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Editorial

Perennial Grains and Oilseeds: Current Status and Future Prospects

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Abstract: The release of cultivars of two perennial grains is a milestone in perennial grain and oilseed development. Agronomic studies can progress by having stable genetics upon which to conduct research. Agriculture has generally committed to enhancing soil health, with perennial grains and oilseeds offering potentially non-animal-related alternatives to our current choices. Utilizing perennial grains and oilseeds offers potential to small-grain producers to improve, or at least maintain, their soil quality as perennial grains generally have little soil disturbance post-seeding. Understanding perennial grain and oilseed development and how they interact with their growth environment will provide us with baselines upon which to gauge agronomic interventions as we attempt to increase productivity without negative environmental impacts.

Keywords: perennial grain; perennial oilseeds; research progress; collaboration

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1. Introduction

Where is agriculture heading? Sustainability, climate change, resiliency, carbon sequestration, sustainable intensification and natural systems agriculture are a few of the terms that are now part of the current discussions surrounding agriculture. The following statement from Klitgaard has influenced my recent thinking on these subjects: "Biophysical economics sees a sustainable economic theory as one that is grounded in the unity of social and natural sciences. The economy is embedded in a finite and non-growing biophysical system and is subject to its laws and its limits" [1] (the emphasis is this author's). This statement can be considered along with the idea that "... there is a growing need for—and interest in—developing a sustain-centric approach to marketing that relaxes the need to maximize financial well-being in order to optimize social and ecological well-being" [2]. These statements encompass the above terms and concepts and place them, I feel, under a clearer perspective. We have finite resources on this planet, and we must consider that they place limits on productivity and that we may have exceeded those limits. The need for and reliance on human-made resources (e.g., many N fertilizers and pesticides) and diverted resources (e.g., land and water) attest to the limits of natural systems to support the human population. Justification for the use of these resources and materials is the need to provide (provisioning) for the human population; however, this is carried out at the expense of the underlying ecosystems (biophysical systems) [3]. Moreover, humankind's accelerated use of these resources (e.g., land, water, N fertilizers, and pesticides) is adding to existential challenges such as climate change [4] and biodiversity loss [5].

Perennial grains and oilseeds have become an active area of research world-wide and are becoming part of the discussion. The release of cultivars in two species, perennial rice (*Oryza sativa* × *O. longistaminata*) [6] and intermediate wheatgrass (Kernza®) (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) [7], demonstrates the potential of this broad research area. This research has also led to agronomic, food quality/food science, ecosystem service and cropping system research into these potential crops alongside the continued breeding of the released crops and/or the domestication of new crops.

This Special Issue of *Agriculture* intends to highlight the scope, progress and promise of this expanding area of agricultural research by presenting work involving agronomic and end-use research that is currently taking place to enhance the production, adoption and use of perennial grains and oilseeds.

2. Background

The increased activity in this area of research was evidenced in a search of the Web of Science database on 24 June 2024 (the core collection was searched for article titles using the terms 'intermediate wheatgrass', 'perennial rice', 'perennial wheat', 'perennial sunflower', 'Silphium', 'perennial sorghum' and 'perennial grains', and each publication was then investigated for its suitability for inclusion) until the end of the year 2023. This yielded 297 publications since 2000, with over 75% being published in 2016 or later (Figure 1). Note that 2022 had the largest number of publications with over 50 manuscripts, which is greater than 2.5 × the total number of publications prior to 2001. While this is a relatively crude measure which likely underestimates the number of publications on perennial grains and oilseeds, it illustrates the current increase in research in this area and, importantly, the number of researchers taking part in it.

