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Embracing Change: Wheat and Wild Relatives Hybridization in Uzbekistan

Gafurov Gafur
International Agriculture University, Lecturer, Agriculture and Farming, Sustainable Development and Food Security, Agricultural Food Business and Marketing
g.gafurov@yahoo.com

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Annotation: Bread plays a vital role in food security and sustenance, especially in regions such as Central Asia, where wheat is the primary crop. In Uzbekistan, wheat is central to both food sovereignty and cultural traditions, with its production and consumption continuing to grow despite challenges such as climate change, water scarcity, and environmental degradation. However, wheat cultivation faces threats from pests, diseases, and climate change, necessitating innovations in breeding and genetic resources to ensure sustainable production. Wheat breeding in the country has progressively emphasized the use of local genetic resources, especially landraces and wild relatives, to boost resilience and productivity. These varieties, which have evolved to withstand the region's challenging conditions, offer crucial traits such as drought resistance, heat tolerance, and disease resistance – essential for adapting to climate fluctuations. Recent efforts to integrate these genetic resources into breeding programs have shown potential in improving both the quality and yield of wheat, thereby enhancing food security and nutritional sustainability. However, ensuring long-term food security in the region will still require effective land management and the responsible use of water resources.

Keywords: Wheat breeding, food sovereignty, climate change, water scarcity, genetic resources, agricultural sustainability.

1. INTRODUCTION

Bread is the head of everything. Ulian et al. (2020) point out that humankind has become dependent on three species, namely, rice, wheat, and maize, which has increased the vulnerability of food systems. Ibba. et al. (2022) reports that over 720 million people worldwide suffer from hunger, and more than three billion lack access to a healthy diet. Behnassi and El Haiba (2022) highlight that war between main grain exporters, Russia and Ukraine has led to increased input prices and global food security concerns. Steinbach (2023) points out that the global food trade, which is crucial for many nations, is experiencing disruptions due to changes in production centers and strain on supply chains. Nugroho et al. (2023) note that these disruptions have a disproportionate impact on vulnerable communities, especially in developing countries, due to their dependence on subsistence agriculture and limited ability to adapt. Zhang et al. (2022) argue that wheat production is essential for ensuring food availability. Ubilava (2017) emphasizes the critical importance of grain markets in Central Asia, where wheat is the most important source of protein, and efficient market operations are crucial for addressing food insecurity. Bobokhonov et al. (2017) observed that grain price relationships in Central Asia vary significantly, with some markets showing strong integration while others remain largely isolated. Morgounov et al. (2007) noted that wheat is grown across 15 million hectares in the region, producing around 22 million tons. In 2023, the FAO (2023) projected that the total regional cereal production would be around 32 million tonnes, almost an annual standard. Wheat production, representing approximately 70% of the overall cereal output was anticipated to be above average, at 22.4 million tonnes. Wheat, essentially, serves as a main determinant of sustenance and an important livestock provision basis in the area, with production, and, thus, self-sufficiency substantially varying between countries.

2. LITERATURE REVIEW

Uzbeks believe that bread is sacred and holds immense social, cultural as well as economic importance. Vavilov (1926) identified the country as the birthplace of wheat, while Tolstoy (1948) mentioned that Transoxiana has records of wheat cultivation dating back to Andronovo culture and Oxus civilization. Bernshtam (1951) notes the presence of numerous stone pit granaries, grain mills, and bronze sickles in the fertile northern and eastern regions of the Fergana valley. Andrianov (1969) reports that archaeological evidence suggest the presence of agricultural civilizations growing wheat along the banks of the Amudarya river. Hamilton and Falconer (1856) cite Strabo, ancient Greek geographer who describes Bactria as a fertile land that produced everything except oil. Haqberdiyeva (2022) references Mahmud Kashgari, an 11th-century linguist and turkologist, who in “Diwan Lughat al-Turk”, provided valuable information about 18 distinct bread types of bread and bread-making technology among the Turkic peoples. In contemporary Uzbekistan, bread plays a crucial role in fostering warm relationships, as per folk tradition, those who have tasted bread together become friends. There is nothing more dreadful than breaking the oath made over bread. The ritual of breaking bread is a significant beginning to any serious matter or meal, symbolizing unity and shared sustenance.

