Annals of Agrarian Science

Journal homepage: http://journals.org.ge/index.php

Diversity of wheat in modern Georgia versus discoveries of the archaeological excavations of the 6,000 BC Neolithic sites of Lower Kartli Region (SE Georgia)

M. Mosulishvili[a,b], D. Bedoshvili[c*], I. Maisaia[d,e], N. Rusishvili[b], N. Ustiashvili[a], G. Chkhutiashvili[f], M. Merabishvili[c]

[a]Institute of Ecology, Ilia State University; 3/5, Cholokashvili Ave., Tbilisi, 0162, Georgia

[b]Georgian National Museum; 3, Purtseladze Str., Tbilisi, 0105, Georgia

[c]Institute of Crop Science, Agricultural University of Georgia; 240, David Aghmashenebeli Alley, Tbilisi, 0159, Georgia

[d]National Botanical Garden of Georgia; 1, Botanikuri Str., Tbilisi, 0105, Georgia

[e]Institute of Botany, Ilia State University; 1, Botanikuri Str., Tbilisi, 0105, Georgia

[f]Scientific-Research Center for Agriculture; 6, Marshal Gelovani Ave., Tbilisi, 0159, Georgia

Received: 05 November, 2020; Accepted: 10 November, 2020

A B S T R A C T

Georgia is one of the most important centers for the diversity of domesticated wheat. It is the only country in the world where all wheat genomes (AA, AABB, AAGG, AAGGAA, AABBDD) and all seven, domesticated hulled wheat species are present. The diversity of the wheat species (15) in Georgia is higher than in any other country including the Fertile Crescent region. Such diversity could originate only in the areas of ancient agricultural traditions. Archaeological excavations of the Neolithic sites of Arukhlo, Khramis Didi Gora and Gadachrili Gora in Kvemo [lower] Kartli Region (south-east Georgia) confirmed that wheat has been cultivated in Georgia since at least 7th and in the beginning of the 6th millennia BC, when the Shulaveri – Shomu Culture appeared in East Georgia. As many as nine wheat species were identified in Arukhlo suggesting that hulled and free-threshing wheats of all ploidy levels were already produced there. Among them, there are 4 species of hexaploid wheats: *T. spelta, T. sphaerococcum, T. aestivum, T. compactum.* Inter-estingly the appearance of naked tetraploid wheat species of *T. carthlicum* and *T. durum* in the oldest layers of Arukhlo. The palaeoethnobotanical material of later Neolithic site Chikhori (Imereti, West Georgia) is identical to the botanical materials of Arkhulo and Khramis Didi Gora.

Keywords: Triticum, Endemic, Hexaploid wheat, Neolithic, Hulled wheat, Georgia.

*Corresponding author: David Bedoshvili; E-mail address: d.bedoshvili@agruni.edu.ge

Introduction

Georgia is one of the most important centers for the diversity of domesticated wheat. It is the only country in the world where all wheat genomes (AA, AABB, AAGG, AAGGAA, AABBDD) and as many as 15 species (s. str.) of wheat (*Triticum boeoticum* Boiss., *T. monococcum* L., *T. dicoccum* (Schrank) Schübl., *T. palaeocolchicum* Menabde, *T. timopheevii* (Zhuk.) Zhuk., *T. durum* Desf., *T. turgidum* L., *T. carthlicum* Nevski, *T. macha* Dekapr. & Menabde, *T. zhukovskyi* Menabde & Ericzjan, *T. turanicum* Jacubz., *T. polonicum* L., *T. spelta* L., *T. compactum* Host, *T. aestivum* L.) are found. Among them 5 species (*T. macha, T. palaeocolchicum, T. timopheevii, T. zhukovskyi* and *T. carthlicum*) are endemics [1-7]. The same diversity is reflected in the material obtained from the archaeological excavations of the 6th millennium BC Neolithic sites of Arukhlo and Khramis Didi Gora in Kvemo [lower]

Kartli Region (southeast Georgia) providing evidence that Georgia is an important center of wheat domestication.

