Science Advances
AAAS

advances.sciencemag.org/cgi/content/full/6/6/eaax0384/DC1

Supplementary Materials for

Origins and insights into the historic Judean date palm based on genetic analysis of germinated ancient seeds and morphometric studies

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Published 5 February 2020, *Sci. Adv.* **6**, eaax0384 (2020)
DOI: 10.1126/sciadv.aax0384

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Table S1. Judean desert archaeological sources of ancient date seeds and their preliminary measurements before planting.

Archaeological site/ Ancient date seed code No.	**Germinated ancient date seeds with identifying moniker**	**Length (mm)**	**Weight (g)**
Qumran ***(Cave FQ37)***			
HU-37-A1		26.7	1.61
HU-37-A2		28.8	1.79
HU-37-A3		30.8	1.99
HU-37-A4	***Jonah***	27.0	1.72
HU-37-A5		31.0	1.70
HU-37-A6	***Uriel***	29.0	1.64
HU-37-A7		33.1	1.84
HU-37-A8	***Boaz***	26.0	1.35
HU-37-A9		30.0	1.89
HU-37-A10		27.3	1.48
HU-37-A11		23.6	1.42
HU-37 -A12		29.0	1.54
HU-37-A13		19.9	0.79
Qumran ***(Cave 13)***			
HU-Q13 -A22		27.0	1.38
HU Q-13-A23	***Judith***	23.0	1.09
HU-Q13-A24		29.8	1.66
HU-Q13-A25		28.5	1.69
Wadi Makukh : ***(Cave 1)***			
HU-WMK-A14	***Hannah***	33.0	2.55
HU-LMK-A26		31.5	1.83

<u>Wadi Makukh</u> ***(Lower Makukh, Cave 6)***			
HU-LMK-A15		27.0	2.06
HU-LMK-A16		27.6	1.66
HU-LMK-A17		25.0	1.56
Wadi Makukh ***(Makukh Qurantel) Cave 24)***			
HU-MQ-A18		33.2	1.84
Wadi Makukh ***(Lower Makukh) Cave 3)***			
HU-LM-A19		23.6	1.55
HU-LM-A20		20.7	1.33
<u>Wadi Kelt</u>			
HU-WQ-A21		23.9	1.20
<u>Masada</u>*			
BI-7	***Adam***	NA	NA

***In the current study, eight ancient date seeds from Masada, (Code numbers BI: 1- 8) obtained from Bar-Ilan University, Israel in 2007 were photographed prior to planting but measurements were not made. Of these, one seed (BI-7, "Adam") was germinated in the current study.**

Table S2. Calibrated calendar ages of germinated ancient date seeds and controls.

Location/sample "*Name*"(code no.) (date*)	Sample code	pMC†	^{14}C age (uncal) yBP	±error (y)	1σ-range & sub-ranges	P (%)‡	2σ-range &sub-ranges	P (%)‡
Masada								
"*Adam"(* BI707)	UZ 5833	78.03	1935	35	25 – 122 calCE	68.2	36 calBCE – 133 calCE	95.4
					25 – 89 calCE	54.5	36 – 30 calBCE	0.8
					102 – 122 calCE	13.7	22 – 10 calBCE	1.8
							2 calBCE – 133 calCE	92.8
***Methuselah (2005)** (Germinated Seed 3) (16)	UZ 5397	79.77	1760	50	220 – 377 calCE	68.2	137 – 386 calCE	95.4
					220 – 347 calCE	66.3		
					371 – 377 calCE	1.9		
***Control Seed 1(2005)**	UZ 5226	76.56	2090	50	176 – 47 calBCE	68.2	351 calBCE – 24 calCE	95.4
							351 – 305 calBCE	4.8
							210 calBCE – 24 calCE	90.6
Wadi Makukh: Cave 1								
Hannah (HUWMKA14)	UZ 6011	78.06	1930	30	29 – 123 calCE	68.2	4 – 131 calCE	95.4
					29 – 38 calCE	7		
					50 – 89 calCE	43.5		
					101 – 123 calCE	17.8		
Qumran: Cave 13								
Judith (HUQ13 A23)	UZ 6168	77.67	1960	25	19 – 71 calCE	68.2	38 calBCE – 115 calCE	95.4
							38 calBCE – 85 calCE	94.7
							111 – 115 calCE	0.7

