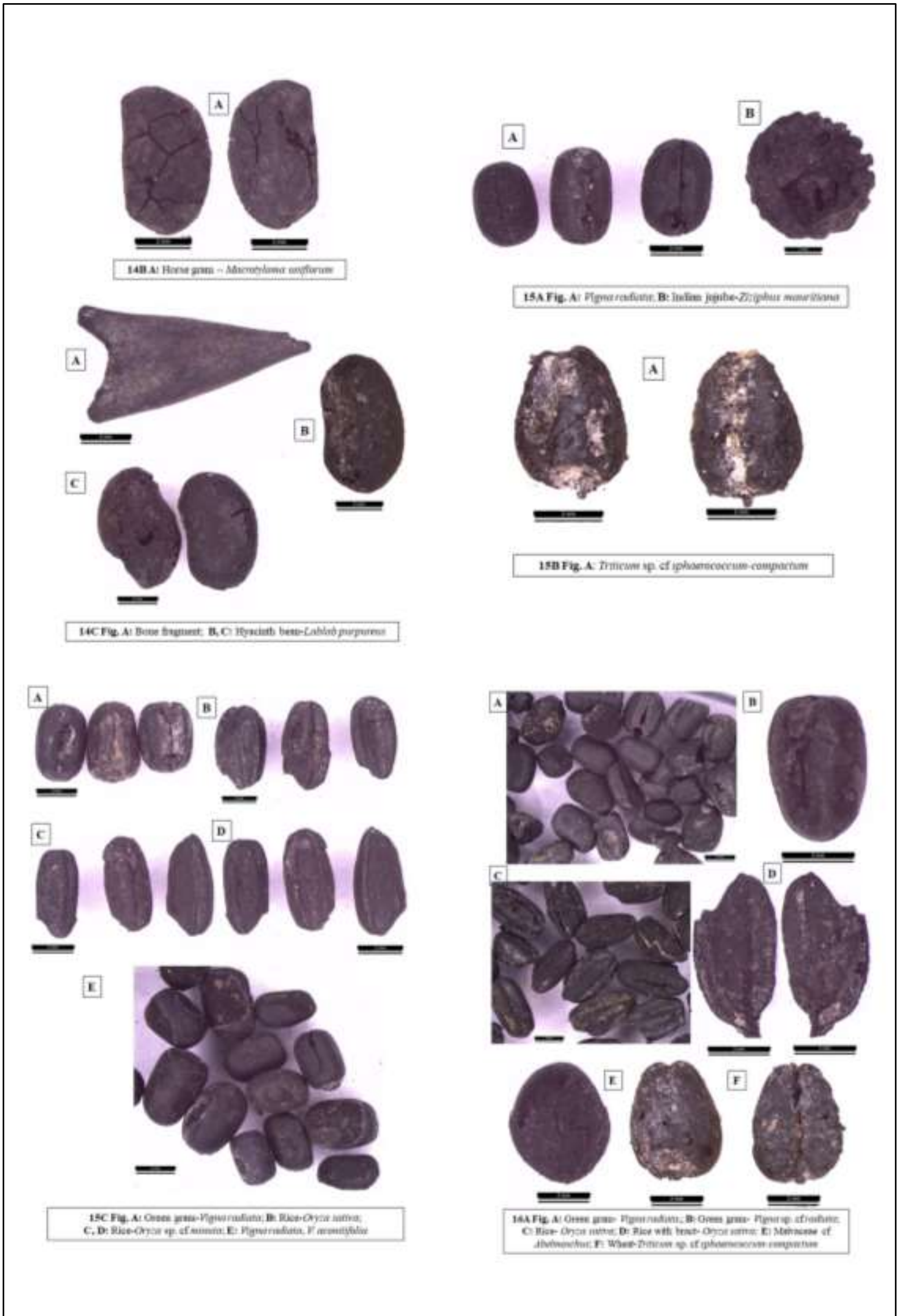


Figure 12: Archaeobotanical remains from Vadnagar

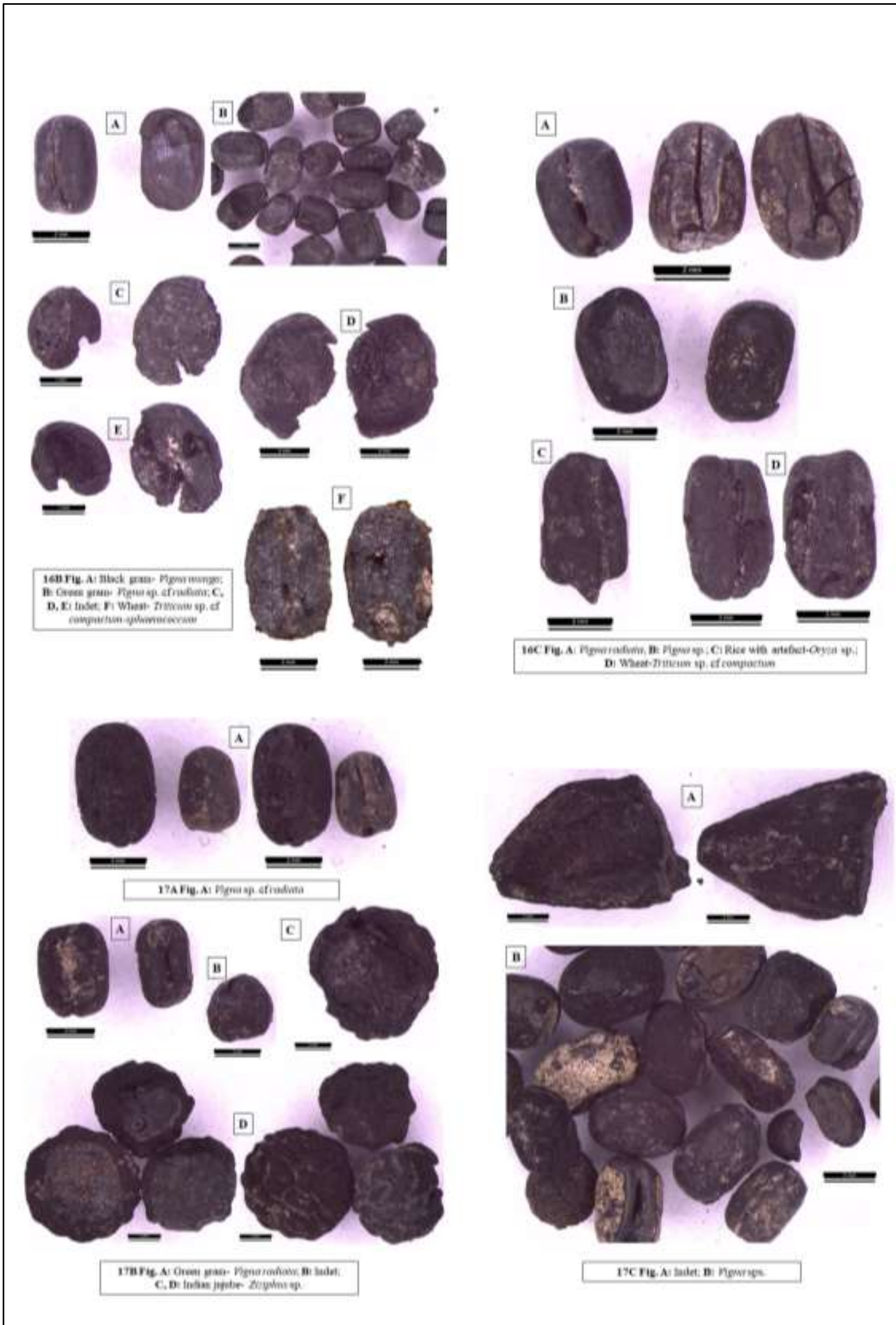


