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Ahituv, H.; Henry, A.G.

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An initial key of starch grains from edible plants of the Eastern Mediterranean for use in identifying archaeological starches

Hadar Ahituv [a,*], Amanda G. Henry [b]

[a] The Institute of Archaeology & The Martin (Szusz) Department of Land of Israel Studies and Archaeology, Bar-Ilan University, Ramat-Gan 5290002, Israel
[b] Faculty of Archaeology, Leiden University, Einsteinweg 2, 2333CC Leiden, the Netherlands

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ABSTRACT

Among archaeological micro-remains, starches can be used as a tool for reconstructing past environments, diets, and trade patterns through the identification of the plants collected and consumed by ancient populations. Starch grains preserved in dental calculus and on stone tools have been recovered from archaeological material from sites around the world. However, the ability to identify archaeological starch grains relies on having a broad (i.e., many taxa) and deep (i.e., many individuals from the same taxon) reference collection from modern plants. Only a small handful of such reference collections have been published, and thus far none have been created for taxa from the Eastern Mediterranean. This region is rich in plants that have been used for their starch-rich seeds and roots since prehistory, and many of the wild taxa are the progenitors of domesticated species that were cultivated in the Neolithic and remain economically important today. To help document the history of human interactions with these plant taxa, we present here a reference collection based on the analysis of 220 individual plant parts (e.g., seeds, tubers) from 188 modern Levantine plant species (both wild and domestic), and three non-native plants that are frequently found as modern contamination. Of the examined plant samples, 110 from 106 taxa (species and subspecies) contained starches. We also provide a key based on this collection to aid in the identification of archaeological starch remains.

1. Introduction

The analysis of starch grains from archaeological material is increasingly used to help reconstruct the past use of plants (Torrence and Barton, 2006; Henry, 2020; Langejans, 2010; Pearsall, 2015). Starches are complex semi-crystalline structures, made of carbohydrates (amylose and amylopectin) produced by plants as a result of photosynthesis (Bertoft, 2017; Robbins and Weier, 1950). The plants use these structures for long-term energy storage, usually in the seeds or grains, and underground storage organs such as rhizomes, tubers and bulbs (Eliasson, 2004). In most higher plants, the starches are formed in specialized organelles (amyloplasts) within the plant cells (BeMiller and Whistler, 2009). The shape, size and features of the starches is genetically controlled (e.g., Toyosawa et al., 2016), which results in different taxa having specific starch shapes (Bertoft, 2017; Henry, 2020).

While not all plants produce starches, and not all starches have unique shapes, the morphological differences among taxa can be used by researchers to identify starches from particular plants. Starches have been recovered from tools used for processing food, such as flaked stone tools (e.g., Langejans, 2012), grindstones (e.g., Fullagar et al., 2008; Liu et al., 2018; Tao et al., 2011) and pottery (e.g., Samuel, 1996a; Saul et al., 2012). They have also been recovered in calculus on teeth (e.g., Hardy et al., 2016; Henry and Piperno, 2008). In many of these studies, starches are the only preserved record of plant use, and have often provided evidence for novel processing techniques [e.g., brewing (Liu et al., 2018)] or early spread of domesticated plants [e.g., maize (Piperno et al., 2009)].

The identification of starches relies on matching the morphological features of archaeological starches to those from modern plants. While many researchers create and curate their own reference collections, these often include few taxa, and are rarely published or made publicly available (for some exceptions, see Hart, 2014; Gismondi et al., 2019). The usefulness of these reference collections is further improved by building dichotomous keys that allow the identification of unknown starches. While some keys have been published for a small handful of taxa [e.g, 10 species of Triticeae from north China (Yang and Perry, 2013) and roughly 100 taxa from the Delaware River region of North America (Messner, 2011)], currently, there exists no identification key

* Corresponding author.
E-mail address: hadarahituv@gmail.com (H. Ahituv).

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for plants from the Near East, despite the importance of archaeobotanical research in the region (as noted by Hart, 2014).

The Eastern Mediterranean has a long history of interaction between humans and plants, and is one of the centers of domestication. Charred and waterlogged plant seeds from archaeological sites have provided evidence that, even prior to domestication, a variety of wild plants were consumed by the various hominin species that occupied this region since at least the Lower Palaeolithic [e.g., Gesher Benot Ya'aqov (Melamed et al., 2016)]. Plant use remained a constant in this region, with evidence spanning from the Middle Palaeolithic [e.g., Kebara cave (Lev et al., 2005)], into the Epipalaeolithic [e.g., Ohalo II (Weiss et al., 2004)], the Pre-Pottery Neolithic periods [e.g., PPNA at Gilgal I (Kislev et al., 2010); PPNB at Yiftahel and Jericho VII (Garfinkel et al., 2012, 1987; Hopf, 1983); and PPNC at Atlit-Yam (Hartmann, 1997)], and finally through the Neolithic and Chalcolithic periods [e.g., Jericho IX, Ras Shamra, Ramad and Tuleilat Ghassul (Meadows, 2005)], until present day (Mayer-Chissick and Lev, 2014).

There are circa 2750–2856 species of wild plants in this region and most of them can be consumed (Danin, 2004; Danin and Fragman-Sapir, 2021). In addition to providing energy and nutrients, many of the plants in this region are also used as raw material for basketry and clothing (e.g., Nosch et al., 2013), building materials (Rosenberg et al., 2020), medicines (Aboelsoud, 2010), fuel (Rowan, 2015), and fodder for domestic animals (Charles, 1998). While much is known about the prehistoric use of plants, these organic materials are not often preserved in the archaeological record (Bar-Yosef, 1998; Haslam, 2004). The analysis of starch grains from archaeological contexts may provide new information about the ancient use of plants (Langejans, 2010).

Therefore the goal of this publication is to provide a reference collection and a key for identifying starch grains commonly found in Near Eastern plants. We examined nearly 200 common plant taxa, collected from the wild and from herbaria and seed repositories, among others. These plants were chosen because they are known to be edible and/or have been identified (primarily as charred seeds) in the archaeological record. Of the 220 plant samples, half contained starches. We present pictures and descriptions of the starches from these 110 plant samples in the supplementary material. Additional photos are available on a Mendeley database (Ahituv and Henry, 2022; https://doi.org/10.17632/xyfnx2g8bn.1). We have created a key, presented below, that will allow researchers to identify, or at least narrow down the possible identity of unknown archaeological starches. Furthermore, we indicate those plants in which we did not observe any starches.

2. Materials and methods

The plants in this reference collection were derived from three main sources: 1) fresh samples that were collected from the wild in Israel by HA, 2) dried seeds from the United States Department of Agriculture National Plant Germplasm system (USDA NPGS) that had been provided to AGH in 2009, and 3) dried seeds or fresh starchy plant parts from the collections or research plots of four botanical gardens in Israel: those from Hebrew University at both Mount Scopus and Givat Ram Campuses, that of Tel Aviv University, and that of the Technion in Haifa. The progenitors of the seeds or plants from the USDA NPGS and the Israeli botanical gardens were originally collected in a variety of locations, which we have included in our descriptions when available. The wild samples collected by HA and those acquired from botanical gardens were gathered during the period of the year when the plant would have been collected for consumption. Seeds and grains were collected in late spring, at the moment when they were dry but still identifiable. Plants with edible roots (tubers, bulbs, rhizomes) were collected in the late autumn, after the growing season but before the plant had dried completely, to allow identification. Fruits were collected when ripe, depending on the taxa.

The plants from the botanical gardens were identified and classified by one or more Israeli taxonomists or by the science director of each garden. The Latin, English and Hebrew names of each plant were matched by cross referencing the expert identification with the information available from eight main sources: 1) The book "Distribution Atlas of Plants in the Flora Palaestina Area" (Danin, 2004), 2) Flora of Israel Online (Danin and Fragman-Sapir, 2021), 3) The Academy of the Hebrew Language ("The Academy of the Hebrew Language," 2021), 4) The Plant List Version 1.1 (Kew Gardens and Missouri Botanical Gardens, 2013), 5) Online Flora of Malta (Mifsud, 2021), 6) Catalogue of Life ("Catalogue of life," 2021). Some of the English common names were found using 7) Wikipedia ("Wikipedia," 2021) and 8) Wildflowers of Israel (Eshel et al., 2021).

As described above, we focused on starch-rich parts of plants

Table 1
Commonly-used domesticated legumes and cereals and their wild progenitors and / or relatives that are included in this reference collection.

Common name	Domesticated taxa	Wild relatives / progenitors*
Green pea	*Pisum sativum* L.	*Pisum elatius* M. Bieb; *Pisum fulvum* Sm.; *Pisum sativum* subsp. *humile* Boiss. & Noë
Chickpea	*Cicer arietinum* L.	*Cicer reticulatum* Ladz.; *Cicer judaicum* Boiss.
Vetch; Bitter vetch	*Vicia sativa* L.; *Vicia ervilia* (L.) Willd.	*Vicia narbonensis* L.; *Vicia galilaea* Plitmann & Zohary
Fava bean; Horse bean	*Vicia faba* L.	Wild relative / progenitor has not yet been identified
Vetchling	*Lathyrus sativus* L.	*Lathyrus cicera* L.
Lentil	*Lens culinaris* Medik.	*Lens orientalis* (Boiss.) Schamlh.; *Lens ervoides* (Brign.) Grande
Barley	*Hordeum vulgare* L. subsp. *vulgare*; *Hordeum vulgare* L. subsp. *distichum*	*Hordeum spontaneum* K. Koch
Rye	*Secale cereale* L.	*Secale montanum* Guss.
Wheat: Emmer; Einkorn; Modern Red Wheat; Modern Durum Wheat	*Triticum turgidum* L. subsp. *dicoccum*; *Triticum monococcum* subsp. *monococcum* L.; *Triticum aestivum* subsp. *aestivum* L.; *Triticum turgidum* subsp. *durum* Desf.	*Triticum turgidum* subsp. *dicoccoides* (Körn. ex Asch. & Graebn.) Schweinf.; *Triticum monococcum* subsp. *boeoticum* Boiss.
Oat	*Avena sativa* L.	*Avena sterilis* L.; *Avena barbata* Pott ex Link; *Avena wiestii* Steud.
Tef	*Eragrostis tef* (Zuccagni) Trotter	Not native - no wild relatives grow in Israel
Sorghum	*Sorghum bicolor* (L.) Moench	Not native - no wild relatives grow in Israel
Common / Proso / Broomcorn millet	*Panicum miliaceum* L.	Wild relative / progenitor has not yet been definitely identified

*According to Zohary and colleagues (2012) and M. Kislev (personal communication).

that were either known to be edible (Melamed, 2003), or that had been found in archaeological sites in Israel and its surroundings (Riehl and Kümmel, 2015). We included both a number of domesticated taxa and their wild progenitors (Table 1) as well as other wild taxa. Finally, we also included plants that are likely found as contamination.

We analyzed each part of the plants that most likely contained starches, focusing on seeds and underground storage organs. In the case of fruits, we examined only ripe individuals. We recognize that this might limit our ability to identify starches in such fruits, as most of the starches have changed to sugars in the ripe fruits. However, most of these fruits are consumed only when ripe. We examined between two and five replicate samples from different individual plants, in order to ensure that our descriptions are as representative as possible. The starch-rich plant part was first sectioned with a scalpel, and the interior was scraped over a glass microscope slide. The small particles were then further sliced or flattened with the flat side of the scalpel, and 20 μl of a 10–12% glycerin solution was added, and the powder mixed into the liquid. The sample was then covered by a 22 × 22 mm cover glass.

Immediately after preparation, every slide was analyzed using a Nikon Eclipse E200 under brightfield and cross-polarized light. Photographs were taken using a GXCAM-U3PRO-6.3 camera, which was controlled by GXCapture-T software for Windows. Measurements were taken and 20 μm scale bars were added to each image using the same software. All of the images in the supplementary data are pairs showing the same field of view, with the left in brightfield illumination, and the right under cross-polarized light. We further provide 30 images per species, with 10 pictures (5 brightfield, 5 cross-polarized) each of three fields of view. These 3300 images are available in a Mendeley database (Ahituv and Henry, 2022).

The starches found in the plants were described in written form following the terminology of the International Code for Starch Nomenclature ("The International Code for Starch Nomenclature," 2011). In all entries, we provide full names in Latin, English and Hebrew (when available). We used the following format: Latin name (syn. Latin synonym name [if applicable]); English name/s [if available]; Hebrew name; synonym name + the abbreviation נ"ש, meaning "synonym name" [if available]. In addition, we also provide information on the source of the plant (wild or botanical garden) and the part of the plant we analyzed. We used the word "collected" to indicate the material that was harvested from the field by HA in 2019–2020. Each entry begins by describing whether the starches are simple or compound, followed by a description of their morphology, the hilum, the extinction cross, the presence and appearance of fissures and distinct lamellae, their surface features and the size range.

After describing all of the starches from all of these plants, we then built a key to aid in the identification of unknown starches based on shared morphological features among the taxa. This key is described in more detail below.