Yigezu et al. (2022) observe that wheat, second only to cotton in importance since independence, plays an essential part in food sovereignty and is politically sensitive. Reeves and Graeme (2016) report that Uzbekistan is the second-largest wheat producer in Central Asia, after Kazakhstan. Khalikulov et al. (2016) note that wheat consumption in Uzbekistan currently exceeds 200 kg per person annually. Babakholov et al. (2018) elaborate on the strategic significance of wheat in Uzbekistan, detailing the issuance of comprehensive plans and directives before planting, specifying the cultivars, planting locations, timing, methods, required inputs, and anticipated yields. Yigezu et al. (2022) document that between 1991 and 2019, the wheat-growing area in the country expanded from 0.63 million hectares to 1.31 million hectares, with 82% of it being irrigated. Over the same period, the mean yield reached 4.65 tons per hectare, resulting in a total production rise to 6.09 million tons. Khalikulov et al. (2016) note that despite significant growth in wheat production since independence, the country still imports approximately 20% of its grain. Over past five years, wheat imports have averaged 3.2 million tons, as per USDA (2021). USDA (2023) estimates wheat consumption at 8.5 million tons in 2022 – 2023, making Uzbekistan a major wheat consumer in Central Asia. However, domestic wheat production covers approximately 78% of this expected supply. Savin et al. (2022) emphasize the need for farmers to make calculated commitments during extreme climatic events, adjusting their methods based on anticipated levels of production and expenses. Leigh et al. (2022) stress the importance of increasing wheat production to address current challenges, which can be achieved by expanding the cultivated area or improving yield per unit area. Cooper et al. (2020) warn against compromising the cultivation of other crops and suggest focusing on wheat production in regions with higher potential for yields.

3. DISCUSSIONS

Zorya, Djanibekov, and Petrick (2019) explain that ineffective land management practices, particularly crop rotation with wheat following cotton, have led to diminished soil fertility and reduced cotton yields. Sutton et al. (2013) anticipate substantial declines in wheat yields by the 2050s, with spring wheat expected to decrease by 41%–57% and winter wheat by 31%–43%. Novikov and Kelly (2017) suggest that the increasing likelihood of dry periods in Uzbekistan may exacerbate desertification in the near future. Asilbekova et al. (2023) emphasize that Uzbekistan ranks 13th globally in terms of drought risk, with a dry and desiccated land area. Naumann et al. (2018) predict a significant rise in the duration and severity of dry periods in the country, considering both moderate and severe climate change scenarios. Currently, primary reason for landscape degradation is low productivity of agriculture, compounded by rising food demand. Orlov et al. (2021) suggest that in Central Asia, elevated carbon dioxide levels and warmer temperatures may lead to higher crop yields, but extreme events like extreme weather can be catastrophic. Vakulchuk et al. (2022) note that the country lacks the resources to effectively address the negative impacts of environmental destabilization. Kucherov et al. (2022) found that the majority of companies in Uzbekistan have not committed to carbon neutrality or zero emissions, as per a 2022 PwC survey. Furtak and Wolinska (2023) note that extreme weather events, which were once rare, are now more frequent, leading to substantial damage to crops and livestock. According to the European Commission (2019), the nation also contends with a significant wildfire hazard. Moreover, Bekchanov and Lamers (2016) emphasize the notable vulnerability of irrigated agriculture to anticipated water scarcity, posing a substantial threat to the sector.