Figure 13: Archaeobotanical remains from Vadnagar

Figure 14: Archaeobotanical remains from Vadnagar

Figure 15: Archaeobotanical remains from Vadnagar

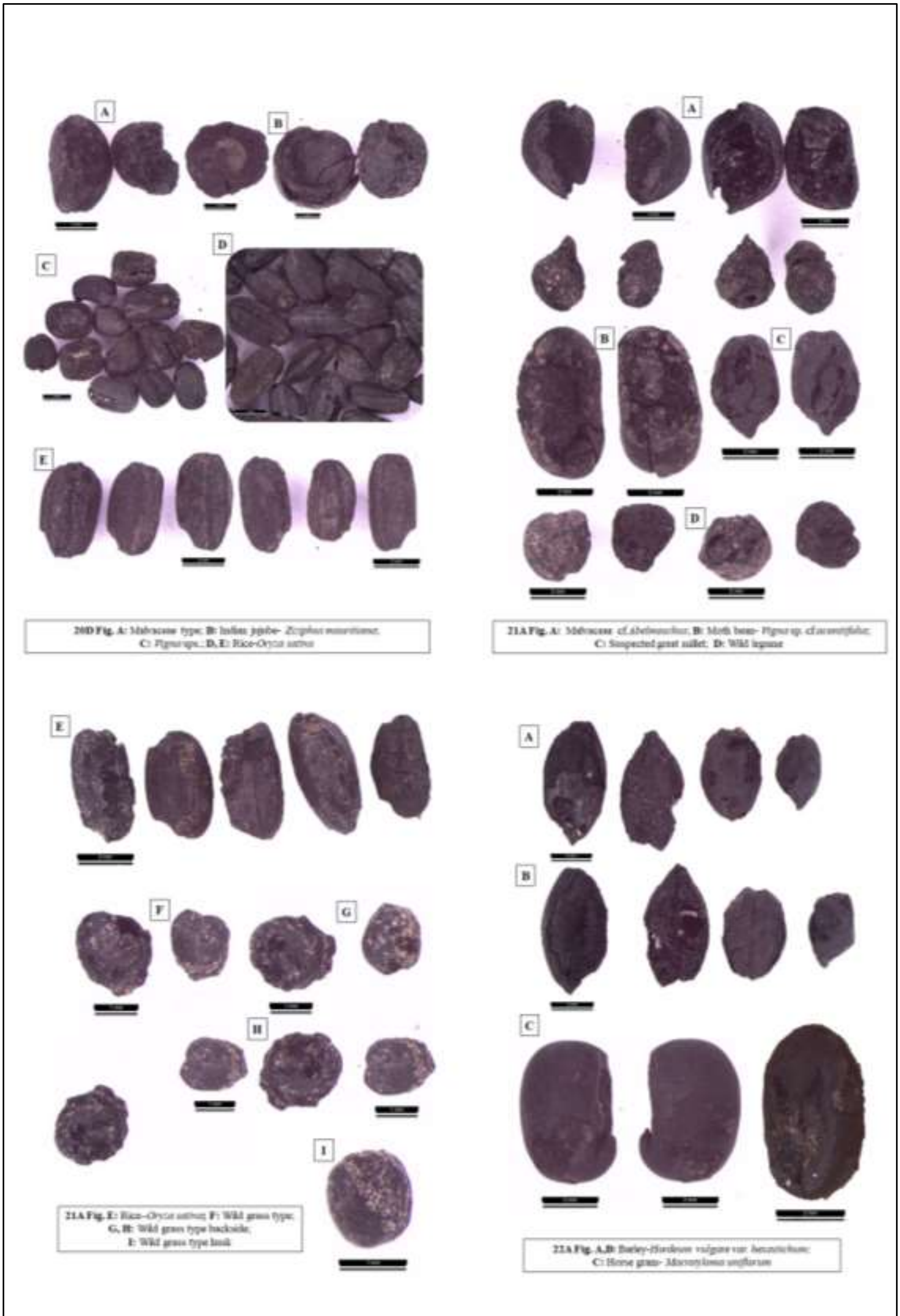


Figure 16: Archaeobotanical remains from Vadnagar

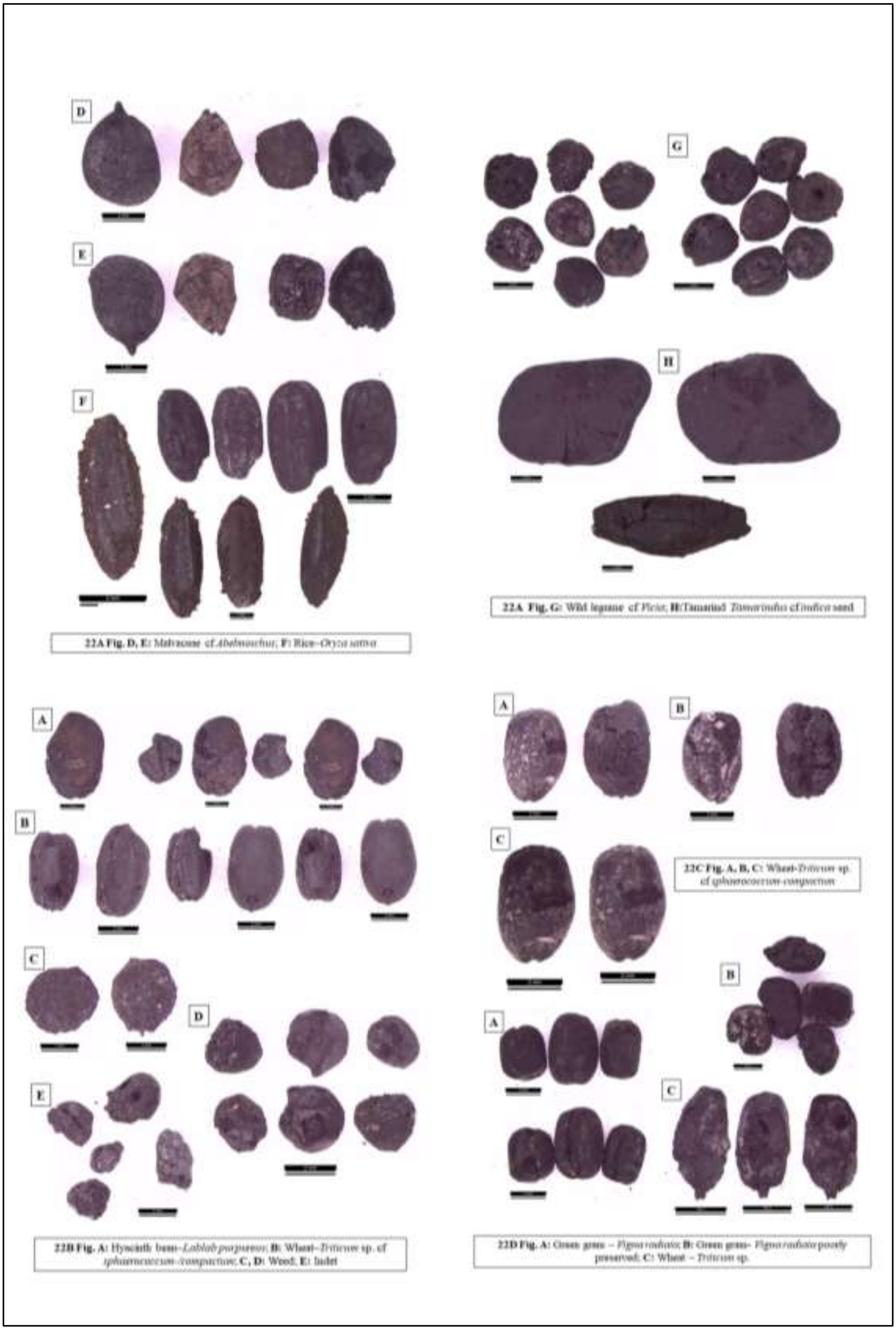


Figure 17: Archaeobotanical