In total we examined 220 plant samples, from 191 taxa (species and subspecies) from 49 families (Table 2). We included taxa currently or historically from the Eastern Mediterranean, including plants native to other regions that were introduced early on to this region (sorghum, broomcorn millet, tef) (Murphy, 2007; Zohary et al., 2012) and species that were used in the past but are now extinct in the area [fox nut (*Euryale ferox*) (Goren-Inbar et al., 2014)] Additionally, we examined three common contaminant species (potato, maize and sweet potato). The plant parts we examined include grains and seeds, tubers, bulbs, rhizomes, stems, roots (and also taproots) and ripe fruit pulps.

3. Results

Of the 220 examined plant samples, exactly half had starches. These 110 plant samples come from 106 taxa and 22 families (Table 2). There was a high degree of variability among the plant families in terms of the number of species that had starches. In some families, such as Nymphaceae, Caryophyllaceae and Fagaceae, all examined species had starches, while in others, such as Fabaceae, only some taxa had starches. Some families, such as Rosaceae, had no taxa with starches. Some of this variation might be driven by the number of taxa in each family that we examined. Furthermore, the presence of starch could not be predicted based on the plant organ. It is not possible to say that all bulbs or tubers have starch, or even that all seeds have starch. The exception to this rule is that, at least among our samples, no ripe fruits had starches. Only the unripe fruit pulp of *Mandragora autumnalis* contained any visible starch (Yahia et al., 2019). Overall, it is very difficult to predict which taxa or which plant parts should contain starches.

In the complete collection of 191 taxa, we examined two plant parts in 27 of them. Of these 27 taxa, 20 species had no starches in any of the parts we examined. Four species had starches in one of the two parts examined (*Althaea officinalis*, *Capparis zoharyi*, *Hordeum bulbosum* and *Sternbergia clusiana*), but in some cases the starches were in the seed and not in the root or bulb, and in other cases the opposite was true. Finally, three had starch in both plant parts (*Alisma plantago-aquatica*, *Arum palaestinum,* and *Mandragora autumnalis*).

We observed a large variety of starch shapes and types among the 110 plant samples. These included both simple and compound starches. Simple starches form singly in amyloplasts. Compound starches occur when multiple starches form in a single amyloplast. Compound starches were observed in their entire form when the component granules do not break apart easily, but in some cases they were observed as isolated component granules. Sometimes, starches appeared as simple, but two crosses were visible under cross-polarized light, indicating they were in fact compound starches. In other publications, starches of this type have been described as either semi-compound, in which two starches are "united by the deposition of a common surrounding layer of starch" (Shannon and Garwood, 1984p. 35), or pseudo-compound, in which a single starch "develops large cracks while remaining a single entity" (French, 1984p. 184). Semi-compound and pseudo-compound describe different developmental processes, but we are unable to visually distinguish between them in the mature samples that we examined. We therefore called this type of starch a "cryptic compound" to include both formation processes. From most to least common, the starch shapes were spherical, polyhedral (e.g., rectangular, pentagonal, hexagonal and more), ellipsoid, ovoid, lenticular, hemispherical, reniform, pyriform, triangular, cylindric, and lumpy/irregular. Interestingly, in some taxonomic groups, the starches from the various species all resemble each other quite closely. This is commonly seen at the genus level (e.g., *Bromus*), sometimes seen at the tribe level (e.g., Triticeae), and occasionally or rarely seen at the family level (e.g., Fagaceae). Some families, such as Poaceae, have a wide variety of starch shapes.

The sizes of the starches also varied significantly, with simple starches and isolated component granules having size ranges from 0.1–1 μm (e.g., *Agrostemma githago*, *Amaranthus blitum*, *Vaccaria hispanica*) and up to 72 μm (*Lilium candidum*). The compound starches range from very small (compounds of two small components) up to 140–150 μm (e.g., *Amaranthus blitum*, *Panicum miliaceum*) and in rare cases up to 200 μm (e.g., *Emex spinosa*).

Some of the species contained a very large range of starch sizes and shapes. In some cases, this size range is so large, and the differences between the biggest and smallest starches so striking, that many authors have referred to the assemblage as 'bimodal' (e.g., Reichert, 1913). This term is frequently applied to members of the Triticeae, especially *Triticum* and *Hordeum*, which have big lenticular starches and small spherical ones. However, the actual size distribution of these starches has not been measured. In order to test whether the starches actually had a bimodal distribution, we measured the sizes in 45 plants from the Poaceae (specifically, the TASH group: *Triticum*, *Aegilops*, *Secale* and *Hordeum* species) and Fabaceae (specifically; *Vicia*, *Lens*, *Pisum* and *Lathyrus* species), as these had the largest range of sizes and most difference between their bigger and smaller shapes. We measured the maximum length of at least 250 starches from each plant in these families, except *Lathyrus clymenum*, in which 149 starches were measured, and *Lathyrus*

ochrus in which 150 were measured, due to low starch numbers in these samples. We then ran a Shapiro-Wilk test of normality using the function 'shapiro.test' in R [version 4.0.5 (2021–03-31) – "Shake and Throw" (R Core Team, 2020)]. In the descriptions we refer to a bimodal distribution only when this test indicates a true bimodal distribution. In some cases there is no true bimodal distribution, yet the smaller starches are shaped differently than bigger ones. Visual inspection of the histogram of sizes often reveals a very long tail, with very few medium-sized starches. In this case we use the phrase "heteromorphic with two main morphologies: smaller and bigger". In one taxon, *Triticum monococcum* subsp. *boeoticum*, the test revealed a multimodal distribution, despite the general appearance of one size class.

We included a large number of species from the Triticeae tribe, especially those in the TASH group (*Triticum*, *Aegilops*, *Secale*, and

Table 2
List of the 220 plant parts that were sampled. The list is organized alphabetically by family, and then alphabetically by genus within family. Some species/subspecies include multiple plant parts. The column "Starch" indicates whether starches were observed.

Plant family	Latin name	Common name	Tested tissue	Hebrew name	Starch	Source
Aceraceae	*Acer monspessulanum* subsp. *microphyllum* (Boiss.) Bornm.	Montpellier maple	Fruit pulp; Seed	אֶדֶר קטן-עלים	No; No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Adoxaceae	*Sambucus nigra* L.	Elder	Fruit pulp; Seed	סמבוק שחור	No; No	A.G. Henry reference collection (collected from a free-growing bush in Leipzig, Germany).
Aizoaceae	*Mesembryanthemum nodiflorum* L.	Slenderleaf iceplant	Seed	אהל מצוי	No	Collections of the Botanical Garden of the Tel-Aviv University.
Amaranthaceae	*Amaranthus blitum* L.	Wild amaranth	Seed	יִרְבּוּז מִבְרִיק	Yes	Collected from the wild, Golani junction, Israel.
Amaryllidaceae	*Allium ampeloprasum* L.	Wild leek	Bulb	שום גבוה	No	Collected fromresearch plot at the Ecological-Botanical Garden of the Technion.
Amaryllidaceae	*Allium rotundum* L.	Sand leek	Bulb	שום עגל	No	Collected from research plot of the Botanical Garden of the Hebrew University on Giva't Ram.
Amaryllidaceae	*Narcissus tazetta* L.	Paperwhite	Bulb	נרקיס מצוי	No	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Amaryllidaceae	*Sternbergia clusiana* (Ker Gawler) Spreng.	Sternbergia	Bulb; Seed	חלמונית גדולה	Yes; No	Collected from research plot at the Ecological-Botanical Garden of the Technion; Collected from the wild, Mt. Meron, Israel.
Amaryllidaceae	*Vagaria parviflora* (Desf. ex Delile) Herb.	/	Bulb	חבצלת קטנת-פרחים	Yes	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Apiaceae	*Coriandrum sativum* L.	Coriander	Seed	גד השדה; ש"נ כוסברה	No	Collections of the Botanical Garden of the Tel-Aviv University.
Apiaceae	*Daucus carota* L.	Wild carrot	Root	גזר קפח; ש"נ גזר הגנה	Yes	Collected from the wild, Nahal ha'shofet valley near Yoknea'm, Israel.
Apiaceae	*Foeniculum vulgare* Mill.	Fennel	Seed	שמר פשוט	No	Collected from research plot of the Botanical Garden of Tel-Aviv University.
Araceae	*Arisarum vulgare* Targ.-Tozz.	Friar's cowl	Tuber	לופית מצויה	Yes	Collected from research plot of the Botanical Garden of Tel-Aviv University.
Araceae	*Arum dioscoridis* SM.	Arum lily	Tuber	לוף מגמר	Yes	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Araceae	*Arum hygrophilum* Boiss.	/	Tuber	לוף ירק	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Giva't Ram.
Araceae	*Arum palaestinum* Boiss.	Black calla; Solomon's lily	Seed; Tuber	לוף ארץ-ישראלי	Yes; Yes	Collected from research plot of the Ecological-Botanical Garden of the Technion; Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Araceae	*Eminium spiculatum* (Blume) Schott	/	Bulb	לוליינית מעבה	Yes	Collected from the wild, Nahal Hashofet forest near Yoknea'm, Israel.
Asclepiadaceae	*Calotropis procera* (Aiton) Aiton f.	Sodom's apple	Seed	פתילת המדבר הגדולה; ש"נ תפוח סדום	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Asparagaceae	*Asparagus aphyllus* L.	Prickly Asparagus	Stem	אספרג החורש	No	Collected from the wild, Nahal ha'shofet valley near Yoknea'm, Israel.
Asparagaceae	*Hyacinthus orientalis* L.	Common Hyacinth	Bulb	יקינתון מזרחי	Yes	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Asparagaceae	*Ornithogalum arabicum* L.	Arab's eye	Bulb	נץ-חלב ערבי	Yes	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Asparagaceae	*Ornithogalum narbonense* L	Narbonne star-of-Bethlehem	Seed	נץ-חלב צרפתי	No	Collections of the Botanical Garden of the Tel-Aviv University.
Asteraceae	*Cichorium endivia* L.	Wild endive	Root; Seed	עלש מצוי	No; No	Collected from research plot at the Ecological-Botanical Garden of the Technion; Collections of the Botanical Garden of the Tel-Aviv University.
Asteraceae	*Cnicus benedictus* L.	/	Seed	דרדר מברך; ש"נ קרצף מברך	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Asteraceae	*Gundelia tournefortii* L.	/	Seed	עכובית הגלגל; ש"נ עכוב	No	Collected from the Arbel Nature Reserve, Israel.
Asteraceae	*Scolymus maculatus* L.	Spotted golden thistle	Seed	חוח עקד	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Asteraceae	*Silybum marianum* (L.) Gaertn.	Cardus marianus	Seed	גדילן מצוי	No	Collected from the wild, Mt. Kotz, Massad, Israel.
Boraginaceae	*Cerinthe palaestina* Eig & Samuelsson	/	Seed	דונגית ארץ-ישראלית	No	Collections of the Botanical Garden of the Tel-Aviv University.
Brassicaceae	*Anastatica hierochuntica* L.	Rose of Jericho	Seed	שושנת יריחו אמתית	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.

(*continued on next page*)

Table 2 (*continued*)

