

Use of molecular genetic methods in wheat taxonomy

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Genus *Triticum* L.

- ▶ High diversity and ecological adaptability;
- ▶ evolved over 7 million years;

Include:

- ▶ Diploid - tetraploid - hexaploid - octaploid species;
- ▶ Wild and domesticated taxa;
- ▶ Number of species depends on the type of classification;
- ▶ several classification systems used in practice;
- ▶ **no wheat classification is based on DNA data;**



Molecular analysis of diploid wheats

- ▶ Wild species (according to van Slageren, 1994):

Triticum urartu Tumanian ex Gandilyan

Triticum monococcum L. subsp. *aegilopoides* Thell

- ▶ Domesticated taxon:

Triticum monococcum L. subsp. *monococcum*

- ▶ ***Triticum - Aegilops* alliance:**

- ▶ Section: *Sitopsis*, subsection ***Truncata*** - *Aegilops speltoides* Tausch, var. *speltoides* and var. *ligustica* (Savig.) Fiori

subsection ***Emarginata***: *Aegilops bicornis* (Forsskål) Jaub. & Spach

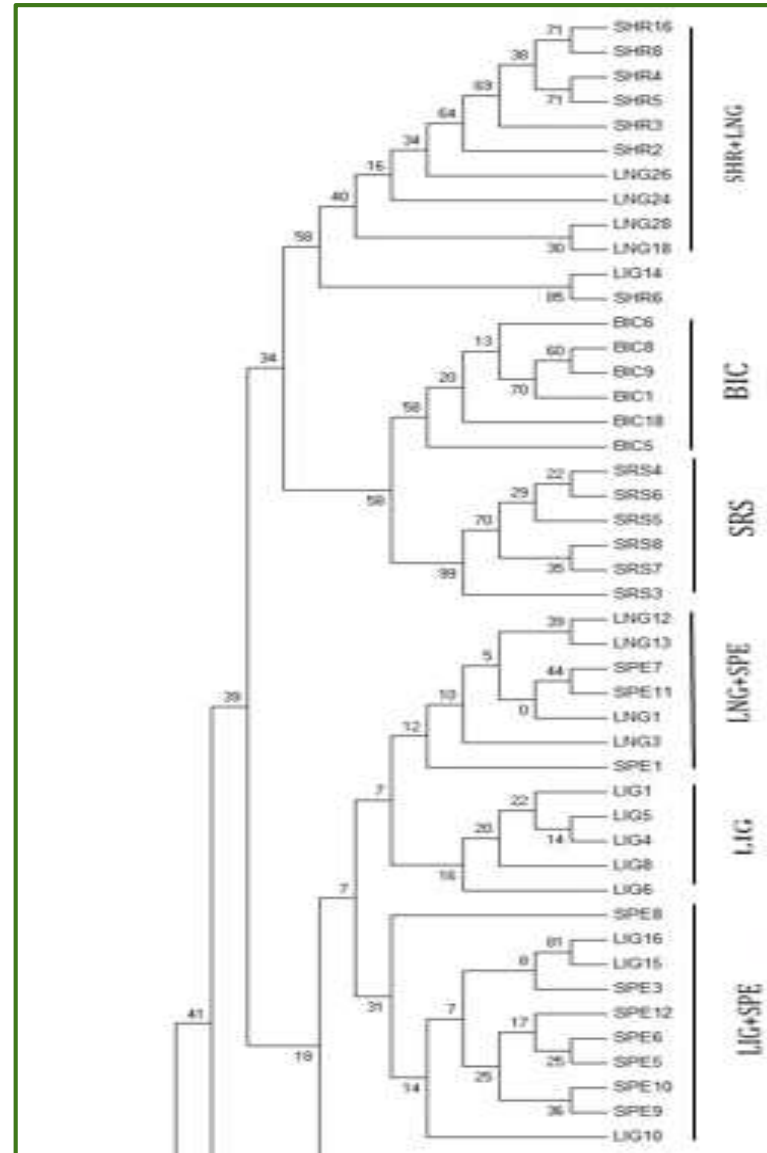
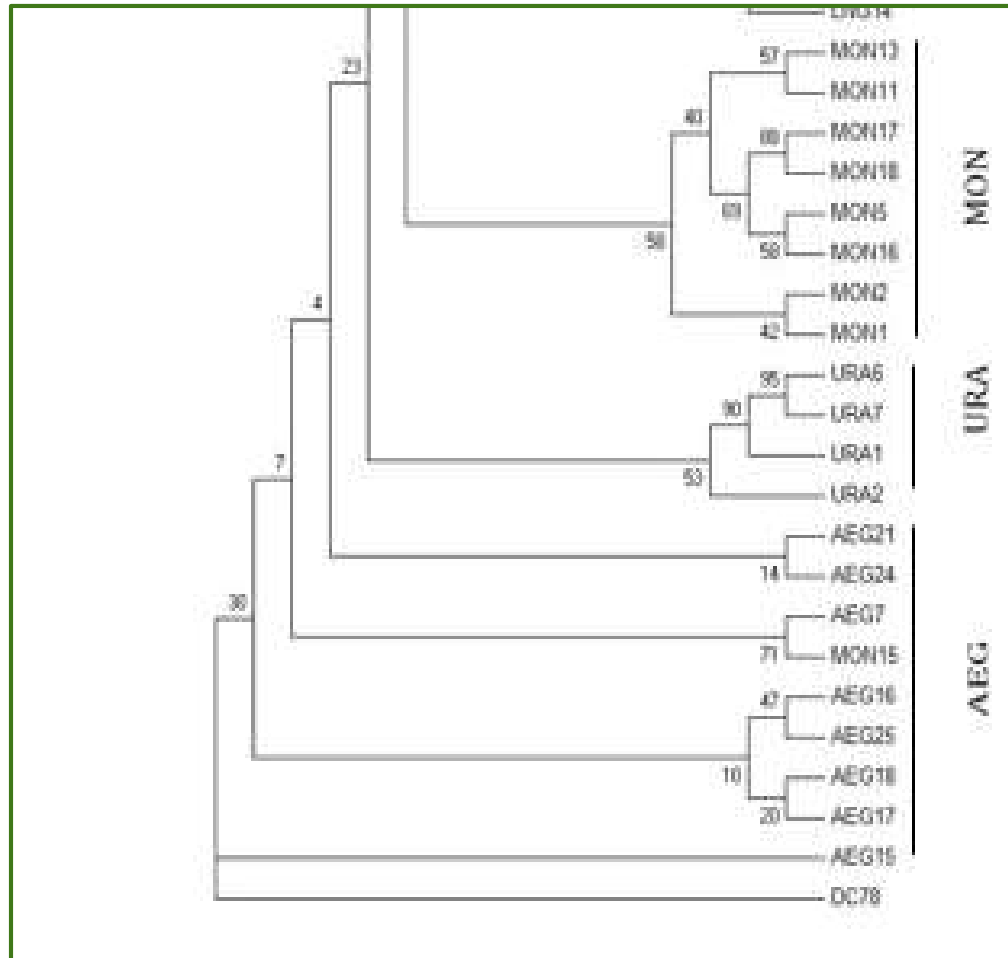
Aegilops searsii Feldman & Kislev ex K. Hammer , *Aegilops sharonensis* Eig

Aegilops longissima species (Schweinf. & Muschl. In Muschl.)



