The Curious Case of "PI 194895"

Sepehr M. Naraghi, Wei Zhang, and Michael McMullen

Contacts: Michael.Mcmullen@ndsu.edu; sepehr.mohajerinarag@ndsu.edu

Introduction

PI 194895 is an oat line listed in the National Plant Germplasm System (NPGS; https://npgsweb.ars-grin.gov/gringlobal/search), and has one of the highest groat β-glucan concentrations (8.41%) and groat protein concentrations (24.0%) of any line in the collection. PI 194895 is designated *Avena sativa* in the NPGS, but recent morphological and cytogenetic evidence suggests that PI 194895 should be classified as the tetraploid oat *A. barbata* ssp. *abyssinica*.

Oats (*Avena sativa* L.) are recognized as one of the healthiest crops for human consumption. One of the most valuable nutritional compounds of oats is β-glucan, a soluble dietary fiber. Many studies have demonstrated the benefits of β-glucan to human health, such as reduction in cardiovascular disease risk, moderating glucose metabolism for type-2 diabetes, lowering low-density lipoprotein cholesterol level, and reducing blood pressure (FDA 1997; Meydani 2009; Grundy et al., 2018).

Because of the nutritional benefit of β-glucan for functional and healthy food products, one of the major goals of oat breeding programs is developing varieties with high β-glucan content. To increase β-glucan diversity in breeding populations, PI 194895 was used as a parent in crosses with *A. sativa* lines. A few F_1 plants were obtained when PI 194895 was used as a pollen parent. All attempts to cross PI 194895 with our breeding lines when used as a female were not successful. F_1 hybrids were highly sterile and produced only a few seeds. Over the course of several generations of selfing, fertility was partially to mostly recovered in the derivatives from these crosses. The breeding behavior and sterility of the derivative lines suggested that PI 194895 is not *A. sativa*.

Does PI 194895 belong to *Avena sativa* L.?

Difficulties in crossing PI 194895 with our breeding lines suggest that it belongs to another species in the genus *Avena*. To test this, we used Ladizinsky's key to the *Avena* species (Ladizinsky, 2012). Ladizinsky's key is based on chromosome numbers, morphological characteristics, place of origin, and ecological preferences of the oat materials.

Chromosome Numbers

Based on the number of chromosomes, oat species can be classified into three ploidy groups: diploids (2n=2x=14), tetraploids (2n=4x=28), and hexaploids (2n=6x=42). We observed the number of mitotic metaphase chromosomes in root-tips of PI 194895 and found 2n=28 (Figure 1). Therefore, PI 194895 is a tetraploid oat and does not belong to *Avena sativa* L. (2n=6x=42), which is a hexaploid species.

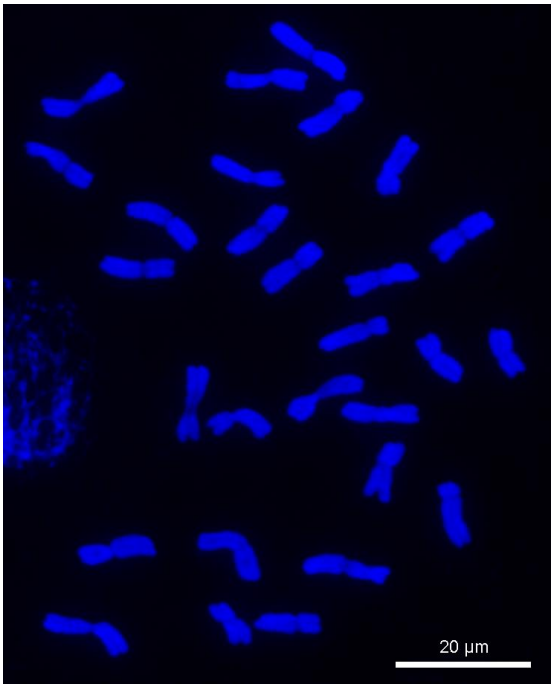

Figure 1. Mitotic metaphase chromosomes of PI 194895, a tetraploid oat (2n=4x=28).

Morphological Characteristics

Of all the oat morphological characteristics, spikelet characteristics are mainly used as diagnostic characteristics for species classification (Ladizinsky, 2012).