remains from Vadnagar

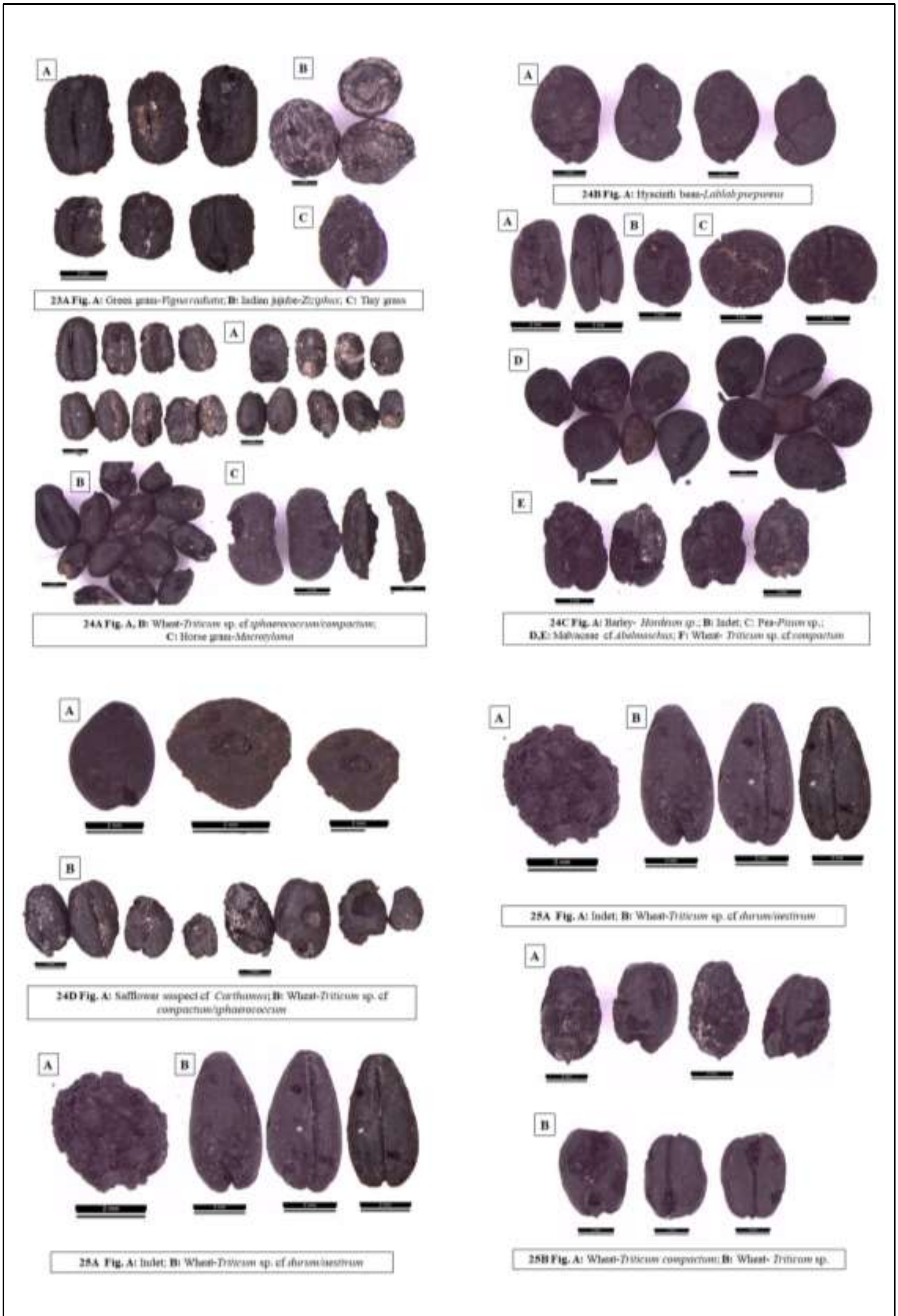


Figure 18: Archaeobotanical remains from Vadnagar

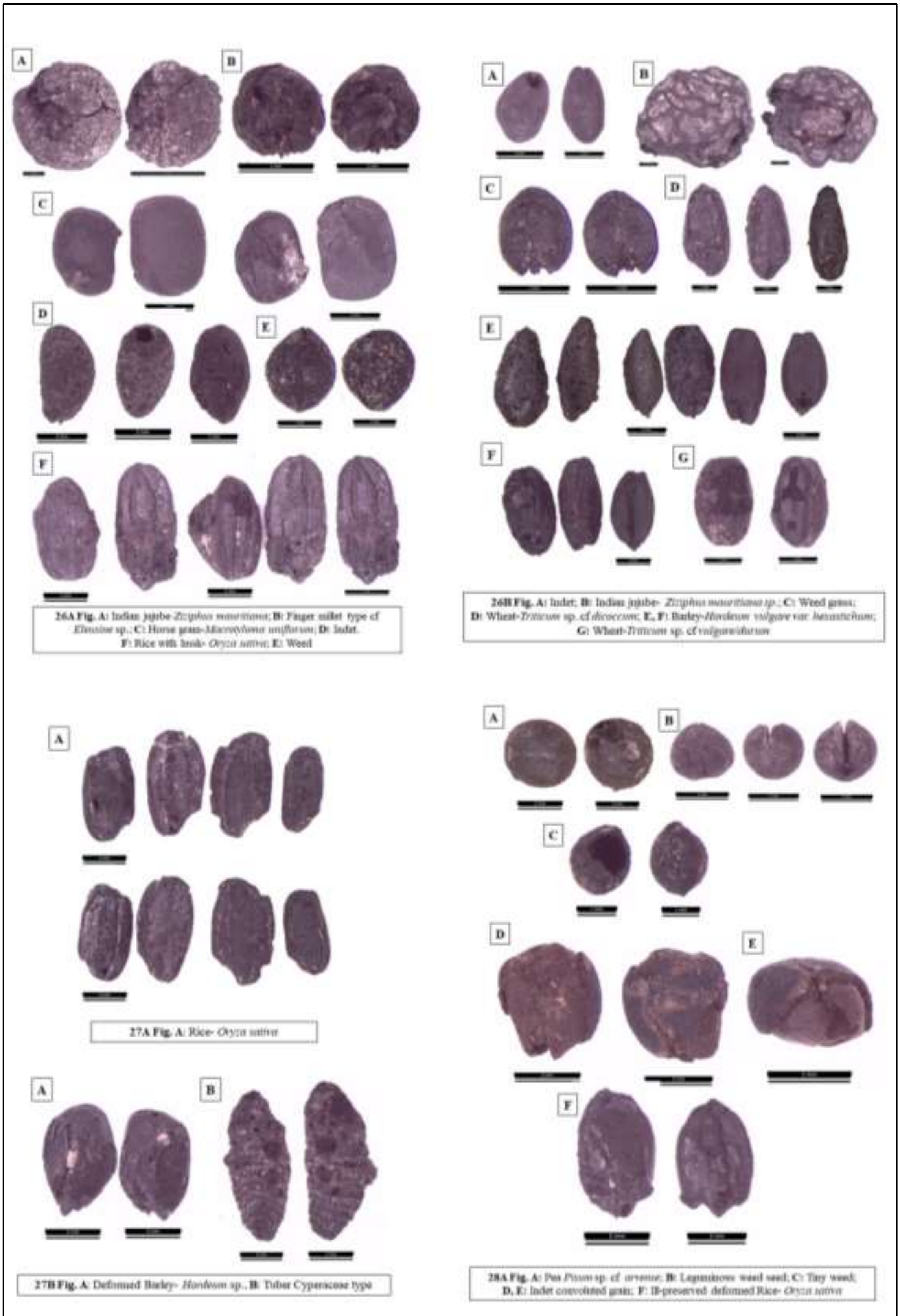