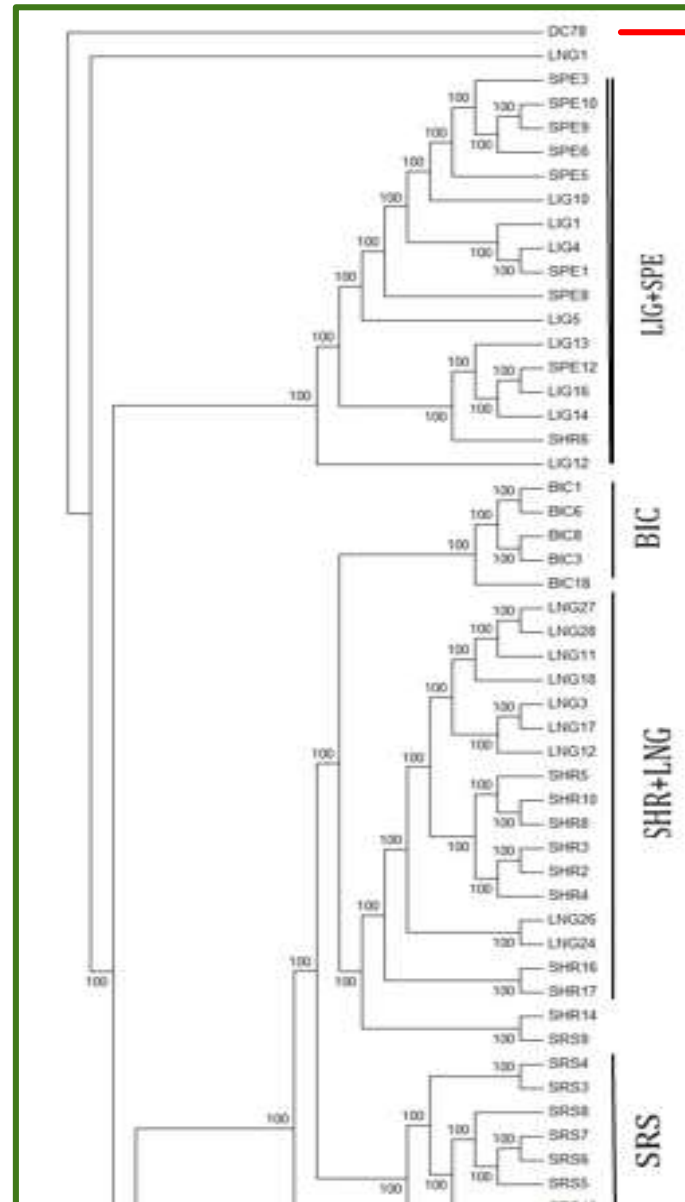
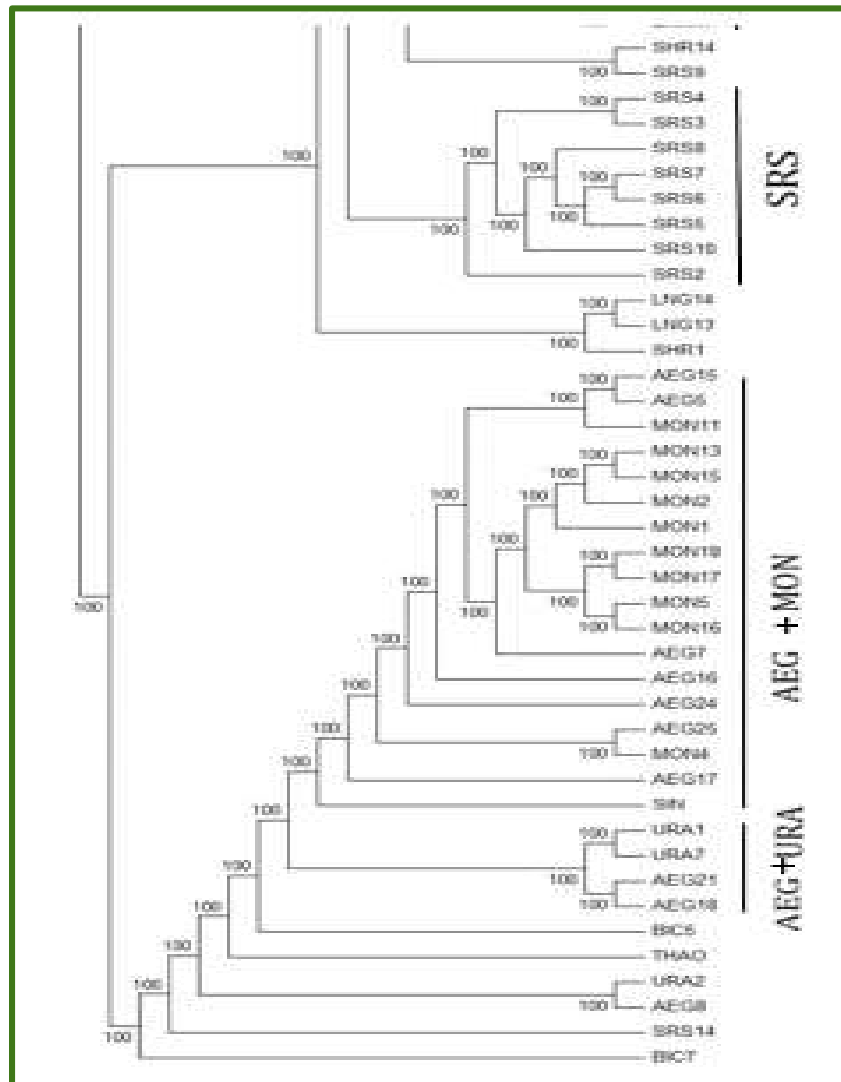
Molecular analysis of diploid wheats

Binary TERGAP DNA polymorphisms
Parsimony method



Molecular analysis of diploid wheats

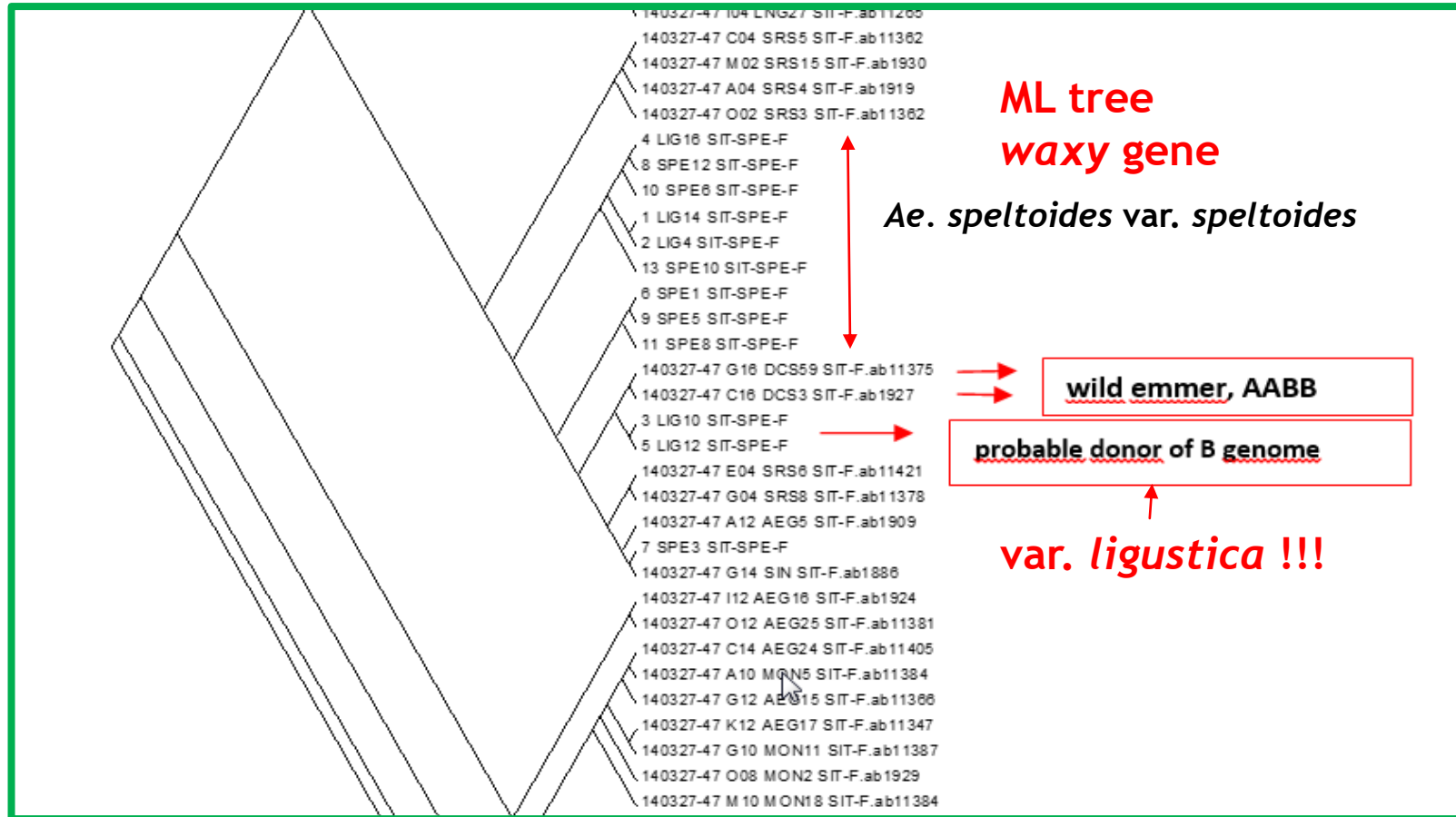
DArT DNA polymorphisms NJ method



outgroup =
Aegilops cylindrica

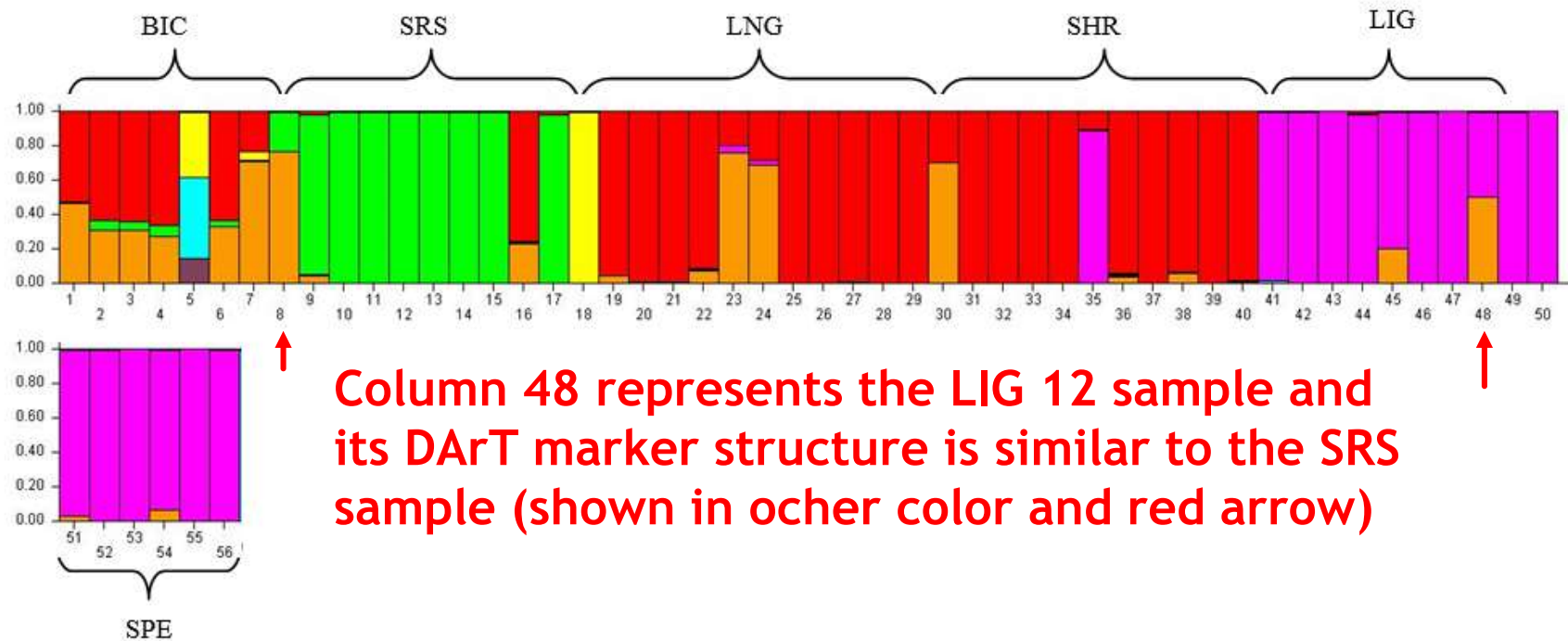


Origin of the B genome in tetraploid wheat *T. turgidum* subsp. *dicoccoides*



Origin of the B genome in tetraploid wheat *T. turgidum* subsp. *dicoccoides*

Aegilops sample diagram obtained with *Structure* programme from binary DArT data