The spikelet characteristics of PI 194895 are as follows (Figure 2.A):

- Number of florets per spikelet are two (Figure 2.B).
- Glumes, lower and upper, are almost equal (Figure 2.B).
- Florets are separating by disarticulation of the second rachilla segment (Figure 2.C).
- Similar to cultivated oats, PI 194895 has a tough rachilla and it is characterized by seed nonshattering characteristics (Figure 2.C).
- Lemmas are coriaceous, white in color, and glabrous (Figure 2.A, B, C).
- Lemma tips have aristulate structure (Figure 2.C).
- Awn is inserted at a point two-thirds up the first lemma (Figure 2.D).
- Awn is only present on the first lemma (Figure 2.D).
- Second rachilla segment is slender, cylindrical, and hairy (Figure 2.E).
- The size of the disarticulation scar is short and callus at the bottom of the dispersal unit is more elliptical (Figure 2.D and E).

The Place of Origin

According to the Germplasm Resources Information Network (GRIN) Global database, seeds of PI 194895 were originally collected from Oromīya, Ethiopia, in 1950 by W. A. Archer, an agricultural explorer from the Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, MD, USA.

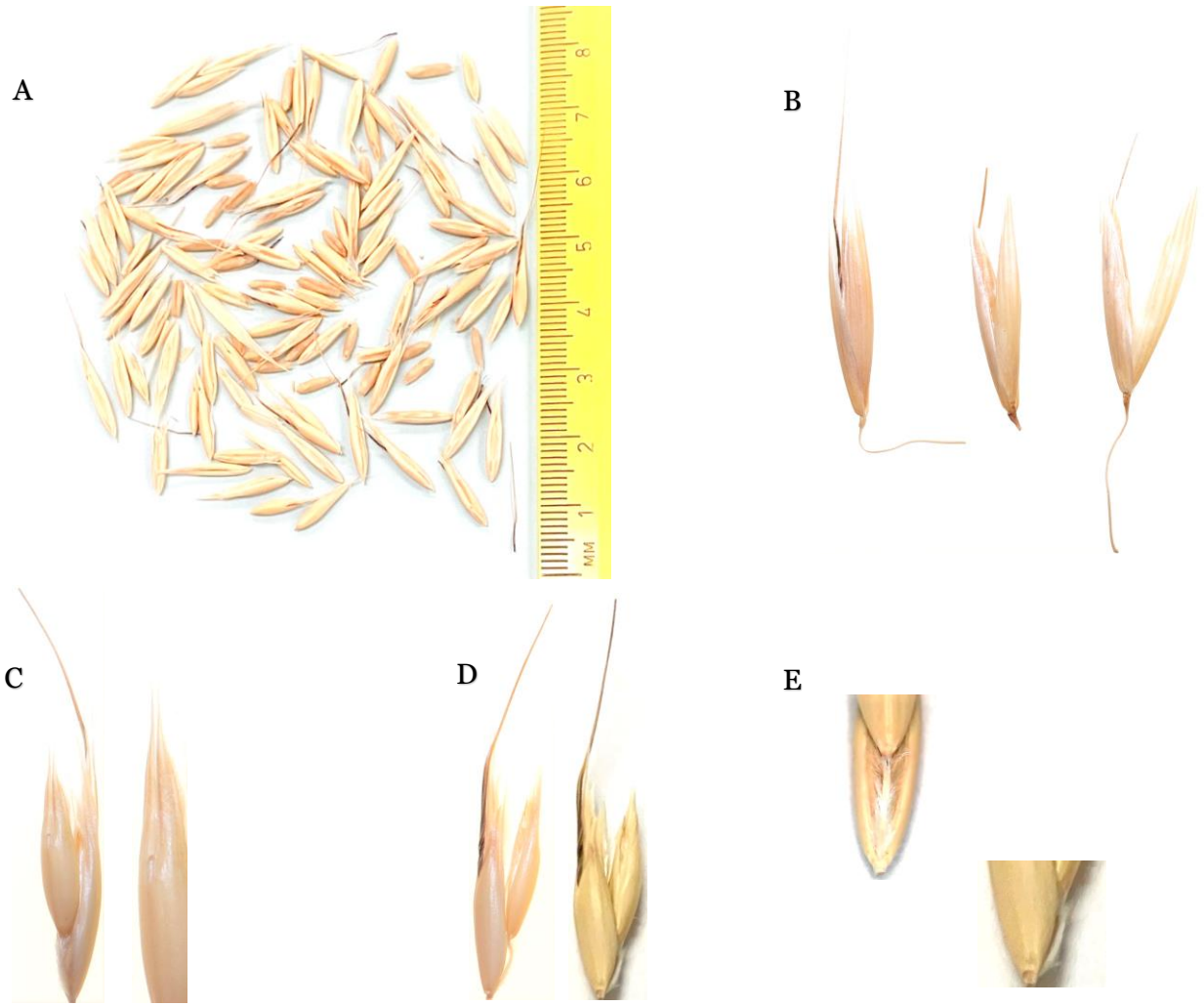

Figure 2. Spikelet and seeds of PI 194895. (A) spikelet and floret characteristics. (B) glume shape. (C) rachilla and lemma characteristics. (D) awn insertion into the lemma. (E) second rachilla and disarticulation scar characteristics.

Stanton and Drosey (1927) and Ladizinsky (1975 and 2012) reported that Ethiopian farmers never grow any oat species purposefully as a crop. However, oats can be found as contaminants or tolerated as weeds in barley or wheat fields. Of all the oat species, apparently only *A. barbata* grew continuously in Ethiopia for many years. However, *A. sterilis* can now be found in Ethiopia because of contaminants in wheat seeds imported over the last few decades (Ladizinsky, 2012).

Ecological Preferences

A. barbata, like other grain crops in Ethiopia, originated in the Middle East. *A. barbata* is grown at 6,500 to 10,000 feet above sea level where, ecologically, the temperature is favorable and, so far, it is not adapted to other ecological niches in Ethiopia (Ladizinsky, 2012).

PI 194895, a Tetraploid Oat, *Avena barbata* ssp. *abyssinica*