Figure 19: Archaeobotanical remains from Vadnagar

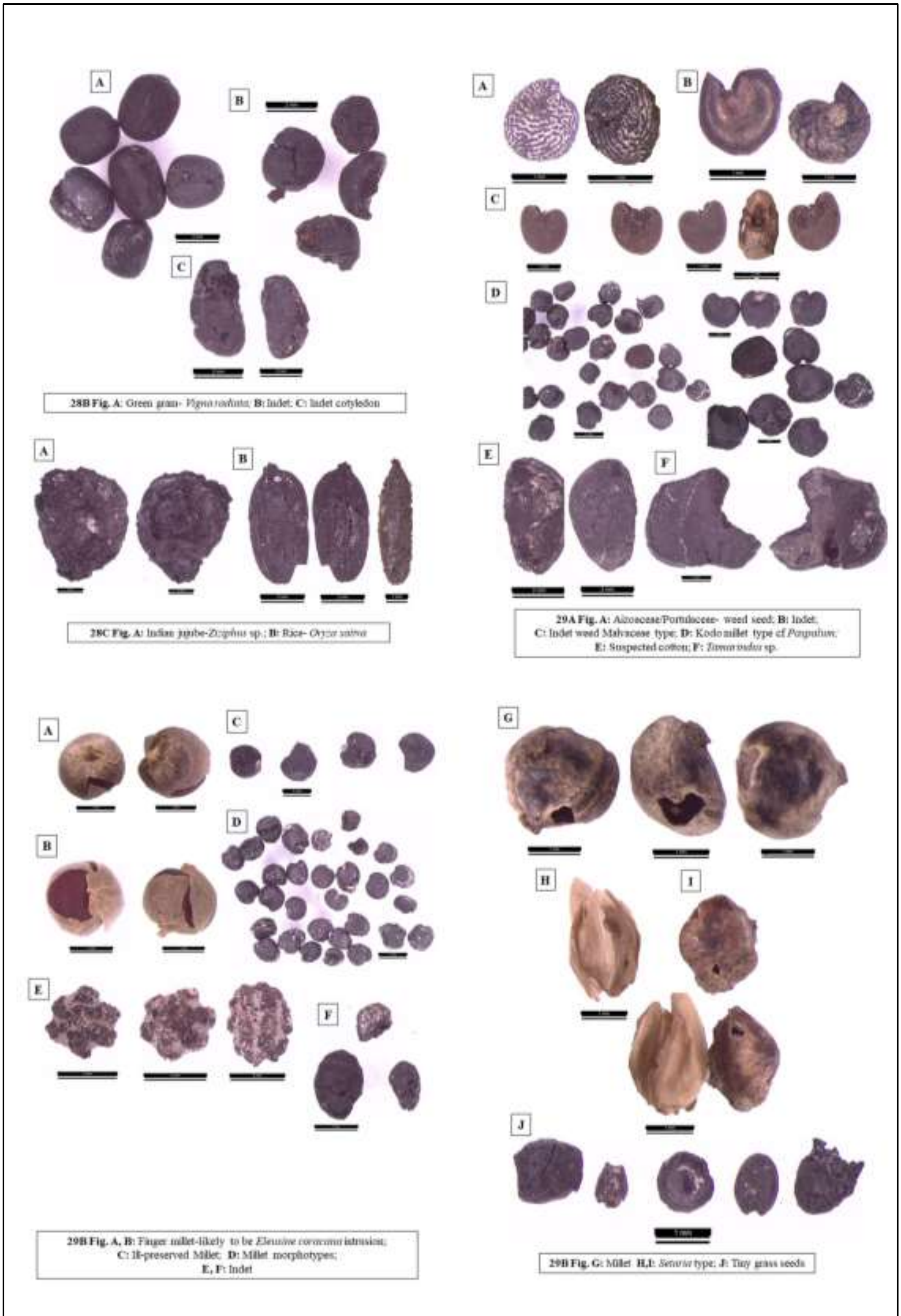
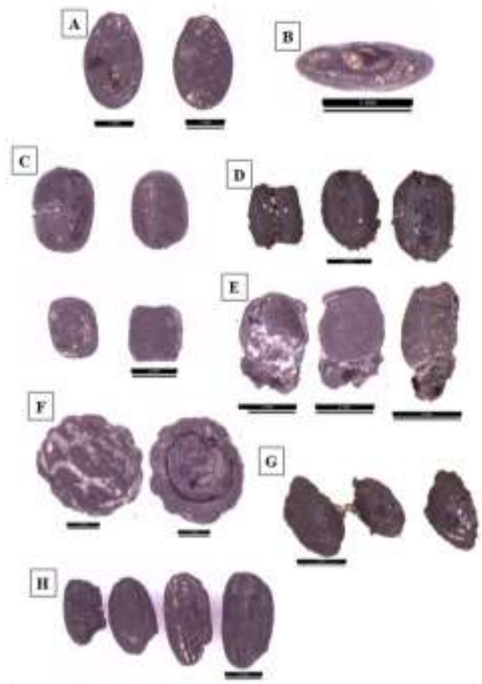