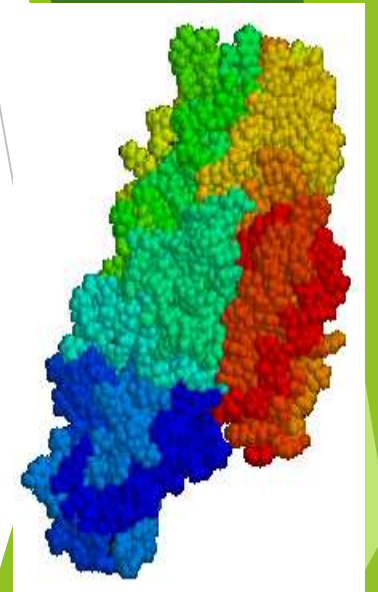
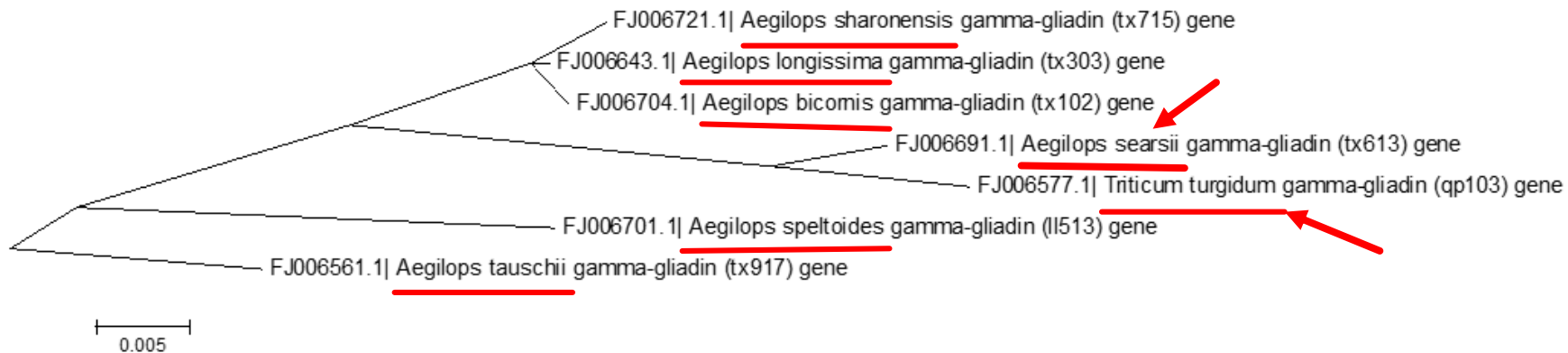


Column 48 represents the LIG 12 sample and its DArT marker structure is similar to the SRS sample (shown in other color and red arrow)

Aegilops searsiii

Origin of the B genome in tetraploid wheat *T. turgidum*

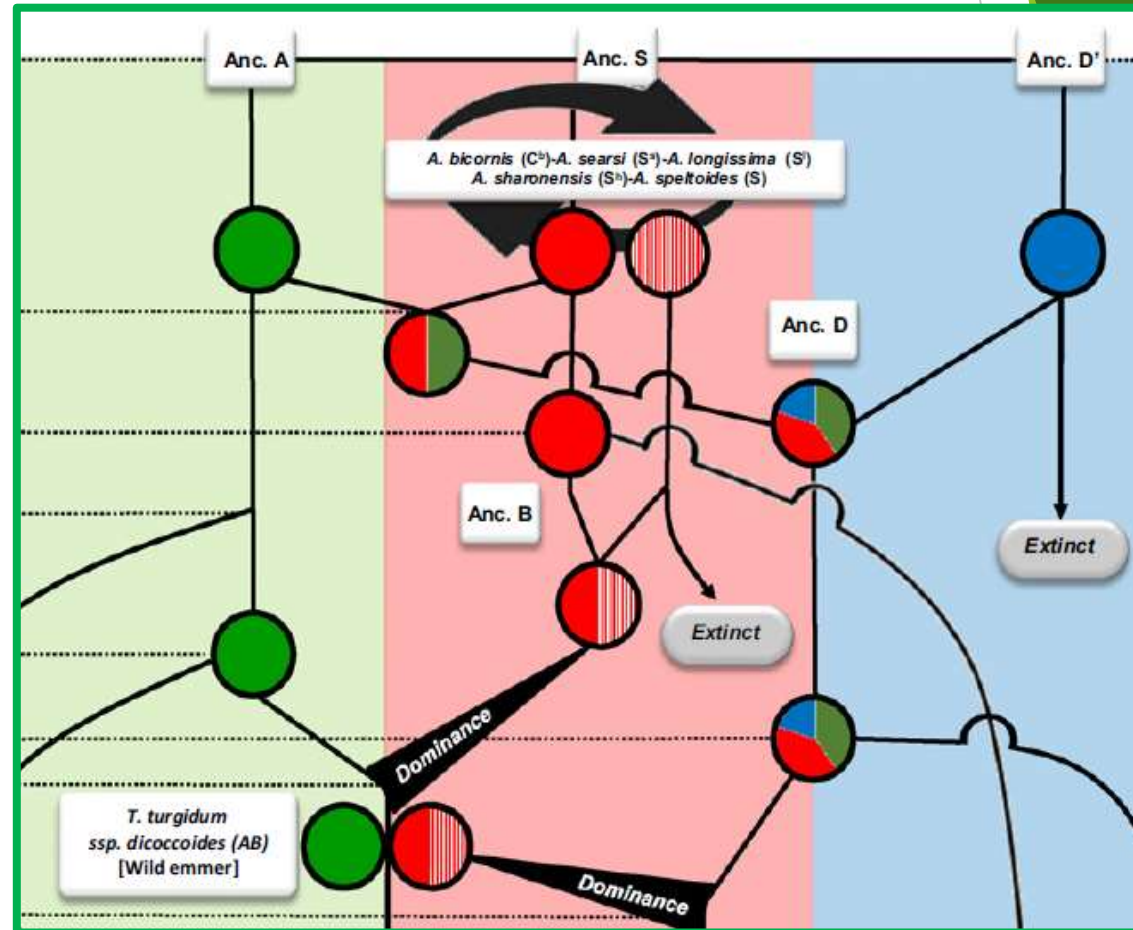
ML tree constructed from gamma-globulin gene sequences downloaded from NCBI database.



gamma-gliadin is a storage protein

Models of B genome origin of polyploid wheats

- ▶ Liu et al. (2003): low-copy non-coding sequence constituting 19% of the long arm chromosome 3B content in wheat exists among all species only in *Ae. searsii*;
- ▶ Zhang et al. (2018): *Ae. speltoides* cannot be considered as an exclusive donor of the B genome, which has a polyphyletic origin;
- ▶ Haider (2012): **donor of the B genome is still relatively unknown and controversial and, hence, remains open**



Wheat evolutionary model according to El Baidouri et al. (2016)

Molecular analysis of tetraploid wheats

► **Wild taxa** (according to van Slageren, 1994):

Triticum turgidum subsp. *dicoccoides* (Körn. ex Asch. & Graebner) Thell.

Triticum timopheevii (Zhuk.) Zhuk. subsp. *armeniicum* (Jakubz.) MacKey

► **Domesticated taxa:**

Triticum turgidum subsp. *dicoccum* (Schrank ex Schübler) Thell.

subsp. *paleocolchicum* (Menabde) Á.Löve & D.Löve

subsp. *carthlicum* (Nevski in Kom.) Á.Löve & D.Löve

subsp. *turgidum*

subsp. *turanicum* (Jakubz.) Á.Löve & D.Löve

subsp. *polonicum* (L.) Thell.

subsp. *durum* (Desf.) Husnot

Triticum timopheevii (Zhuk.) Zhuk. subsp. *timopheevii*

Molecular analysis of tetraploid wheats

- ▶ Other taxa according to Hammer et al. (2011)

T. ispahanicum Heslot

T. aethiopicum Jakubz.

T. jakubzineri Udacz et Schachm.

T. militinae Zhuk. et Migush.

- ▶ Tetraploidization events occurred between the last 0.7 - 0.4 Myr (emmer and *timopheevii*), ct DNA (Gornicki et al., 2014);

- ▶ Tetraploid wheat formation < 0,5 Myr, ACC loci (Chalupska et al. 2008)

- ▶ Emmer domestication

Karacadag Mountains, Diyarbakir, Turkey (Özkan et al., 2002, 2005, 2011); evidence based on DNA analysis;

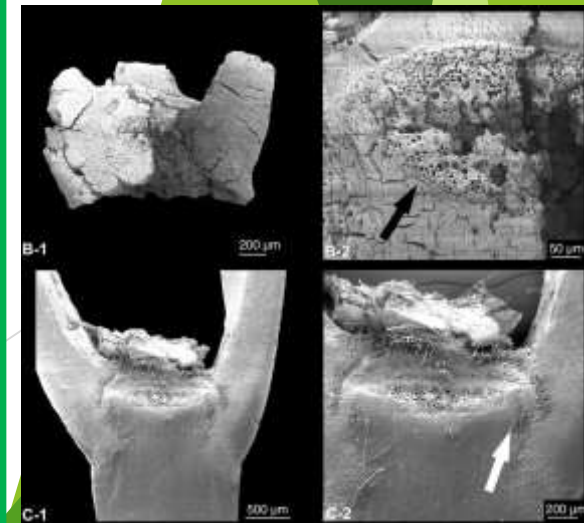
- ▶ Emmer domestication ?