Main part

Ancient domesticated hulled wheat species survived until the 1970-ies in the western provinces of Georgia, such as Lechkhumi, Racha and Svaneti. As a rule, more advanced species replace their predecessors due to higher productivity or better adaptation to local environment or crop management practices. That is why hexaploid free-threshing wheat replaced hulled wheats almost in all ancient wheat growing regions including the Fertile Crescent countries, where some of the ancient wheats were domesticated. In contrast to the other countries, West Georgia is a rare example of a country, where wheat species of different epochs are produced in the same area and as part of the same production system. It is worth of mentioning that ancient hulled wheat and free-threshing wheat species have been produced together in Lechkhumi, Racha, and Svaneti for at least 8000 years. However, this diversity of Georgian wheat is under the threat of extinction, particularly since the 1980s and 1990s and nowadays Georgian endemic species are not cultivated anymore in the places of their origin, in the provinces of Lechkhumi, and Racha (West Georgia).

Fig. 1. *Snakvi - the oldest tool for harvesting hulled wheat species of makha and zanduri*

Georgia is the only country in the world where all 7 species of hulled wheat are present (among them 4 endemic species). Georgian endemic hulled wheat species play important role in the evolution of wheat. They represent ancient, relict species, showing all directions and transitional stages in wheat evolution from diploid to tetraploid and hexaploid species [8]. The relict tools used to collect hulled wheat spikes (with brittle rachis) have survived up to present day in Georgia. This is a woody tool, known as 'Shnakvi' (Fig. 1), originally created for wheat, and a stone mortar (Fig. 2) for dehusking (peeling) ears of hulled wheat - makha and zanduri.

According to Nesbitt and Samuel [9] Agriculture in Transcaucasia has always been characterized by great diversity in the range of crops. This must be due in part to isolation of regions within the highly mountainous landscape. The same diversity is found in ancient plant remains [9: 80].

Wheat diversity in archaeological excavations of the Neolithic sites in Georgia

Fig. 2. *Stone mortar "chamuri" for dehusking ears of hulled wheat*

The earliest aceramic (lacking pottery) Neolithic sites in Georgia have been mainly found on the Black Sea coast and in the Colchic (Kolkheti) lowlands (west Georgia). The Neolithic revolution probably began in Georgia in the 8th millennium BC [10,000 BP]. According to the archeological findings, the Neolithic revolution in Georgia is characterized by a number of innovations: tool production by means of scrubbing and polishing hard rocks, or by means of a macrolithic technique (bilateral slicing), the new shapes of tools, and the advent of pottery production [10].

Fig. 3. *Female figurines from the Neolithic sites of the Lower Kartli Region*

At the end of the 7th and in the beginning of the 6th millennia BC a Neolithic culture known as the Shulaveri – Shomu Culture appeared in East Georgia [11]. It was diffused over what is now south-eastern Georgia, mainly in Kvemo [Lower] Kartli Region and characterized by settlements in villages, circular vaulted mud-brick homes and farm buildings, tools (made of obsidian, stone, bone and horn). Also female figurines (Fig.3) reflecting fertility beliefs, clay vessels decorated with relief and notched ornaments (Fig. 4) and the farming of domestic animals (cattle, pigs) and cultivation of cereals (wheat, barley) [5, 12]. Wheat, barley, oil-fiber crops, legumes were widely cultivated along with the vineyards and fruit gardens [3, 4, 13, 14].