Figure 20: Archaeobotanical remains from Vadnagar

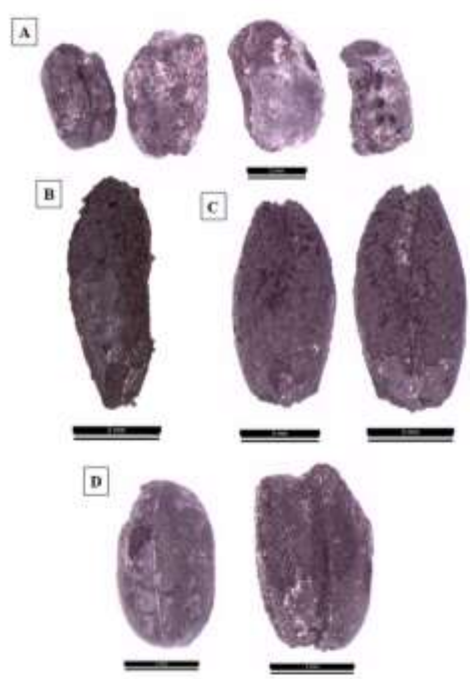
Locus: A1-33-94

Stratigraphical chart – Cultural/ Environmental

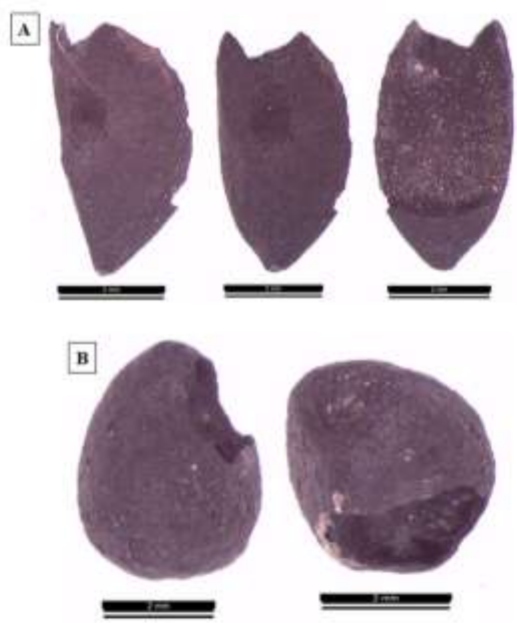
Lab Serial No.	Depth (cm)	Layer	Period		Cultural Association	Broad Geological/ Environmental Zonation
1A	1377 to 1400 cm	24				
1B	1400 to 1418 cm	24				
1C	1418 to 1431 cm	24				
2A	1431 to 1456 cm	25				
2B		25				



1A Fig. A, B: *Cucumis* type; **C, D:** Green gram-*Vigna radiata*; **E:** Indet legume cotyledon; **F:** Indian jujube holding seed- *Ziziphus* sp. cf *mauritiana*; **G:** Rice-*Oryza sativa*-embryo top view; **H:** Rice- *Oryza sativa*



1B Fig. A: Ill-preserved-*Vigna* sp.; **B:** Barley-*Hordeum vulgare*; **C:** Ill-preserved Barley-*Hordeum vulgare*; **D:** *Vigna* sp.



1C Fig. A: Emblic myrobalan fragment-*Phyllanthus emblica*; **B:** Malvacese type

Figure 21: Archaeobotanical remains from Vadnagar

Figure 22: Archaeobotanical remains from Vadnagar

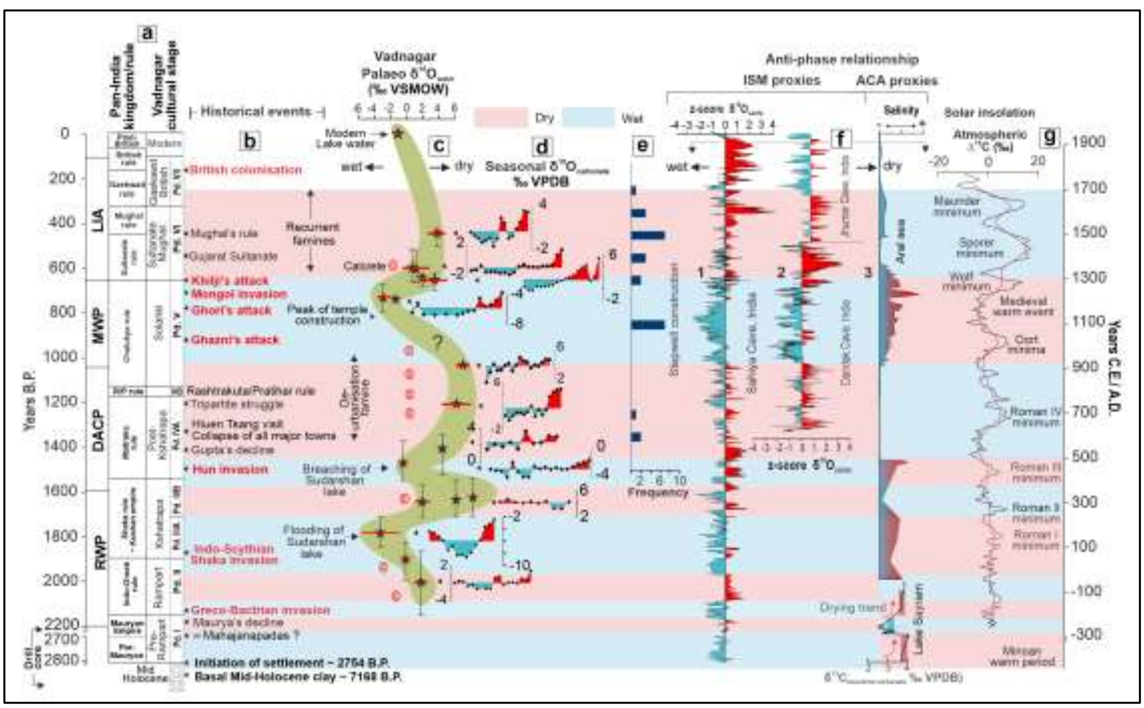


Figure 23: Cultural stages at Vadnagar along with pan-India kingdom rulers against the global climate phases and Climate reconstruction (Sarkar et.al. 2024)

Discussion

Plant economy is represented by more than 30 species and around 50 morphotypes comprising Cereals, Pulses, Legumes (Pulses), Oil seeds, Tubers, trees, Crop-associated weeds, and tiny food residue (Figure 3- 22). A few excreta (faecal) remains of insects and insect parts occur incidentally with grains. Botanical names are not given here to ensure easy readability and comprehension. Scientific botanical names have new name been given in various write-ups stated above (Please consider new names like Vigna in place of Phaseolus, Macrotyloma uniflorus in place of Doichos biflorus, and Lablab purpureus in place of Dolichos lablab).