Ancient								
Palm frond (control)	UZ 5731	76.88	2055	35	152 – 2 calBCE	68.2	171 calBCE – 21 calCE	95.4
Qumran: Cave 37								
Boaz (HU37A8)	UZ 6167	77.47	1990	25	37 calBCE – 51 calCE	68.2	44 calBCE – 63 calCE	95.4
					37 – 31 calBCE	5.8		
					21 – 11 calBCE	10.3		
					2 calBCE – 30 calCE	37.6		
					38 – 51 calCE	14.5		
Jonah (HU37A4)	UZ 6043	78.2	1915	25	65 – 124 calCE	68.2	25 – 134 calCE	95.4
					65 – 92 calCE	36.2		
					98 – 124 calCE	32		
Uriel (HU37A6)	UZ 6169	78.19	1915	25	65 – 124 calCE	68.2	25 – 134 calCE	95.4
					65 – 92 calCE	36.2		
					98 – 124 calCE	32		
Control seed (HU37A11)	UZ6382	78.13	1918	25	61-124 calCE	68.2	25-132cal CE	95.4
					61-91 calCE			
					99-124 calCE			

***Samples from previous 2005 study *(16)*, † pMC = percent of modern carbon,**

‡ P = probability.

Table S3. Size parameters of 18 ungerminated ancient date seeds retrieved from potting soil.

ID Code No.	Width (mm)	Length (mm)
HU-37-A1	10.5	26.7
HU-37-A2	10.0	28.8
HU-37-A5	10.1	31.0
HU-37-A3	9.9	30.8
HU-37-A7	10.2	33.1
HU-37-A9	10.8	30.0
HU-37-A10	10.0	27.3
HU-37-A11	10.4	23.6
HU-37-A13	8.6	19.9
HU-LM-A19	11.0	23.6
HU-LM-A20	10.9	20.7
HU-LMK-A15	12.1	27.0
HU-LMK-A16	10.6	27.6
HU-LMK-A26	11.0	31.5
HU-MQ-A18	10.0	33.2
HU-Q13-A24	10.41	29.8
HU-Q13-A25	10.1	28.5
HU-WQ-A21	10.0	23.9
Mean	10.4	27.6

Table S4. Comparison of 18 ungerminated ancient date seeds with current date seeds from cultivated varieties and wild individual date palms.

Source	Number of Seeds	Length (mm)	Width (mm)
Ungerminated ancient date seeds	18	27.62 ± 3.96 (min=19.87; max=33.24)	10.38 ± 0.71 (min=8.56; max=12.08)
Current seeds from cultivated varieties and wild individuals	1108	19.96 ± 4.73 (min=11.72; max=36.31)	8.12 ± 1.05 (min=5.85; max=11.40)
Current seeds from cultivated varieties	928	20.60 ± 4.70 (min=12.78; max=36.31)	8.33 ± 1.02 (min=5.89; max=11.40)
Current seeds from wild individuals	180	16.69 ± 3.39 (min=11.72; max=24.07)	7.08 ± 0.46 (min=5.85; max=8.51)

Table S5. Date palm varieties used for the genotyping reference matrix to compare ancient genotypes with current varieties.

Varieties	Origin	Sex
Amir Hajj	Iraq	F
Barhi	Iraq	F
Halawi	Iraq	F
Khadrawi	Iraq	F
Khastawi	Iraq	F
Khyara	Iraq	F
Tabarzal	Iraq	F
Zahidi	Iraq	F
Ashrassi	United Arab Emirates	F
Nagal	United Arab Emirates	F
Fardh female	United Arab Emirates	F
Khor	United Arab Emirates	F
Fardh #4	United Arab Emirates	M
AbuKibal	United Arab Emirates	F