Plant family	Latin name	Common name	Tested tissue	Hebrew name	Starch	Source
Brassicaceae	*Brassica nigra* (L.) W.D.J.Koch	Black mustard	Seed	כְּרוּב שָׁחֹר	No	A.G. Henry reference collection.
Brassicaceae	*Brassica tournefortii* Gouan	Asian mustard	Seed	כְּרוּב הַחוֹף	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Butomaceae	*Butomus umbellatus* L.	Umbelled flowering-rush	Rhizome	בּוֹצִיץ סוּכָכִי	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Cannabacaea	*Celtis australis* L.	European nettle tree	Fruit pulp; Seed	מִישׁ דְּרוֹמִי	No; No	Collections of the Botanical Garden of the Tel-Aviv University.
Capparaceae	*Capparis zoharyi* Inocencio, Rivera et Alcaraz	Jerusalem caper	Root; Seed	צְלָף קוֹצָנִי; ש"נ צְלָף זֹהֲרִי	Yes; No	Collected from the wild, Golani junction, Israel; Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Caryophyllaceae	*Agrostemma githago* L.	Common corn-cockle	Seed	אַגְרוֹסְטֶמֶת הַשָּׂדוֹת	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Mt. Avital, Ramat Hagolan, Israel).
Caryophyllaceae	*Alisma plantago-aquatica* L.	Water plantain	Root; Seed	כַּף-צְפַרְדֵּעַ לַחָכִית	Yes; Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram; Collections of the Botanical Garden of the Tel-Aviv University.
Caryophyllaceae	*Paronychia argentea* Lam.	Silver Nailwort	Seed	אַלְמֻוֹת הַכֶּסֶף	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Mt. Kramin, Ramat Hagolan, Israel).
Caryophyllaceae	*Vaccaria hispanica* (Mill.) Rauschert.	Cowherb	Seed	סְבוֹנִית הַשָּׂדֶה	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Cistaceae	*Cistus creticus* L.	Soft-hairy rockrose	Seed	לוֹטֶם שָׂעִיר	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	Sweet potato	Stem-tuber	לְפוּפִית הַבָּטָטָה; ש"נ בָּטָטָה	Yes	Purchased in grocery store, Tiberias, Israel.
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	Desert squash	Seed	אֲבַטִּיחַ הַפְּקוּעָה	No	Collections of the Botanical Garden of the Tel-Aviv University.
Cyperaceae	*Cyperus macrorrhizus* Nees	/	Nutlet	גֹּמָא מְגֻבָּב	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Cyperaceae	*Cyperus rotundus* L.	Coco-grass	Bulb; Seed	גֹּמָא הַפְּקָעִים	No; No	Collected from research plot of the Botanical Garden of Tel-Aviv University.
Cyperaceae	*Scirpus maritimus* L.	Sea clubrush	Seed	אַגְמוֹן יַמִּי	Yes	Collected from the wild, lakeshore of the Kinneret, Tiberias, Israel.
Dipsacaceae	*Cephalaria syriaca* (L.) Schrad.	Syrian Cephalaria	Seed	שִׁלְמוֹן סוּרִי	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Ericaceae	*Arbutus andrachne* L.	Strawberry tree	Fruit pulp	קְטוֹלָב מְצוּי	No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Euphorbiaceae	*Chrozophora tinctoria* (L.) Raf.	Dyer's croton	Fruit pulp; Seed	לְשִׁישִׁית הַצְּבָעִים	No; No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Anagyris foetida* L.	Bean-clover	Seed	צִחְנָן מַבְאִישׁ	No	Collected from the wild, Mt. Meron, Israel.
Fabaceae	*Astragalus hamosus* L.	Hooked Milkvetch	Seed	קְדֵדָה הָאַנְקוֹלִים	No	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Ceratonia siliqua* L.	Carob	Pod (inner part); Seed	חָרוּב מְצוּי	No; No	Collected from the wild, Mt. kotz, Massad, Israel.
Fabaceae	*Cercis siliquastrum* L.	/	Seed	כְּלִיל הַחוֹרֶשׁ	No	Collected from the wild, Mt. kotz, Massad, Israel.
Fabaceae	*Cicer arietinum* L.	Chickpea	Seed	חִמְצָה תַּרְבּוּתִית	Yes	Purchased from Whole Foods Market in Washington, DC.
Fabaceae	*Cicer judaicum* Boiss.	Wild chickpea	Seed	חִמְצָה שְׂסוּעָה	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Cicer reticulatum* Ladz.	Wild chickpea	Seed	חִמְצָה מְרֻשֶּׁתֶת	Yes	Collected from research plot at the agricultural research organization (ARO) - Volcani center by Shmuel (Muli) Galili.
Fabaceae	*Glycyrrhiza echinata* L.	Chinese licorice	Seed	שׁוּשׁ קוֹצָנִי	No	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Glycyrrhiza glabra* L.	Liquorice	Root	שׁוּשׁ קָרֵחַ	Yes	Purchased as root segment in a spice stall in the open market of Tiberias, Israel.
Fabaceae	*Indigofera coerulea* Roxb.	/	Seed	נִיל מְכֻסִּיף	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus. (originally acquired from the Botanical Garden of Ein Gedi Nature Reserve).
Fabaceae	*Lathyrus aphaca* L.	Yellow Pea	Seed	טִפַּח מְצוּי	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Carmel Mountains, Israel).
Fabaceae	*Lathyrus cicera* L.	Red pea	Seed	טִפַּח חִמְצָתִי	Yes	A.G. Henry reference collection, USDA NPGS Accession number PI 237639.
Fabaceae	*Lathyrus clymenum* L.	Spanish vetchling	Seed	טִפַּח סְפָרַדִּי	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild near Ramat Hasharon, Israel).
Fabaceae	*Lathyrus ochrus* (L.) DC	Winged Vetchling; Cyprus vetch; Pale Pea	Seed	טִפַּח גָּדוֹל	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Dora swamp, Netanya, Israel).

(*continued on next page*)

Table 2 (*continued*)

Plant family	Latin name	Common name	Tested tissue	Hebrew name	Starch	Source
Fabaceae	*Lathyrus sativus* L.	Grass pea	Seed	טִפַּח תִּרְבּוּתִי	Yes	A.G. Henry reference collection, USDA NPGS Accession number PI 283547.
Fabaceae	*Lens culinaris* Medik.	Brown lentil; Red lentil	Seed; Seed	עֲדָשָׁה תִּרְבּוּתִית	Yes	Purchased in grocery store, Tiberias, Israel.
Fabaceae	*Lens ervoides* (Brign.) Grande	Wild lentil	Seed	עֲדָשָׁה מְצוּיָה	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Lens orientalis* (Boiss.) Schamlh.	Wild Lentil	Seed	עֲדָשָׁה מִזְרָחִית	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Lotus creticus* L.	Bird's-foot trefoils	Seed	לוֹטוּס מִכְסִיף	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Lotus edulis* L.	/	Seed	לוֹטוּס נֶאֱכָל	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Lotus palustris* Willd.	/	Seed	לוֹטוּס הַבִּצּוֹת	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Lupinus pilosus* L.	Blue lupine	Seed	תֻּרְמוּס הֶהָרִים	No	Collected from a modern Israeli field near Giva't Avni, Israel.
Fabaceae	*Medicago astroites* (Fisch. & C.A. Mey.) Trautv.	/	Seed	גַּרְגְּרָנִית מְאֻצְבַּעַת; ש"נ גַּרְגְּרָנִית הַכּוֹכָב	No	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Medicago lupulina* L.	Black medick	Seed	אִסְפְּסֶת זְעִירָה	No	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Medicago polymorpha* L.	California burclover	Seed	אִסְפְּסֶת מְצוּיָה	No	A.G. Henry reference collection, USDA NPGS Accession number PI 577409.
Fabaceae	*Medicago sativa* L.	Alfalfa	Seed	אִסְפְּסֶת תִּרְבּוּתִית	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the margins of a cultivated field, Tzurim valley, Jerusalem).
Fabaceae	*Pisum elatius* M. Bieb	Wild pea	Seed	אֹפּוֹן קִפְּחִ	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Pisum fulvum* Sm.	Wild pea	Seed	אֹפּוֹן מְצוּי	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally acquired from the collections of the Neot Kdumim Biblical Landscape Reserve).
Fabaceae	*Pisum humile* Boiss. & Noë	Wild pea	Seed	אֹפּוֹן נָמוּךְ	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Pisum sativum* L.	Green pea	Seed	אֹפּוֹן תִּרְבּוּתִי	Yes	Purchased from Whole Foods Market in Washington, DC.
Fabaceae	*Prosopis farcta* (Banks & Sol.) J.F. Macbr.	Syrian mesquite	Seed	יִנְבּוּט הַשַּׂדֶה	No	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Trigonella foenum-graecum* L.	Fenugreek	Seed	גַּרְגְּרָנִית יְוָנִית; ש"נ גַּרְגְּרָנִית הַחִלְבָּה	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Vicia bithynica* (L.) L.	Bithynian vetch	Seed	בִּקְיָה אֲנָטוֹלִית	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Acre valley, Israel).
Fabaceae	*Vicia ervilia* (L.) Willd.	Bitter vetch	Seed	בִּקְיַת הַכַּרְשִׁינָה	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fabaceae	*Vicia faba* L.	Faba bean; Horse bean	Seed	פּוֹל	Yes	A.G. Henry reference collection, USDA NPGS Accession number PI 253808.
Fabaceae	*Vicia galilaea* Plitmann & Zohary	Wild vetch	Seed	בִּקְיַת הַגָּלִיל	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Vicia monantha* Retz.	Wild vetch	Seed	בִּקְיָה מְדֻרְבֶּנֶת	Yes	A.G. Henry reference collection, USDA NPGS Accession. Number W6 17410.
Fabaceae	*Vicia narbonensis* L.	Narbon vetch	Seed	בִּקְיָה צָרְפָתִית	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Fabaceae	*Vicia sativa* L.	Garden vetch	Seed	בִּקְיָה תִּרְבּוּתִית; ש"נ בִּקְיָה צָרַת עֲלִים	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Fagaceae	*Castanea sativa* Mill.	Sweet chestnut	Nut	עַרְמוֹן	Yes	Purchased in grocery store, Tiberias, Israel.
Fagaceae	*Quercus boissieri* Reut.	Cyprus oak	Acorn	אַלּוֹן הַתּוֹלָע	Yes	Collected from the wild, Carmel Mountains, Israel.
Fagaceae	*Quercus calliprinos* Webb	Israeli oak	Acorn	אַלּוֹן מְצוּי	Yes	Collected from the wild, Massad, Israel.
Fagaceae	*Quercus ithaburensis* Decne.	Mount Tabor oak	Acorn	אַלּוֹן הַתָּבוֹר	Yes	Collected from the wild, Carmel Mountains, Israel.
Iridaceae	*Crocus hyemalis* Boiss. & Blanche	Winter saffron	Bulb	כַּרְכֹּם חַרְפִּי	No	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Iridaceae	*Moraea sisyrinchium* (L.) Ker-Gawler	Barbary nut	Bulb	אֲחִיאִירוס מְצוּי; ש"נ צְהֳרוֹן מְצוּי; 'אירוס אַחַר הַצָּהֳרַיִם	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Iridaceae	*Romulea bulbocodium* (L.) Sebastiani & Mauri	/	Seed	רוֹמוּלֵאָה סַגְלוֹלִית	No	Collections of the Botanical Garden of the Tel-Aviv University.
Juncaceae	*Juncus acutus* L.	Spiny rush	Seed	סְמַר חַד	Yes	Collected from the wild, Ein Afek Nature Reserve near Kiryat motzkin, Israel.
Lamiaceae	*Mentha aquatica* L.	Water mint	Seed	נַעֲנָע הַמַּיִם	No	Collected from research plot at the Botanical Garden of Tel-Aviv University.
Lamiaceae	*Salvia verbenaca* L.	Wild clary	Seed	מַרְוָה מְצוּיָה	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Liliaceae	*Asphodeline lutea* (L.) Rchb.	King's spear	Rhizome	עִירְיוֹנִי צָהֹב	No	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Liliaceae	*Asphodelus ramosus* L.	Branched asphodel	Rhizome	עִירִית גְּדוֹלָה	No	

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Table 2 (*continued*)

Plant family	Latin name	Common name	Tested tissue	Hebrew name	Starch	Source
						Collected from research plot of the Botanical Garden of the Hebrew University on Giva't Ram.
Liliaceae	*Lilium candidum* L.	Madonna lily	Bulb	שׁוֹשַׁן צָחֹר	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Liliaceae	*Tulipa agenensis* DC.	Sharon tulip	Bulb; Stem	צִבְעוֹנִי הֶהָרִים	No; No	Collected from the wild, near Elyakim, Israel.
Linaceae	*Linum bienne* Mill.	Pale	Seed	פִּשְׁתָּה צָרַת-עֲלִים	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Linaceae	*Linum usitatissimum* L.	Flax	Seed	פִּשְׁתָּה תַּרְבּוּתִית	No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Lythraceae	*Lythrum salicaria* L.	Purple loosestrife	Root	שַׂנִּית גְּדוֹלָה	No	Collected from the Hulla Valley Nature Reserve, Israel.
Malvaceae	*Althaea officinalis* L.	Marsh-mallow	Root; Seed	נְטוֹפִית רְפוּאִית	Yes; No	Collected from research plot at the Ecological-Botanical Garden of the Technion; Collections of the Botanical Garden of the Tel-Aviv University.
Malvaceae	*Corchorus trilocularis* L.	/	Seed	מְלוּכִיָּה מְשֻׁלֶּשֶׁת	No	Collections of the Botanical Garden of the Tel-Aviv University.
Malvaceae	*Malva nicaeensis* All.	Common mallow	Root	חֲלָמִית מְצוּיָה	Yes	Collected from the wild, Giva't avni, Israel.
Malvaceae	*Malva parviflora* L.	Cheeseweed	Seed	חֲלָמִית קְטַנַּת-פְּרָחִים	No	Collections of the Botanical Garden of the Tel-Aviv University.
Malvaceae	*Malva sylvestris* L.	Wilde Malve	Seed	חֲלָמִית גְּדוֹלָה	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Myrtaceae	*Myrtus communis* L.	Common myrtle	Fruit pulp; Seed	הֲדַס מְצוּי	No; No	Collected from the wild, Carmel Mountains, Israel.
Nymphaeaceae	*Euryale ferox* Salisb.	Fox nut	Seed	אַיְרִיָּל קוֹצָנִי	Yes	Purchased in a market, Thailand.
Nymphaeaceae	*Nuphar lutea* (L.) Sm.	Yellow Pond-lily	Rhizome	נוּפָר צָהֹב	Yes	Collected from the Hulla Valley Nature Reserve, Israel.
Nymphaeaceae	*Nymphaea alba* L.	White water lily	Rhizome	נִימְפֵאָה לְבָנָה	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Oleaceae	*Fraxinus angustifolia* Vahl subsp. *syriaca* (Boiss.) Yalt.	/	Seed	מֵילָה סוּרִית	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Tel Dan Nature Reserve, Israel).
Oleaceae	*Olea europa*ea L.	Olive	Fruit pulp	זַיִת אֵירוֹפִּי	No	Collected from the wild, Netofa Valley, Israel.
Papilionaceae	*Colutea istria* Mill.	/	Seed	קַרְקַשׁ צָהֹב	No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Papilionaceae	*Melilotus albus* Medik. ex Desr.	White sweet clover	Seed	דִּבְשָׁה לְבָנָה	No	Collections of the Botanical Garden of the Tel-Aviv University.
Pinaceae	*Pinus halepensis* Mill.	Aleppo Pine	Seed	אֹרֶן יְרוּשָׁלַיִם	No	Collected from the wild, Carmel Mountains, Israel.
Plantaginaceae	*Plantago major* L.	Broadleaf plantain	Seed	לְחֶךְ גָּדוֹל	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Aegilops geniculata* Roth	Ovate goatgrass	Grain	בֶּן-חִטָּה בִּיצָנִי	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Aegilops kotschyi* Boiss.	Goatgrass	Grain	בֶּן-חִטָּה מִדְבָּרִי	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Aegilops longissima* Schweinf. & Muschl.	Goatgrass	Grain	בֶּן-חִטָּה אֲרִיכָא	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Aegilops peregrina* (Hack.) Maire & Weiller	Goatgrass	Grain	בֶּן-חִטָּה רַב-אַנְפִּין	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Aegilops searsii* Feldman & Kislev ex Hammer	Goatgrass	Grain	בֶּן-חִטַּת סִירְס	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Aegilops sharonensis* Eig	Goatgrass	Grain	בֶּן-חִטָּה שָׁרוֹנִי	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Poleg Nature Reserve, Israel).
Poaceae	*Aegilops speltoides* Tausch	Goatgrass	Grain	בֶּן-חִטָּה קְטוּעַ	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Beit Netofa valley, Israel).
Poaceae	*Aegilops vavilovii* (Zhuk.) Chennav	Goatgrass	Grain	בֶּן-חִטָּה מְעֻבָּה	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Arundo donax* L.	Giant reed	Grain	עִבְקָנָה שְׂכִיחָ	No	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Avena barbata* Pott ex Link	Wild oat	Grain	שִׁבֹּלֶת-שׁוּעָל מִתְפָּרֶקֶת	Yes	Collected from the wild, Ztippori, Israel.
Poaceae	*Avena sativa* L.	Oat	Grain	שִׁבֹּלֶת-שׁוּעָל תַּרְבּוּתִית	Yes	Purchased in grocery store, Tiberias, Israel.
Poaceae	*Avena sterilis* L.	Wild oat	Grain	שִׁבֹּלֶת-שׁוּעָל נְפוּצָה	Yes	Collected from the wild, Ztippori, Israel.
Poaceae	*Avena wiestii* Steud.	Wild oat	Grain	שִׁבֹּלֶת-שׁוּעָל עַרְבָתִית	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Bromus alopecuros* Poir.	Weedy brome	Grain	בְּרוֹמִית זְנַב-הַשּׁוּעָל	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Bromus fasciculatus* C. Presl	Mediterranean Brome	Grain	בְּרוֹמִית מְאֻגֶּדֶת	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected

(*continued on next page*)

Table 2 (*continued*)

Plant family	Latin name	Common name	Tested tissue	Hebrew name	Starch	Source
						from the wild, Orvim Reservoir, Ramat Hagolan, Israel).
Poaceae	*Bromus japonicus* Thunb.	Japanese brome	Grain	בְּרוֹמִית יַפָּנִית	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally acquired from the collections of the Neot Kdumim Biblical Landscape Reserve).
Poaceae	*Bromus lanceolatus* Roth	Woolly Brome	Grain	בְּרוֹמִית אִזְמֶלָנִית	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Orvim Reservoir, Ramat Hagolan, Israel).
Poaceae	*Bromus scoparius* L.	Twiggy brome	Grain	בְּרוֹמִית הַמְּטאֲטֵא	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Bromus tectorum* L.	Drooping brome	Grain	בְּרוֹמִית הַגַּגוֹת	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Beit HaKerem neighborhood, Jerusalem, Israel).
Poaceae	*Catabrosa aquatica* (L.) P. Beauv.	Water whirl-grass	Grain	סִפָּה הַמַּיִם	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Desmazeria philistaea* (Boiss.) H. Scholz	/	Grain	אֲדַמְדֶּמִית פְּלִשְׁתִּית	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Echinochloa crusgalli* (L.) P. Beauv.	Cockspur; Barnyard millet	Grain	דְּחָנִית הַתַּרְנְגוֹלִים	Yes	A.G. Henry reference collection, USDA NPGS Accession number PI 649330.
Poaceae	*Eragrostis sarmentosa* (Thunb.) Trin.	Lovegrass	Grain	בֶּן-חִילְף הַבְּצוֹת	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, winter swamp near Hadera's train station, Israel).
Poaceae	*Eragrostis tef* (Zuccagni) Trotter	Teff	Grain	בֶּן-חִילְף טֶף	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Hordeum bulbosum* L.	Wild barley	Bulb; Grain	שְׂעוֹרַת הַבֻּלְבּוֹסִין	No; Yes	Collected from the wild, Ztippori, Israel.
Poaceae	*Hordeum geniculatum* All.	Wild barley	Grain	שְׂעוֹרָה נִימִית	Yes	Collected from the wild near Tiberias, Israel.
Poaceae	*Hordeum glaucum* Steud.	Wild barley	Grain	שְׂעוֹרַת הָעִכְבָּר; ש"נ שְׂעוֹרָה מִכְחִילָה	Yes	Collected from the wild, Ztippori, Israel.
Poaceae	*Hordeum spontaneum* K. Koch	Wild barley	Grain	שְׂעוֹרַת הַתָּבוֹר	Yes	Collected from the wild, Golani junction, Israel.
Poaceae	*Hordeum vulgare* subsp. *distichum* L.	Two-rowed barley	Grain	שְׂעוֹרָה תַּרְבּוּתִית דּוּ־טוּרִית	Yes	Collected from a cultivated field near Giva't Avni, Israel.
Poaceae	*Hordeum vulgare* subsp. *vulgare* L.	Six-rowed barley	Grain	שְׂעוֹרָה תַּרְבּוּתִית שֵׁשׁ־טוּרִית	Yes	Collected from a cultivated field near Tiberias, Israel.
Poaceae	*Lolium perenne* L.	Perennial ryegrass	Grain	זוּן רַב-שְׁנָתִי	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Lolium persicum* Boiss. & Hohen. ex Boiss.	Persian ryegrass	Grain	זוּן פָּרְסִי	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Lolium temulentum* L.	Bearded ryegrass	Grain	זוּן מְשַׁכֵּר	Yes	Collections of the Herbarium of the Hebrew University on Givat Ram (originally collected from a cultivated field, Netofa Valley, Israel).
Poaceae	*Panicum miliaceum* L.	Proso millet	Grain	דֹּחַן תַּרְבּוּתִי	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Phragmites australis* (Cav.) Trin. ex Steud.	Common reed	Rhizome	קָנֶה מָצוּי	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Poaceae	*Piptatherum miliaceum* L. Coss.	Smilo grass	Grain	נִשְׂרָן הַדֹּחַן	Yes	Collected from the wild, Ztippori, Israel.
Poaceae	*Polypogon monspeliensis* (L.) Desf.	Annual beard-grass	Grain	עִבְדְּקָן מָצוּי	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Poaceae	*Secale cereale* L.	Rye	Grain	שִׁיפוֹן תַּרְבּוּתִי	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Secale montanum* Guss.	Wild rye	Grain	שִׁיפוֹן הֶהָרִים	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from the wild, Mt. Hermon valley, Israel).
Poaceae	*Sorghum bicolor* (L.) Moench	Sorghum	Grain	דּוּרָה תַּרְבּוּתִית	Yes	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Stipa capensis* Thunb.	Mediterranean needle-grass	Grain	מִלְעָנִיאַל מָצוּי	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Stipa parviflora* Desf.	/	Grain	מִלְעָנִיאַל קָטָן-פְּרָחִים	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally collected from Ezuz, Israel).
Poaceae	*Triticum aestivum* subsp. *aestivum* L.	Common wheat; Bread wheat	Grain	חִטַּת הַלֶּחֶם	Yes	Collected from a cultivated field near Giva't Avni, Israel.
Poaceae	*Triticum monococcum* subsp. *boeoticum* Boiss.	Wild einkorn	Grain	חִטַּת הַבָּר חַד־גַּרְגִּירִית	Yes	Collections of the Herbarium of the Hebrew University on Givat Ram. (N.B. this seed was collected in 1933).
Poaceae	*Triticum monococcum* subsp. *monococcum* L.	Einkorn	Grain	חִטָּה חַד־גַּרְגִּירִית	Yes	Collected from research plot at the agricultural research organization (ARO) - Volcani center by

(*continued on next page*)

Table 2 (*continued*)

Plant family	Latin name	Common name	Tested tissue	Hebrew name	Starch	Source
						Roi Ben David. Seed provided by Roi Ben David from ARO - Volcani.
Poaceae	*Triticum turgidum* subsp. *dicoccoides (Körn. ex Asch. & Graebn.) Schweinf.*	Wild emmer	Grain	חִטַּת הַבָּר דּוּ־גַּרְגִּירִית	Yes	Collected from the margins of a field, Rehaniya, Israel.
Poaceae	*Triticum turgidum* subsp. *dicoccum* Schrank ex Schübl.	Emmer	Grain	חִטָּה דּוּ־גַּרְגִּירִית	Yes	A.G. Henry reference collection, acquired in Turkey.
Poaceae	*Triticum turgidum* subsp. *durum* Desf.	Durum wheat	Grain	חִטַּת דורום	Yes	Collected from a cultivated field near Golani junction, Israel.
Poaceae	*Urochloa mutica* (Forssk.) Nguyen	Para grass	Grain	נִסְמָנִית קִפְחַת; ש"נ דְּחָנָן קִפְחַ	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Poaceae	*Zea mays* L.	Maize	Grain	תִּירָס	Yes	A.G. Henry reference collection, purchased from Whole Foods Market in Washington, DC, 2008.
Polygonaceae	*Emex spinosa* (L.) campd.	Devil's thorn	Seed	אֲמִירָ קוֹצָנִי	Yes	Collections of the Botanical Garden of the Tel-Aviv University.
Polygonaceae	*Rumex pulcher* L.	Fiddle dock	Seed	חֲמְעָה יָפָה	Yes	Collections of the Botanical Garden of the Hebrew University on Mount Scopus (originally acquired from the collections of the Ecological-Botanical Garden of the Technion collection).
Primulaceae	*Cyclamen persicum* Mill.	Persian cyclamen	Seed; Tuber	רַקֶּפֶת מְצוּיָה	No; No	Collected from the wild, Mt. kotz, Massad, Israel.
Rhamnaceae	*Paliurus spina-christi* Mill.	Jerusalem thorn	Seed	אֶשְׁמָר קוֹצָנִי; ש"נ שְׁמִיר קוֹצָנִי	No	Collected from research plot of the Botanical Garden of the Hebrew University on Givat Ram.
Rhamnaceae	*Rhamnus alaternus* L.	/	Fruit pulp; Seed	אֶשְׁחָר רְחַב-עֲלִים	No; No	Collected from the wild, Mt. Meron, Israel.
Rhamnaceae	*Rhamnus punctata* Boiss.	/	Fruit pulp; Seed	אֶשְׁחָר מְנֻקָּד	No; No	Collected from the wild, Mt. Meron, Israel.
Rhamnaceae	*Zizifus spina-christi* (L.) Desf.	Christ's thorn jujube	Fruit pulp	שִׁיזָף מְצוּי	No	Collected from the wild near Tiberias, Israel.
Rosaceae	*Amygdalus ramonensis* Danin	Wild Ramon almond	Fruit pulp; Seed	שְׁקֵד רְמוֹן	No; No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Rosaceae	*Crataegus aronia* (L.) DC.	/	Fruit pulp; Seed	עֲזְרָר קוֹצָנִי	No; No	Collected from the wild, Mt. Meron, Israel.
Rosaceae	*Prunus ursina* Kotschy	/	Fruit pulp; Seed	שִׁזִּיף הַדֹּב	No; No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Rosaceae	*Pyrus syriaca* Boiss.	Syrian pear	Fruit pulp	אַגַּס סוּרִי	No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Rosaceae	*Rosa arabica* Crép.	Rose	Fruit pulp	וֶרֶד עֲרָבִי	No	Collected from research plot of the Botanical Garden of the Hebrew University on Mount Scopus.
Rosaceae	*Rosa canina* L.	/	Fruit pulp; Seed	וֶרֶד הַכֶּלֶב	No; No	Collected from research plot at the Ecological-Botanical Garden of the Technion.
Rosaceae	*Rubus sanctus* Schreb.	Holly bramble	Fruit pulp; Seed	פִּטֶּל קָדוֹשׁ	No; No	Collected from the wild, Carmel Mountains, Israel.
Rosaceae	*Sarcopoterium spinosum* (L.) Spach	Prickly	Fruit pulp; Seed	סִירָה קוֹצָנִית	No; No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Rubiaceae	*Crucianella macrostachya* Boiss.	Crossworts	Seed	צְלָבִית אֲרֻכַּת-שִׁבֹּלֶת	No	Collected from the wild, Kalanit, Israel.
Rubiaceae	*Galium tricornutum* Dandy	Rough corn bedstraw	Seed	דִּבְקָה מְשֻׁלֶּשֶׁת	No	Collections of the Botanical Garden of the Tel-Aviv University.
Rubiaceae	*Rubia tinctorum* L.	Rose madder	Fruit pulp; Seed	פּוּאַת הַצְּבָעִים	No; No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Salvadoraceae	*Salvadora persica* L.	Arak	Fruit pulp	סַלְוַדוֹרָה פָּרְסִית	No	Collections of the Botanical Garden of the Hebrew University on Mount Scopus.
Solanaceae	*Mandragora autumnalis* Bertol.	Mandrake	Fruit pulp; Taproot	דּוּדָא רְפוּאִי	Yes; Yes	Collected from the wild, Nahal ha'shofet forest near Yoknea'm, Israel.
Solanaceae	*Solanum tuberosum* L.	Potato	Stem-tuber	תַּפּוּחַ אֲדָמָה; ש"נ תַּפּוּד	Yes	Purchased in grocery store, Tiberias, Israel.
Styracaceae	*Styrax officinalis* L.	/	Seed	לְבֻנָה רְפוּאִי	No	Collections of the Botanical Garden of the Tel-Aviv University.
Typhaceae	*Typha domingensis* (Pers.) Steud.	Southern cattail	Rhizome	סוּף מְצוּי	Yes	Collected from the wild near Hamat Gader Park, Israel.
Vitaceae	*Vitis vinifera* L.	Grapevines	Fruit pulp; Seed	גֶּפֶן הַיַּעְרוֹת; ש"נ גֶּפֶן הַיַּיִן תת-מין הַיַּעְרוֹת	No; No	Collected from cultivated field, Mt. kotz, Massad, Israel.