Major cereals include Rice, Wheat, and Barley, Millets include Sorghum (Jowar), Bajra (Pearl millet), Ragi (African millet), Italian millet (Setaria), Kodo Millet, etc. Pulses include Green gram (Moong), Black gram (Urd), Moth Bean, Cow Pea, Pigeon pea (Urhar), Chickpea (Gram), Green Pea (Matar), Horse-gram (Kulathi), Lentil, wild legume, Vetch(wild-bean), Methi? Etc. Oil seeds include Safflower and sesame. Cotton also possibly existed as a cash crop. Major trees included Indian Jujube (Ber), Indian Tamarind (Desi Imli), Babul (Acacia), Indian Gooseberry (Amla) etc. Tubers belonging to the Cyperaceae (Nagarmotha in Marathi language family existed perhaps as a medicinal plant. Several wild legumes existed as weeds and some wild unidentifiable grass seeds existed as fodder remains. A few doubtful seeds of Plantago (isafghul/Isabgol) existed, it could have been an introduction to Vadnagar from the Kutch region. A few wild Bhindi seeds did exist as a weedy element of ancient crop fields.

A Table of the ubiquity of different above mentioned important taxa has been given for appreciating changing/fluctuating plant economy over four acceptable broad geo-environmental zonal phases such as Historical /Roman Warm Phase (RWP- includes Rampart, Kshatrapa, part of post-Kshtrapa periods), Dark Age Cold Phase (DACP- post-Kshatrapa period), Medieval Warm Phase (MWP- Solanki periods) and Little Ice Age (LIA –Sultanate-Mughal and Gaekwad) has been given.

This study speaks for the resilience of ancient inhabitants of Vadnagar who successfully continued to exist without any break in occupations despite fluctuating environment from semi-arid to Arid-draughty to arid and back to present-day semi-arid conditions. This was possible because of artificial tank technological skills making the availability of water available during lean seasons and for successful reversion of agricultural activities (especially for rice cultivation) during post-Medieval periods.This is an extract report of our research study. Owing to the demand for the brevity of words, detailed bibliographic references are avoided.

Subsistence Economy and Summary

Overall studies taken up of palaeo-botanical and archaeo-zoological finds (animal bone remains/faunal remains) recovered from the excavation at Vadnagar reveal evolutionary development in plant exploitation strategies since pre-2nd century BCE till present.

Agricultural Adaptation and Resilience Through the Exchange of Ideas and Knowledge – A Classic Example from Vadnagar as a Result of Archaeobotanical Findings: The impacts of historical climate change on past agricultural production contribute to a better understanding of the impacts of projected climate change by providing empirical data for resilient human responses. This study explores the periods of dynastic transitions and crop production in semi-arid northwest India through several global climate events, the Roman Warm Period (RWP, 250 BCE-400 CE), Dark Age Cold Period and Medieval Warm Period (MWP, 500 CE-1300 CE) and Little Ice Age (LIA, 1350 CE-1850 CE). Palaeo-environmental data indicate the region witnessed mild to intense monsoon precipitation during the Historic and Medieval periods. During the post-Medieval period (1300-1900 CE; LIA) archaeobotanical evidence suggests a resilient crop economy based on small-grained cereals (C4 plants) as a human adaptation in response to the prolonged weakening of monsoonal precipitation (Pokharia et.al. 2024).

The study presents an archaeological and botanical record spanning the last two millennia in arid Northwest India. The temporal scale of these data is unprecedented for the region and provides insight into the ways that variation in agricultural production allowed responses to Late Holocene climate changes. These long-term data allow insight into resilient responses in food production to meet the challenges of projected future climate change.

While longer-term environmental were likely drivers of changing cultivation patterns around Vadnagar, this took place in a highly resilient subsistence tradition. The archaeobotanical data studied here, as well as other regional case studies, indicate that Indian farmers of the northwest arid zones were in the past able to adapt to climate events of the last two millennia, expanding the agricultural package to capitalise on higher precipitation and able to shift to more arid-adapted crops during climate deteriorations.

While future climate change may be more pronounced than previous Holocene shifts, and may increase the likelihood of catastrophic events, Pokharia and others (2024) argue that variability among archaeo-botanical datasets from sites where occupation was continuous through multiple, changed environmental conditions provide useful insight into ways that these impacts may be reduced. A resilient response to future conditions would require considered management of water resources, labour, food production and distribution in northwest India.

Isotopic and phytolith data from Vadnagar (field season 2016-19) provide a clear signal of local environmental conditions and how they changed over two millennia from the Early Historical period to the early post-medieval eras. Significantly, these changes are congruent with palaeo-climate studies from the northern Indian subcontinent, especially indicating weaker summer monsoon precipitation associated with the Little Ice Age. The archaeo-botanical evidence for agriculture from the site suggests a resilient agricultural system, with a diverse cropping system that shifted to a highly drought-tolerant millet-focused regime in response to the weakened ISM from ca. 1400 CE.

Environmental Studies Based on Molluscan Shell: The oxygen isotopes in carbonates provide information on the temperature and rainfall of a particular region. Vadnagar excavation has found many archaeological carbonate shells of molluscan, both marine and terrestrial. While the oxygen isotopes of marine shells reveal the climatic conditions in the ocean, the terrestrial shells tell the climatic conditions over the land. Several marine and terrestrial shells have already been dated by the AMS radiocarbon method and analysed for isotopic compositions. The results suggest variation in Indian monsoon through different archaeological periods in Vadnagar including phases of extreme aridity. The relationship of different cultural levels with the climate has been examined. Also, climate modelling was carried out to find out the driving forces behind these changes in monsoon (Sarkar et.al. 2024).