Hilali Saudi	United Arab Emirates	F
Hilali	United Arab Emirates	F
Hilali Pakistani	United Arab Emirates	F
Khalass	United Arab Emirates	F
Khnezi	United Arab Emirates	F
Chichi	United Arab Emirates	F
Abou Mâan	United Arab Emirates	F
Nabtet Sultana	United Arab Emirates	F
Brem	United Arab Emirates	F
Rezez	United Arab Emirates	F
Nabtet Ali	United Arab Emirates	F
Sucary	United Arab Emirates	F
Aziz	United Arab Emirates	F
Lulu	United Arab Emirates	F
Nabtet Soumoud	United Arab Emirates	F
Nabtet Seif	United Arab Emirates	F
Sagaï	United Arab Emirates	F
Khsab	United Arab Emirates	F
Khasif	United Arab Emirates	F
Madrasi	United Arab Emirates	F
Ambara	United Arab Emirates	F
Ammari	Tunisia	F
Arechti	Tunisia	F
Assouli Gabes	Tunisia	F
Bessir Helou	Tunisia	F
Deglet Bey	Tunisia	F
Deglet Nour	Tunisia	F
Donga Gabes	Tunisia	F
Fezzani	Tunisia	F
Gasbi	Tunisia	F
Goundi	Tunisia	F
Hamra	Tunisia	F
Hissa Gabes	Tunisia	F
Horra	Tunisia	F
Kenta	Tunisia	F
Kentichi	Tunisia	F
Khadhouri Gabes	Tunisia	F
Lagou	Tunisia	F
Lemsi Gabes	Tunisia	F
Louzi Gabes	Tunisia	F
Tazerzist	Tunisia	F
Tantabecht	Tunisia	F
Bou Feggous Tunisia	Tunisia	F
Sayass Gabes	Tunisia	F

Medjoul	Morocco	F
Oum Nhel	Morocco	F
Bit Djej	Morocco	F
Ahardane	Morocco	F
Black Bousthammi	Morocco	F
Jihel	Morocco	F
Tadmant	Morocco	F
Bouzegar	Morocco	F
Aguelid	Morocco	F
Mahalbit	Morocco	F
Bouslikhn	Morocco	F
Najda	Morocco	F
Tarzaoua	Morocco	F
Oskri	Morocco	F
Bourer	Morocco	F
Hafsa	Morocco	F
Hayani	Egypt	F
Malakabi	Egypt	F
Deqqna	Egypt	F
Wardi	Egypt	F
Beda Rufaya	Egypt	F
Qaraqoda	Egypt	F
Rotob	Egypt	F
Samany	Egypt	F
Tagtagt	Egypt	F
Ghazâli	Egypt	F
Aghram Aghzâl	Egypt	F
Amhat	Egypt	F
Barthamoda	Egypt	F
Barakawi	Egypt	F
Bint Aïsha	Egypt	F
Zaghloul	Egypt	F
El-Shabal	Egypt	F

Table S6. Genetic diversity within ancient genotypes and geographic date palm groups.

	Iraq	UAE	Tunisia	Morocco	Egypt	Ancient dates
N_A	3.474	5.368	5.263	5.684	6.053	4.316
$N_{A,P}$	3.474	3.421	3.474	4.105	4.263	4.316
H_e	0.618	0.530	0.572	0.592	0.529	0.496
H_o	0.532	0.515	0.554	0.587	0.587	0.555
F_{IS}	-0.155	0.016	0.005	0.001	0.112	0.143
A_r	3.150	3.570	3.670	4.090	4.140	3.590

N_A= number of alleles per group; $N_{A,P}$= number of alleles with a frequency >5 %; H_e =expected heterozygosity; H_o =observed heterozygosity; F_{IS}=fixation index values; A_r=allelic richness.

Table S7. Genetic distances (Cavalli-Sforza and Edwards) (*40*) between ancient genotypes and current varieties.*

