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Muhammad Asif
Muhammad Iqbal
Harpinder Randhawa
Dean Spaner

Managing and Breeding Wheat for Organic Systems

Enhancing Competitiveness Against Weeds

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Muhammad Asif
Dean Spaner
Agricultural, Food and Nutritional Science
University of Alberta
Edmonton, AB
Canada

Muhammad Iqbal
National Agricultural Research Centre
Islamabad
Pakistan

Harpinder Randhawa
Agriculture and Agri-Food Canada
Lethbridge Research Centre
Lethbridge, AB
Canada

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Preface

Breeding for organic agriculture is gaining enormous attention in the scientific community due to burgeoning trade, production, and consumption of organic produce. It is well established that organically managed lands represent a different environment than conventionally managed lands mainly due to the presence of large weeds populations. Wheat is one of the most produced and consumed cereal grains worldwide. Weed infestation is a ubiquitous threat to the production of major cereal crops including wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and rice (*Oryza sativa* L.). This threat needs to be minimized in order to maximize global crop production and to meet the food demand of the ever-increasing human population. Currently, farmers control weed infestation mainly through the application of herbicides. According to Transparency Market Research, herbicide is the largest category in the crop protection sector that contributed about $19.9 billion in 2011. The use of herbicides is increasing on an annual basis. The continuous exposure of weed species/plants to strong herbicides has inevitably resulted in the development of herbicide-resistant weed populations in at least 80 crops in 63 countries (http://www.weedscience.com), which poses a major threat/challenge to global food production and security. This widespread evolution of herbicide-resistant weed species necessitates the development of alternate weed control strategies. Therefore, interest in breeding cereals, especially wheat, to enhance competitive ability is growing among the scientific community. Various traits of economic importance, conferring competitive ability against weeds, have been identified along with improved understanding of allelopathy. The combined effects of competition and allelopathy offer a great potential to achieve maximum weed suppression. Breeding efforts have resulted in the development of weed suppressive rice cultivars that are commercially available in China and the USA, whereas research work is being conducted in many parts of the world, including Canada, to develop a highly competitive wheat ideotype.

In planning this monograph, our main intent was to (i) describe and critically review key aspects of breeding wheat for organically managed systems to enhance competitive ability against weeds and (ii) to provide a unique and time-based resource for plant breeders, agronomists, teachers, students, and weed scientists around the globe to seek information on a discipline of crop competitiveness. Consequently, this brief is divided into five chapters which are arranged in logical progression. Chapter 1 highlights the importance, history, production, and

utilization of wheat from a global perspective. Chapter 2 begins with a brief overview of organic agriculture and extends a comprehensive discussion on crop–weed competitiveness. It also identifies traits of interests in different crops to breed for competitiveness and presents trait association to competitive ability in crop plants. Various strategies to control weed infestation and to enhance competitive ability through management, genetics, or genomic approaches have been presented in Chap. 3. It highlights various molecular studies undertaken to identify molecular markers linked with various traits conferring competitive ability in cereal crops. Chapter 4 provides strategies to breed wheat for disease resistance, quality, allelopathy, and earliness for organic systems. Chapter 5 summarizes the brief and outlines studies conducted during the last 5 years to examine competitive ability in various cereal crops throughout the world.

The brief is presented in a logical format making it available to a wide range of readers including plant breeders, agronomists, weed scientists, graduate, and undergraduate students involved in the field of agriculture and related disciplines, to help them in devising breeding strategies to deal with the problem of weed/weed infestation by enhancing/improving crop competitiveness.

Contents

Abbreviations

AMs	Arbuscular Mycorrhizas
BX	Benzoxazinoids
CPSW	Canada Prairie Spring Wheat
CSA	Canada Seed Act
CWRS	Canada Western Red Spring
DH	Doubled Haploid
DNA	Deoxyribonucleic acid
FAO	Food and Agriculture Organization
FHB	Fusarium Head Blight
FPPA	Federal Plant Protection Act
GFD	Grain Fill Duration
GFR	Grain Fill Rate
GMO	Genetically Modified Organisms
IWM	Integrated Weed Management
IWMS	Integrated Weed Management Strategy
LAI	Leaf Area Index
MAB	Marker Assisted Breeding
MAS	Marker Assisted Selection
NUE	Nutrient Use Efficiency
NWCA	Noxious Weed Control Act
PAR	Photosynthatically Active Radiation
PCR	Polymerase Chain Reaction
PGPR	Plant Growth Promoting Rhizosphere
QTL	Quantitative Trait Loci
RAPD	Random Amplified Polymorphic DNA
RFLP	Restriction Fragment Length Polymorphism
RIL	Recombinant Inbred Line
RUE	Radiation Use Efficiency
SNP	Single Nucleotide Polymorphism
SSR	Simple Sequence Repeat
UN	United Nations
US	United States
WHO	World Health Organization

Chapter 1
Wheat: The Miracle Cereal

Abstract Wheat is one of the most important cereal crops. It covers the largest area under any single crop in the world. It feeds about 40 % of the world's population and provides 20 % of the caloric and protein requirements in human nutrition. Wheat also occupies a central position in maintaining world's food security. Following incorporation of semi-dwarfing genes, wheat production doubled in the 1960s, an era called the Green Revolution. The Green Revolution resulted in the development of semi dwarf wheat cultivars that were highly responsive to inorganic fertilizer application, were early maturing and resistant to lodging. Semi dwarf cultivars also remained resistant to various diseases for many decades. Wheat genetic gains are less than 1 % per annum which are not sufficient to meet the future food demand of ever increasing human population. This chapter addresses importance, history, production and utilization of wheat from different perspectives.

Keywords Allohexaploid · Grain texture · Hardness · Protein · Starch · *Triticum turgidum* · *Triticum aestivum*

1.1 Importance

Bread or common wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and ranks third in production after maize and rice. Wheat covers 17 % of the global crop acreage (217 million ha) with production of 675 million tons (Fig. 1.1). China is the largest producer of wheat with 117.4 million tons, followed by India producing 86.9 million tons (Fig. 1.2). The yield and production of wheat crop has been substantially increased during the last 50 years, whereas the area under wheat almost remained constant (Fig. 1.1). Bread wheat feeds about 40 % of the world's population and provides 20 % of the caloric and protein requirements in human nutrition (Gupta et al. 2005). For technical purposes wheat has been divided into different classes that include hard, medium, and soft (based on grain hardness); white, amber, or red (based on bran color) and;

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