Variation in the Indian summer monsoons (ISM) of different settlement periods at Vadnagar was constrained by both bulk and isotope sclerochronology (seasonality) of molluscan shells. The isotope data, supplemented by other climate proxies and historical texts, suggest that each of these periods flourished during a good ISM phase e.g. between 1st century CE and 3rd century CE. (mid-Roman warm period-RWP), mid-5th century CE – mid-6th century CE (early Dark age cold period-DACP), and 10th century CE – mid-14th century CE (Medieval warm period MWP). Conversely, the arid/hyper-arid phases witnessed a decline in material culture, craftsmanship, and/or increased social instability. These correspond to 1st century BCE – mid-1st century CE (early RWP), 3rd century CE – mid-5th century CE. (late RWP), and mid-6th century CE – 10th century CE. (mid-to-late DACP), and mid-14th century CE-mid 18th century CE. (Little Ice age-LIA). Effective adoption of various water conservation means during weak monsoons by the successive inhabitants led to the sustenance of the city for such a long period. Comparison of proxy climate data from India and Arid Central Asia (ACA) with the coupled General Circulation Climate model-generated precipitation suggests that the repeated invasion/ human migration of central Asian warriors during this period occurred during phases when the ACA was hyper-arid and uninhabitable, but the agrarian subcontinent was prosperous with relatively stronger ISM (Figure 23).

Twenty-five samples retrieved from six trenches were radiocarbon-dated by accelerator mass spectrometry (AMS). The earliest settlement at Vadnagar occurred at 2754 yr. B.P. just above a ~ 7168-year-old mid-Holocene virgin soil that did not yield any archaeological remains. The contact between this soil and the age of the first layer of settlement marks a geological hiatus and suggests that the first human habitation at Vadnagar started during the Early Iron Age or close to the second urbanisation phase of *Mahajanapadas* (2550-2300 yr. B.P.).

The studies suggest Vadnagar is as old as Late Vedic or Early Iron Age period almost 800 to 700 BCE. Over these long years, the settlements experienced periodic prosperity and decline during good monsoon and bad monsoon times respectively. Yet the settlers never deserted and continued to stay back by their resilience and by adopting water conservation techniques. In a way, the people at Vadnagar stayed for nearly 3000 years in a single place without desertion. This is even longer than recorded settlements for the Indus Valley civilisation when the people could not survive more than 2000 years at any single site.

Conclusions

This study gives a fair idea of changing subsistence and plant economy and relationship with the fluctuating environment and human adaptations in a drought-prone semi-arid landscape set up, over a continuous habitation over 2000 years. The most interesting aspect of the vanagar archaeobotanical study is occurrence of draught resistant hardy millet species (jowar,bajra, panicum, ragi, etc. withstanding monsoon rainfall vagaries) which have probably contributed towards sustenance and continuation through adverse environmental conditions besides barley, wheat and rice (last two needing irrigation support unlike hardy millets). In Semiarid parts of western India distinct archaeobotanical occurrence has been noted since Harappan times as noted at sites like Rojdi(Weber, 1991), Kuntasi(Kajale, 1996, 2003), Shikarpur(VisnuMittre, R. Savithri, Chanchala, etc. summarized in Pokharia A.K. et al, 2014), Kanmer(Pokharia Kharakwal,et al, 2011). The Harappan legacy of millet cultivation continued through Chalcolithic culture as reflected at Late Jorwe phase of Inamgaon (Kajale, 1988), especially during late Jorwe phase when the intense cultivation of wheat during Malwa and early Jorwe got reduced because of unfavorable environmental conditions after 1000B.C. Millet cultivation did continue during 1st millennium B.C. sites and picked up momentum during historical periods, as seen at semi-arid Vadnagar. The tradition of double cropping (winter, summer) has obviously continued for atleast 5000 years as seen from its continuity since Harappan, Neolithic-Chalcolithic, Megalithic, Historical and into the present day. More archaeobotanical studies on historical and medieval sites in western India are needed although we have mentions of millets cultivation from written historical sources. Thus, Millets in general could serve a time-tested remedy to manage the adverse environmental fluctuations in the era of recent climate changes.

In fact, the present archaeobotanical study of Vadnagar along with ancient records from other semiarid and arid regions could serve as application of ancient traditional knowledge for surving/ mitigating uncertainty of todays “climate change scenarios” and to ensure sustainable food supply in the event of failure of high yielding varieties (insecticide and synthetic fertilisers dependant) of wheat-rice complex (needing irrigation) with its ecological side-effects. And the consumption of millets is also encouraged with respect to people suffering from Diabetes Melitus (DM 2) in view of its slow and sustained release of glucose into the blood circulation after digestion.Thus, the nutritional and health benefits are being duly acknowledged in India and elsewhere in the world. Thus, purely academic sounding discipline like archaeobotany can offer valuable historical insights and applications into the areas of modern agriculture for sustainability. There could also be an agricultural economical angle to millet cultivation visa vis wheat-rice. As per our recollection goes (especially mdk just because of being the eldest member!), India was a food grain shortage country until she introduced hybrid varieties as a part of the Green Revolution in the 1960’s. Thanks to the then government policy makers, scientists and crop varieties and Indian farmers that our country became food grain exporter within 2-3 decades. Surely scientists are also thinking about what sorts of wheat and rice varieties we grow in India. The two main factors provoking rethinking appear to be environmental impact and ability to withstand climate change. The hybrid varieties are negative on environment and perhaps fragile on climate change, Production of hybrid varieties is subsidized. Would the traditional varieties of crops and especially millets come back if similar subsidy encouragement is provided to them? Surely, this is being analysed carefully by the scientists and govt. policy experts.

No wonder, it is heartening to see that Food and Agriculture Organization and United Nations has recognised 2023 as International Year of Millets or IYM2023 for awareness about health and nutritional benefits of millets. The Indian Government proposed to celebrate 2023 as International Year of Millets.

Acknowledgements

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