	Uriel	Methuselah	Boaz	Hannah	Jonah	Judith	Adam
Abou_Man	0.3460	0.1879	0.4557	0.2212	0.3626	0.3460	0.1724
AbuKibal	0.3431	0.1988	0.3252	0.1626	0.3391	0.3557	0.1850
Aghra_Ag	0.3086	0.4155	0.2781	0.3321	0.2574	0.3862	0.4350
Aguelid	0.2655	0.2529	0.4460	0.3155	0.3167	0.3655	0.2821
Ahardane	0.2476	0.3891	0.4057	0.4057	0.2350	0.3960	0.4293
Ambara	0.4000	0.2419	0.4362	0.2752	0.4167	0.3626	0.2350
Amhat	0.3431	0.2488	0.3724	0.2850	0.3931	0.2891	0.2460
Ami_Hajj	0.3557	0.3212	0.2810	0.2293	0.3183	0.3862	0.3460
Ammari	0.2919	0.4126	0.2919	0.3155	0.2350	0.4655	0.3391
Arechti	0.2476	0.3488	0.4626	0.3931	0.3557	0.3931	0.3114
Ashrassi	0.2919	0.3517	0.3988	0.2850	0.2948	0.4155	0.3350
Assouli	0.3057	0.3252	0.4529	0.3683	0.3362	0.3862	0.2626
Aziz	0.3086	0.2891	0.3391	0.2667	0.3391	0.2891	0.3086
Barakawi	0.3252	0.4626	0.3252	0.3626	0.3017	0.4167	0.4126
Barhi	0.2919	0.2517	0.3557	0.2000	0.3391	0.3488	0.2850
Barthamo	0.2155	0.4167	0.2850	0.3419	0.2850	0.4695	0.4431
Beda_ruf	0.2321	0.3598	0.2919	0.3488	0.3155	0.3695	0.3931
Bess-Hel	0.2712	0.3293	0.5195	0.4029	0.3862	0.3960	0.3419
Bint_Ais	0.2821	0.2655	0.3960	0.2655	0.3862	0.3891	0.2626
Bit_Djej	0.2212	0.3557	0.3419	0.3793	0.2476	0.3764	0.4252
Bla_BoS	0.3764	0.3155	0.3252	0.2683	0.2931	0.3086	0.3431
Bou_Feg	0.2086	0.3293	0.4488	0.3655	0.3224	0.3960	0.3321
Bourer	0.2976	0.3419	0.3614	0.3931	0.3045	0.3333	0.3988
Bouslikh	0.2448	0.2586	0.4391	0.3391	0.3264	0.3517	0.2821
Bouzegar	0.3362	0.3391	0.2821	0.2586	0.2695	0.3321	0.3667
Brem	0.3086	0.2891	0.3391	0.2598	0.3391	0.2891	0.3086