Chogha Golan, Zagros Mountains, Ilam province, Iran;

- ▶ 9 800 years before, domesticated type of emmer appeared;

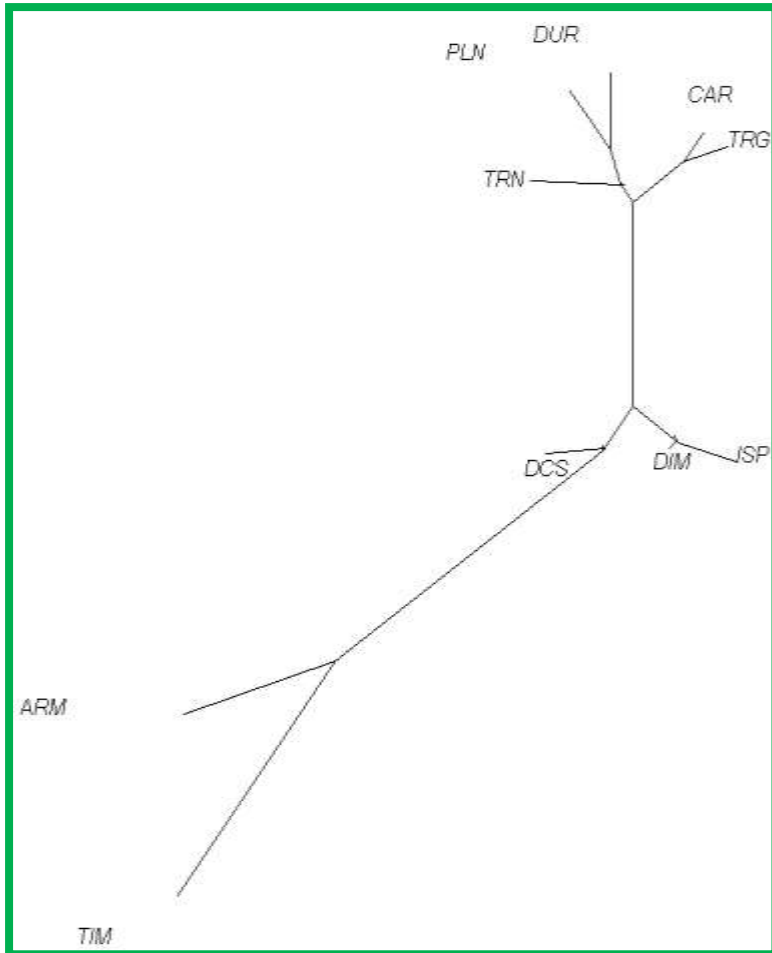
Evidence based on archeological findings;

Riehl et al. (2013), *Science*

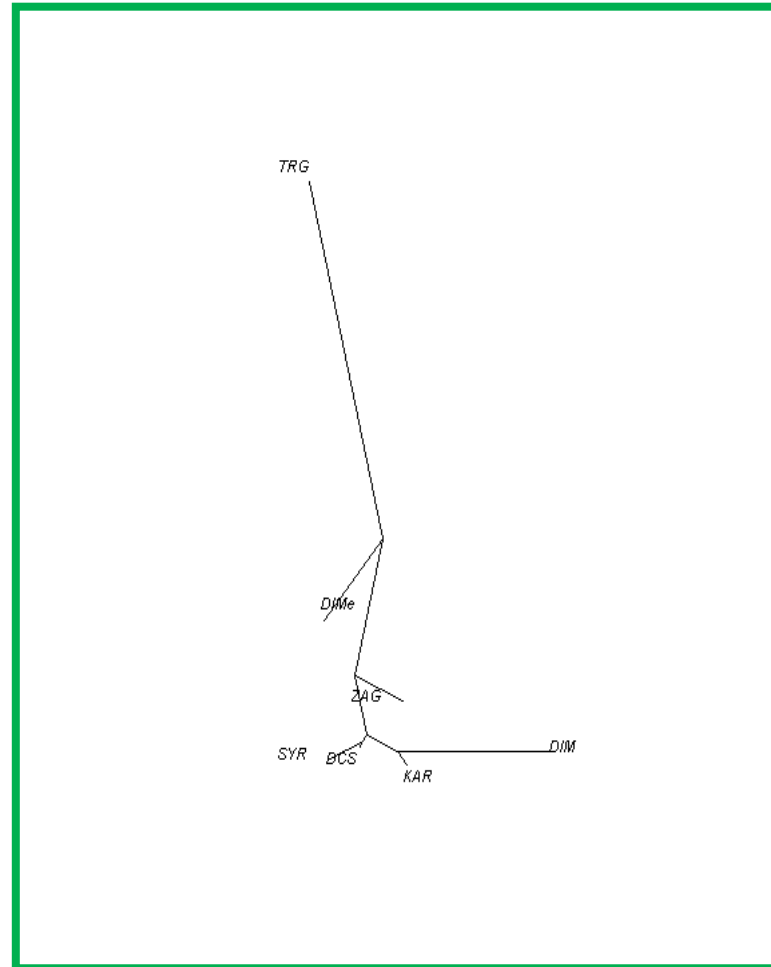


Molecular analysis of tetraploid wheats

Divergence of tetraploid taxa based on Fst distances calculated from DArT data



DArT, NJ tree, Fst values, wild and domesticated populations



Ancient Egypt 1352-1336 BC



Divergence of tetraploid wheats

Are these taxa independent species? F_{st} values, TERGAP

	ARM	TIM	DCS	DIM	ISP	TRG	CAR	DUR	TRN
ARM									
TIM	0.74626								
DCS	0.75865	0.80239							
DIM	0.78857	0.81647	0.34673						
ISP	0.86276	0.87274	0.55356	0.31096					
TRG	0.83807	0.86047	0.69048	0.69585	0.78792				
CAR	0.85720	0.87220	0.69542	0.67436	0.77711	0.35256			
DUR	0.87393	0.88742	0.69393	0.71421	0.80301	0.56458	0.51276		
TRN	0.82108	0.83871	0.62963	0.61907	0.71503	0.50076	0.45976	0.40908	
PLN	0.87830	0.88457	0.71743	0.74249	0.78916	0.66808	0.66692	0.55543	0.41429

Divergence of tetraploid wheats

Where was the emmer domesticated? Fst values, DArT

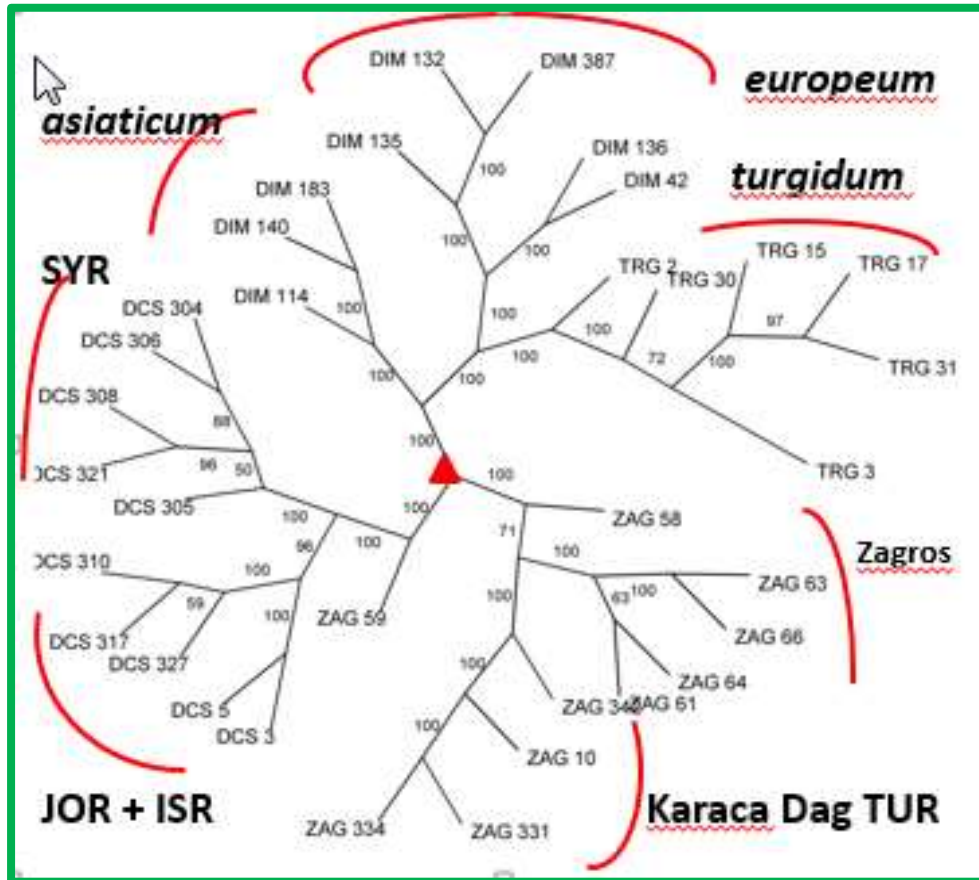
	ARM	DCS	SYR	ZAG	KAR	DIM	DIMe	TRG
ARM	0.00000							
DCS	0.82419	0.00000						
SYR	0.84794	0.23802	0.00000					
ZAG	0.82661	0.35673	0.37454	0.00000				
KAR	0.85133	0.40680	0.43341	0.16756	0.00000			
DIM	0.88683	0.57635	0.62801	0.47653	0.55970	0.00000		
DIMe	0.84552	0.49785	0.53460	0.41429	0.48806	0.49080	0.00000	
TRG	0.92226	0.73896	0.78666	0.68907	0.79195	0.89451	0.64451	0.00000



