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Data Article

Isotopic insights from carpological remains: One of the first datasets for the Italian Bronze age

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A B S T R A C T

Even though agriculture already spread into Eurasia during the Neolithic, the transition between the Copper Age and the Bronze Age was the time where Italian communities tuned horticultural techniques to foster the soil productivity. Carbon and nitrogen stable isotope analyses could be leveraged to identify some of those practices, such as manuring and

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irrigation. The former could spike the nitrogen values of plants, while water availability affects the carbon values.
This work provides one of the first datasets of isotopic data for seeds from four Bronze Age Italian sites spanning overall from the end of the 3rd millennium to the first half of the 2nd millennium BCE: pile-dwelling of Ledro (TN, Trentino Alto Adige), settlement of S. Maria in Belverde (SI, Tuscany), Grotta Nuova (VT, Latium), and Grotta di Pastena (FR, Latium).
One-hundred eighty seeds were first classified, then carbon and nitrogen stable isotope analysis were carried out for broad beans, wheat, emmer and barley. The obtained values were compared to predictive models to enhance the understanding of the agricultural efforts for each community. The provided dataset would be beneficial for future research on agricultural practices, subsistence strategies identification, and even local ecological reconstruction, as it represents one of the most extensive surveys for carbon and nitrogen stable isotopes values for plants in the focused time span.

Specifications Table

Subject	Social Sciences - Archaeology.
Specific subject area	Stable isotope analysis is used to identify the subsistence strategies. The field is rich in data related to faunal and human diet, plant values are often underrepresented.
Type of data	Table, Graph, Figure; Raw, Analyzed.
Data collection	Taxonomic identification was performed visually, through comparison collections and atlases [1]. Carbon and nitrogen stable isotope analyses were carried out on each carpological remain. An established protocol is not currently available [2,3]; therefore, two different methods were applied: ABA pre-treatment protocol [8], and no pre-treatment [2]. Each grain was weighed and analysed twice [2,4]; we retained all the samples returning positive organic yields, as no consensual criteria exist to assess the preservation of charred seeds and chaff [4,5,6]. Descriptive tests (T-test and Mann-Whitney) were performed, and individual data were visualized through scatter plots.
Data source location	Carpological remains of pile-dwelling of Ledro were collected from: • *Institution: University of Padua;* • *City/Region: Padua; Veneto* • *Country: Italy.* Carpological remains of S. Maria in Belverde were collected from: • *Institution: Civic Museum of the Prehistory of Mount Cetona;* • *City/Region: Cetona; Tuscany* • *Country: Italy.*

(*continued on next page*)

	Carpological remains of Grotta Nuova were collected from: • *Institution: University of Florence* • *City/Region: Florence; Tuscany* • *Country: Italy.* Carpological remains of Grotta di Pastena were collected from: • *Institution: Laboratory of Prehistory – University of Rome Tor Vergata;* • *City/Region: Rome; Latium;* • *Country: Italy.* Sample preparation: • *Institution: Centre of Molecular Anthropology for Ancient DNA Studies – University of Rome Tor Vergata* • *City/Region: Rome; Latium;* • *Country: Italy.* Mass spectrometry analysis: • *Institution: Edmund Mach Foundation, Research and Innovation Centre - Traceability Unit;* • *City/Region: San Michele all'Adige; Trentino-Alto Adige;* • *Country: Italy.*
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/4wkc6mvf9g.2 Direct URL to data: https://data.mendeley.com/datasets/4wkc6mvf9g/2
Related research article	Not applicable

1. Value of the Data

- To the best of our knowledge, the dataset is one of the first compiled for stable isotope data from carpological remains from the Italian Early-Middle Bronze Age. The data will be handful for subsistence strategy reconstructions. As reported in multiple research articles, the isotopic reconstructions are often affected by the lack of specific endpoint. This dataset is going to partially fill the gap for what concerns the Italian Bronze Age.
- The data could be beneficial to researchers on Italian Bronze Age aiming to elucidate the local economic strategies, as well as to scholars whose research is grounded on the identification of human diet and technological improvements in past communities. Indeed, the generated data could be ultimately employed to represent feasible endpoints for multi-proxy modelling.
- The data can be used as a baseline for isotopic analysis of dietary habits, as well as for environmental reconstructions. Moreover, they are a useful tool for bayesian linear models (e.g., Fraser's model) and bayesian mixed models (FRUITS).