Chichi	0.2988	0.1407	0.3891	0.1879	0.2960	0.2891	0.1488
Degl_Bey	0.1821	0.3960	0.3419	0.4155	0.2683	0.4626	0.4598
Degl_Nou	0.2891	0.3224	0.4155	0.2960	0.2919	0.3862	0.2252
Deqqna	0.3281	0.3655	0.3155	0.3529	0.3281	0.4500	0.3960
Donga	0.2919	0.3557	0.3419	0.2793	0.1850	0.3793	0.3155
Fard_F	0.3460	0.1045	0.4391	0.2017	0.3626	0.3017	0.1695
Fardh4	0.3321	**0.0948**	0.4695	0.2224	0.3626	0.3557	0.1419
Fezzani	0.2362	0.3155	0.4057	0.4529	0.3264	0.3850	0.3029
Gasbi	0.3614	0.4086	0.3919	0.3488	0.3114	0.4460	0.4321
Ghazali	0.4155	0.4557	0.4224	0.4195	0.2919	0.4431	0.4252
Goundi	0.2586	0.3172	0.4626	0.4293	0.3821	0.3793	0.3155
Hafsa	0.2057	0.3586	0.4460	0.4224	0.2793	0.3960	0.3529
Halawi	0.3529	0.2362	0.4195	0.2057	0.3293	0.3960	0.2724
Hamra	0.4293	0.3557	0.3586	0.3293	0.3752	0.3960	0.3183
Hayani	0.3764	0.3362	0.3488	0.2752	0.3724	0.3793	0.2891
Hila_Pak	0.2988	0.2781	0.3252	0.2155	0.2960	0.3724	0.2724
Hila_Sau	0.3391	0.1143	0.4695	0.2350	0.3391	0.3155	0.1752
Hilali	0.2224	0.1448	0.3391	0.2017	0.3362	0.3252	0.1960
Hissa	0.2821	0.3598	0.3919	0.3793	0.2655	0.4086	0.3764
Horra	0.2574	0.4488	0.2988	0.3155	0.2448	0.4098	0.3919
Jihel	**0.1074**	0.3224	**0.1017**	0.2529	0.2448	0.3724	0.3988
Kenta	0.2517	0.3293	0.4460	0.3724	0.2793	0.3960	0.3155
Kentichi	0.2350	0.3212	0.4931	0.3960	0.3488	0.4057	0.3960
Khadhour	0.2586	0.3293	0.4557	0.4391	0.3598	0.4252	0.3224
Khadrawi	0.3695	0.1919	0.3850	0.2391	0.2586	0.2821	0.2333
Khalass	0.3764	0.1448	0.4557	0.1879	0.3431	0.3252	**0.0960**
Khasif	0.3833	0.2126	0.4793	0.2350	0.3500	0.3724	0.1988
Khastawi	0.3488	0.2724	0.2557	**0.1350**	0.2960	0.3695	0.3183
Khnezi	0.3833	0.1598	0.3683	0.1948	0.3557	0.3557	0.1781
Khor	0.3557	0.1488	0.4598	0.1976	0.4057	0.3545	0.1752
Khsab	0.3724	0.1821	0.3212	0.2029	0.2781	0.3057	0.2114
Khyara	0.3126	0.2919	0.4362	0.3557	0.3764	**0.2712**	0.3126
Lagou	0.2155	0.3195	0.4391	0.3586	0.3224	0.3960	0.3252
Lemsi	0.2114	0.3391	0.4557	0.3919	0.3321	0.4224	0.3350
Louzi	0.2626	0.3833	0.3252	0.3126	0.2224	0.3891	0.3391
Lulu	0.4195	0.2460	0.4126	0.2391	0.3419	0.3557	0.1919
Madrasi	0.2224	0.1321	0.3724	0.2391	0.3431	0.3252	0.2086
Mahalbit	0.1281	0.2764	0.3391	0.2695	0.2724	0.3919	0.3224
Malakabi	0.3488	0.4626	0.3195	0.3988	0.2891	0.4667	0.4321
Medjool	0.3293	0.3931	0.3517	0.3529	**0.1655**	0.4155	0.3460
Nabt_Ali	0.3321	0.1879	0.3724	0.2017	0.2988	0.3655	0.1862
Nabt_Sei	0.3517	0.2143	0.3350	0.2000	0.2879	0.2931	0.2017
Nabt_Sou	0.4098	0.1183	0.4598	0.2310	0.4195	0.3626	0.1252
Nabt_Sul	0.4029	0.1534	0.3988	0.1781	0.4029	0.3098	0.1919
Nagal	0.3362	0.1793	0.4264	0.2183	0.4362	0.3448	0.1948
Najda	0.1810	0.3557	0.2172	0.3264	0.2545	0.3793	0.4029
Oskri	0.2988	0.3683	0.4529	0.3448	0.3057	0.4293	0.2960
Oum_Nhel	0.3224	0.3460	0.3752	0.3155	0.2821	0.4029	0.3252

Qaraqoda	0.4252	0.5431	0.3155	0.4029	0.3586	0.4391	0.5500
Rezez	0.3931	0.1919	0.4391	0.1879	0.3264	0.3891	0.1724
Rotob	0.3155	0.4333	0.2695	0.2948	0.2460	0.3960	0.4126
Sagai	0.4167	0.1643	0.4626	0.1672	0.3833	0.3488	0.1488
Samany	0.2017	0.2833	0.2891	0.2391	0.2655	0.3655	0.2793
Sayass	0.2960	0.3695	0.3517	0.2988	0.2114	0.3960	0.3419
Sucary	0.3362	0.1752	0.4224	0.2529	0.2960	0.3086	0.1724
Tabarzal	0.3695	0.2695	0.3655	0.1529	0.2919	0.3557	0.2557
Tadmant	0.2891	0.2350	0.3821	0.2586	0.3195	**0.2614**	0.2362
Tagtagt	0.3321	0.4529	0.3252	0.3793	0.2419	0.4293	0.4333
TantaBec	0.2919	0.2310	0.3764	0.2614	0.3724	0.3126	0.2391
Tarzaoua	0.2224	0.3695	0.4252	0.4086	0.3195	0.4155	0.4167
Tazerzis	0.2960	0.2114	0.3891	0.2183	0.3431	0.3155	0.2167
Wardi	0.3833	0.4764	0.2350	0.2810	0.3029	0.4529	0.4764
Zaghloul	0.2241	0.3419	0.3960	0.3598	0.3252	0.3431	0.3391
Zahidi	0.2919	0.2712	0.2793	0.1488	0.3891	0.3764	0.2545

