Response to comments of Anonymous Referee #2

General comments

Millet agriculture were initially domesticated in northern China and played an important role in early agriculture evolution and the formation of the Chinese civilization. The manuscript reports a dataset of archaeobotanical macroremains spanning the Neolithic and Bronze Ages in northern China. Authors also suggest a significant spatiotemporal divergence of millet agriculture, discuss the past human-environment interaction, and provide a valuable perspective of agricultural sustainability for the future. This manuscript meets the scope of Earth System Science Data and could arise a wide audience as well. I would like to suggest a publication after a moderate revision.

Response: Thanks for the helpful comment. Our point-by-point responses are provided below.

Specific comments

1. In Introduction Part and Fig. 1. I suggest that authors check the names of different regions in North China, which belong to geographical division or archaeological culture division. For example, many archaeological sites distribute in Loess Plateau and are not in Guanzhong basin. Yanbei region is not clear.

Response: The reference for the names of different regions has been revised, and a brief introduction to the geographical and archaeological division of the six subregions has been added in Lines 73–79. Archaeological sites distributed on the Chinese Loess Plateau were divided into the Yanbei region in the north and Guanzhong region in the south by bondary of 37°N.

Lines 73–79

The Liaoxi region is situated in the west of Liaoning Province and southeast of Inner Mongolia Autonomous Region; to the west, the Yanbei region is situated in the central-south of Inner Mongolia Autonomous Region and north of Shaanxi, Shanxi, and Hebei Provinces, northern parts of Chinese Loess Plateau; in the westmost, the Ganqing region is situated in the northeast of Qinghai Province and central-south of Gansu Province. The Guanzhong region is located in the southeast of Gansu Province and south of Shaanxi Province, which is merged into the Central Plains in some studies; to the east, the Central Plains is located in the south of Shanxi Province, and the bulk of Henan Province; the Haidai region is mainly located in the Shandong Province.

References

Yan, W. M.: Cradle of Oriental Civilization. In: The origins of agriculture and rise of civilization, Yan, W. M. (Ed.), Science Press, Beijing, 2000.

2. A reference (Zhou et al., 2011) need to be cited which has discussed the significant divergence of millet west Loess Plateau around 5500 BP.

Response: A new reference (Zhou et al., 2011) has been added in Line 40.

References

Zhou, X. Y., Li, X. Q., Zhao, K. L., Dodson, J., Sun, N., and Yang, Q.: Early agricultural development and environmental effects in the Neolithic Longdong basin (eastern Gansu), Chinese Sci. Bull., 56, 762, https://doi.org/10.1007/s11434-010-4286-x, 2011.

3. In Discuss Part.

Line 170-175

The description on "The spread of millet intensified from the late Yangshao to Longshan periods in two directions (Figures 5C–D and H–I): westward routine to the Ganqing region and northward routine to the Yanbei region" and Fig. 5 need more evidences and the references to support

Response: More evidence of routes and dates in the two directions had been added in Lines 188–192, and new references supporting the spread of millet agriculture had also been added.

Lines 188–192

The discontinuous agricultural region linked together at stage II and expanded to marginal areas without solid evidence of agriculture prior to 6000 cal BP. The spread of millet intensified from the late Yangshao to Longshan periods in two directions (Figures 5C–D and H–I): westward routine to the Ganqing region along the Wei River and Hexi corridor around 5400 cal BP (Leipe et al., 2019); and northward routine to the Yanbei region along the middle Yellow River around 5200 cal BP (Bao et al., 2018).

References

Bao, Y. G., Zhou, X. Y., Liu, H. B., Hu, S. M., Zhao, K. L., Atahan, P., Dodson, J., and Li, X. Q.: Evolution of prehistoric dryland agriculture in the arid and semi-arid transition zone in northern China, PLoS One, 13, e0198750, https://doi.org/10.1371/journal.pone.0198750, 2018.

Leipe, C., Long, T. W., Sergusheva, E. A., Wagner, M., and Tarasov, P. E.: Discontinuous spread of millet agriculture in eastern Asia and prehistoric population dynamics, Sci. Adv., 5, eaax6225, https://doi.org/10.1126/sciadv.aax6225, 2019.

4. Line 195-210

The discussion on the possible biases of archaeobotanical macroremains and the reason of divergence of the foxtail and broomcorn millet need to add some information on the different ecological habits and the way of seed yield from the foxtail and broomcorn millet. I think that the discussion of phytolith and Fig. 6 are not necessary, which can't support the changes and divergence of the foxtail and broomcorn millet during the Neolithic.

Response: Different ecological habits and the seed yield of foxtail and broomcorn millets have been added in Lines 227–234. Though discussion of phytolith (Fig. 6) didn't support the transition from broomcorn to foxtail millet, it could also provide a valuable perspective for comparison to that of charred seeds.

Lines 227–234

Furthermore, the way of seed yield may also affect the biases between foxtail and broomcorn millet. Morphological data from the northern Chinese Loess Plateau showed that the size of broomcorn millet increased significantly during 5500–4000 cal BP, while that of foxtail millet didn't exhibit an obvious increasing trend (Bao et al., 2018). Given the contemporaneous increasing human population, the crop yield was supposed to increase to feed a large population. Nevertheless, the increasing yields of broomcorn millet may depend on the increase in the seed size, while that of foxtail millet may result from the increase in the number of seeds per plant. Thus, the different ways of seed yield may also be one cause of the increase in the proportion of foxtail millet within the total seed number of seeds. In brief, both biases in the carbonization process and the way of seed yield may have exaggerated the proportion of foxtail millet.

5. Line 259-269

The manuring enhanced the crop yields and provide the possible reasons that human adapt the environmental changes and can't well understand the divergence of the foxtail and broomcorn millet around 6000 BP. Authors need to more discussions on the driving factors.

Response: More discussions about the relationship between field manuring practices and different crop yields have been added in Lines 297–301. Given the yield of foxtail millet was typically twice that of broomcorn millet, the ancient human may choose to cultivate more foxtail millet to maximize crop yield on the condition of enough fertilizer.

Lines 297–301

Besides, a recent study in the Dadiwan site also suggested an intensive crop–livestock system was in practice around 5500 cal BP (Yang et al., 2022). Considering the yield of foxtail millet was typically twice that of broomcorn millet, the dramatic increase in soil fertilization may promote the conscious choice of high-yield foxtail millets to maximize agricultural productivity.

References

Yang, J. S., Zhang, D. J., Yang, X. Y., Wang, W. W., Perry, L., Fuller, D. Q., Li, H. M., Wang, J., Ren, L. L., Xia, H., Shen, X. K., Wang, H., Yang, Y. S., Yao, J. T., Gao, Y., and Chen, F. H.: Sustainable intensification of millet–pig agriculture in Neolithic North China, Nat. Sustain. https://doi.org/10.1038/s41893-022-00905-9, 2022.