2. Background

Human management of soils parallelizes with the fostering of farming practices, supporting both sedentary lifestyles and trade economy. In Europe, specifically in Netherlands, Switzerland, Germany and Great Britain, the oldest evidence related to soil management date back to the late Neolithic, even though it spikes significantly during the Bronze Age. Archaeological evidence related to agricultural practices is hard to identify due to the destruction of soils or associated structures. However, several studies demonstrated that carbon and nitrogen stable isotope analyses of plant remains are effective approaches to detect the use of specific cultural strategies [3,7,8].

The Italian peninsula is rich in carpological deposits due to the numerous known protohistoric settlements and ritual caves. However, to the best of our knowledge, only a few surveys reported the isotopic values for those plant remains [9]. Thus, this work aims to provide one of the first isotopic datasets for carpological remains dated to the Early-Middle Bronze Age from Italian archaeological contexts (Fig. 1). The comparison with already available data from heterogeneous locations allows for assuming the occurrence of manuring/watering of the soils to improve the plant yield, which could be consistent with the increasing demand of the complex societies considered in the time span.

Fig. 1. Geographical distribution of archaeological sites investigated: 1) pile-dwelling of Ledro, 2) settlement of S. Maria in Belverde di Cetona, 3) Grotta Nuova, 4) Grotta di Pastena.

3. Data Description

Carbon and nitrogen stable isotope analyses have been carried out on 180 carpological remains from the pile-dwelling of Ledro, settlement of S. Maria in Belverde, Grotta Nuova and Grotta di Pastena (Table 1).

Table 1
Details of analyzed specimens.

Taxon	Archaeological site	N. of grains analyzed
Vicia faba	S. Maria in Belverde	10
	Grotta Nuova	34
	Grotta di Pastena	37
Hordeum vulgare	Ledro	23
	Grotta Nuova	5
	Grotta di Pastena	18
Triticum monococcum/dicoccum	S. Maria in Belverde	3
	Grotta Nuova	5
	Grotta di Pastena	22
Triticum aestivum	Grotta di Pastena	23

The relative abundance of ^{13}C and ^{15}N is expressed per mill (‰) through δ notation (respectively, $\delta^{13}C$ and $\delta^{15}N$) in agreement with the international standards – Vienna Pee Dee Belemnite (VDB) for $\delta^{13}C$ and atmospheric nitrogen (AIR) for $\delta^{15}N$ – according to the relationship: $\delta iE = (iRSA - iRREF) / iRREF$, where "i" is the mass number of the heavier isotope of the E element, RSA is the isotope ratio of the sample, and RREF is the relevant internationally recognized reference material [10]. $\Delta^{13}C$ values reflect plants' water availability and are calculated following Farquhar et al. [11]; in the formula, $\delta^{13}C_{air}$ was estimated through the AIRCO2_LOESS calculator [12].

The isotopic values are accessible on Mendeley Data repository (DOI: 10.17632/4wkc6mvf9g.2) and plotted in Fig. 2. Isotope data were successfully obtained for all the materials, except for one sample of *Triticum monococcum/dicoccum* from S. Maria in Belverde (Figs. 3–6).