Hordeum), as well as members of the Fabeae tribe (*Lens*, *Vicia*, *Pisum*, *Lathyrus*) as these were the close relatives and progenitors of many domesticates. We found, as in other studies, members of the TASH group contained very characteristic lenticular starches, which are circular to subcircular or even D-shaped in plan view, and biconvex or compressed ovals in side view (e.g., Piperno et al., 2004). We did not see this starch shape in any of the other taxa we examined, though we note that similar starches have been found in chili peppers (Perry et al., 2007). In some cases it is possible to distinguish among these closely related species, but there is a high degree of overlap. Similarly, many members of the Fabeae tribe, along with members of the genus *Cicer*, have a characteristic irregular ovoid shape marked by a mesial longitudinal cleft fissure. Again, in some cases it is possible to identify individual species, but generally there is a high degree of similarity among these taxa.

Finally, we observed material from the plant cells that were not starch but which may aid in identification. Several of the taxa we examined contained raphides (long calcium oxalate crystals). These were commonly found in the tubers of *Arum* sp., *Arisarum vulgare*, *Ornithogalum arabicum*, and *Eminium spiculatum*. When present, we included a brief description of the raphide shapes. In one plant, *Lathyrus cicera,* we observed small cubic minerals that may be druses, a more blocky, crystalline form of calcium oxalate.

3.1. Organization of the Key

After describing all of the starches we examined, we then used the morphological features of the starches to build a diagnostic key, so that unknown starches might be identified. The first level of the key separates simple from compound starches. As mentioned above, compound starches can be seen in their entire form when the starches do not break apart easily, but they can also be seen as isolated component granules, which can make the diagnosis difficult. Therefore we include a category for starches that have pressure facets, which can indicate they were either simple starches that formed close to each other (such as with *Zea mays*) or isolated component granules (as is often the case with *Avena sativa*). We also noted that some starches had both simple and compound starches, with some species having mostly simple starches with just a few compounds, and others being mostly compound with a few simple ones. These taxa appear in multiple places on the key, under both simple and compound. We also included a category for the "cryptic compounds" described above.

Given the variability in shapes within some species, certain taxa appear multiple times in the key. The key is not designed to indicate individual taxa, but to provide a narrowed list of potential matching species for the researcher to check, using the descriptions and photos provided in our supplementary information and on our Mendeley database. We have provided in Fig. 1 a schematic representation of the main shapes described in the key.

3.2. The Key

The key is designed as a series of questions to help a researcher identify an unknown starch. Start at the top and follow through to the various subsections. Often, multiple species produce similar starches and we recommend checking all of the taxa in one category. We occasionally provide one or more of the following types of additional

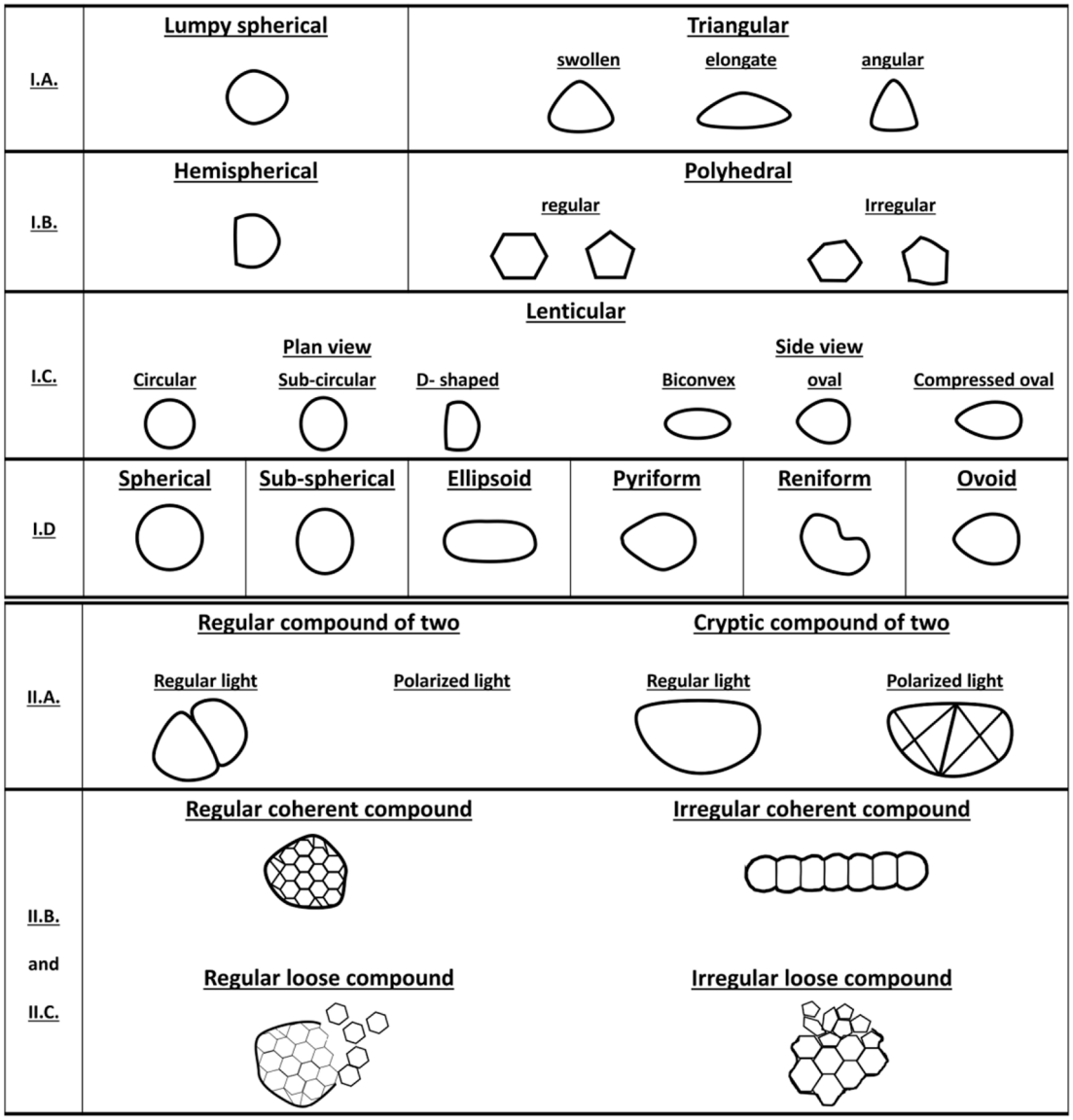

Fig. 1. A schematic representation of the main shapes described in the key.

information in parentheses after each species: 1) what plant part that category of starches was found in, 2) how frequently that particular starch category is found in that species, 3) which starches within that species fall into that category (e.g., the bigger starches), or 4) extra diagnostic information (i.e., presence of additional features that differentiate that species from others in the same category).

For defining starches start here:

What is the shape of your starch?

- Starch appears simple, or is an isolated component granule (i.e., a single starch with one extinction-cross)……..Go to Key I
- Starch appears compound, or appears in a cluster (i.e., multiple starches attached to each other, with multiple extinction crosses, and more or less clear divisions between component granules). ……..Go to Key II
- Starch appears simple (i.e., with a single smooth outline and no visible divisions between component granules) but has multiple hila and/or multiple extinction crosses. This may be a 'cryptic compound'. Many taxa form cryptic compounds, but often the overall shape is the same for the simple starches, so try to follow Key I based on the general shape of the starch. Check especially the following lines: I.D.1, I.D.2, I.B. We have also included taxa which have cryptic compounds in Key II, from line II.A.

Key I: Starch has a single extinction cross and a single smooth outline, and therefore may be simple or an isolated component granule

What is the shape of your starch in 3D?

- Lumpy spherical/triangular: three curved sides, or one side with a more distinct curve than the others……..go to line I.A.
- Hemispherical or polyhedral: one or more, more-or-less flat facet. ……..go to line I.B.
- Lenticular: circular, sub-circular, or D-shaped in plan view, biconvex or oval to compressed oval in side view……..go to line I.C.
- Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid. ……..go to line I.D.

I.A. Triangular: three sides that are almost always slightly curved, or one side with a more distinct curve than the others

- Is it an isosceles triangle with a very wide base and low height, with rounded, inflated sides, and blunt corners, and sometimes slightly bent "inflated banana" shape?……..go to line I.A.1
- Is it an isosceles triangle with a wide base and medium height, with mostly straight sides, and blunt corners?……..go to line I.A.2
- Is it an isosceles to equilateral triangle, with mostly straight sides, and somewhat angular corners?……..go to line I.A.3

I.A.1 Swollen triangular: an isosceles triangle with a very wide base and low height, with rounded, inflated sides, and blunt corners, and sometimes slightly bent "inflated banana" shape

5.4 *Sternbergia clusiana* (Ker Gawler) Spreng.
17.1 *Cistus creticus* L.
25.2 *Quercus boissieri* Reut.
25.3 *Quercus calliprinos* Webb
25.4 *Quercus ithaburensis* Decne.
39.32 *Lolium perenne* L. (this is smaller than in *Quercus*)

I.A.2 Elongated triangular: an isosceles triangle with a wide base and medium height, with mostly straight sides, and blunt corners

5.4 *Sternbergia clusiana* (Ker Gawler) Spreng.
17.1 *Cistus creticus* L.
24.9 *Glycyrrhiza glabra* L.
25.1 *Castanea sativa* Mill.
25.4 *Quercus ithaburensis* Decne.
39.32 *Lolium perenne* L.

I.A.3 Angular triangular: an isosceles to equilateral triangle, with mostly straight sides, and somewhat angular corners

16.4 *Paronychia argentea* Lam.
25.4 *Quercus ithaburensis* Decne.

I.B. Hemispherical or Polyhedral: one or more, more-or-less flat surfaces that meet at angles

- Are there many facets and angles that are mostly the same size, shape and orientation to each other (Regular polyhedral)?. ……..go to line I.B.1
- Are there many facets, which are of uneven sizes, or is there a mix of angular and very rounded edges (Irregular polyhedral)?. ……..go to line I.B.2
- Is there only one or possibly two adjacent facets, while the rest of the starch is very rounded (Hemispherical)?……..go to line I.B.3

I.B.1 Regular polyhedral: Facets and angles more or less the same size, shape and orientation to each other

- Is the starch bigger than 5 μm?……..go to line I.B.1.a
- Is the starch smaller than 5 μm?……..go to line I.B.1.b

I.B.1.a Regular polyhedral bigger than 5 μm

7.1 *Arisarum vulgare* Targ.-Tozz.
7.2 *Arum dioscoridis* SM.
7.3 *Arum hygrophilum* Boiss.
7.4 *Arum palaestinum* Boiss. (seed)
7.5 *Arum palaestinum* Boiss. (tuber)
18.1 *Ipomoea batatas* (L.) Lam.
20.3 *Scirpus maritimus* L. (very angular)
25.3 *Quercus calliprinos* Webb
27.1 *Juncus acutus* L. (hilum is a bit wide and pit-like)
32.4 *Malva nicaeensis* All.
39.10 *Avena barbata* Pott ex Link
39.12 *Avena sterilis* L.
39.13 *Avena wiestii* Steud.
39.14 *Bromus alopecuros* Poir. (rare)
39.16 *Bromus japonicus* Thunb. (rare)
39.17 *Bromus lanceolatus* Roth
39.22 *Echinochloa crusgalli* (L.) P.Beauv.
39.32 *Lolium perenne* L. (commonly cuboid)
39.35 *Panicum miliaceum* L.
39.41 *Sorghum bicolor* (L.) Moench (facets are not very flat)
39.51 *Zea mays* L. (facets are not very flat)
40.1 *Emex spinosa* (L.) campd.
40.2 *Rumex pulcher* L. (rounded angles)
46.2 *Mandragora autumnalis* Bertol. (taproot) (rare)

I.B.1.b Regular polyhedral smaller than 5 μm

7.1 *Arisarum vulgare* Targ.-Tozz.
7.2 *Arum dioscoridis* SM.
7.3 *Arum hygrophilum* Boiss.