Divergence of wild emmer populations

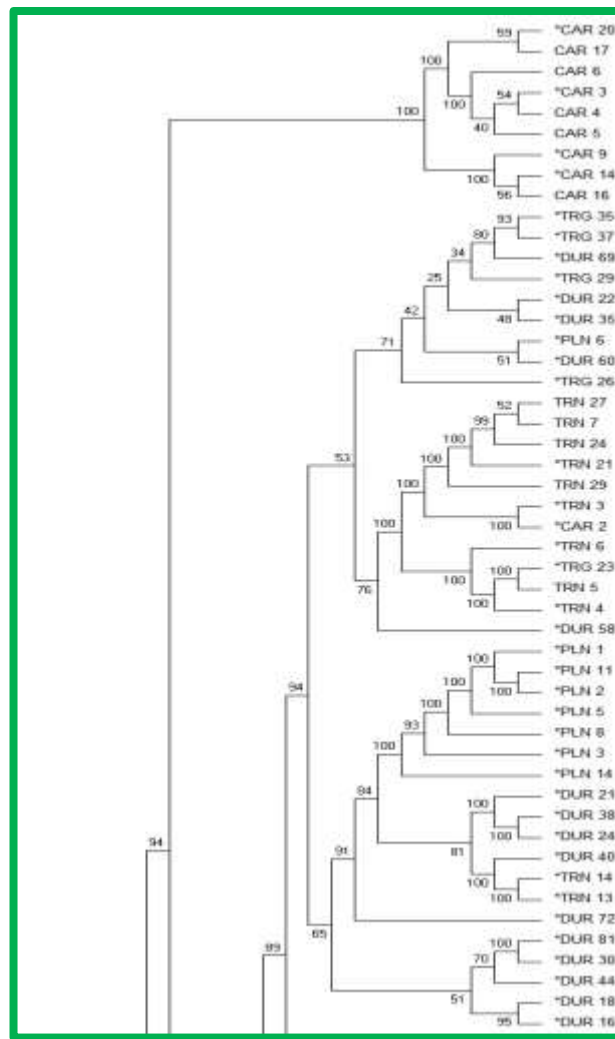
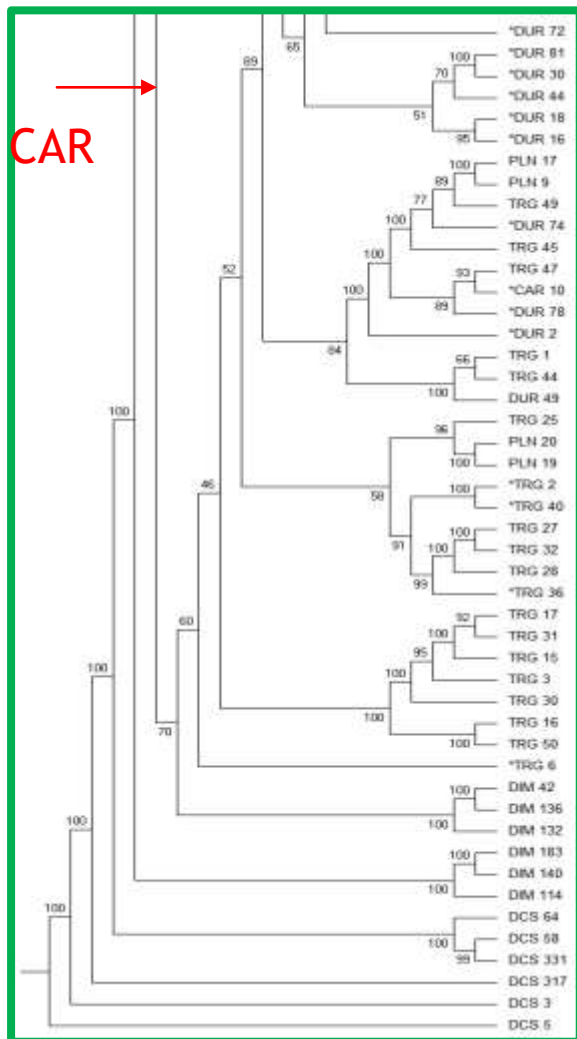
NJ tree, DArT DNA polymorphisms

Two races of wild emmer



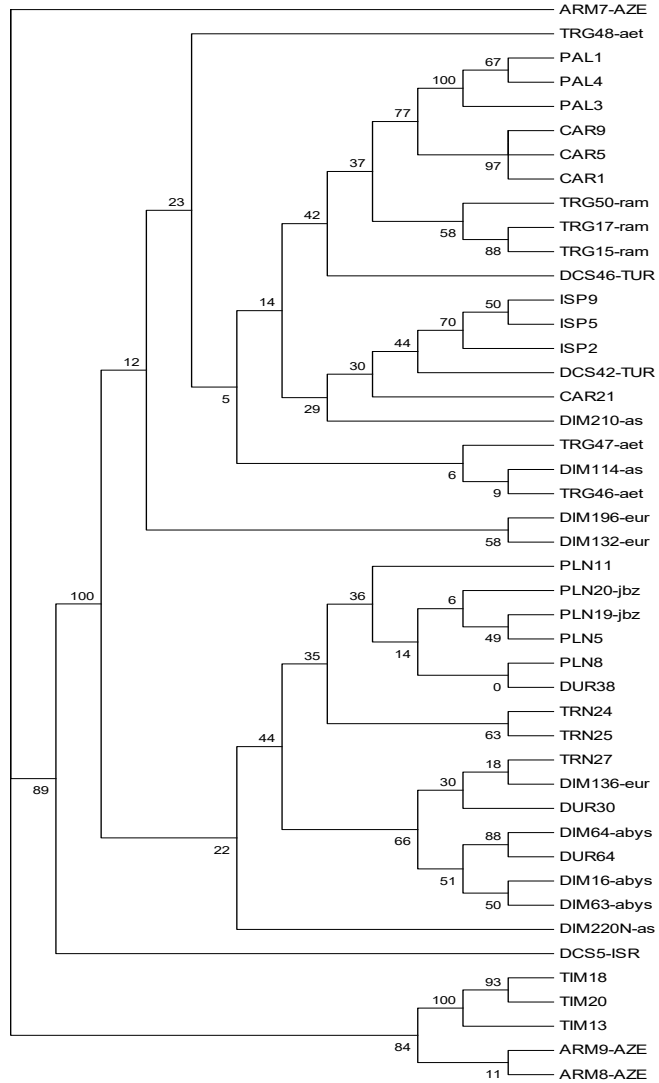
Evolution of tetraploid wheats, NJ, DArT

How did tetraploid taxa evolve? In the form of divergence?



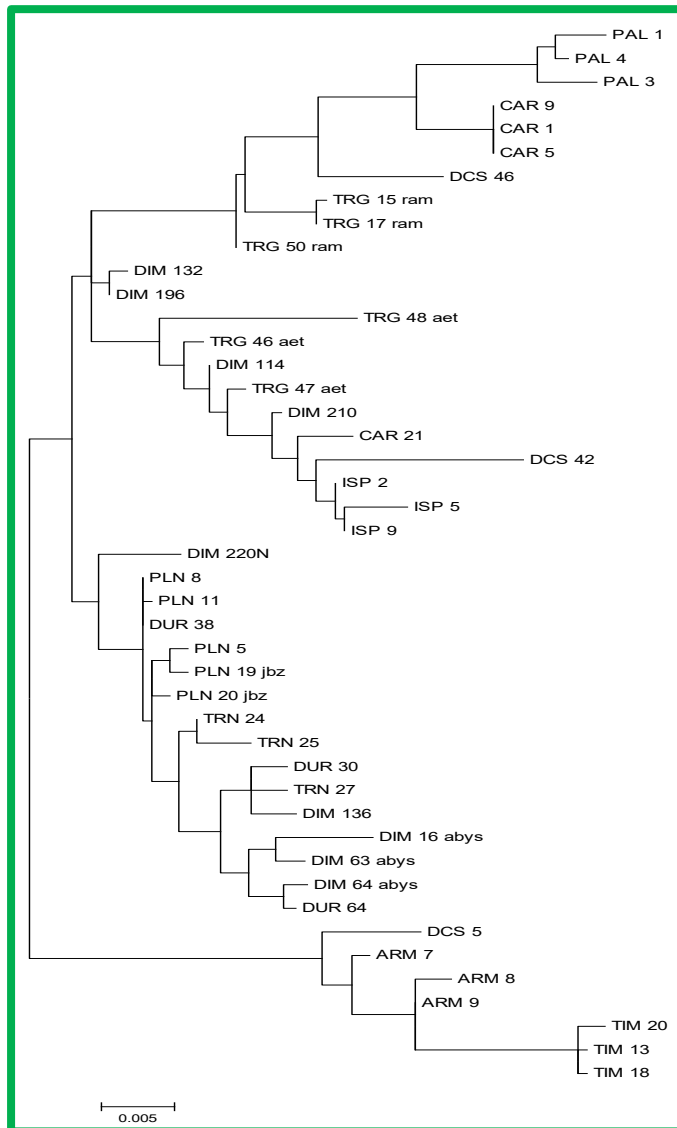
Evolution of tetraploid wheats according to pseudogenes