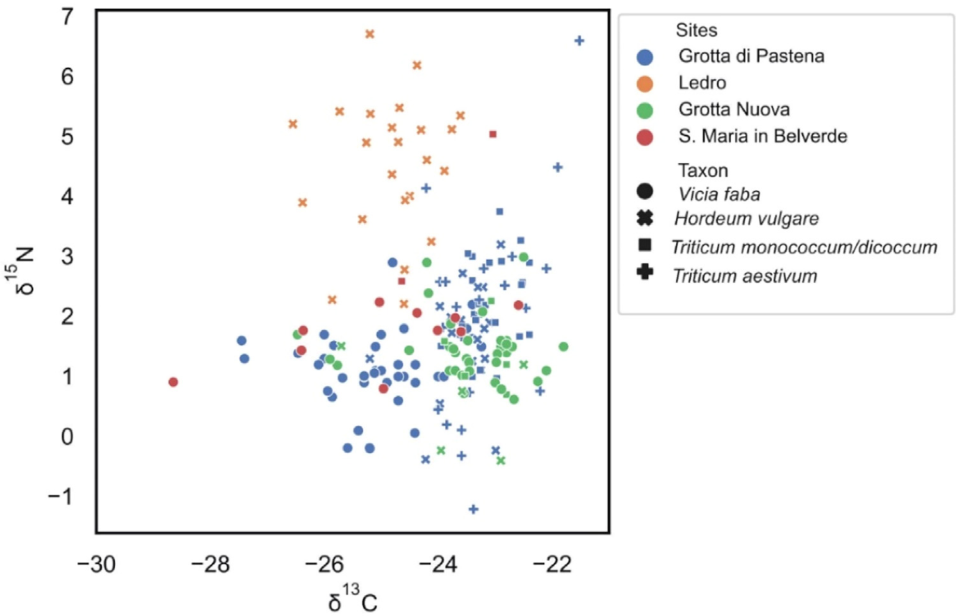

Fig. 2. Isotope data dispersion of the examined carpological remains.

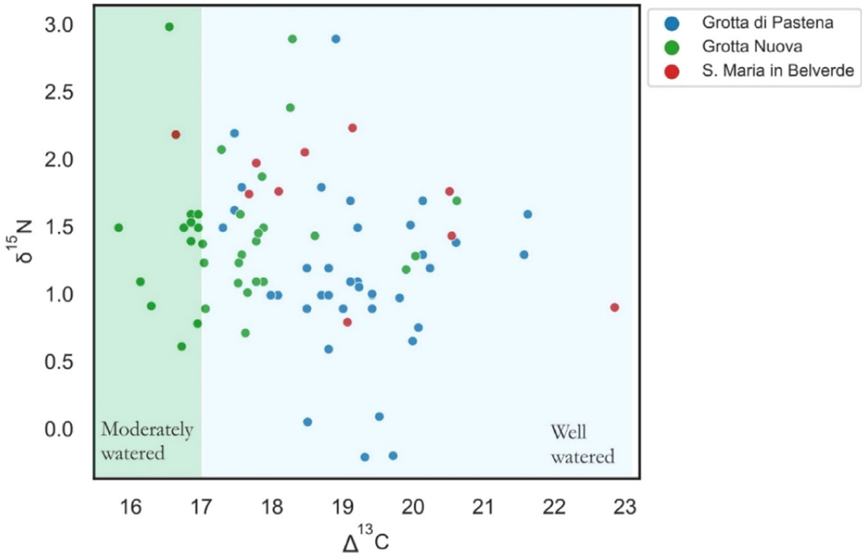

Fig. 3. The variability in nitrogen values for *Vicia faba* suggests the practice of fertilization: only with δ^{15}N higher than 0 ‰ it is possible to assume a consistent manuring for legumes [7,8,14]. Broad beans from S. Maria in Belverde and Grotta Nuova seem to have been subjected to a more intensive fertilization than those present in the Grotta di Pastena. Δ^{13}C ratios suggest different watering strategies [12,13]: some *Vicia faba* specimens from Grotta Nuova were moderately watered. Conversely, the remaining seeds, as well as those from S. Maria in Belverde and Grotta di Pastena, were well watered.