Baboev et al. (2015) explain that bread wheat has adapted to regional harsh conditions over millennias. Kong et al. (2020) underscore the present risks posed by biotic factors, including pests, roundworms, fungal, viral, and bacterial diseases, as well as abiotic factors such as high temperature, shortage of water, cold, and brininess, to wheat production. Buronov et al. (2023) suggest that addressing organic and inorganic pressures is vital for improving wheat productivity in various settings. Amangeldikyzy et al. (2023) observe that while chemicals can protect crops and maintain productivity, their high costs and environmental impacts underscore the importance of developing disease-resistant cultivars that are both effective and environmentally friendly. Pironon and Soto Gomez (2021) propose that a seamless adaptation to future environmental conditions can be accomplished through a range of well-orchestrated initiatives that prioritize the symbiotic diversity within agriculture. Yang et al. (2023) advocate for microbiome management as a prudent approach for achieving balanced agricultural productivity whereas Tittonell et al. (2020) support biodiversity-based agriculture. Allaby et al. (2019) assert that providing breeders with an array of genetic resources is essential for optimizing crop improvement strategies. However, they note that domestication bottlenecks have limited the genetic diversity of modern breeding populations. Salgotra and Chauhan (2023) point to the importance of preserving plant congenital resources and making their omics data accessible to enhance crop varieties through molecular breeding, including genome editing. Trethowan and Mujeeb-Kazi (2008) note that crop wild relatives of wheat often show superior adaptation to challenging climatic conditions.

Engels and Thormann (2020) suggest that the domestication of wild ancestors is the origin of most crops. Tekin et al. (2022) emphasize that congeners are a valuable foundation for crop biodiversity that was lost during the industrialization of agriculture. Renzi et al. (2022) suggest that biorepository archives, which encompass underutilized crop varieties, are a valuable resource for developing novel varieties. Dwivedi et al. (2019) describe landraces as cultivars with a long history, usually exceeding 50 years, safeguarded by local communities, and appreciated for their ability to withstand environmental stresses. Bohra et al. (2021) underscore that a substantial fraction (80%) of characteristics passed on from crop wild relatives to cultivated crop varieties pertains to resistance against diseases and pests. Bohra et al. (2022) continues that incorporating crop wild varieties in breeding programs has led to substantial economic gains in agriculture worldwide, contributing an estimated US $186.3 billion annually to the global economy as of 2020. Salgotra and Chauhan (2023) stress the importance of landraces and wild relatives, highlighting their value in enhancing biodiversity and sustainability, which must be preserved. Saini et al. (2022) also point out the role of wild relatives in improving the balanced protein and nutrient content of durum wheat. Schouten et al. (2019) propose that incorporating wild species into breeding programs can aid in replenishing lost diversity from erosion and enriching the diversity of crops. According to Sall et al. (2018), these relatives also possess a wider range of genes related to stress tolerance.

4. CONCLUSIONS

Sharma et al. (2013) mention that for twenty years, seeds of wheat cultivars were mainly imported from Russia to Uzbekistan, covering significant areas of the country. However, these varieties were vulnerable to diseases and experienced reduced yields due to their late maturation. Hovmøller et al. (2017) emphasize the significance of managing stripe rust in Uzbekistan, with support from ICARDA, CIMMYT, BGRI, and FAO aiding regional wheat initiatives in comprehending disease distribution and variety of pathogens. Sapakhova et al. (2022) underscore the challenges in wheat productivity and grain quality in the country, largely due to the susceptibility of most bread wheat cultivars to stress factors. Ahmad et al. (2019) argue about the importance of selecting high-yielding, disease-resistant wheat varieties in wheat-producing nations such as Uzbekistan. They emphasize that using wheat genotypes with maximum variability is crucial for increasing yield. Baboev et al. (2021) highlight the notable potential of prehistoric wheat cultivars in Uzbekistan for breeding and enhancement, having adapted over centuries to local conditions, exhibiting traits such as drought resistance, heat and salt tolerance, winter hardiness, and sturdy, non-crumbling grains. The authors also report that 30 wild wheat varieties were gathered and studied during scientific expeditions in Tengri Tagh mountain ranges of Uzbekistan, underscoring the rich genetic diversity present in the region. Yigezu et al. (2022) observe that between 1942 and 2019, the national variety catalogue registered 184 wheat varieties, consisting of 167 bread and 17 durum types. Among these, 91 bread wheat varieties, including 14 rainfed, and 12 durum wheat varieties, were developed in the country, accounting for 50% of the total. Winfield et al. (2017) state that extensive landrace collections preserved within repositories of genetic materials have been analyzed through genomic techniques to harness advantageous traits in wheat breeding. Shewry (2018) states that wheat landraces have attracted significant interest in recent years due to the potential health benefits associated with their grains. FAO (2015) finds that landraces in the nation exhibit lower productivity than commercial cultivars. Despite this, they are more valuable for enhancing wheat quality, potentially creating new varieties that are nutritionally beneficial for human well-being. Therefore, Kline et al. (2020) recommend enhancing participatory breeding with local communities for a process that aligns with current scientific trends and economic needs. Turaev et al. (2023) emphasize that creating and introducing new wheat cultivars well-adapted to local farming systems will be vital in ensuring a stable and sufficient supply of wheat, a main staple food crop of Uzbekistan.