Consensus parsimony tree



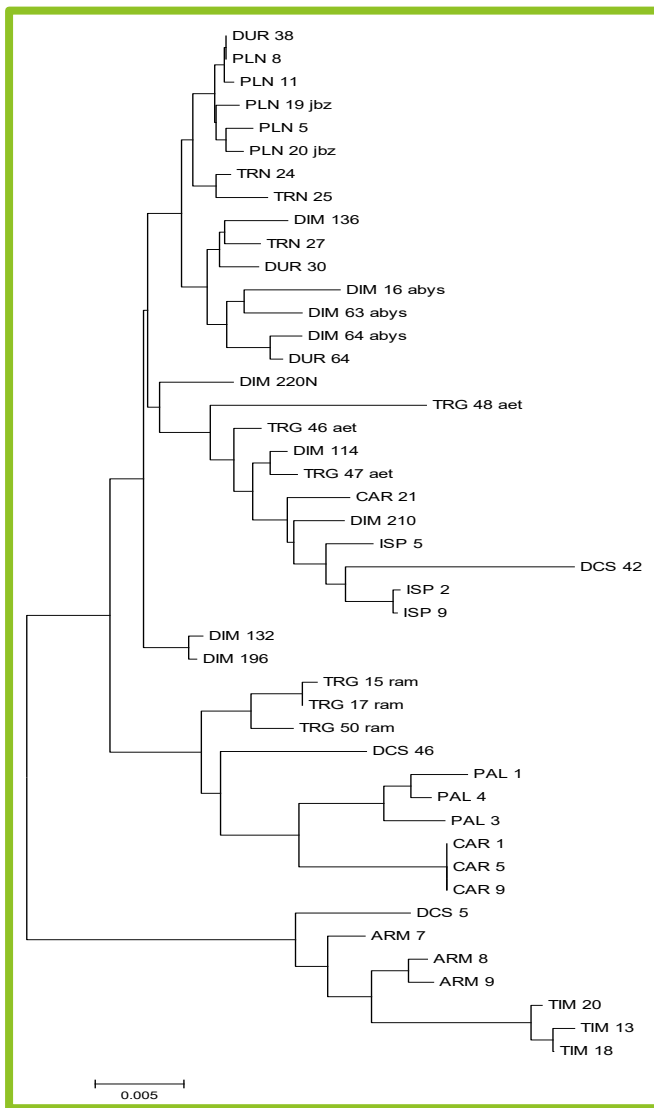
Evolution of tetraploid wheats according to pseudogenes

ML tree obtained of concatenated sequences of four pseudogenes



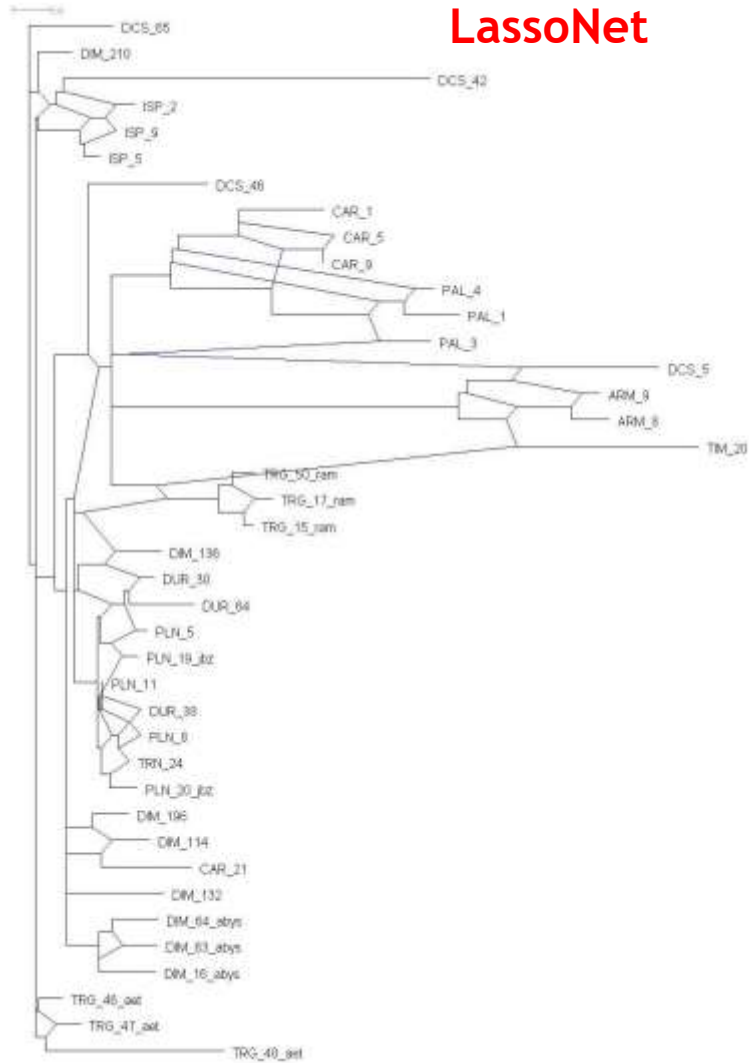
Evolution of tetraploid wheats according to pseudogenes