Nine species of wheat were found in the 6th millennium BC Neolithic settlements of Arukhlo in Lower Kartli Region (south-east Georgia): *Triticum boeoticum, T. monococcum, T. dicoccum, T. carthlicum, T. durum, T. spelta, T. compactum* , *T. sphaerococcum* Percival, *T. aestivum*, eight of which are domesticated species [15]. According to Rusishvili [15], this appearance of naked tetraploid (AABB) wheat species of *T. carthlicum* and *T. durum* in the oldest layers of Arukhlo is the earliest. As many as seven species of domesticated wheat dating back to 8,000 BP were identified in the archaeological excavations of Lower Kartli (south-eastern Georgia) in Khramis Didi Gora: *Triticum monococcum, T. dicoccum, T. durum, T. spelta, T. sphaerococcum, T. compactum, T. aestivum* alongside with other 'founder' crops: barley (*Hordeum vulgare* and *H. distichum*), oat (*Avena sativa*), rye (*Secale cereale*), lentils (*Lens esculenta*), peas (*Pisum sativum*) and bitter vetch (*Vicia ervilia*) [15-18]. By and large, macrofossil remains of crops cultivated by the Neolithic people of the South Caucasus were the same as those 'founder' crops of the Fertile Crescent and the Levant [19-21].

Palaeobotanical material and analyzes of archeological excavations of the Neolithic sites in Georgia shows, that free-threshing, hexaploid wheat species are dominant. Quantity preference of free-threshing wheat species *T. aestivum/compactum*, is evident, percentage of these soft wheat grain is 50-75% of all wheat population [15, 22]. Emmer wheat (*T. di-*

Fig. 4. *8000 years old clay vessels (Kvevri), decorated with relief and notched ornaments from the Neolithic sites of Arukhlo and Khramis Didi Gora in the Lower Kartli Region, SE Georgia (from the Georgian National Museum)*

coccum) is the second most abundant wheat species at Neolithic sites (Arukhlo, Khramis Didi Gora), a staple crop second only to soft wheat (*T. aestivum*/*compactum*). Percentage of emmer wheat is 25-31%. Emmer wheat were less common in Bronze (ca. 3000 BC) and Iron Age [15, 22, 23, 24].

According Bastert-Lamprichs et al. [26] agriculture in Arukhlo was already well developed in the 6th millennium BC (Fig. 5). A variety of cereals were cultivated: almost the entire range of early

Fig. 5. *View of the archeological site of Arukhlo, the Neolithic site of Lower Kartli Region (from [24] photo by S. Hansen)*

domesticated crops is available in Arukhlo. Archeological findings include grains and ears of wheat, which are not cultivated today. For example, the ancient hulled wheat einkorn (*Triticum monococcum*) and emmer wheat (*Triticum dicoccum*), as well as naked wheat (*Triticum aestivum* / *compactum*) can be found in Arukhlo [26]. The excavation in the burnt area in Arukhlo also brought to light a rich assortment of charred botanical remains (Fig. 6), among others two complete emmer spikes [25].

According to Esakia and Rusishvili [27], the paleoethnobotanical material of the late Neolithic Chikhori (Imereti, West Georgia) is identical to the botanical materials of Arkhulo and Khramis Didi

Fig 6. *Emmer spike in the burnt area in Arukhlo (from [24]; photo by S. Hansen)*

Gora. On all these monuments (Arkhulo, Khramis Didi Gora, Chikhori) the dominance of the naked free-trashing *T. aestivo-compactum* type was recorded, which implies a high level of wheat evolution. According to the data obtained, in the agriculture of the settlement soft wheat of the *T. aestivo-compactum* type and naked barley *Hordeum nudum* already existed. The existence of mixed sowing of wheat and barley are also assumed [27]. Besides Arukhlo and Khramis Didi Gora, the carbonized grains of *T. dicoccum*, *T. spelta* and *T. aestivum* were also found at Gadachrili Gora, a Neolithic Age (5783 cal. BC or 7775 cal. BP) settlement hill in southeastern Georgia [12]. Wheat grains from Arukhlo, Khramis Didi Gora and Gadachrili Gora provided the earliest archaeological evidence of existence of hulled hexaploid *T. spelta* in the Near East in ca. 6,000 – 5,800 BC. According to Maghradze et al. [28] carbonized seeds of founder crops such as wheat, barley, bitter vetch, lentil, pea together with seeds of some weeds were discovered at "Gadachrili Gora", confirm the presence of agriculture in Lower Kartli (southeastern Georgia) 8,000 years ago [28, 24].