5. REFERENCES

1. Ahmad, H.M., Awan, S.I., Aziz, O., Ali, M.A. (2019) Multivariative Analysis of some Metric Traits in Bread Wheat (Triticum aestivum L.). Journal of Pharmacognosy and Phytochemistry, 8.
2. Allaby, R.G., Ware, R. L., Kistler, L. (2019). A re-evaluation of the domestication bottleneck from archaeogenomic evidence. Evol. Appl. 12 (1), 29–37.
3. Amangeldikyzy, Z., Galymbek, K., Gabdulov, M., Amangeldi, N., Irkitbay, A., Suleimanova, G., Sapakhova, Z. (2023). Identification of new sources of wheat stem rust resistance genes. Res. Crop. 24(1):15-27.
4. Andrianov, B.V. (1969). Ancient irrigation system Aral Sea area. Moscow (in Russian).
5. Asilbekova, K., Yarullina, Z., Plocen, M., Sherimbetov, K., Li, T., Talipov, J., Abdullayev, U., Makhmudov, B., Shokirov, N., Abdukhalikov, J., Tursunaliyev, A., Usmanova, S., Mirshina, O. (2023). National State of the Environment Report: Uzbekistan.
6. Babakholov, S., Kim, K.R., Lee, S.H. (2018). Agricultural transition and technical efficiency: an empirical analysis of wheat-cultivating farms in Samarkand Region, Uzbekistan.
7. Baboev, S., Morgounov, A. Muminjanov, H. (2015). Wheat Landraces in Farmers' Fields in Uzbekistan: National Survey, Collection, and Conservation. FAO, Ankara.
8. Baboev, S., Muminjanov, H., Turakulov, K., Buronov, A., Mamatkulov, I., Koc, E., Ozturk, I., Dreisigacker, S., Shepelev, S., Morgounov, A. (2021). Diversity and sustainability of wheat landraces grown in Uzbekistan. Agron. Sustain. Dev. 41, pp. 1–13, 34.
9. Behnassi, M., El Haiba, M. (2022). Implications of the Russia–Ukraine war for global food security. Nat. Human Behav.
10. Bekchanov, M., Lamers, J.P. (2016). Economic costs of reduced irrigation water availability in Uzbekistan (Central Asia). Regional environmental change, 16(8).
11. Bernshtam, A.N. (1951). Ancient Fergana. Tashkent (in Russian).
12. Bobokhonov, A., Pokrivcak, J., Rajcaniova, M. (2017). The impact of agricultural and trade policies on price transmission: The case of Tajikistan and Uzbekistan. The Journal of International Trade and Economic Development, 26, 677–692.
13. Bohra, A., Kilian, B., Sivasanka, S., Caccamo, M., Mba, C., McCouch, S.R., Varshney, R.K. (2021). Reap the crop wild relatives for breeding future crops. Trends Biotechnol.
14. Bohra, A., Kilian, B., Sivasankar, S., Caccamo, M., Mba, C., McCouch, S. R., et al. (2022). Reap the crop wild relatives for breeding future crops. Trends Biotechnol. 40 (4), 412–431.
15. Buronov, A., Amanov, B., Muminov, Kh., Tursunova, N., Umirova, L. (2023). Polymorphism and inheritance of gliadin proteins in wheat landraces of Uzbekistan. SABRAO J. Breed. Genet. 55(3): 671-680.
16. Cooper, M., Tang, T., Gho, C., Hart, T., Hammer, G., Messina, C. (2020). Integrating genetic gain and gap analysis to predict improvements in crop productivity. Crop Sci. 60: 582–604.