Min Evol tree obtained of concatenated sequences of four pseudogenes

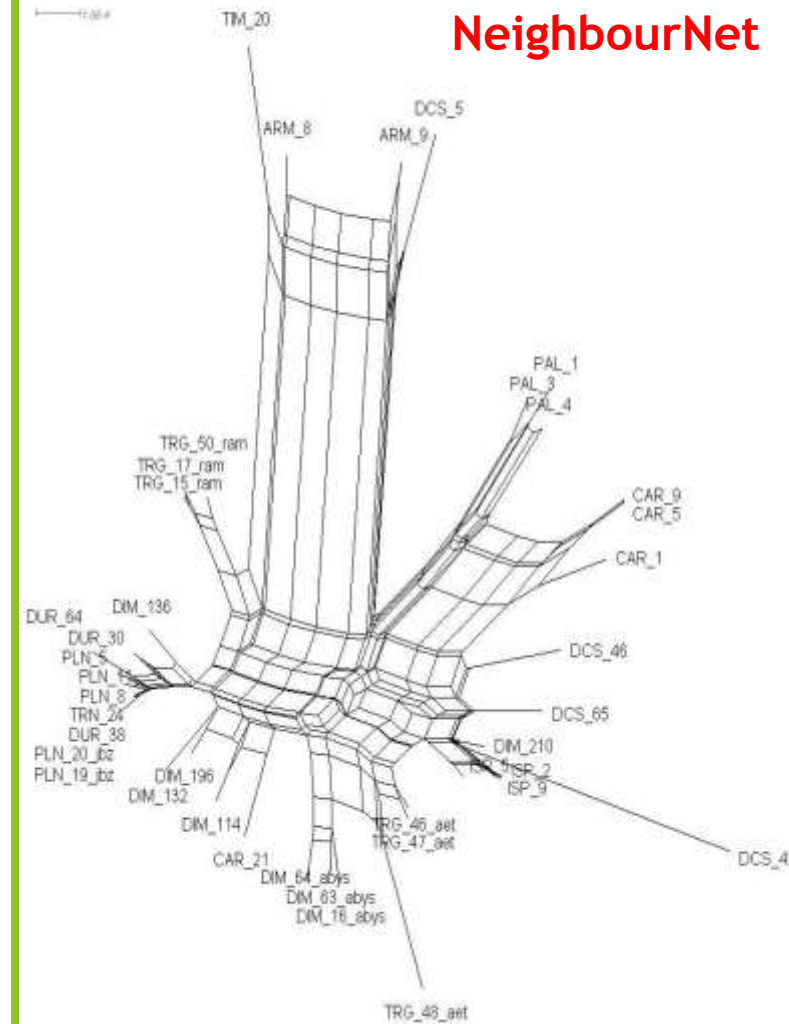


Evolution of tetraploid wheats according to pseudogenes, SplitsTree v.4

LassoNet



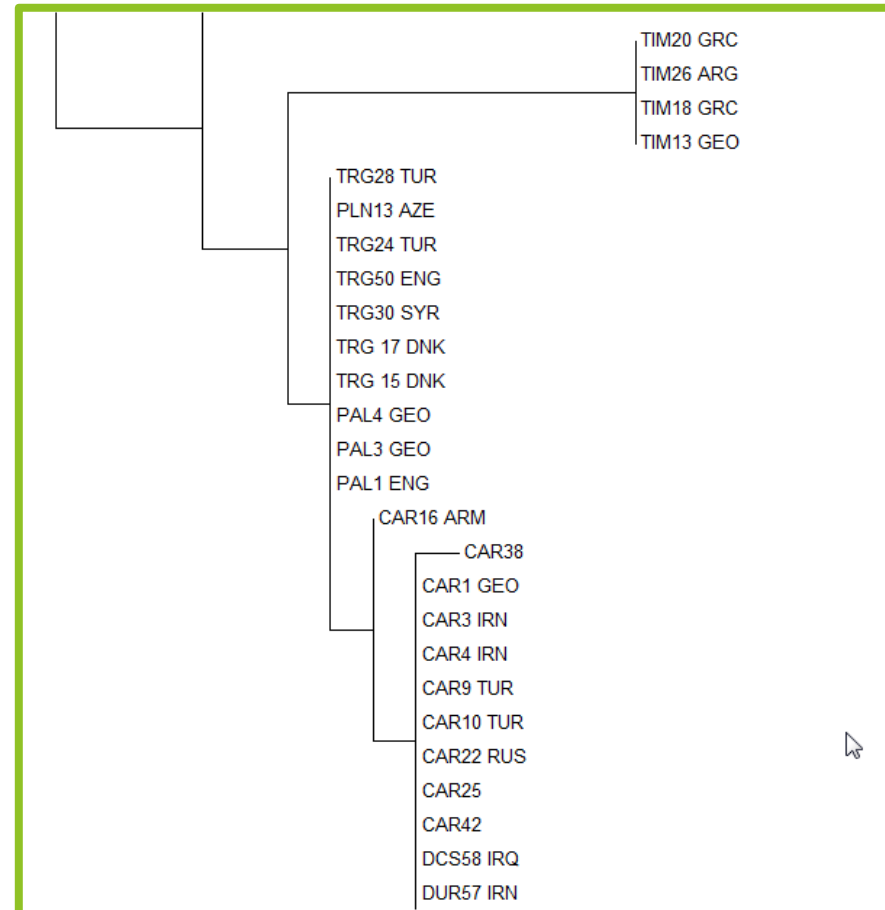
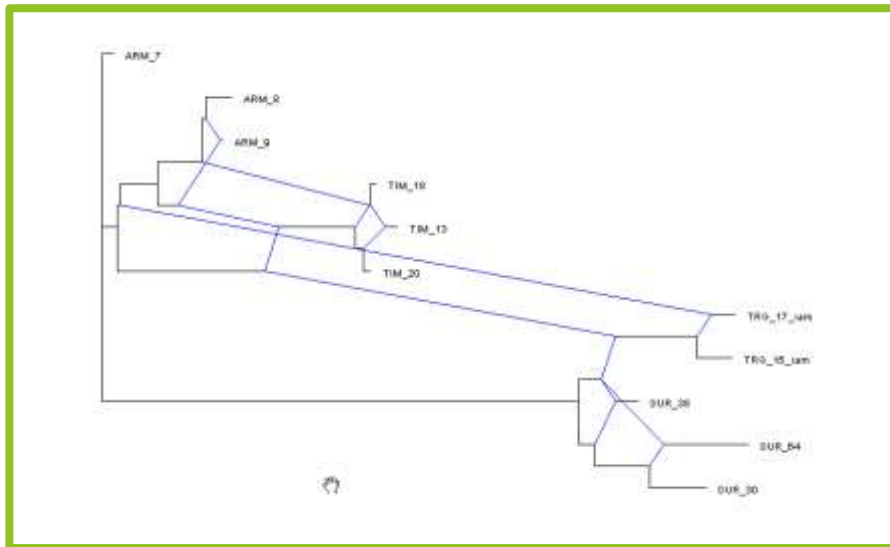
NeighbourNet



Reticulated origin of tetraploid wheats

Triticum timopheevii subsp. *timopheevii*, **TIM**

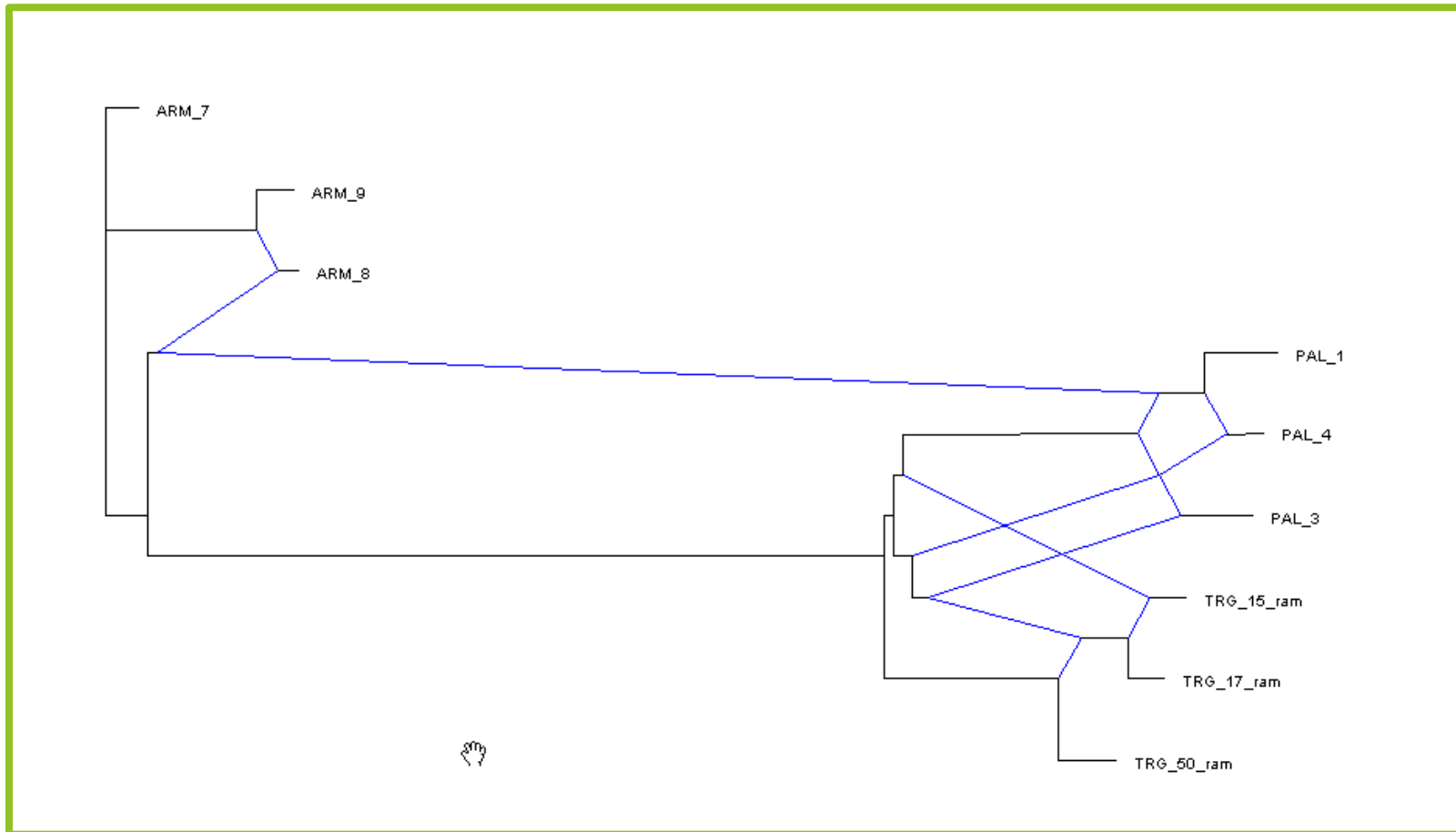
***Timopheevi* is not a domesticate but evolved by hybridization !!!!!**



Reticulated origin of tetraploid wheats

Triticum turgidum subsp. *paleocolchicum*, **PAL**

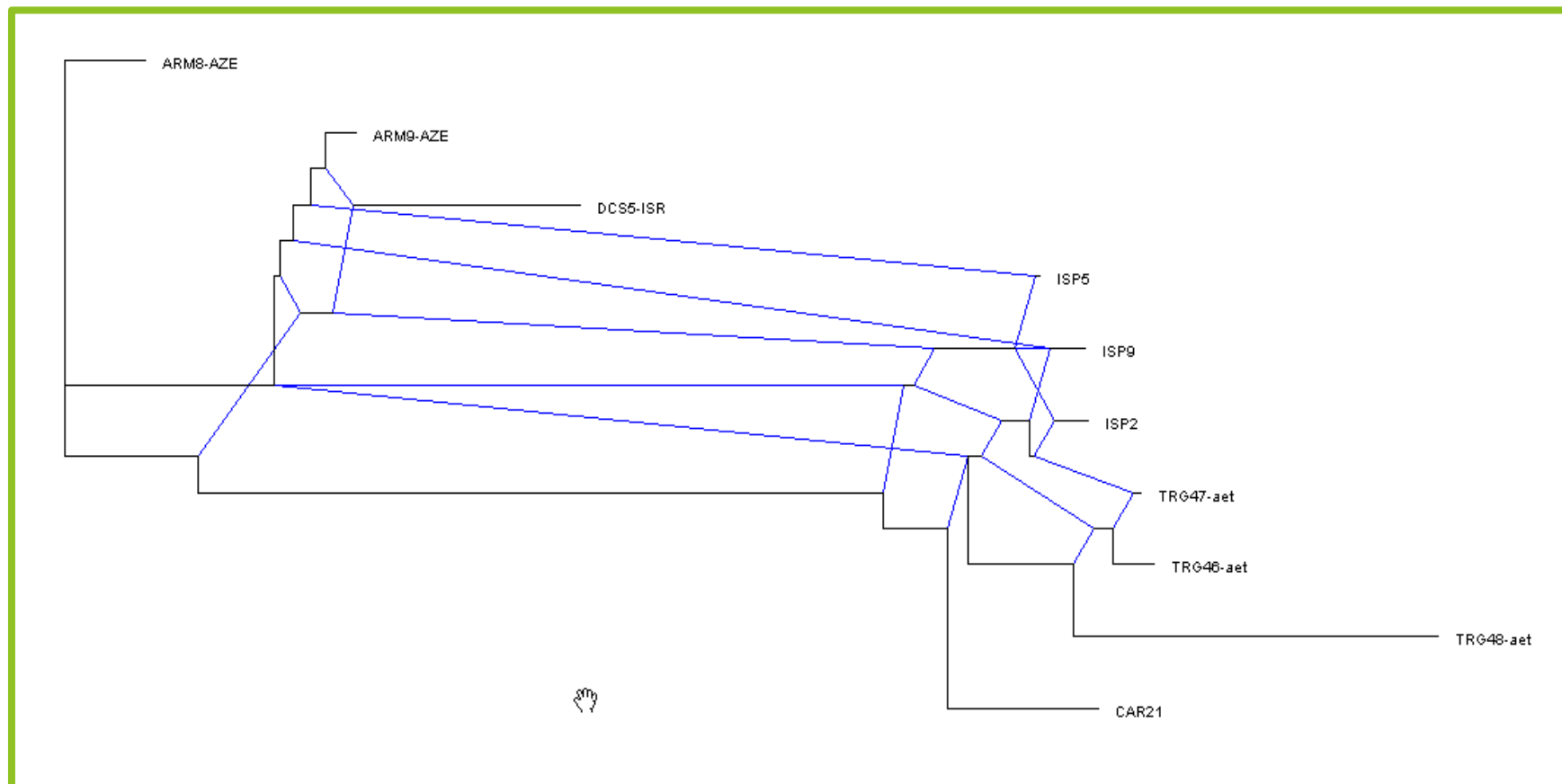
The parents of PAL are ARM and TRG ramosum