7.4 *Arum palaestinum* Boiss. (seed)
7.5 *Arum palaestinum* Boiss. (tuber)
7.6 *Eminium spiculatum* (Blume) Schott
18.1 *Ipomoea batatas* (L.) Lam.
19.3 *Aegilops longissima* Schweinf. & Muschl.
19.6 *Aegilops sharonensis* Eig
25.2 *Quercus boissieri* Reut. (rare)
25.3 *Quercus calliprinos* Webb
27.1 *Juncus acutus* L. (hilum is a bit wide and pit-like)
32.4 *Malva nicaeensis* All. (rare)
39.10 *Avena barbata* Pott ex Link (sub-angular)
39.11 *Avena sativa* L. (more rounded)
39.12 *Avena sterilis* L. (more rounded)
39.13 *Avena wiestii* Steud.
39.14 *Bromus alopecuros* Poir. (rare)
39.16 *Bromus japonicus* Thunb. (rare)
39.17 *Bromus lanceolatus* Roth
39.31 *Hordeum vulgare* subsp. *vulgare* L.
39.32 *Lolium perenne* L. (often cuboid)
39.35 *Panicum miliaceum* L.
39.45 *Triticum monococcum* subsp. *boeoticum* Boiss.
39.46 *Triticum monococcum* subsp. *monococcum* L.
39.51 *Zea mays* L.
40.1 *Emex spinosa* (L.) campd.
40.2 *Rumex pulcher* L. (rounded angles)
46.2 *Mandragora autumnalis* Bertol. (taproot)

I.B.2 Irregular polyhedral: The facets are of uneven sizes, or there is a mix of angular and very rounded edges

– Is the starch bigger than 5 μm?……..go to line I.B.2.a
– Is the starch smaller than 5 μm?……..go to line I.B.2.b

I.B.2.a Irregular polyhedral bigger than 5 μm

16.2 *Alisma plantago-aquatica* L. (root)
18.1 *Ipomoea batatas* (L.) Lam.
25.2 *Quercus boissieri* Reut. (irregular hemispherical)
25.3 *Quercus calliprinos* Webb
27.1 *Juncus acutus* L. (hilum is a bit wide and pit-like)
32.4 *Malva nicaeensis* All. (mostly with one facet)
39.13 *Avena wiestii* Steud.
39.36 *Phragmites australis* (Cav.) Trin. ex Steud. (up to 2 pressure facets)
39.37 *Piptatherum miliaceum* L. Coss. (up to 2 or 3 pressure facets and others are angular)
39.51 *Zea mays* L.
46.1 *Mandragora autumnalis* Bertol. (fruit pulp)
48.1 *Typha domingensis* (Pers.) Steud. (mixed forms- triangular, rectangular polygonal, pentagonal, etc.)

I.B.2.b Irregular polyhedral smaller than 5 μm

16.4 *Paronychia argentea* Lam. (mixed forms- triangular, rectangular polygonal, pentagonal, etc.)
18.1 *Ipomoea batatas* (L.) Lam.
27.1 *Juncus acutus* L. (hilum is a bit wide and pit-like)
32.4 *Malva nicaeensis* All. (mostly with one facet)
34.1 *Euryale ferox* Salisb.
39.13 *Avena wiestii* Steud. (more spherical, ovoid, triangular)
39.22 *Eragrostis sarmentosa* (Thunb.) Trin.
39.23 *Eragrostis tef* (Zuccagni) Trotter
39.36 *Phragmites australis* (Cav.) Trin. ex Steud. (up to 2 pressure facets)
39.37 *Piptatherum miliaceum* L. Coss. (up to 2 or 3 pressure facets and others are angular)
39.38 *Polypogon monspeliensis* (L.) Desf.
39.51 *Zea mays* L.
46.1 *Mandragora autumnalis* Bertol. (fruit pulp)
48.1 *Typha domingensis* (Pers.) Steud. (mixed forms- triangular, rectangular polygonal, pentagonal, etc.)

I.B.3 Hemispherical: One or two adjacent facets, while the rest of the starch is very rounded

15.1 *Capparis zoharyi* Inocencio, Rivera et Alcaraz
25.2 *Quercus boissieri* Reut.
32.4 *Malva nicaeensis* All.
39.1-8, 39.26-31, 39.39-40, 39.44-49 TASH species (see note with line I.C. below)
39.51 *Zea mays* L. (the very smallest grains can be elongated hemispherical)
46.2 *Mandragora autumnalis* Bertol. (taproot)

I.C. Lenticular: circular, sub-circular, or D-shaped in plan view, biconvex or oval to compressed oval in side view

In our study area, this type of starch is found almost exclusively in seeds of the "TASH" group: *Triticum*, *Aegilops*, *Secale* and *Hordeum* (fruits from the modern introduced domesticated species in the Solanaceae, including chili peppers and possibly tomatoes, also contain similar starches). There is much overlap among the TASH taxa. We have tried to find distinctive features that allow the separations among taxa, but we recommend checking all members of this group.

– Does starch have a visible hilum (refractive, distinct or indistinct), which may be marked by a thin straight line or fissure ("thumbnail fissure")?……..go to line I.C.1
– Does starch have an invisible hilum?……..go to line I.C.2

I.C.1 Lenticular starch with a visible hilum (refractive, distinct, or indistinct) which may be marked by a thin straight line or fissure ("thumbnail fissure")

– Does the starch have visible lamellae (alternating bands of light and dark areas within the starch), either faint or clear?. ……..go to line I.C.1.a
– Does the starch have no visible lamellae?……..go to line I.C.1.b

I.C.1.a Lenticular starch with a visible hilum and visible lamellae

39.1 *Aegilops geniculata* Roth (up to 26 μm)
39.2 *Aegilops kotschyi* Boiss. (up to 40 μm)
39.3 *Aegilops longissima* Schweinf. & Muschl. (up to 42 μm)
39.4 *Aegilops peregrina* (Hack.) Maire & Weiller up to 40 μm)
39.5 *Aegilops searsii* Feldman & Kislev ex Hammer (rare),(up to 23 μm)
39.6 *Aegilops sharonensis* Eig (up to 46 μm)
39.7 *Aegilops speltoides* Tausch (rare),(up to 26 μm)
39.8 *Aegilops vavilovii* (Zhuk.) Chennav (up to 45 μm)
39.39 *Secale cereale* L. (up to 45 μm)
39.40 *Secale montanum* Guss. (rare),(up to 50 μm)
39.44 *Triticum aestivum* subsp. *aestivum* L. (up to 40 μm)
39.47 *Triticum turgidum* subsp. *dicoccoides* (Körn. ex Asch. & Graebn.) Schweinf. (up to 27 μm)
39.48 *Triticum turgidum* subsp. *dicoccum* Schrank ex Schübl. (up to 40 μm)
39.49 *Triticum turgidum* subsp. *durum* Desf. (up to 45 μm)

I.C.1.b Lenticular starch with visible hilum but no visible lamellae

39.26 *Hordeum bulbosum* L. (up to 16 μm)

39.27 *Hordeum geniculatum* All. (up to 26 μm)
39.28 *Hordeum glaucum* Steud. (up to 21 μm)
39.29 *Hordeum spontaneum* K. Koch (rare),(up to 22 μm)
39.40 *Secale montanum* Guss. (up to 50 μm)
39.46 *Triticum monococcum* subsp. *monococcum* L. (rare),(up to 30 μm)

I.C.2 Lenticular starch with invisible hilum

– Does the starch have visible lamellae (alternating bands of light and dark areas within the starch), either faint or clear?. ……..go to line I.C.2.a
– Does it have no visible lamellae?…….. ……..go to line I.C.2.b

I.C.2.a Lenticular starch with invisible hilum and visible lamellae

39.31 *Hordeum vulgare* subsp. *vulgare* L. (up to 25 μm)

I.C.2.b Lenticular starch with Invisible hilum and no visible lamellae

39.29 *Hordeum spontaneum* K. Koch (up to 22 μm)
39.30 *Hordeum vulgare* subsp. *distichum* L. (up to 28 μm)
39.45 *Triticum monococcum* subsp. *boeoticum* Boiss. (up to 15 μm)
39.46 *Triticum monococcum* subsp. *monococcum* L. (up to 30 μm)

I.D. Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid

– Does the starch have a mesial longitudinal cleft fissure (MLCF - a large, variably branching fissure running through the center of the starch along the long axis of the grain, sometimes clearly visible only from one side)?…….go to line I.D.1
– Does the starch have no MLCF?…….go to line I.D.2

I.D.1 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch has a mesial longitudinal cleft fissure (MLCF)

In our study area, the MLCF is found in starches from the seeds of plants in the Cicereae and Fabeae tribes in the Fabaceae family, particularly *Cicer*, *Lens*, *Lathyrus*, *Pisum*, *Vicia* (the MLCF is also found in the starches of non-native Fabaceae, including *Phaseolus*).

– Is the MLCF thick with a bold dark area at the center of the starch?. ……..go to line I.D.1.a
– Is the MLCF thin with a faint dark area at the center of the starch?. ……..go to line I.D.1.b

I.D.1.a Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid, has a thick, dark MLCF

– Does it have distinct lamellae mostly throughout the grain?. ……..go to line I.D.1.a.1
– Does it have invisible or indistinct lamellae?…….go to line I.D.1.a.2

I.D.1.a.1 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid, has a thick dark MLCF and has distinct lamellae mostly throughout the grain

– 24.5 *Cicer arietinum* L. (lamellae continuous in smaller starches, discontinuous in larger ones)
24.13 *Lathyrus clymenum* L. (the bigger starches)
24.14 *Lathyrus ochrus* (L.) DC
24.19 *Lens orientalis* (Boiss.) schamlh.
24.29 *Pisum fulvum* Sm.
24.30 *Pisum humile* Boiss. & Noë (the bigger starches)
24.31 *Pisum sativum* L. (the bigger starches)
24.35 *Vicia ervilia* (L.) Willd. (the bigger starches)
24.36 *Vicia faba* L.
24.37 *Vicia galilaea* Plitmann & Zohary
24.38 *Vicia monantha* Retz.

– **I.D.1.a.2 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid, has a thick dark MLCF has invisible or indistinct lamellae**

24.7 *Cicer reticulatum* Ladz. (the smaller starches)
24.12 *Lathyrus cicera* L. (MLCF sometimes splits at the ends)
24.13 *Lathyrus clymenum* L. (the smaller starches)
24.16 *Lens culinaris* Medik. (brown variety)
24.17 *Lens culinaris* Medik. (red variety)
24.18 *Lens ervoides* (Brign.) Grande
24.29 *Pisum fulvum* Sm.
24.30 *Pisum humile* Boiss. & Noë (the smaller starches)
24.31 *Pisum sativum* L. (the bigger starches)
24.34 *Vicia bithynica* (L.) L. (rare)
24.35 *Vicia ervilia* (L.) Willd. (the smaller starches)
24.37 *Vicia galilaea* Plitmann & Zohary (rare)

I.D.1.b MLCF is thin and with a faint dark area

– Does it have distinct lamellae mostly throughout the grain?. ……..go to line I.D.1.b.1
– Does it have invisible or indistinct lamellae?…….go to line I.D.1.b.2

I.D.1.b.1 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid, starch with thin, faint MLCF and distinct lamellae

24.6 *Cicer judaicum* Boiss. (lamellae continuous in smaller starches, discontinuous in larger ones)
24.7 *Cicer reticulatum* Ladz. (the bigger starches)
24.15 *Lathyrus sativus* L. (has the most distinctive lamellae from all *Lathyrus* species)
24.19 *Lens orientalis* (Boiss.) schamlh.
24.28 *Pisum elatius* M. Bieb (the bigger starches)
24.34 *Vicia bithynica* (L.) L.
24.36 *Vicia faba* L.
24.37 *Vicia galilaea* Plitmann & Zohary
24.38 *Vicia monantha* Retz.
24.39 *Vicia narbonensis* L.
24.40 *Vicia sativa* L.

– **I.D.1.b.2 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid, starch with thin faint MLCF and invisible or indistinct lamellae**

24.6 *Cicer judaicum* Boiss. (lamellae are discontinuous in the bigger starches)
24.7 *Cicer reticulatum* Ladz. (the small starches)
24.11 *Lathyrus aphaca* L.
24.18 *Lens ervoides* (Brign.) Grande (rare)
24.28 *Pisum elatius* M. Bieb (the smaller starches)
24.34 *Vicia bithynica* (L.) L.
24.37 *Vicia galilaea* Plitmann & Zohary (rare)
24.39 *Vicia narbonensis* L. (rare)
24.40 *Vicia sativa* L. (rare)

I.D.2 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid, starch and without a mesial longitudinal cleft fissure (MLCF)

Many of the species in this list can also produce faceted (hemi-spherical or polyhedral) starches and sometimes also compounds. These are not very common, but you may want to also check line I.B. and in key II.