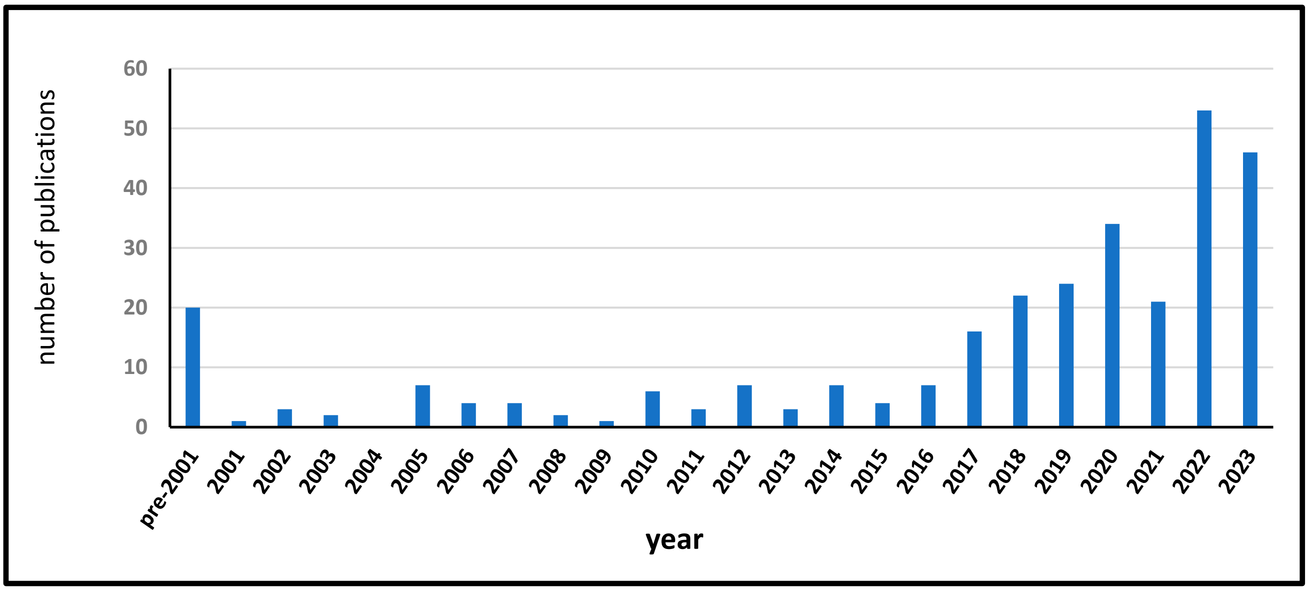

Figure 1. The distribution of perennial grain and oilseed manuscripts identified through a search on the Web of Science database on 24 June 2024 for titles including the terms 'intermediate wheatgrass', 'perennial rice', 'perennial wheat', 'perennial sunflower', 'Silphium', 'perennial sorghum' and 'perennial grains'. After the search, each indicated article was investigated for its suitability for inclusion. This excludes any manuscripts published in this Special Issue.

Perennial grains and oilseeds are currently challenged with respect to sustainable yields [8,9]. However, the degradation of the resource upon which field crop growth is reliant, i.e., the soil, continues to demand increasing investments, especially in non-renewable resources (fertilizers, pesticides, etc.), in the maintenance of all crop yields. Perennial crops would also benefit from some of the additional resources that annual crops receive and will likely require some additions to be sustainably productive. Recent genetic gains in wheat yield have averaged about 1% yr^{-1} [10]. However, a model of Canadian canola yields predicts a major decrease (21–42% between 2041 and 2070, with the decrease being location-dependent) under certain climate change scenarios in the middle of this century [11]. Challenges such as the increase, maintenance of, or decline in yield will be present for all crops in the future. This is why plant breeders are in demand.

Many annual crop species have been domesticated and developed over many millennia (e.g., wheat [12] and rice [13]). Modern interest in perennial grains was re-ignited by the

Rodale Institute, who investigated perennial species for potential domestication [14], with the baton being passed to The Land Institute [15–17]. International meetings have taken place over the past decade that have spread interest and cooperation around the world. For example, international groups looked at the domestication of perennial crops [18] and the potential of perennial wheat across four continents [19], and they further collaborated to garner a better understanding of the environmental stimuli affecting the reproductive development of intermediate wheatgrass [20]. Collaborative works such as these will be critical in establishing these potential crops and, more importantly, in providing an understanding of their development and potential benefits to the environment. Additionally, collaboration will continue to involve additional researchers from already active areas and other areas of science (e.g., modelers, soil scientists, animal scientists, agricultural meteorologists, food scientists, economists, etc.) as we attempt to realize the potential of this area of cropping system development.

Cultivar release provides opportunities to researchers, as they now have a relatively stable genetic base upon which to test agronomic hypotheses, which is a novel development in the research on perennial grains, specifically perennial rice and intermediate wheatgrass. Secondly, these opportunities provide critical baselines for future comparisons. Research to date has either been carried out on breeding populations or on composite materials from breeding nurseries. The diversity within and between these sources can allow for variable responses to agronomic treatments.