17. Dwivedi, S., Goldman, I., Ortiz, R. (2019). Pursuing the potential of heirloom cultivars to improve adaptation, nutritional, and culinary features of food crops. Agronomy, 9, 441.
18. Engels, J.M.M., Thormann, I., 2020. Main challenges and actions needed to improve conservation and sustainable use of our crop wild relatives. Plants 9, 968.
19. European Commission (2019). INFORM Index for Risk Management. Uzbekistan Country Profile.
20. FAO. (2015). Wheat Landraces in Farmers’ Fields in Uzbekistan: National Survey, Collection, and Conservation, by Baboev, S., Morgounov, A., Muminjanov, H. Ankara, Turkey.
21. FAO. (2023). Crop Prospects and Food Situation – Triannual Global Report No. 3, November 2023. Rome.
22. Furtak, K., Wolinska, A. (2023). The Impact of Extreme Weather Events as a Consequence of Climate Change on the Soil Moisture and on the Quality of the Soil Environment and Agriculture—A Review. CATENA, 231.
23. Hamilton, H.C., Falconer, W. (1856). The Geography of Strabo. Vol. 2. London: Bohn HG; p. 252-253.
24. Haqberdiyeva, F. (2022). The Importance and Some Rituals Relating To Bread in Uzbek Families. International Journal of Academic Multidisciplinary Research. Vol. 6 Issue 3, pp. 133-136.
25. Hovmøller, M.S., Rodriguez-Algaba, J., Thach, T., Justesen, A.F., Hansen, J.G. (2017). Report for Puccinia striiformis race analyses and molecular genotyping 2016. Global Rust Reference Center (GRRC), Aarhus University, Flakkebjerg, DK-4200 Slagelse, Denmark. pp. 7.
26. Ibba, M.I., Gupta, O.P., Govindan, V., Johnson, A.A.T., Brinch-Pedersen, H., Nikolic, M., et al. (2022). Editorial: Wheat biofortification to alleviate global malnutrition. Frontiers in Nutrition. 9.
27. Khalikulov, Z., Sharma, R.C., Amanov, A., Morgounov, A. (2016). The history of wheat breeding in Uzbekistan. In: Bonjean A, Angus W, van Ginkel M (eds) The World Wheat Book: A History of Wheat Breeding, vol 3. Lavoisier, Paris, pp. 249–282.
28. Kline, K. L., Ramirez, L. F., Sum, C., Lopez-Ridaura, S., & Dale, V. H. (2020). Enhance indigenous agricultural systems to reduce migration. Nature Sustainability, 3(2), 74–76.
29. Kong, L., Liu, Y., Wang, X., Chang, C. (2020). Insight into the role of epi13 genetic processes in abiotic and biotic stress response in wheat and barley. International Journal of Molecular Sciences. 21.
30. Leigh, F.J., Wright, T.I.C., Horsnell, R.A., Dyer, S., Bentley, A.R. (2022). Progenitor species hold untapped diversity for potential climate-responsive traits for use in wheat breeding and crop improvement. Heredity (Edinb). 128: 291–303.
31. Mirzabaev, A., Bezner Kerr, R., Hasegawa, T., Pradhan, P., Wreford, A., Cristina Tirado von der Pahlen, M., Gurney-Smith, H. (2023). Severe Climate Change Risks to Food Security and Nutrition. Clim. Risk Manag. 39.
32. Morgounov, A., Gómez-Becerra, H.F., Abugalieva, A., Dzhunusova, M., Yessimbekova, M., Muminjanov, H., Zelrnskiy, Y., Cakmak, I. (2007). Iron and zinc grain density in common wheat grown in Central Asia. Euphytica, 155, 193–203.

33. Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., Feyen, L. (2018). Global Changes in Drought Conditions Under Different Levels of Warming. Geophysical Research Letters, 45(7).
34. Novikov, V., Kelly, C. (2017). Climate Change and Security in Central Asia. Geneva: ENVSEC.
35. Nugroho, A.D., Prasada, I.Y., Lakner, Z. (2023). Comparing the Effect of Climate Change on Agricultural Competitiveness in Developing and Developed Countries. J. Clean. Prod., 406.
36. Nunes, L.J.R. (2023). The Rising Threat of Atmospheric CO2 : A Review on the Causes, Impacts, and Mitigation Strategies. Environments, 10, 66.
37. OpenAI. 2024. ChatGPT.
38. Orlov, A., Daloz, A.S., Sillmann, J. et. al. (2021) Global economic responses to heat stress impacts on worker productivity in crop production. Econ Dis Cli Change 5:367–390.
39. Pironon, S., & Soto Gomez, M. (2021). Plant agrodiversity to the rescue. Nature Climate Change, 11(1), 6–8.
40. Reeves, T.G., Graeme, T. (2016). Save and Grow in practice: Maize, rice, wheat.
41. Renzi, J. P., Coyne, C. J., Berger, J., Von Wettberg, E., Nelson, M., Ureta, S., et al. (2022). How could the use of crop wild relatives in breeding increase the adaptation of crops to marginal environments? Front. Plant Sci. 13.
42. Sall, A. T., Cisse, M., Gueye, H., Kabbaj, H., Ndoye, I., Filali-Maltouf, A., Belkadi, B., El-Mourid, M., Ortiz Rios, R., Bassi, F. M. (2018). Heat tolerance of durum wheat (Triticum durum desf.) elite germplasm tested along the Senegal River. Journal of Agricultural Science, 10.
43. Saini, P., Kaur, H., Tyagi, V., Saini, P., Ahmed, N., Dhaliwal, H.S., Sheikh, I. (2022). Nutritional value and end-use quality of durum wheat. Cereal Res Commun.
44. Salgotra, R.K., Chauhan, B.S. (2023). Genetic Diversity, Conservation, and Utilization of Plant Genetic Resources. Genes. 14:174.
45. Sapakhova, Z., Irkitbay, A., Madenova, A., Suleimanova, G. (2022). Mitigation effect of salicylic acid on wheat (Triticum aestivum L.) under drought stress. Res. Crop. 23: 267-275.
46. Savin, R., Cossani, C.M., Dahan, R., Ayad, J.Y, Albrizio, R., Todorovic, M., Karrou, M., Slafer, G.A. (2022). Intensifying cereal management in dryland Mediterranean agriculture: rainfed wheat and barley responses to nitrogen fertilisation. European Journal of Agronomy, 137.
47. Schouten, H. J., Tikunov, Y., Verkerke, W., Finkers, R., Bovy, A., Bai, Y., et al. (2019). Breeding has increased the diversity of cultivated tomato in the Netherlands. Front. Plant Sci. 10.
48. Sharma, R.C., Rajaram, S., Alikulov, S., Ziyaev, Z., Hazratkulova, S., Khodarahami, M., Nazeri, S.M., Belen, S., Khalikulov, Z., Mosaad, M., Kaya, Y., Keser, M., Eshonova, Z., Kokhmetova, A., Ahmedov, M.G., Jalal Kamali, M.R., Morgounov, A.I. (2013) Improved winter wheat genotypes for Central and West Asia. Euphytica 190(1):19–31.
49. Shewry, P.R. (2018).Do ancient types of wheat have health benefits compared with modern bread wheat? J Cereal Sci 79:469-476.
50. Steinbach, S. (2023). The Russia–Ukraine War and Global Trade Reallocations. Econ. Lett.