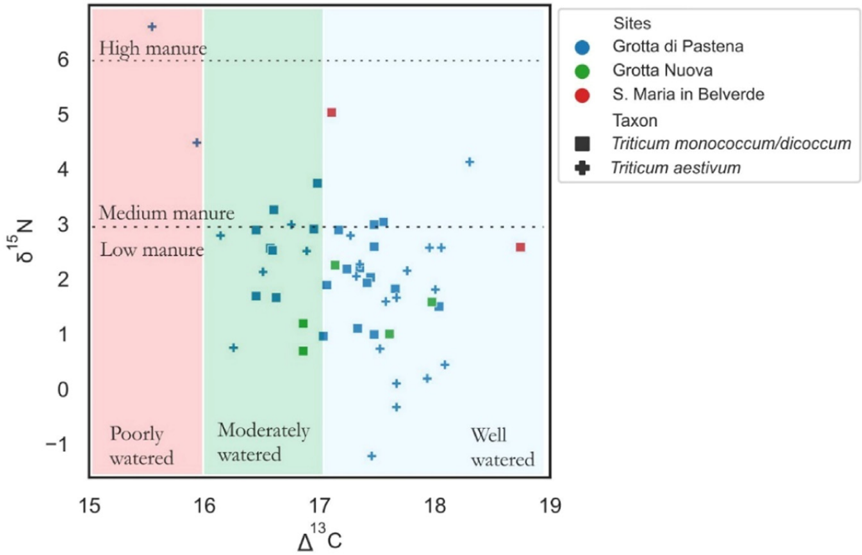

Fig. 4. Cereals (*Triticum monococcum/dicoccum* and *Triticum aestivum*) from S. Maria in Belverde, Grotta Nuova and Grotta di Pastena are heterogeneous with respect to Δ^{13}C and δ^{15}N. Soils where emmer from S. Maria in Belverde was harvested had been manured. Conversely, seeds from caves appear to have been poorly fertilized (no more than 10ton/ha, according to [7]). *Triticum monococcum/dicoccum* specimens from S. Maria in Belverde and Grotta Nuova were well watered, whereas seeds from Grotta di Pastena present a higher variability of values leading to hypothesize two different methods of irrigation, as suggested by Δ^{13}C ratios [13]. Wheat grains were well watered despite manure levels being scarce or absent, except for two outliers, whose values could suggest a shortage of water and an intense use of fertilization.

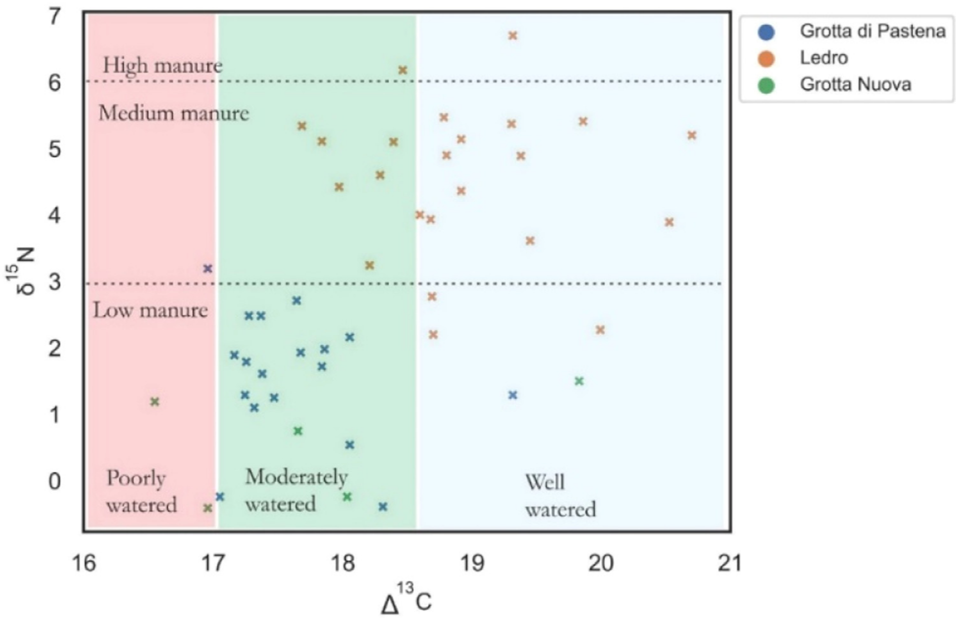

Fig. 5. Samples of *Hordeum vulgare* present substantial differences between northern and central Italy. Barley specimens from Grotta Nuova and Grotta di Pastena are consistent with the absence of fertilizing practices. Conversely, Ledro seeds values suggest intense fertilization [3,7,8]. Moreover, grains from the three sites were moderate and well-watered [12].