The benefits and issues of using mixtures of species (bi- and polyculture) [21,22] are aspects that have drawn researchers to this area, and they also sparked my initial interest [23]. The implementation of polycultures is dependent upon cultivar development. However, the use of different breeding methods is likely required for complimentary development [23,24].

The timing of growth and development within a growing season is not only critical in the realization of perennial survival [25] but also in reproductive growth and grain yield realization. Understanding the developmental cycle [20,26] provides a backbone upon which to develop agronomic practices and programs and to understand the developmental impacts of these practices. Crop response to fertility applications may be influenced by both the fertility amount and timing of application(s). Agriculture's reliance upon both irrigation water and N additions will continue due to the expected increase in demand for agricultural outputs to meet growing population estimates [27], especially with plant breeding's current inability to meet the expected increases (10). Excess water or nitrogen can delay the phenological development of a crop [28]. It is important for precipitation, nutrition and plant water needs to be matched up to ensure adequate productivity.

3. Progress in Perennial Grains and Oilseeds

The work reported in this Special Issue all relate to intermediate wheatgrass (Kernza®). The topics range from establishment parameters to end use. The reports cover the early plant development of this perennial grain [29], how to manage a stand of intermediate wheatgrass for prolonged productivity [30], the adaptability of intermediate wheatgrass to Western Canadian production [31], nitrogen use and nitrogen use efficiency at different phenological timings [32] and the nutritional quality of intermediate wheatgrass as a human food [33]. Two studies indicated high protein contents in the grain and end-use products, which could provide a premium for this grain.

4. Future of Perennial Grains

Commentaries on the detriments of monocultures and on the general narrowing of the genetic basis of crop production are appearing [34]. While the narrowing of the genetics in crop production helps increase crop productivity, it can lead to catastrophic susceptibility to biotic forces [35]. Conserving the diversity in crop wild relatives and wild species is advantageous to the sustainability of crop species and biodiversity in general [36]. In *Secale cereale*, a general diversification of phenotypes developed from weedy escapes of the cultivated form in the West Coast region of the United States [37] indicates the need for, or a preference of, diversity in nature.

The economics of the current research environment is driven by an expected economic return for the economy. An economic value was given to the biophysical economy, and thus to the potential for humankind to persist, and it is thus generally dismissed as an externality. The damage caused by downstream impacts of agricultural (or other economic) activities have long been borne by society, and then begrudgingly. While this is somewhat changing, it would seem beneficial to prioritize the planet's ability to continue providing for humankind (and all other species as well). Agricultural research that provides greater benefits to the survival of the planet, without a direct economic benefit to an industry partner, has received a pauper's share of research funding [38]. As this editorial was being conceived, a USD 44B deal to buy Twitter (now known as X) was announced [39]. While it is a communications tool, its potential long-term survival (and profitability) is not something that is essential for humankind. An annual investment of 1/1000th of the original price would be considered a major coup for perennial grain and oilseed research, which has been drawing attention to this issue [38]. Better yet, the investment of the value lost in this transaction (e.g., the value as of January 2024 was estimated to be between USD 12.5B and USD 19B [40]) on agricultural-related climate change issues, including perennial grains and oilseeds, would have had a greater impact on the health of the planet than the investment in Twitter. Investments from the public sector have been shown to be critical in the development of new crops; however, once the crops are developed, private sector research tends to take over (e.g., canola [35]). The currency for food production (soil health) is currently being devalued as we attempt to meet the demands of an ever-growing population. The limits of the biophysical system have also been exceeded [1].

Perennial grains offer many potential benefits to our agricultural systems [41]. Work on many aspects of these potential and emerging crops is expanding, with the largest cohort of researchers in its history now being engaged in the many aspects of perennial crop development and use (Figure 1). Hopefully, society's attitudes will continue to broaden [1,2] and provide a greater acceptance of the value that is accrued through cultivating herbaceous perennials [42] to support the development of these potential crops. This Special Issue will hopefully provide a glimpse into the current research areas being explored by researchers in this area of specialization.

Conflicts of Interest: The author declares no conflict of interest.

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