Wheat grains found in Chihori are small (L = 4.33 mm), which is typical of club wheat (*T. compactum*). The index of length to width is 1.8. Such high ratio is typical for bread wheat (*T. aestivum*). Since a sharp boundary between these two species is impossible to identify, wheat grains of such type are considered as a *T. aestivo-compactum* [27].

Not more than 1 or 2 species of domesticated wheat (*T. monococcum*, and/or *T. dicoccum*) were found in almost all of the Anatolian and Mesopota- mian Neolithic sites, which are contemporary with Arukhlo [5, 10]. Comparisons between the Shulaveri-Shomu complex and the contemporary Halaf and Hassuna cultures in northern Mesopotamia, and Hacilar in Anatolia show that the cereals cultivated in Transcaucasia are much more diverse than in Anatolia and Mesopotamia [11]. Hamon [11] proposed that the great variety of endemic wheat species in the South Caucasus could have favored local domestication of cereals, even if these cereals were already cultivated in the Near East.

Georgian endemic wheat species as a healthy food

Georgian endemic wheat species Colchic emmer -*T. palaeocolchicum* [29] is very similar to wild forms of wheat due to its morphological characteristics. The important agricultural characteristics include: resistance to fungal diseases abundance of fertile spikelets (34-39 spikelets per spike), broad leaves, tall strong stems (100-120 cm tall) used as feed are

important for wheat breeding. Grains of 'Kolkhik asli' are distinguished by high protein content, and high lysine content in protein. *T. macha* (makha) bread was highly priced among the local population. It was white, tasty and fragrant and able to stay soft for several days. It was considered an honor to treat guests with 'makha' bread at feasts. 'Zanduri' landrace is considered as the most special local population. Three species are identified in the 'zanduri' population: 1. *T. monococcum* ('gvatsa [narrow] zanduri'); 2. *T. timopheevii* ('chelta [wider] zanduri') and 3. *T. zhukovskyi* ('zanduri'). 'Chelta zanduri owing to its special immunity to fungal diseases, deserves particular attention. Bread baked from 'chelta zanduri' (*T. timopheevii*) flour is very tasty and flavorful, it remains soft for the whole week. 'Zanduri' (*T. zhukovskyi*) is known as drought and frost resistant plant. It is known by growth potential in all kinds of soils (even in limestone). Free-thrashing endemic wheat species 'Dika' (*T. carthlicum*) is characterized by early yielding, easy threshing, resistance to flattening and grain dropping. Grains of 'dika' are also distinguished by their high protein and lysine content. 'Dika' as a highland crop (grows up to 2200 - 2300 m above sea level), is well adapted to severe conditions of the Greater and the Lesser Caucasus Mountains. Its important feature is good bread bake ability. This species is characterized by strong immunity to diseases, frost resistance and a short vegetation period [30].

Endemic Georgian wheat species are important breeding material as they are characterized with high resistance to biotic and abiotic stresses and high grain protein content. The local endemic species are unique as they combine wild and domesticated traits. 15 species of wheat, 188 varieties were registered till 60-70-ies of the last century [7]. At present the situation has radically changed, as the local varieties occupy insignificant areas and their on-farm conservation is under threat. It is necessary preserve the diversity of wheat both at genbank and farms and to restore its production in the places of its origin (especially in Lechkhumi and Racha).

Conclusion

The archeological excavations confirm that wheat has been cultivated on the territory of Georgia since the Neolithic period (from the late 7th and in the beginning of the 6th millennia BC). By that time wheat in Georgia was presented with high diversity including domesticated species providing evidence that wheat cultivation had begun in the 7th millennium BC. These species represent ancient, relict species, showing all directions and transitional stages in wheat evolution from diploid to tetraploid and hexaploid species and suggesting that the South Caucasus might have played an important role in wheat evolution.