***Genetic distances between ancient genotypes and their closest current varieties are in bold.**

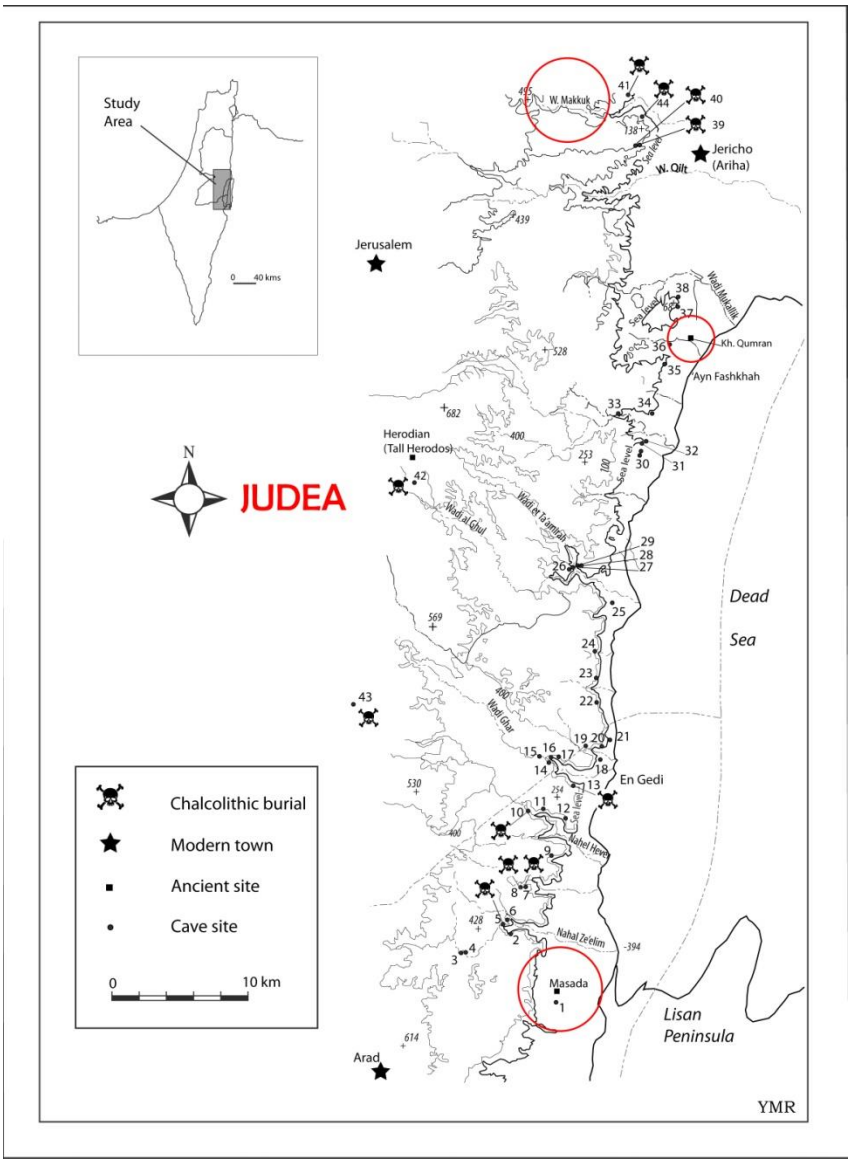

Fig. S1. Map of Judean desert sites where ancient seeds were discovered. Discovery sites are circled in red. (Adapted from: *The Judean Desert as a Chalcolithic Necropolis by David Ilan and Yorke Rowan, J. Med Archaeology 28.2 (2015) 171-194,* with the authors permission).