51. Sutton, W.R., Srivastava, J.P., and Neumann, J.E. (2013). Looking Beyond the Horizon: How Climate Change Impacts and Adaptation Responses Will Reshape Agriculture in Eastern Europe and Central Asia. Washington, DC: World Bank.
52. Tekin, M., Emiralioğlu, O., Yeken, M.Z, Nadeem, M.A, Çiftçi, V., Baloch, F.S. (2022). Wild Relatives and their Contributions to Wheat Breeding. Ancient Wheats. 14: 197–233.
53. Tittonell, P., Piñeiro, G., Garibaldi, L.A., Dogliotti, S., Olff, H., Jobbagy, E.G. (2020). Agroecology in large scale farming—A research agenda. Front. Sustain. Food Syst. 4.
54. Tolstoy, S.P. (1948). Ancient Khorezm. Moscow State University: Moscow, Russia, p. 269. (In Russian)
55. Trethowan, R. M., Mujeeb-Kazi (2008). Novel germplasm resources for improving environmental stress tolerance of hexaploid wheat. Crop Science, 48.
56. Turaev, O.S., Baxadirov, U.S., Norbekov, J.K., Erjigitov, D.S., Dolimov, A.A., Tursunmurodova, B.T., Ziyayev, Z.M., Kushanov, F.N. (2023). Application of DNA marker technology in bread wheat (Triticum aestivum L.) research in Uzbekistan. Acad. Research Edu. Sci. 4(2), 175-185, (In Uzbek).
57. Ubilava, D. (2017). The ENSO effect and asymmetries in wheat price dynamics. World Development, 96, 490–502.
58. Ulian, T., Diazgranados, M., Pironon, S., Padulosi, S., Liu, U., Davies, L., Howes, M. R., Borrell, J. S., Ondo, I., Pérez-Escobar, O. A., Sharrock, S., Ryan, P., Hunter, D., Lee, M. A., Barstow, C., Łuczaj, Ł., Pieroni, A., Cámara-Leret, R., Noorani, A., Mattana, E. (2020). Unlocking plant resources to support food security and promote sustainable agriculture. Plants, People, Planet, 2(5), 421–445.
59. USDA. (2021). Grain: World Markets and Trade. USDA Foreign Agricultural Service.
60. USDA. (2023). Grain: World Markets and Trade. USDA Foreign Agricultural Service.
61. Vakulchuk, R., Isataeva, A., Kolodzinskaia, G., Overland, I., Sabyrbekov, R. (2022) Fossil fuels in Central Asia: trends and energy transition risks. Cent Asia Reg Data Rev 28:1–6.
62. Vavilov, N.L. (1926). Studies on the Origin of Cultivated Plants; Institute of Applied Botany and Plant Breeding: Leningrad, Russia, p. 78.
63. Winfield, M. O., Allen, A. M., Wilkinson, P. A., Burridge, A. J., Barker, G. L. A., Coghill, J., Waterfall, C., Wingen, L. U., Griffiths, S., Edwards, K. J. (2017). High density genotyping of the A.E. Watkins Collection of hexaploid landraces identifies a large molecular diversity compared to elite bread wheat. Plant Biotechnology Journal, 16, 165–175.
64. Yang, S., Liu, H., Xie, P., Wen, T., Shen, Q., Yuan, J. (2023). Emerging pathways for engineering the rhizosphere microbiome for optimal plant health. J. Agric. Food Chem. 71.
65. Yigezu, A.Y., Bishaw, Z., Niane, A.A., Nurbekov, A. (2022). Political Economy of the Wheat Sector in Uzbekistan: Seed Systems, Variety Adoption, and Impacts.
66. Zhang, T., van der Wiel, K., Wei, T., Screen, J., Yue, X., Zheng, B. et al. (2022). Increased wheat price spikes and larger economic inequality with 2 ^{0}C global warming. One Earth. 5: 907–916.
67. Zorya, Sergiy, Nodir Djanibekov, and Martin Petrick. (2019). Farm Restructuring in Uzbekistan: How did it go and what is next? -:World Bank.