Acknowledgements

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSF) Grant Number FR 17_566.

References

[1] L. L. Dekaprelevich, The role of Georgia in Origination of Wheat, Bulletin of the Academy of Sciences of Georgian SSR, vol. 2 (1942a) 153-160.

[2] L. L. Dekaprelevich, The role of Georgia in Origination of Wheat, Bulletin of the Academy of Sciences of Georgian SSR, vol. 5, (1942b) 445-500.

[3] V. L. Menabde, Wheats of Georgia, Institute of Botany, Academy of Sciences of Georgian SSR. Publishing House of Academy of Sciences of Georgian SSR, 1948. (in Russian).

[4] A. D. Gorgidze, Phylogenesis of Georgian Endemic Wheats, Metsniereba, Tbilisi, 1977.

[5] N. Bregadze , Georgia as an Independent Center of Origin of Agriculture, Publishing House Samshoblo, Tbilisi, 2004 (in Georgian).

[6] P. Naskidashvili, I. Naskidashvili, M. Naskidashvili, G. Ghughunishvili, D. Lobzhanidze, J. Kakhadze, K. Mchedlishvili, G. Chkhutiashvili, T. Loladze and N. Gakharia, Wheat of Georgia and Breeding Work on It (in Georgian language), Mtsignobari, Tbilisi, 2013, p. 688.

[7] M. Mosulishvili, D. Bedoshvili and I. Maisaia, A consolidated list of Triticum species and varieties of Georgia to promote repatriation of local diversity from foreign genebanks, Annals of Agrarian Science, vol. 15, No.1 (2017) 61-70.

[8] M. Mosulishvili, D. Bedoshvili, I. Maisaia and G. Chkhutiashvili, Georgia, the South Caucasus as the homeland of the hexaploid wheat, Annals of Agrarian Science, vol. 17,3 (2019) 287–297.

[9] M. Nesbitt and D. Samuel, From staple crop to extinction? The archaeology and history of hulled wheats, in: Hulled wheats. Promoting the conservation and use of underutilized and neglected crops 4. Proceedings of the 1st International Workshop on Hulled Wheats, Castelvecchio Pacoli, Tuscany (Italy), International Plant

