Perennial wheat: a paradox with possibility

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Abstract

Perennial crops provide a yet to be tested opportunity for sustaining production and profit of agricultural systems. Wild species could be domesticated or annual crops hybridised with perennial relatives. In particular, the development of perennial wheat could have a major impact in winter-cereal-growing regions. A number of issues will challenge the use of perennial wheat in current farming systems. To perenniate, plants must expend resources to ensure survival, which potentially comes at a cost to fecundity. This trade-off will probably reduce harvest index and grain yield, unless plants can access additional resources. Drought tolerance will be vital if perennial wheat is to persist. Summer dormancy may be required in drier regions, as is seen in perennial temperate forage grasses. Tolerance of soil conditions that currently limit annual wheat or other perennial plant options (e.g. soil acidity and waterlogging) would be valuable. Grain quality and traits that improve harvestablity such as synchronous tiller initiation, flowering and maturity, and seed retention will also be important. Perennial wheat could provide a source of inoculum for canopy-borne fungal diseases and harbour other pests, both of which may pose a risk to other crops. Resistance to major pests and diseases will be mandatory and may actually be improved from crosses with wild perennial relatives. Despite these challenges, perennial wheat may offer advantages over current wheat production such as reduced energy use, hydrological improvements to reduce waterlogging, nitrate leaching, groundwater recharge and salinity, weed control benefits, provision of higher quality stubble during summer and autumn, reduced risk, and flexibility between grazing and grain enterprises.

Introduction

Problems such as dryland salinity have arisen from heavy reliance of agricultural systems on annual crops and pastures. Return of perennial plants to the landscape is a logical response. Perennial forages and agroforestry are being increasingly exploited, but perennial grain crops also provide possibilities to maintain production and profit, and improve sustainability. Few research efforts have tackled this opportunity; a notable exception being an exploration of domesticating a native perennial grass, *Microleana stipoides* (Davies *et al*. 2005). Hybridizing annual crops with perennial relatives is also another option for breeding perennial grain crops (Cox *et al*. 2005b). Despite the wide range of possible perennial crop species, wheat is a key priority to explore because it dominates grain production in southern Australia and is the largest grain crop world-wide. Two active breeding programs in the USA, at Washington State University and The Land Institute, have achieved some initial success. However, these developments with perennial wheat in North America may have limited applicability to Australian environments and farming systems. This paper considers the potential opportunities, constraints and risks for perennial wheat before significant investment is warranted in Australia.

Potential constraints and risks

It can be anticipated that perennial wheat will have reduced grain production compared to annual wheat. Perennial plants generally allocate more energy to their root systems and defence structures and compounds, because they must tolerate environmental extremes and defend themselves against herbivores and pathogens. Wild annual plants generally have a greater reproductive allocation than wild perennials, thus some researchers have concluded that perennial grain crops will be less productive than annual grain crops (Wagoner 1991). However, De Haan *et al*. (2005) propose that perennials could produce more photosynthate because they have a longer growing season and have developed a large living root system which has explored a greater soil volume and thus has greater access to nutrients and water. If the energetic cost of perenniation can be met by this additional production compared with annuals, then a similar amount of grain could be produced provided harvest index is similar. The relative performance of annuals and perennials may not be constant across all environments. For example, perennials might be better suited to situations where annuals do not capture all available resources, such as soils with low water holding capacity or high rainfall environments. In addition, lower productivity of perennial wheat would mean that tolerance of soil or climatic conditions that currently limit annual wheat or other perennial plant options (e.g. soil acidity and waterlogging) would greatly improve its appeal. For perennial wheat to persist in most grain growing areas, drought tolerance will be vital. This may require some degree of summer dormancy, as demonstrated in perennial temperate forage grasses (Norton *et al*., 2006), but deep roots and other physiological adaptations to drought will also be valuable.

In a perennial crop, phenological control of tiller initiation, flowering and maturity will be vital to achieve synchronised grain ripening and harvesting. Seed retention will also be important. Crosses between wheat and its wild relatives or domesticated wild grasses are unlikely to have equivalent grain characteristics to current bread wheat cultivars. Initially, perennial wheat could be used as a feed grain or may possess other grain characteristics (e.g. novel proteins) that might be useful for human consumption or alternative products.

A major concern is the potential for perennial wheat to harbour disease and pests of other crops. In particular the potential to provide a green host during summer and thus provide a green bridge for foliar fungal diseases such as stem, leaf and stripe rusts is anticipated. Diseases that increase over time, such as viruses and soil- and residue-borne root pathogens could cause a decline in perennial plant performance. Other unforseen minor pathogens might also increase. Genetic resistance to major disease threats would be required and should inhibit the transmission of inoculum from perennial wheat to other crops. High levels of genetic resistance to many common wheat diseases, such as wheat streak mosaic virus, barley yellow dwarf virus, stripe, stem and leaf rust, eyespot and Cephalosprium stripe, have been found in wild relatives of wheat (Cox *et al*. 2005a). Nonetheless, the use of perennial wheat would pose new disease management challenges.

Potential benefits of perennial wheat

Despite these challenges, perennial wheat offers potential advantages over current annual wheat production. A number of hydrological benefits would result if perennial wheat was deep-rooted , such as reduced soil waterlogging, reduced sub-soil acidification associated with nitrate leaching, and decreased groundwater recharge and dryland salinity. Perennial wheat represents the next step in reduced tillage farming systems and could have similar benefits of improving soil health, structure and microbial activity. Perennial cover during summer would also decrease soil erosion and compete with weeds. Reductions in risk and lower input costs due to reductions in energy use and improved nutrient use efficiency would improve the economic attractiveness compared to annual wheat. In mixed cropping-livestock systems, perennial wheat might provide higher quality stubble for grazing livestock during summer and autumn and increase flexibility between grazing and grain enterprises.

Conclusion

While the prospect of perennial wheat as a commercial reality is still far off in the future, and a number of potential problems will need to be overcome for it to be successful, the concept of a perennial grain crop has a number of attractions for improving the sustainability of Australian farming systems.

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