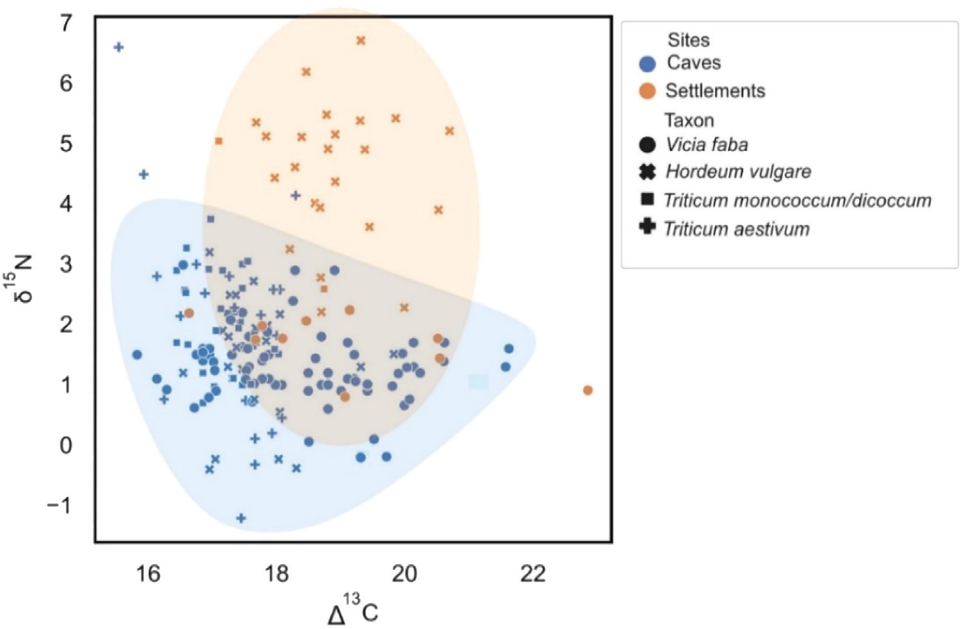

Fig. 6. Comparison between isotopic values from settlements and caves.

Carpological remains have been tested to describe basic differences through Wilcoxon–Mann–Whitney test (Table 2a, 2b, 2c, 2d). Legumes and cereals appear significantly different in both carbon ($p = 0.0002$) and nitrogen values ($p = 6.53E-09$), in accordance with the different type of seeds and human management of crops.

Table 2a
p-value (in the upper triangular matrix) and *U* (in the lower triangular matrix) obtained through Wilcoxon-Mann-Whitney test comparing samples of *Vicia faba*.

	$\delta^{13}C$ – $\Delta^{13}C$		
	S. Maria in Belverde	Grotta Nuova	Grotta di Pastena
S. Maria in Belverde	–	0.005	0.5
Grotta Nuova	71	–	6.86E-08
Grotta di Pastena	159.5	160	–
	$\delta^{15}N$		
	S. Maria in Belverde	Grotta Nuova	Grotta di Pastena
S. Maria in Belverde	–	0.8	0.01
Grotta Nuova	107.5	–	0.04
Grotta di Pastena	85.5	453.5	–

Table 2b
p-value obtained through Wilcoxon-Mann-Whitney test comparing samples of *Triticum monococcum/dicoccum*.

	$\delta^{13}C$ – $\Delta^{13}C$
	Grotta Nuova
Grotta di Pastena	0.6
	$\delta^{15}N$
	Grotta Nuova
Grotta di Pastena	0.03

Table 2c
p-value obtained through t-test comparing samples of *Triticum aestivum*.

	Grotta di Pastena
$\delta^{13}C$ – $\Delta^{13}C$	0.8
$\delta^{15}N$	0.8

Table 2d
p-value (in the upper triangular matrix) and *U* (in the lower triangular matrix) obtained through t-test comparing samples of *Triticum aestivum*.

	$\delta^{13}C$		
	Ledro	Grotta Nuova	Grotta di Pastena
Ledro	–	0.04	3.66E-06
Grotta Nuova	22	–	1
Grotta di Pastena	30.5	44.5	–
	$\delta^{15}N$		
	Ledro	Grotta Nuova	Grotta di Pastena
Ledro	–	0.0006	2.09E-07
Grotta Nuova	0	–	0.03
Grotta di Pastena	9.5	16	–

4. Experimental Design, Materials and Methods

Before proceeding with stable isotope analysis, the samples were subjected to taxonomic analysis through visual inspection of sieved samples. Seeds from Ledro, Grotta Nuova and Grotta di Pastena were analyzed at the Environmental Archaeology Laboratory of Durham University [15] and at the Laboratory of Archaeology at the University of Rome Tor Vergata using a microscope and with the help of modern comparative collections and illustrated atlases [1]. Plant remains from S. Maria in Belverde were analyzed by Carra et al. [16].