Genetic Resources Institute, 1996, pp. 41–100.
[10] L. Dzidziguri, The oldest agriculture of the South Caucasus,The Journal of the Centre for Archaeological Studies of the Georgian Academy of Sciences, vol. Supplements II, p. 343, 2000 (in Georgian).
[11] C. Hamon, From Neolithic to Chalcolithic in the Southern Caucasus: Economy and Macrolithic Implements from Shulaveri-Shomu sites of Kwemo-Kartli (Georgia), Paléorient, vol. 34, (2008) 85-135.
[12] M. Jalabadze, K. Esakia, N. Rusishvili, E. Kvavadze, I. Koridze, N. Shakulashvili and M. Tsereteli, "Report on Archaeological work carried out on Gadachrili Gora in 2006- 2007, Dziebani, Journal of the Archaeology, vol. 19 (2010) 17- 24,(in Georgian).
[13] I. Maisaia, Our National Treasure, Georgia's Cereal, Oil and Fiber Crops, DM Color, Tbilisi, 2009.
[14] L. Pruidze, I. Maisaia, S. Sikharulidze and M. Tavartkiladze, Our Dailiy Bread. Georgia - the Ancient Cradle of Agriculture, Publishing House Palitra, Tbilisi, 2016, p. 140.
[15] N. Rusishvili, Fossil Wheat from the Territory of Georgia, Flora, Geobotany and Palaeobotany, vol. 1, 1988 (in Russian).
[16] G. N. Lisitsyna, The Caucasus a centre of ancient farming in Eurasia, in: Plants and ancient man: studies in palaeoethnobotany, W. van Zeist and W. A. Casperie, Eds., Rotterdam (the Netherlands), Balkema, 1984, p. 285–292.
[17] O. Lortkipanidze, Archä ologie in Georgien: von der Altsteinzeit zum Mittelalter, Weinheim: VCH, Acta Humaniora, 1991, p. 347.
[18] K. Kushnareva, he Southern Caucasus in Prehistory: Stages of Cultural and Socioeconomoc Development from the Eighth to the Second Millennium BC, University of Pennsylvania Press, Philadelphia, 1997.
[19] G. N. Lisitsyna and L. V. Prischepenko, Paleoetnobotanicheskie nakhodki Kavkaza i blizhnego Vostoka [Paleobotanical data from the Caucasus and the Near East], Nauka, Moscow, 1977 (in Russian).
[20] C. Chataigner, La Transcaucasie au Néolithique et au Chalcolithique [Transcaucasia during the Neolithic and Chalcolithic], vol. 624, Oxbow Books Oxford, UK, 1995 (in France).
[21] D. Zohary and M. Hopf, Domestication of plants in the old world: The Origin and Spread of Cultivated Plants in West Asia, Europe and the Nile Valley, 3rd ed., Univ. Press, Oxford, 2000.
[22] N. Rusishvili, Cultivated plants in the early settlements of Georgia. Paleobotanical studies. Dissertation, Academy of Sciences of Moldova SSR, Kishinev, 1990 (in Russian).
[23] I. Maisaia, T. Shanshiashvili and N. Rusishvili, Crops of Colchis, Metsniereba, Tbilisi, 2005 (in Georgian).
[24] M. Mosulishvili, D. Bedoshvili, I. Maisaia, G. Chkhutiashvili & N. Ustiashvili, *Aegilops tauschii*, the D-genome donor of *Triticum* and, the geographic origin of hexaploid wheat. Annals of Agrarian Science, vol. 18, no. 4 (2020) 437–447.
[25] S. Hansen and M. Ullrich, Report on the 2012 – 2014 Excavation Campaign in Arukhlo, Archäologie in Iran und Turan, vol. 16, 2017, pp. 201- 222.
[26] K. Bastert-Lamprichs, N. Benecke, S. Hansen and R. Neef, Der Beginn der Landwirtschaftim Südkaukasus. Die Ausgrabungen in Aruchlo in Georgien, DAI Eurasien Abteilung, Berlin, 2012 (in German).
[27] K. Esakia and N. Rusishvili., Chikhori setlement according to paleoethnobotanical and trace data, The Journal of the Centre for Archaeological Studies of the Georgian Academy of Sciences, vol. 6, (2000) 13-15 (in Georgian).
[28] D. Maghradze, G. Samanishvili, L. Mekhuzla, I. Mdinaradze, G. Tevzadze, A. Aslanishvili, P. Chavchanidze, D. Lordkipanidze, M. Jalabadze,
E. Kvavadze, N. Rusishvili, E. Nadiradze , G. Archvadze, P. McGovern, P. This, R. Bacilieri, O. Failla, G. Cola, L. Mariani, N. Wales, M. T. Gilbert, L. Bouby, T. Kazeli, L. Ujmajuridze, S. Batiuk, A. Graham, L. Megrelidze, T. Bagratia and L. Davitashvili, Grape and wine culture in Georgia, the South Caucasus, in: BIO Web of Conferences 7, 03027; 39th World Congress of Vine and Wine, 2016.
[29] M. Mosulishvili, I. Maisaia, K. Batsatsashvili, (2511) Proposal to conserve the name Triticum palaeocolchicum against T. karamyschevii (Poaceae). Taxon. 66, 2: 519-521.
[30] M. Mosulishvili, D. Bedoshvili, T. Samadashvili, G. Chkhutiashvili and I. Maisaia, The ancient, traditional Georgian: diversity, conservation and endemic taxa a focus on health and nutrition, Abstract, Proceedings of the 1st International Workshop, Bologna, Italy, 2018.