LETTER

Reply to Rieseberg and Burke, Heiser, Brown, and Smith: Molecular, linguistic, and archaeological evidence for domesticated sunflower in pre-Columbian Mesoamerica

In response to Rieseberg and Burke's comment (1), we have no objection to the assessment that eastern North American landraces and modern cultivars are most closely related to wild populations of *Helianthus annuus* L. in the central Mississippi Valley region. We are familiar with both of the relevant molecular studies because we (D.L.L. and R.B.) collaborated on the first of those studies (2) and provided the wild sunflower germplasm from Mexico. The two Mexican domesticated samples used in the study, also used in the Wills and Burke study (3), were originally purchased in Jalisco markets. At least one of those samples, *maiz negro*, is believed to have been hybridized with modern varieties (4), and the *maiz de teja* specimens may have been genetically contaminated as well. During our field work in Mexico we visited hundreds of marketplaces from Chiapas to Chihuahua and encountered only commercially produced sunflower seeds. We wish to promote molecular studies that will adequately address questions relating to independent sunflower domestication in Mexico. The use of two samples purchased in marketplaces, as occured in the previous molecular studies, provides an inadequate test of the Mexican sunflower domestication hypothesis. This hypothesis will be tested most effectively by collecting sunflower germplasm directly from indigenous people in Mexico and running the same experiments with well provenienced and thoroughly documented material.

The main point about Heiser's work (4–6) is that he rejects the idea of domesticated sunflower in Mexico prior to the arrival of the Spaniards. We respond to his most salient points. Among the Nahuatl speakers of Puebla, we recorded two names for sunflower, "chimalacatl" and "chimalxochitl" (sometimes transcribed as "chimalsuchitl"). These words mean "shield reed" and "shield flower," respectively. They are derived from the Aztec word "chimalli," or "shield," referring to the ancient Aztec armament that became obsolete soon after the Spanish conquest (Terry Kaufman, personal communication). Although we did not encounter the word "chimalacaxochitl" among our informants, it is undoubtedly a word related to the other two and seems to refer only to the floral portion of the plant.

In essence, three 16th-century Spanish observers, Hernández (7), Sahagún (8), and Molina (9), documented the Aztec use of domesticated sunflower in central Mexico and recorded the same sunflower terms we encountered in modern Nahua villages. We acknowledge that the illustrations in Hernández are similar to those in other herbals and that not all of the illustrations of Hernández are original, probably because of the loss of his original manuscript in the Escorial fire and because of a tendency of printers at the time to "share" blocks of illustrations. Nevertheless, we would argue, for reasons stated in our article (10), that Hernández's information is still fundamentally useful.

The second chronicler, Sahagún, provided descriptions and illustrations of a variety of rituals involving the use of what Dibble and Anderson, English translators of the Sahagún volume, stated was likely to have been *Helianthus annuus* L. (8). We disagree with Heiser's assessment that the drawings in the Florentine Codex do not resemble domesticated sunflower. Although it is true that the drawings are stylistic, this phenomenon can be attributed to the fact they were drawn by Aztec artists who had a non-Western world view and craft tradition. In figure 30 of ref. 8 the floral portion of the drawing clearly resembles a composite, or member of the Asteraceae family. The man in the image holds a stout peduncle attached to a large receptacle or floral base. The portion of the head with disc flowers is surrounded by the area of ray, or ligulate, flowers. Significantly, the size of the disc area is approximately double the size of the man's fist. There are no Asteraceae flowers in this part of the world, other than domesticated *H. annuus*, that have a discoidal area that large. Finally, the flower in question is labeled in the text with the Nahuatl name for sunflower, "chimalsuchitl."

Brown (11) has overlooked the archaeological data that demonstrate Mesoamericans were using domesticated sunflower in pre-Columbian times. If he is correct in his assertion that there were no words for sunflower "in any ancestral language spoken after 2000 B.P.," then the people who were cultivating sunflower lacked a name for their cultigen. This scenario is highly unlikely. During our study we solicited the advice of numerous linguists and indigenous informants (10). Particularly persuasive were the linguistic data from our Nahua informants. In addition, we found the Otomi evidence to be compelling. Their word for sunflower, "dä nukhä," which means "flower of the sun god," represents another reference to pre-Columbian religious practice. What is fascinating about this term is the way it connects to anthropologist James Dow's description (12) of the modern Otomi's extensive use of sunflowers in their churches and religious ceremonies.

Smith's letter (13) contains a number of statements with which we disagree. First, if the Santa Leticia achene is indeed *H. annuus*, it must have been from a cultivated plant, as Miksicek suggests (14), because El Salvador is well outside the range of wild sunflower (15). Second, the statement that domesticated sunflower appears in eastern North America (ENA) by 2800 B.C. has not been substantiated for reasons discussed elsewhere (16). The earliest solid evidence for domesticated sunflower in ENA appeared ≈1200 cal B.C. at Marble Bluff (17), long after the fully domesticated sunflower evidence at San Andrés in Mexico (18). Third, the images and descriptions of the San Andrés disseminules (see ref. 10) were scrutinized by PNAS reviewers, and the data, once again, were found to be convincing. The San Andrés finds,

although the sample size is small, are important because they represent the earliest fully domesticated sunflower, dating to 2875–2482 cal B.C. The Cueva del Gallo sunflower data reinforce the earlier information from Tabasco and document beyond any reasonable doubt that sunflower was a pre-Columbian domesticate in Mesoamerica.

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