– Does it have visible lamellae?……..... ……..... go to line I.D.2.a
– Does it hasn't visible lamellae?……..... ……..... ……..go to line I.D.2.b

- **I.D.2.a Starch without MLCF and with visible lamellae**

– Is the hilum centric (in the middle of the starch)?. ……..... ……..... ……..go to line I.D.2.a.1
– Is the hilum eccentric (close to one end)?……..... ……..... ……..go to line I.D.2.a.2

I.D.2.a.1 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF, with visible lamellae and a centric hilum

25.4 *Quercus ithaburensis* Decne. (hilum mostly obscured by refractive fissure)
39.41 *Sorghum bicolor* (L.) Moench (hilum mostly obscured by straight-line/X/Y-fissure)

I.D.2.a.2 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF, with visible lamellae and an eccentric hilum

16.3 *Alisma plantago-aquatica* L. (seed), (less common)
29.3 *Lilium candidum* L. (the medium and the bigger starches)
39.41 *Sorghum bicolor* (L.) Moench (hilum mostly obscured by straight-line/X/Y-fissure)
46.3 *Solanum tuberosum* L. (the medium and bigger starches)

- **I.D.2.b Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF and without visible lamellae**

– Does starch have a centric, refractive hilum (hilum changes from black to white in different focal planes)?……..... ……..... ……..go to line I.D.2.b.1
– Does it have an eccentric, refractive hilum?……..... ……..... ……..go to line I.D.2.b.2
– Does it have an eccentric, unmarked hilum?……..... ……..... ……..go to line I.D.2.b.3
– Does it have an invisible hilum (possibly due to the very small size of the starch)?……..... ……..... ……..go to line I.D.2.b.4

I.D.2.b.1 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF, without visible lamellae, and with a centric, refractive hilum

– 5.4 *Sternbergia clusiana* (Ker Gawler) Spreng. (centric to slightly eccentric) (obscured by refractive fissure)
6.2 *Daucus carota* L. (spherical)
7.1 *Arisarum vulgare* Targ.-Tozz. (hilum sometimes obscured by fissure)(spherical)
7.2 *Arum dioscoridis* SM. (hilum often obscured by fissure), (spherical)
7.3 *Arum hygrophilum* Boiss.(spherical)
7.4 *Arum palaestinum* Boiss. (seed),(spherical)
7.5 *Arum palaestinum* Boiss. (tuber),(hilum sometimes obscured by fissure),(spherical)
7.6 *Eminium spiculatum* (Blume) Schott (spherical)
15.1 *Capparis zoharyi* Inocencio, Rivera et Alcaraz (spherical)
16.2 *Alisma plantago-aquatica* L. (root), (irregular spherical to ovoid)
16.3 *Alisma plantago-aquatica* L. (seed), (lenticular / flattened ovoid)
16.4 *Paronychia argentea* Lam.
17.1 *Cistus creticus* L. (hilum obscured by refractive fissure)
24.9 *Glycyrrhiza glabra* L. (hilum obscured by refractive fissure)
25.1 *Castanea sativa* Mill. (hilum obscured by refractive fissure)
25.2 *Quercus boissieri* Reut. (hilum rarely obscured by refractive fissure)
25.3 *Quercus calliprinos* Webb (hilum rarely obscured by refractive fissure)
25.4 *Quercus ithaburensis* Decne. (less common without lamellae), (hilum commonly obscured by refractive fissure)
26.2 *Moraea sisyrinchium* (L.) Ker-Gawler (hilum commonly obscured by stellate / X / Y-fissure)
29.3 *Lilium candidum* L. (the smaller starches), (spherical)
32.1 *Althaea officinalis* L.
32.4 *Malva nicaeensis* All. (the bigger starches)
34.1 *Euryale ferox* Salisb.
39.10 *Avena barbata* Pott ex Link
39.11 *Avena sativa* L. (hilum sometimes obscured by fissures)
39.12 *Avena sterilis* L.
39.13 *Avena wiestii* Steud.
39.14 *Bromus alopecuros* Poir.
39.17 *Bromus lanceolatus* Roth
39.18 *Bromus scoparius* L.
39.19 *Bromus tectorum* L. (hilum sometimes obscured by fissures)
39.20 *Catabrosa aquatica* (L.) P. Beauv.
39.22 *Echinochloa crusgalli* (L.) P.Beauv.
39.23 *Eragrostis sarmentosa* (Thunb.) Trin. (hilum is a bit wide and pit-like),
39.24 *Eragrostis tef* (Zuccagni) Trotte (irregular spherical)
39.33 *Lolium persicum* Boiss. & Hohen. ex Boiss.
39.34 *Lolium temulentum* L.
39.36 *Phragmites australis* (Cav.) Trin. ex Steud. (hilum is a bit wide and pit-like)
39.51 *Zea mays* L. (hilum mostly obscured by straight-line / X / Y-fissure)
40.1 *Emex spinosa* (L.) campd.
40.2 *Rumex pulcher* L.
46.1 *Mandragora autumnalis* Bertol. (fruit pulp)
46.3 *Solanum tuberosum* L. (the smaller starches)
48.1 *Typha domingensis* (Pers.) Steud.

I.D.2.b.2 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF, without visible lamellae, with an eccentric, refractive hilum

5.4 *Sternbergia clusiana* (Ker Gawler) Spreng.
5.6 *Vagaria parviflora* (Desf. ex Delile) Herb. (hilum sometimes obscured by regular fissure in larger starches)
9.3 *Ornithogalum arabicum* L.
25.1 *Castanea sativa* Mill. (less common),(hilum obscured by refractive fissure)
25.2 *Quercus boissieri* Reut. (most starches),(hilum rarely obscured by refractive fissure)
25.3 *Quercus calliprinos* Webb (most starches), (hilum rarely obscured by refractive fissure)
27.1 *Juncus acutus* L. (hilum is a bit wide and pit-like)
32.4 *Malva nicaeensis* All. (the bigger starches)
34.2 *Nuphar lutea* (L.) Sm.
34.3 *Nymphaea alba* L. (hilum obscured by refractive fissure)
39.37 *Piptatherum miliaceum* L. Coss.
39.51 *Zea mays* L. (hilum often obscured by straight-line / X / Y-fissure)
46.1 *Mandragora autumnalis* Bertol. (fruit pulp)
46.2 *Mandragora autumnalis* Bertol. (taproot)
48.1 *Typha domingensis* (Pers.) Steud.

I.D.2.b.3 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF, without visible lamellae, and with an eccentric, unmarked hilum

18.1 *Ipomoea batatas* (L.) Lam. (hilum sometimes obscured by fissure)
25.2 *Quercus boissieri* Reut. (less common)

I.D.2.b.4 Spherical, sub-spherical, ellipsoid, pyriform, reniform or ovoid starch without MLCF, without visible lamellae, and invisible hilum (the position of the hilum is indicated by the center of the extinction cross)

4.1 *Amaranthus blitum* L. (not possible to determine due to small size)
9.2 *Hyacinthus orientalis* L. (eccentric)
13.1 *Butomus umbellatus* L. (centric)
16.1 *Agrostemma githago* L. (not possible to determine due to small size)
16.5 *Vaccaria hispanica* (Mill.) Rauschert. (not possible to determine due to small size)
20.1 *Cyperus macrorrhizus* Nees (centric)
32.4 *Malva nicaeensis* All. (sometimes centric and sometimes not due to the shape of the starch, mostly invisible in the smaller starches)
39.15 *Bromus fasciculatus* C. Presl (centric)
39.16 *Bromus japonicus* Thunb. (centric)
39.32 *Lolium perenne* L. (indistinct extinction cross, cross is probably centric)
39.38 *Polypogon monspeliensis* (L.) Desf. (not possible to determine due to small size)

Key II: Starch appears compound, or appears in a cluster (i.e., multiple starches attached to each other, with multiple extinction crosses, and more or less clear divisions between component granules)

How many components are in the compound?

– Are there two to five component granules in the compound?. ……..……..……..……..go to line II.A.
– Are there more than six to twenty component granules?. ……..……..……..……..go to line II.B.
– Are there more than twenty components?…….....…….....……...go to line II.C.

II.A. Two to five component grains in the compound

There is often no clear distinction between two, three, four and five-component granules, so it may be good to check all species in this category.

– Are there two to three components?…….....…….....……...go to line II.A.1
– Are there more than three components?…….....…….....……...go to line II.A.2

■ **II.A.1 Two to three component grains are in the compound**
  – Do the components have a mesial longitudinal cleft fissure (MLCF - a large, variably branching fissure running through the center of the starch along the long axis of the grain, sometimes clearly visible only from one side)?. ……..……..……..……..go to line II.A.1.a
  – Do the components have no MLCF?…….....…….....……...go to line II.A.1.b

II.A.1.a A compound of two to three components, with the components having an MLCF

24.7 *Cicer reticulatum* Ladz. (cryptic compound)
24.11 *Lathyrus aphaca* L. (cryptic compound)
24.13 *Lathyrus clymenum* L. (cryptic compound)
24.15 *Lathyrus sativus* L. (cryptic compound)
24.30 *Pisum humile* Boiss. & Noë (cryptic compound)
24.31 *Pisum sativum* L. (cryptic compound)
24.34 *Vicia bithynica* (L.) L. (cryptic compound)
24.35 *Vicia ervilia* (L.) Willd. (both cryptic and non-cryptic compound)
24.36 *Vicia faba* L. (cryptic compound)
24.40 *Vicia sativa* L. (cryptic compound)

II.A.1.b A compound of two to three components, without the components having an MLCF

5.6 *Vagaria parviflora* (Desf. ex Delile) Herb. (both cryptic and non-cryptic compound)
5.4 *Sternbergia clusiana* (Ker Gawler) Spreng.
7.6 *Eminium spiculatum* (Blume) Schott
9.2 *Hyacinthus orientalis* L.
9.3 *Ornithogalum arabicum* L. (cryptic compound)
16.2 *Alisma plantago-aquatica* L. (root)
16.4 *Paronychia argentea* Lam.
25.2 *Quercus boissieri* Reut.
25.3 *Quercus calliprinos* Webb
25.4 *Quercus ithaburensis* Decne.
32.4 *Malva nicaeensis* All.
39.3 *Aegilops longissima* Schweinf. & Muschl. (the smaller starches)
39.6 *Aegilops sharonensis* Eig (the smaller starches)
39.10 *Avena barbata* Pott ex Link
39.14 *Bromus alopecurus* Poir. (cryptic compound)
39.18 *Bromus scoparius* L. (cryptic compound)
39.19 *Bromus tectorum* L. (cryptic compound)
39.20 *Catabrosa aquatica* (L.) P. Beauv.
39.36 *Phragmites australis* (Cav.) Trin. ex Steud.
39.37 *Piptatherum miliaceum* L. Coss.
39.45 *Triticum monococcum* subsp. *boeoticum* Boiss. (the smaller starches)
39.46 *Triticum monococcum* subsp. *monococcum* L. (the smaller starches)
46.2 *Mandragora autumnalis* Bertol. (taproot)

II.A.2 Three to five component grains in the compound

5.4 *Sternbergia clusiana* (Ker Gawler) Spreng.
7.6 *Eminium spiculatum* (Blume) Schott
9.2 *Hyacinthus orientalis* L.
16.4 *Paronychia argentea* Lam.
39.6 *Aegilops sharonensis* Eig (equatorial groove)
39.13 *Avena wiestii* Steud.

- **II.B. Six to twenty component grains in the compound**
  – Is the compound regularly shaped (i.e., described by a single geometric term such as spherical) and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (regular coherent compound)?. ……..……..……..……..go to line II.B.1
  – Is the compound regularly shaped but the individual components can break off easily or the compound breaks apart easily (regular loose compound)?…….....…….....……...go to line II.B.2
  – Is the compound irregularly shaped (i.e., cannot be described by a single geometric term such as spherical) and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (irregular coherent compound)?…go to line II.B.3
  – Is the compound irregularly shaped but the individual components can break off easily or the compound breaks apart easily (irregular loose compound)?…….....…….....……...go to line II.B.4

II.B.1 Regular coherent compound of six to twenty components

– Is the compound spherical to ellipsoid?……..…….go to line II.B.1.a
– Is the compound polyhedral?……..…….go to line II.B.1.b
– Is the compound ovoid?……..…….go to line II.B.1.c

II.B.1.a Regular coherent compound with six to twenty components and a spherical to ellipsoid shape

32.4 *Malva nicaeensis* All.
39.10 *Avena barbata* Pott ex Link
39.11 *Avena sativa* L. (less common)
39.12 *Avena sterilis* L. (polyhedral to sub-spherical)
39.33 *Lolium persicum* Boiss. & Hohen. ex Boiss.
39.34 *Lolium temulentum* L. (less common than regular loose compound)

II.B.1.b Regular coherent compound with six to twenty components and a polyhedral shape

39.10 *Avena barbata* Pott ex Link

II.B.1.c Regular coherent compound with six to twenty components and an ovoid shape

20.3 *Scirpus maritimus* L. (angular, less common than loose compound)
32.4 *Malva nicaeensis* All.
39.13 *Avena wiestii* Steud. (the smaller compounds)
39.33 *Lolium persicum* Boiss. & Hohen. ex Boiss.