Reticulated origin of tetraploid wheats

Triticum ispahanicum, **ISP**

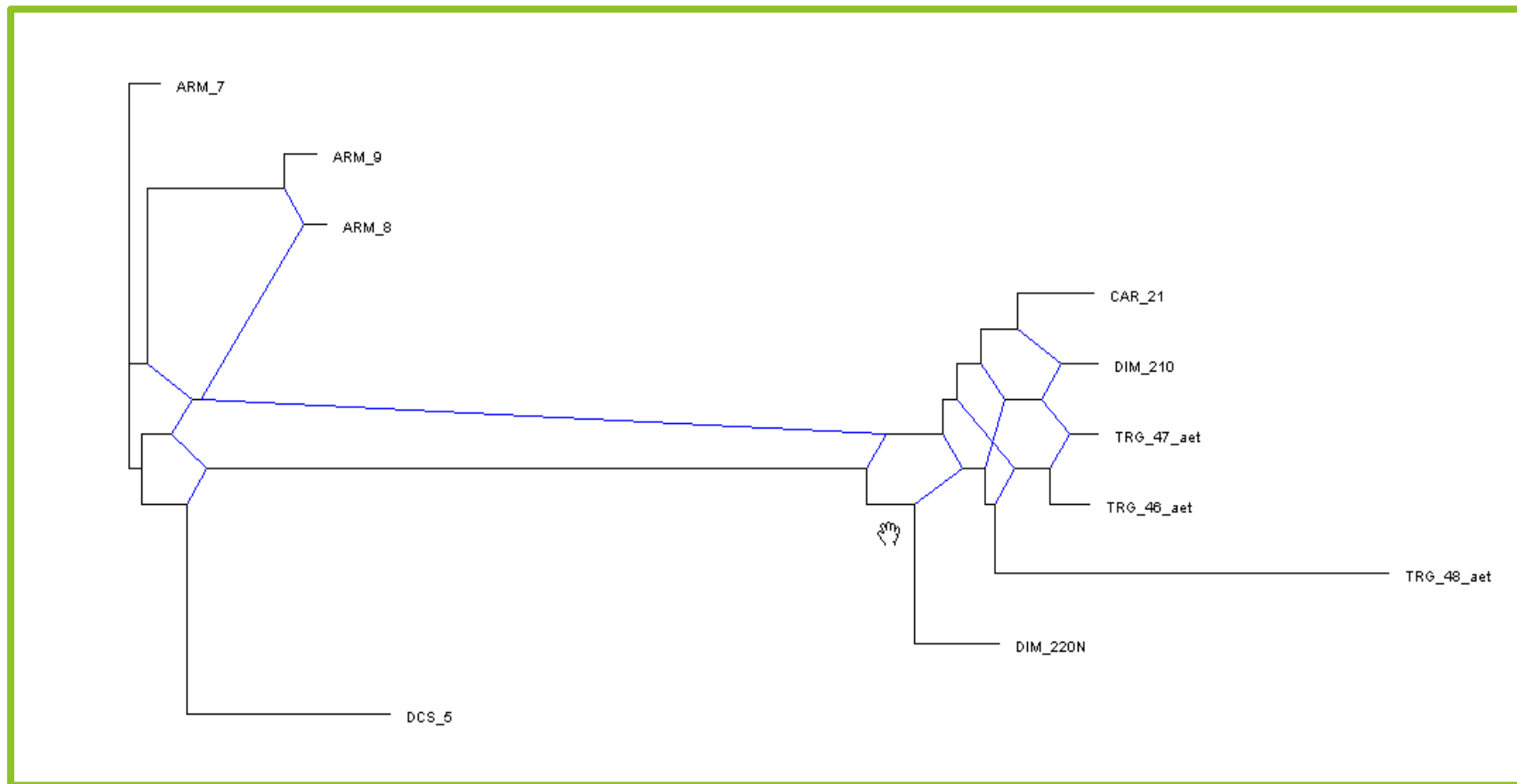
ISP is probably derived from CAR 21 x ARM. *Aethiopicum* is certainly not its parent.



Reticulated origin of tetraploid wheats

Triticum aethiopicum, **AET**

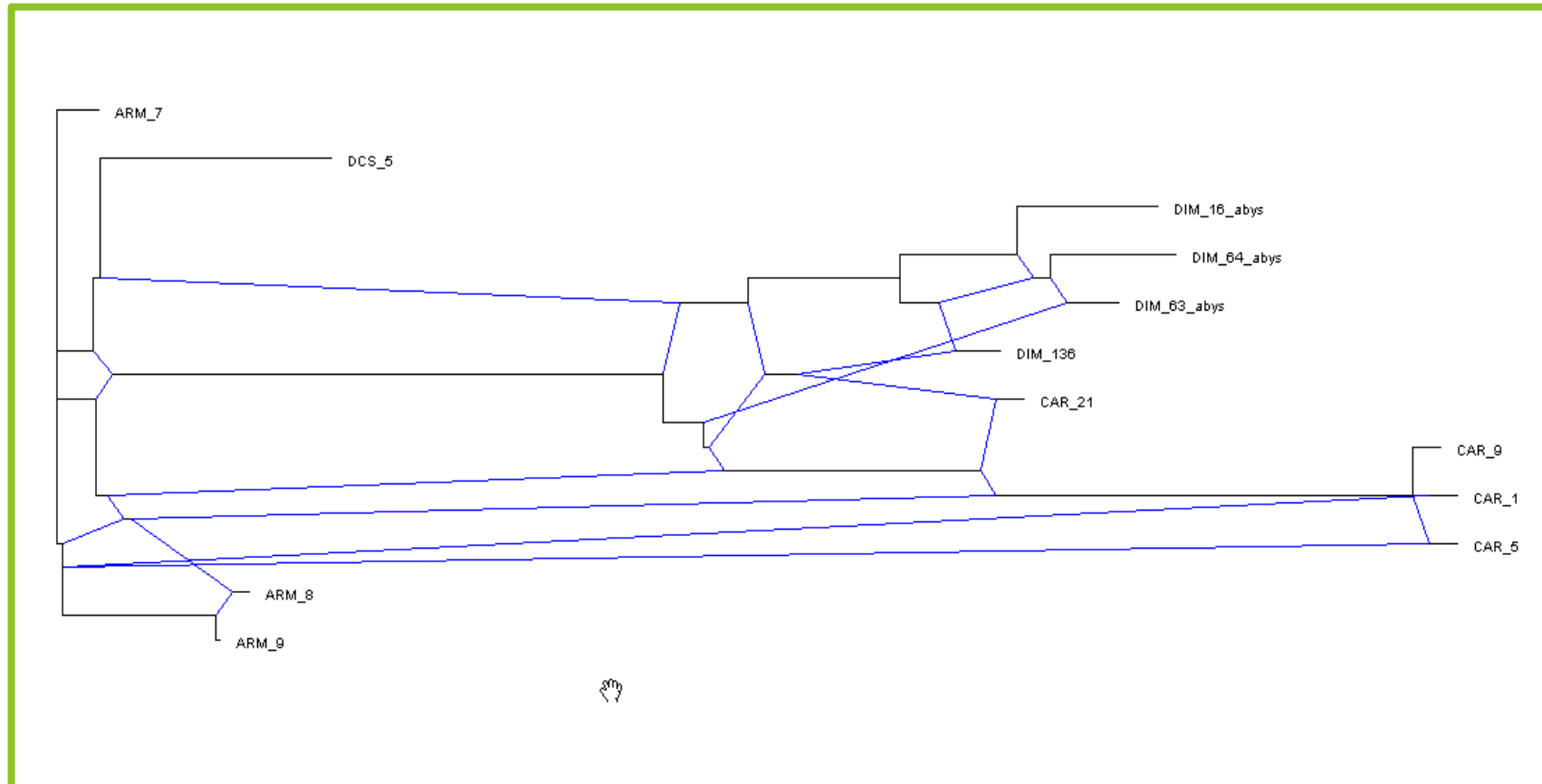
The parents of the *aethiopicum* samples were the *proto-carthlicum* CAR 21 and the Iranian sample DIM 220, which is from Isfahan province.



Reticulated origin of tetraploid wheats

Triticum dicoccum scv. *abyssinicum*, **ABYS**

The parents of the *abyssinicum* samples were *proto-carthlicum* CAR 21 and some of wild emmer (DCS) samples.



Time estimation of tetraploid taxa origin

