Organic wheat: Lessons learned and challenges remaining

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Abstract
Wheat has been an important part of the human diet for millennia. The increase in demand for wheat grown organically in the United States and globally reflects the growing interest in organic food and food products. A symposium on organic wheat production was held during the annual meeting of the American Society of Agronomy in Baltimore, MD, during 2021. Presenters discussed the state-of-the-science on organic wheat research. Papers were solicited following the symposium for inclusion in this special section. As a result, five papers are included in this special section: four focus on organic wheat research in North America while one discusses results of a European study.

> "We did not domesticate wheat. It domesticated us."
>
> From Sapiens: A Brief History of Humankind
> by Yuval Noah Harari

Wheat (*Triticum* spp.) has been a staple in the human diet from before recorded history. Archeological evidence suggests that wheat and barley (*Hordeum vulgare* L.) were an important part of the diet of the earliest farmers in the Near East somewhere between 9000 and 7000 BC (Bell, 1987). Einkorn (*Triticum monococcum* L.) and emmer (*Triticum turgidum* L.) were grown by these agriculturalists rather than common hexaploid wheat (*Triticum aestivum* L. emend. Thell.) that was developed later. Wheat is the most widely grown crop globally, cultivated on more than 240 million ha in 2022 (FAO, 2024). The United States is a major exporter of wheat, along with Argentina, Australia, the European Union, Kazakhstan, Russia, and Ukraine (Sowell, 2024). However, US wheat production and exports have been in long-term decline because of growth in competition from overseas suppliers, resulting in farmers abandoning wheat for other crops that can be grown more profitably (Sowell, 2024).

Though total wheat production has trended downward in the United States, the opposite has occurred for wheat grown organically. For example, US production of organic wheat totaled 260,821 MT on 110,629 ha in 2011 (USDA NASS, 2012). By 2021, those numbers had increased to total production of 340,128 MT grown on 152,441 ha (USDA NASS, 2022). The premium paid for wheat grown organically ranged from ∼125% to almost 300% higher than the price paid for nonorganic wheat grown in the United States between 2011 and 2016 (Reaves et al., 2019). As a result, net marginal returns were almost 80% higher when growing wheat organically than conventionally in 2016.

The United States is the largest market for organic food and drink products in the world. Nearly 45% of total global sales for organic food and drink products occurred in the United States in 2022 (Trávníček et al., 2024). Demand for food and nonfood items grown organically increased from USD 31 billion in 2013 to USD 62 billion in 2022 (McNeil, 2024). This includes around 300,000 metric tons of cereal grains that were imported into the United States in 2022 (Willer et al., 2024).

In particular, imports of organic durum wheat (*T. turgidum* spp. *durum* L.) increased substantially (Koory et al., 2022).

The growth in organic farming, food, and food products in the latter half of the 20th century spurred the establishment of new research on organic production methods (Lockeretz et al., 1980). By the early 2000s, papers presenting results of organic farming research were published routinely in the *Agronomy Journal* (e.g., Andrews et al., 2002; Corbin et al., 2010; Delate & Cambardella, 2004; Teasdale et al., 2007). Organic farming researchers were gathering regularly to share experiences and brainstorm about possible collaborative projects during the annual meeting of the American Society of Agronomy (ASA). In 2005, the Committee on Organic and Sustainable Agriculture (COSA) was established formally within ASA to give members a forum for exchanging ideas and networking (Sara Uttech, ASA, personal communication, July 7, 2024). A summary of the activity of COSA within ASA was provided by Heckman et al. (2013) at the 2013 annual meeting of ASA. COSA encouraged members to become more involved in society leadership.

Society members within the Integrated Agricultural Systems section (A8) formally petitioned ASA leadership for inclusion of organic farming within the organizational structure in 2008. This led to the establishment of the Organic Management Systems division (A12) within ASA in 2009. One outcome from the formation of this division was representation on the ASA Board of Directors, where policy and direction of the society were established. Kathleen Delate of Iowa State University was the Organic Management Systems division board representative in 2009.

The Organic Management Systems division was replaced with the Organic Management Systems Community (A012.2) when ASA was reorganized in 2010, and divisions were replaced with sections and communities. This community is very active and contained 2904 members in 2024 (Sarah Paese, ASA, personal communication, July 3, 2024). Community activities have included sponsorship of a symposium at the annual meeting of ASA each year. These symposia covered a variety of topics through 2021 but never focused on organic wheat production. With that in mind, a symposium entitled *Organic Wheat Systems: Lessons Learned and Challenges Remaining* was held during the 2022 ASA annual meeting in Baltimore, MD. Speakers discussed the results of organic wheat research across the United States, highlighting successes and identifying obstacles to successful production of organic wheat. Following the meeting, symposium speakers were invited to submit papers to the *Agronomy Journal*. Invitations also were extended to a select number of scientists with long histories of organic wheat research. The five papers published in this section are the result of this solicitation.