Once the taxonomic determination was completed, the stable isotope analyses pretreatment started. As an established protocol for carrying out stable isotope analysis on carpological remains is not currently available [2,3,17], we decided to use two different methods to test whether or not the chemical pre-treatment altered the isotopic signatures of the grains: 20 samples were analyzed through the ABA pre-treatment protocol [3], the other seeds were crashed individually in a mortar, and inlet into the isotope ratio mass spectrometer. The obtained results from these two different methods were compared and they resulting to be statistically similar.

Since no specific guidelines rules for rejecting plant isotope measurements based on their C/N ratios have not been codified yet, each grain has been measured three times in order to consider the measurements reliable, as suggested by Mueller-Bieniek et al. [3] and O'Connel et al. [5]. Carpological remains were prepared at the Centre of Molecular Anthropology for Ancient DNA Studies of the University of Rome "Tor Vergata". Ratios of carbon and nitrogen stable isotope were measured in a double run on a Delta Plus XP isotope ratio mass spectrometer coupled with a Flash 1112 Elemental Analyser via a Conflow IV interface (Thermo Scientific Milan, Italy) at the Food Quality and Nutrition Department, Traceability Unit – Fondazione Edmund Mach.

The estimation of manuring rates was addressed through the comparison with already available methodological approaches [7,14,18]. We are aware that the ecological differences could be misleading, however, we can note that all the studies demonstrate that cereals not subjected to fertilization have a baseline δ^{15}N around 2.5 ‰, and manuring can significantly alter nitrogen values up to a maximum of +6 ‰ depending on the intensity of fertilization [7,8,14]. Consequently, intermediate δ^{15}N values between 2.5 ‰ and 6 ‰ could be related to different agriculture strategies [14]. Conversely, legumes present naturally nitrogen values around 0 ‰, and only an intensive fertilization with animal cages (>70 t/ha) can increase nitrogen values to reach +3 ‰ [7,14]; moreover, the values of legumes could be altered according to the isotopic signature of the fertilizer used.

Seeds watering status has been established through carbon values. Plants react to a decrease in water availability through stomatal closure, and δ^{13}C is a good indicator of the water status [12]. During the Holocene there were several fluctuations of CO_2, therefore, water availability was calculated using the Δ^{13}C values, as explained above. Δ^{13}C values reflect plants' water status during their life cycle, which was influenced both by natural precipitation and human management [13]. Wallace et al. [13] identified three different water statuses of crops, which depend on the availability of water during plants growth.

Carbon values do not change significantly (~ 0.2 ‰) in charred specimens, unlike δ^{15}N, that is more sensitive [3]. These alterations are strictly linked to the thermal conditions and the duration of exposure to fire [3,7,18–20]. To sort it out, the correction by subtracting 0.31 ‰ from δ^{15}N of burnt seeds has been suggested to approximate the pristine values [20].

Limitations

The only limitation encountered in this study concerns the small sample of seeds from the settlement of S. Maria in Belverde, due to the limited number of seeds stored in the Civic Museum of the Prehistory of Mount Cetona. However, overall, the number of seeds analysed in all other sites is consistent, and the aforementioned limitation is not significant in terms of the data obtained.

Ethics Statement

The authors have read and follow the ethical requirements for publication in Data in Brief. We confirm that the current work does not involve human subjects, animal experiments, or any data collected from social media platforms.

CRediT Author Statement

Francesca Cortese: Conceptualization, Methodology, Investigation, Formal Analysis, Data curation, Software, Writing – original draft, Writing – review & editing, Funding acquisition, **Flavio De Angelis:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Validation, **Luana Bontempo:** Methodology, Formal analysis, Data curation, Validation, Supervision, **Nicola Carrara:** Resources, Validation, Supervision, **Maria Teresa Cuda:** Resources, Validation, Supervision, **Elisa Dalla Longa:** Resources, Validation, Supervision, **Jacopo Moggi Cecchi:** Resources, Validation, Supervision, **Lucia Sarti:** Resources, Validation, Supervision, **Letizia Silvestri:** Resources, Validation, Supervision, **Olga Rickards:** Resources, Validation, Supervision, Funding acquisition, **Mario Federico Rolfo:** Resources, Validation, Supervision, Funding acquisition.

Data Availability

Isotopic insights from carpological remains: one of the first datasets for the Italian Bronze Age (Original data) (Mendeley Data).

Acknowledgments

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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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