PI 194895 is labeled as *A. sativa* in the GRIN-Global database. Cytogenetic and morphological evidence suggests that PI 194895 is *A. barbata* ssp. *abyssinica* (which is also called *A. abyssinica* Hochst.) because of the 28 chromosomes, its spikelet characteristics (such as glabrous and white color lemma, spikelet separating from pedicel by facture, and hairy second rachilla segment), and Ethiopia being its place of origin.

PI 194895 seeds seem to be a form of *A. barbata* ssp. *abyssinica* cultivated with barley in Ethiopia. It is practically impossible to separate ssp. *abyssinica* seeds from barley spp. seeds because of the threshing methods used by farmers in Ethiopia, the non-shattering characteristic of ssp. *abyssinica* when its spikelet is mature, and the similar shape, size, and weight of barley spp. and ssp. *abyssinica* seeds. Weeding can only be done after emergence of the panicle in ssp. *abyssinica* (and preferably not in dry years) to avoid reducing the yield of the barley.

We now have enough seed to evaluate the derivative lines from PI 194895 for grain β-glucan and protein content. Therefore, it is our hope that the lines derived from this potential new germplasm source will provide necessary diversity for improving β-glucan and protein content in oat breeding programs.

References

FDA. (1997). Food labeling, health claims: Soluble dietary fiber from certain foods and coronary heart disease. Federal Register, 62, 3584–3601.

Grundy, M. M. L., Fardet, A., Tosh, S. M., Rich, G. T., & Wilde, P. J. (2018). Processing of oat: the impact on oat's cholesterol lowering effect. Food & Function, 9(3), 1328-1343. doi:10.1039/c7fo02006f

Ladizinsky, G. (1975). Oats in Ethiopia. Economic Botany, 29(3), 238–241. http://www.jstor.org/stable/4253612

Ladizinsky, G. (2012). Studies in oat evolution: A man's life with Avena. In Oat morphology and taxonomy: The biological species of Avena and their main sub species. Springer Science & Business Media.

Meydani, M. (2009). Potential health benefits of avenanthramides of oats. Nutrition Reviews, 67(12), 731-735. doi:10.1111/j.1753-4887.2009.00256.x

Stanton, R. and Dorsey, E. (1927). Morphological and cytological studies of an oat from Ethiopia. Amer. Soc. Agron. Journ. 19:804-818.