Core Ideas

- Demand is increasing for wheat grown organically.
- A need exists for research to solve problems encountered by organic wheat growers.
- Results of research discussed in five papers can be used to guide future research on organic wheat production.

Burke et al. (In press) identified weed management as a major challenge when growing wheat organically in the US Pacific Northwest, a region with a strong and growing demand for organic food products. These researchers noted that perennial weeds including Canada or creeping thistle [*Cirsium arvense* (L.) Scop.] and field bindweed (*Convolvulus arvensis* L.) pose a particular threat when growing organic wheat, though annual species including cheatgrass (*Bromus tectorum* L.) and wild oat (*Avena fatua* L.) can also be serious weed pests. They suggested that barley and particularly alfalfa (*Medicago sativa* L.) enhanced suppression of field bindweed when incorporated into wheat-based rotations, while alfalfa and winter triticale (×*Triticosecale* Wittmack) improved creeping thistle control, noting that triticale and alfalfa were not widely grown because of limited marketing options in the region. A few cultural (e.g., crop seeding density) and mechanical (e.g., interrow cultivation) practices that can impact weed pressure were discussed, and then attention was given to emerging technologies like optical sensor systems that can be used to direct precision application of herbicides approved for use in organic systems.

Larson et al. (In press) investigated the impact of incorporating forages, grazing, and tillage reductions on creeping thistle control in organic wheat-based systems in the US Great Plains. These authors found that three years of alfalfa suppressed creeping thistle when incorporated into a 4-year sequence with wheat, which was in agreement with Burke et al. (In press). Larson et al. (In press) also identified extensive fallow (two consecutive years), during which cultivation was used to control creeping thistle, as an effective strategy for reducing creeping thistle density and biomass, though tillage seemed to hasten thistle invasion into new areas. Moreover, the authors questioned use of extensive tilled fallow for creeping thistle control because of soil health concerns. In contrast, 3-year sequences of various annual crop species were not effective in reducing creeping thistle density or biomass in a fourth-year wheat crop. Larson et al. (In press) concluded that preceding wheat with alfalfa is effective in suppressing creeping thistle in the wheat phase but may result in low wheat yields if adequate time is not provided for soil-water recharge.

Idowe et al. (In press) summarized the results of a Utah-based study investigating the impacts of infrequent applications of composted dairy manure + straw bedding on organic winter wheat performance and soil health. These researchers reported that grain yield remained elevated almost three decades after 50 Mg ha^{-1} of compost was applied. Plant-available P, acid phosphatase activity, and total soil N also were higher in composted plots, as was soil organic C and dehydrogenase enzyme activity. The authors speculated that improvements in soil health resulting from a single compost application may improve the resilience of organic wheat-based farming in regions that are becoming drier because of climate change.

Stedden et al. (2024) discussed the opportunities and challenges of growing wheat and other small-grain crops organically in US Midwest and Northeast regions. In these two regions, maize (*Zea mays* L.) and soybean (*Glycine max* L.) are the dominant organic field crops grown. They pointed out that incorporating small grains into maize/soybean-based cropping systems diversifies crop rotations, creating in-season weed control and cover crop benefits. Growing wheat and other small-grain crops provide access to new markets including a burgeoning local food market in the US Northeast. Better distribution of labor can result when small grains are incorporated into maize/soybean cropping systems since the latter two crops' planting and harvest windows occur at different times. Stedden et al. (2024) also identified challenges when growing small-grain crops in the US Midwest and Northeast, including a lack of storage and processing infrastructure that supports expansion of wheat and other small-grain crop production in these regions. Stedden et al. (2024) suggested that additional work is needed to improve weed management, increase access to plant-available N, and enhance climate change resilience when growing these crops.

Antichi et al. (In press) discussed results of a 15-year study comparing durum wheat [*Triticum turgidum* spp. *durum* (Desf.) Husn.] performance as part of the long-term Mediterranean Arable Systems Comparison Trial (MASCOT) in Pisa, Italy. On average, durum wheat yield was about a third less when grown organically than conventionally in that study, with the yield gap widening over time. The researchers found greater temporal variation in grain yield when durum wheat was grown in the organic system. In part, lower grain yield in the organic system was attributed to greater weed competition, with biomass production by weeds as much as 10 times greater in organic plots. Soil organic matter was higher in organic plots but not total soil N, and P levels were lower by the end of the study, suggesting that heavy reliance on the natural cycling of nutrients failed to meet the fertility needs of durum wheat grown organically. Antichi et al. (In press) concluded that effective weed suppression is essential for reducing the durum wheat yield gap between organic and conventional systems. They suggested that the divergent temporal trends in durum wheat grain yield and soil fertility between management systems support the establishment and continuation of long-term studies comparing organic and conventional production methods.

AUTHOR CONTRIBUTIONS

Patrick M. Carr: Conceptualization; project administration; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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