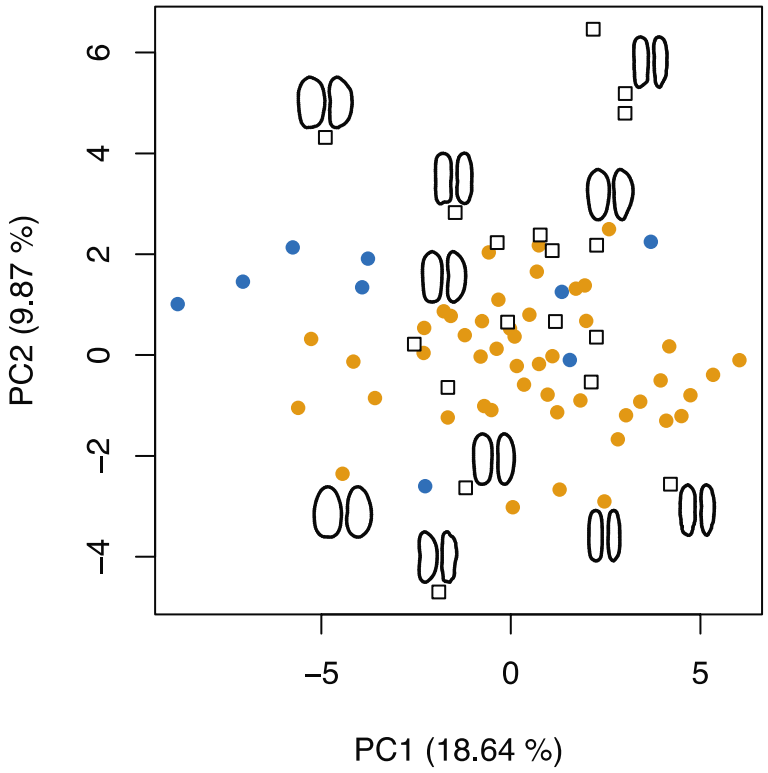

Fig. S2. PCA comparing current and ancient date (*P. dactylifera*) seeds. Principal Component Analysis (PCA) biplot of axes 1 - 2 (variance explained is indicated in parentheses) performed on 64 Fourier coefficients representing the dorsal and lateral seed shapes of 54 current samples represented by 20 seeds each and 18 ancient seeds. One dot/square represents one seed accession of current cultivar (orange dot), wild (blue dot) and ancient (white square). Outlines (left: dorsal side, right: lateral side; size standardized) of seeds of several *Phoenix* consensus individuals are represented.

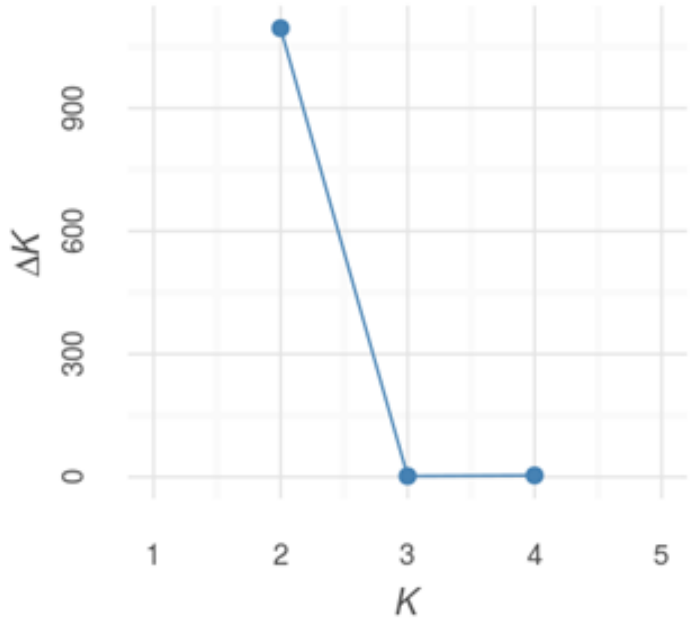

Fig. S3. Log probabilities between *K* values according to (*44*). ΔK plotted against K values. The maximum value is obtained at k=2 indicating that the date palm accessions were differentiated into two clusters, Eastern and Western.