II.B.2 The compound of six to twenty components is regularly shaped and the individual components can break off easily or the compound breaks apart easily (regular loose compound)

– Is the compound ovoid, reniform, spherical to ellipsoid?. ……..…….go to line II.B.2.a
– Is the compound polyhedral?……..…….go to line II.B.2.b

II.B.2.a Regular loose compound with six to twenty components and an ovoid, reniform, spherical or ellipsoid shape

39.34 *Lolium temulentum* L.
39.37 *Piptatherum miliaceum* L. Coss. (spherical)

II.B.2.b Regular loose compound with six to twenty components and a polyhedral shape

20.3 *Scirpus maritimus* L. (angular, most common)

II.B.3 The compound of six to twenty components is irregularly shaped and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (irregular coherent compound)

– Is the compound lumpy spherical?……..…….go to line II.B.3.a
– Is the compound irregular polyhedral?……..…….go to line II.B.3.b
– Is the compound amorphic line?……..…….go to line II.B.3.c

II.B.3.a Irregular coherent compound with six to twenty components and a lumpy spherical shape

39.11 *Avena sativa* L. (common)
39.13 *Avena wiestii* Steud.

II.B.3.b Irregular coherent compound with six to twenty components and irregular polyhedral shape

32.4 *Malva nicaeensis* All.

II.B.3.c Irregular coherent compound with six to twenty components and forms in a single amorphic line

9.2 *Hyacinthus orientalis* L.
16.4 *Paronychia argentea* Lam.

II.B.4 The compound of six to twenty components is irregularly shaped and the individual components can break off easily or the compound breaks apart easily (irregular loose compound)

– Is the compound polyhedral?……..…….go to line II.B.4.a
– Is the compound polyhedral to rectangular.……..…….go to line II.B.4.b

II.B.4.a Irregular loose compound with six to twenty components and a polyhedral shape

39.24 *Eragrostis tef* (Zuccagni) Trotter

- **II.B.4.b Irregular coherent compound with six to twenty components and a polyhedral to rectangular shape**

39.35 *Panicum miliaceum* L.

II.C. More than 20 component grains in the compound

– Is the compound regularly shaped (i.e., described by a single geometric term such as spherical) and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (regular coherent compound). ……..…….go to line II.C.1
– Is the compound regularly shaped but the individual components can break off easily or the compound breaks apart easily (regular loose compound)?……..…….go to line II.C.2
– Is the compound irregularly shaped (i.e., cannot be described by a single geometric term such as spherical) and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (irregular coherent compound)?…go to line II.C.3
– Is the compound irregularly shaped but the individual components can break off easily or the compound breaks apart easily (irregular loose compound)?……..…….go to line II.C.4

II.C.1 A compound with 20+ component grains, that is regularly shaped and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (i.e., regular coherent compound)

– Is the compound elongate and pointed ellipsoid?. ……..…….go to line II.C.1.a
– Is the compound rectangular/rhombuses?……..…….go to line II.C.1.b
– Is the compound polyhedral?……..…….go to line II.C.1.c
– Is the compound spherical to ellipsoid?……..…….go to line II.C.1.d
– Is the compound ovoid?……..…….go to line II.C.1.e

II.C.1.a Regular coherent compound of 20+ components, with elongate and pointed ellipsoid shape

– 16.1 *Agrostemma githago* L.

II.C.1.b Regular coherent compound of 20+ components with a rectangular/rhombus shape

– 40.1 *Emex spinosa* (L.) campd.

II.C.1.c Regular coherent compound of 20+ components with a polyhedral shape

4.1 *Amaranthus blitum* L.
39.10 *Avena barbata* Pott ex Link
39.38 *Polypogon monspeliensis* (L.) Desf.

II.C.1.d Regular coherent compound of 20+ components with a spherical to ellipsoid shape

39.10 *Avena barbata* Pott ex Link
39.12 *Avena sterilis* L. (polyhedral to subspherical)
39.32 *Lolium perenne* L.
39.33 *Lolium persicum* Boiss. & Hohen. ex Boiss.
39.34 *Lolium temulentum* L. (less common than regular loose compound)
39.38 *Polypogon monspeliensis* (L.) Desf. (spherical to polyhedral and asymmetric ellipsoid)

II.C.1.e Regular coherent compound of 20+ components with an ovoid shape

39.33 *Lolium persicum* Boiss. & Hohen. ex Boiss.

II.C.2 The 20+ component grains compound is regularly shaped but the individual components can break off easily or the compound breaks apart easily (regular loose compound)

– Is the compound rectangular?……..……..go to line II.C.2.a
– Is the compound spherical to ellipsoid and ovoid?. ……..……..go to line II.C.2.b
– Is the compound prismatic and elongate ellipsoid?. ……..……..go to line II.C.2.c

II.C.2.a Regular loose compound of 20+ components with a rectangular shape

39.22 *Echinochloa crusgalli* (L.) P.Beauv.

II.C.2.b Regular loose compound of 20+ components with a spherical to ellipsoid and ovoid shape

39.34 *Lolium temulentum* L. (most common)

II.C.2.c Regular loose compound of 20+ components with a Regular loose compound of 20+ components with a prismatic and elongate ellipsoid shape

16.4 *Paronychia argentea* Lam. (most common)

II.C.3 The 20+ component grains compound is irregularly shaped and formed as a coherent unit, with individual components that do not break off easily and a very defined outer margin (irregular coherent compound)

16.4 *Paronychia argentea* Lam. (less common),(prismatic and elongate ellipsoid)

II.C.4 The 20+ component grains is compound irregularly shaped and the individual components can break off easily or the compound breaks apart easily (irregular loose compound)

– Is the compound sub-spherical?……..……..go to line II.C.4.a
– Is the compound polyhedral?……..……..go to line II.C.4.b
– Is the overall shape of the compound unclear because the outer margin is not preserved due to components breaking off?. ……..…….. go to line II.C.4.c

II.C.4.a Irregular loose compound of 20+ components with a sub-spherical shape

– 34.1 *Euryale ferox* Salisb.

II.C.4.b Irregular loose compound of 20+ components with a polyhedral shape

– 39.24 *Eragrostis tef* (Zuccagni) Trotter

II.C.4.c Irregular loose compound of 20+ components with the overall shape of the compound is unclear because the outer margin is not preserved due to components breaking off, (check also other "loose" compounds)

7.4 *Arum palaestinum* Boiss. (seed)
40.2 *Rumex pulcher* L.

3.3. Limitations of the key

The diversity of shapes and distinctive features of many taxa allowed us to produce a key that should aid the researcher in identifying unknown archaeological starches. However, we note several limitations to starch research in general and to our project in particular that must be considered when using this key. These include problems of sampling bias and contamination.

First, despite our best efforts, we recognize that we have sampled only a portion of the available plant species. In Israel alone there are over 2700 wild plant species. We examined only 188 plant taxa that have been previously suggested to be edible or important, but which represent only a small fraction of the potentially usable plants from this region.

Second, we targeted the plant parts that are known to contain storage starches, such as the seeds, nuts, grains, rhizomes, bulbs, and tubers. While plants can also produce starch grains in their leaves, these transitory starches are usually meant as short-term energy storage for the night, and are usually very small and of little to no diagnostic use. In contrast, the starches formed in the storage organs are bigger and have more characteristic forms. Our reference collection is, however, biased against plants that were used only for their leaves.

Third, the majority of the seeds and grains we examined came from botanical collections that had been compiled between 15 and 1.5 years prior to our analysis. The seeds from the United States Department of Agriculture National Plant Germplasm System (USDA NPGS) were provided to AGH in 2009. Notably, the *Triticum monococcum* subsp. *boeoticum* Boiss. grains we examined were collected much longer ago, in 1933. In contrast, the tubers, rhizomes, bulbs, roots, and stems were examined immediately after they were collected from the wild. While the starches of seeds and nuts are remarkably stable when the entire form has been undisturbed [and in fact, ancient seeds have been induced to grow (Sallon et al., 2008)], there might be a difference in the appearance of very fresh versus dried starches.

While we observed starches in exactly half of the plant parts we examined (110 plant parts), we did not see any in the other half, despite these plants being identified as edible or found in archaeological sites. This pattern might be due to several factors. Some of these starch-less plants or plant parts could provide oil (e.g., *Linum usitatissimum*; *Brassica nigra*), sugars, or other carbohydrates such as inulin (e.g., *Cyclamen persicum*) instead of or in addition to starch. Others might be used for their secondary compounds as medicines or poisons (e.g., *Althaea officinalis*; *Styrax officinalis*). Some are used as glue (e.g., *Asphodelus ramosus*). Some were used for mat weaving (e.g., *Arundo donax*; *Typha domingensis*; *Phragmites australis*; *Juncus acutus*), and others for perfume (e.g., *Cyperus rotundus*) and soap (*Vaccaria hispanica*) (Zohary and Feinbrun-Dothan, 1929). However, some of the plants may in fact have starches, but we simply did not observe them. We expected to find starches in seeds from several species in Poaceae (e.g., *Arundo donax*; *Desmazeria philistaea*; *Stipa parviflora*; *Stipa capensis* and *Urochloa mutica*) but did not observe any, possibly because the grains we were able to

acquire from these taxa may have been in poor condition.

We also recognize that starches can sometimes be difficult to identify in archaeological contexts and that distinctive features may not be preserved or visible. This might limit a researcher's ability to use our key. Furthermore, some objects preserved in archaeological contexts might appear similar to starches (e.g., coccoliths, see for examples Henry, 2020). These cannot be identified by the key we have provided.

Finally, there is the consideration of contamination. Starches are ubiquitous in human environments, greatly increasing the potential for modern material to be found on archaeological samples. Starchy foods comprise the majority of most human diets and are widely used in animal feeds as well. They are also used in industrial processes to stabilize and improve the texture of various materials, including paper, adhesives, , aluminum foil, soap, paint, gloves, textiles, plastics , and other beauty and medical products (Ellis et al. 1998; BeMiller and Whistler, 2009). Starch grains are small and can become airborne, and can travel long distances in the air and through ventilation systems (Newsom and Shaw, 1997). The ubiquity of starches means that most laboratory settings can become easily contaminated, as can the tools and supplies used by the researcher when performing their starch grain analysis (Crowther et al., 2014). Furthermore, the samples themselves may have become contaminated during excavation or storage. Simply touching objects with unwashed hands after eating is enough to transfer a measurable number of starches to otherwise starch-free objects (Henry, 2010).

Given this risk for contamination, we provide a description of the starches that are most commonly used in industrial applications, namely maize, potato, and wheat (Grüll et al., 2005). We also looked at another common food taxa that is not native to our study area, namely sweet potato (*Ipomoea batatas*). Maize, potato and sweet potato are native to the Americas. Therefore, these types should be absent from the archaeobotanical record of the Near East prior to the 1500s. Finding starches from the North American taxa in Near Eastern samples that are older than 1500 CE should be considered as a strong indication of contamination. However, care must be taken in the identification, as some native Israeli plants (e.g., *Arum* species; *Lilium candidum*) have starch grains that somewhat resemble those of maize or potato.

Wheat starches are more problematic. Studies of Near Eastern archaeology often seek to document the domestication of wheat and related taxa, which share very similar starch morphologies. Wheat and its relatives have been used by humans for a very long time in the Near East. For example, a charred seed of *Triticum turgidum* subsp. *dicoccoides* was identified at Ohalo II, dating to 23,000 BP (Piperno et al., 2004). Given this long history of use, we should expect to find starch grains from members of the Triticeae tribe on archaeological materials. It is possible, if challenging, to identify differences between modern domesticated wheat starches and some of its wild relatives and progenitors. However, such identification is usually based on the frequencies of certain traits within an assemblage, and it is extremely difficult to identify the species of an individual Triticeae starch grain. To help differentiate modern contamination from ancient wheat starches, the researcher must recognize the starch morphologies of modern wheat varieties, use sampling methods that are proven to reduce the risk of contamination, and regularly assess potential contamination, such as by taking on-site control samples and performing lab contamination tests. We provide a description of modern bread wheat in order to assist in this identification.

4. Conclusions

A better understanding of the use of plants in the past allows us to more fully appreciate how previous populations interacted with their landscapes, developed new technologies, and lived from day to day. This study is part of a special issue seeking to explore how plants may have been used through the study of artifacts, with the specific aim of discussing current approaches to identify the preparation and usage of plant resources in the past. Here we have reviewed the potentials of starch grain analyses, and provided a description of starch grains from Near Eastern plants that were known to be used in the past, as well as a key to aid in the identification of unknown starch grains. These data provide the baseline that will allow researchers to better identify the preparation and uses of plant resources in a region that is long-recognized for complex human-plant interactions. We hope that by sharing these descriptions, photos, and key, we make starch research more accessible, so that it might become an integral part of the analysis of any site in the Eastern Mediterranean, and beyond.

CRediT authorship contribution statement

Hadar Ahituv: Conceptualization, Methodology, Investigation, Visualization, Funding acquisition. **Amanda G. Henry:** Conceptualization, Methodology, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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