SYNTHETIC WHEAT; A NEW HOPE FOR THE HUNGRY WORLD

Rashid Mehmood Rana*, Muhammad Bilal, Shoaib Ur Rehman, Farrukh Iqbal and Muhammad Kausar Nawaz Shah

Department of Plant Breeding & Genetics, PMAS-Arid Agriculture University Rawalpindi, Pakistan

ABSTRACT

Wheat is an important staple food and most widely grown cereal of the world. The dependence of large population on this food crop and increasing population of the world requires much more wheat to be produced. Efforts were made to increase wheat productivity and a remarkable success named "Green Revolution" boosted the wheat productivity in 1960s. However, by the course of time, no further significant improvement was noted. Through successive struggles, scientists developed synthetic wheat, derived from cross between *Triticum turgidum* L. and *Aegilops tauschii* (ancestors of bread wheat; *Triticum aestivum*). These synthetic wheat cultivars proved a great source of unexplored genetic variability and possessed improved traits like high yield, tolerance to abiotic and biotic stresses etc. Currently, new synthetic wheat has been developed, named as "super wheat" having at least 30 % higher yield than the existing wheat cultivars. This article summarizes the efforts made and goals achieved in the field of wheat breeding with special reference to synthetic wheat.

Keywords: Green revolution; Super wheat; World population

INTRODUCTION

Wheat is an ancient crop being used as staple food in several areas of the world. Wheat includes different species which are classified according to their ploidy level. The most cultivated one is common/bread wheat (*Triticum aestivum*), a hexaploid wheat having 42 chromosomes. Wheat grain contains high nutrient contents including proteins, carbohydrates, lipids and vitamins. High nutrient contents especially carbohydrates makes wheat as most important staple food around the world. Global wheat demand is increasing as the population of the world is increasing which is expected to grow by 32 % in the year 2050 (Weigand, 2011). Estimated demand of wheat in 2010 reached 666 million metric tons (MMT) and projected up to 880 MMT by 2050 (Weigand, 2011).

Efforts have been made to increase the yield of wheat using classical breeding techniques. However, that improvement stood stagnant after it achieved a certain level of improvement. In 1960s, that stagnation in yield was broken and achieved robust increase in the productivity of wheat. This breakthrough was acknowledged as "Green Revolution" by, William Gaud, the former director of USAID, who said,

"*These and other developments in the field of agriculture contain the makings of a new revolution. It is not a violet Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution.*"

After green revolution, plant scientists developed several high yielding varieties which helped in reducing food security problem in developing countries. This yield improvement is associated with genetic improvement in yield potential and biotic and abiotic stress adaptation (Rana et al., 2013) (Reynolds and Borlaug, 2006). Several traits were modified/introduced in new wheat varieties developed after green revolution including short stature fertilizer responsiveness and number of grains/spike etc. (Gollin et al., 2005). All these traits contributed significantly towards the yield. However, successive use of these varieties in the upcoming breeding program narrowed down the genetic base of wheat (Shiva, 1992). Therefore, after a certain level of improvement, no further significant improvement has been reported in wheat productivity, while the world population is still increasing (Fig. 1). This situation demands a new green revolution to feed the growing world. The existing narrow genetic diversity and unavailability of the traits for further improvement forced the scientists to search for traits in other species. This search laid the foundation for synthetic breeding, a new hope for upcoming green revolution.

**Corresponding author:* e-mail: rashid_cabb@hotmail.com

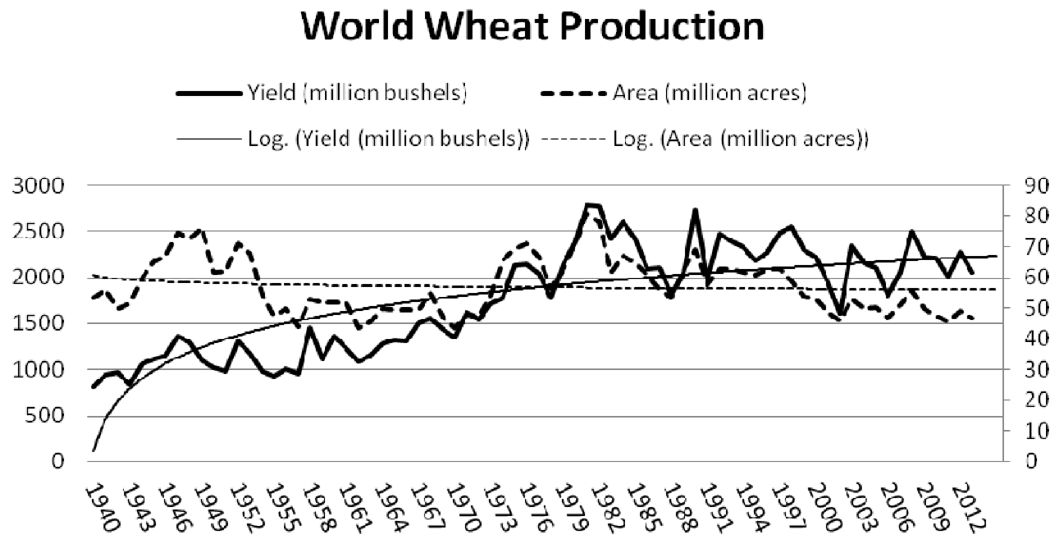

Fig. 1: World wheat production and cultivated area
Source: USDA (http://www.ers.usda.gov/data-products/wheat-data.aspx#25170)

Synthetic wheat
Synthetic wheat is produced by the hybridization of *Triticum turgidum* L. with *Aegilops tauschii* (Talbot, 2011). The resultant hexaploid synthetic wheat works as a genetic bridge between wild and cultivated wheat (Calderini and Ortiz-Monasterio, 2003a). Primary synthetics are bridging lines used for the introgression of the genetic material into modern bread wheat from its progenitor species (*T. turgidum* and *Ae. tauschii*; Talbot, 2011). Production of synthetic wheat involves screening subspecies and accessions of *T. turgidum* and *Ae. Tauschii* for characters desired in hybrids resulting from their cross (Talbot, 2011). In early 1900's, first attempt was made to develop synthetic wheat with "synthetic spelta" created during a study to determine the progenitors of *T. aestivum* subsp. spelta Thell, an earliest allopolyploid hybrid form of bread wheat was termed as "synthetic hexaploid wheat" by Mcfadden and Sears in 1946 (Talbot, 2011). Once created, the synthetic wheat can be used to develop F_1 synthetic derivatives after crossing with bread wheat cultivars, (Lange and Jochemsen, 1992; Trethowan and Mujeeb-Kazi, 2008). Since late 1980s CIMMYT has developed more than 1000 cultivars of primary synthetic wheat from wheat wide crossing program (Lage et al., 2004).

Synthetic hexaploid wheat has been verified as a valuable source of resistance or tolerance to biotic and abiotic stresses. The hybrid produced from a cross between synthetic wheat and an improved variety showed twice genetic diversity as compared to its parents (Kazi and Van Ginkel, 2004). The synthetic wheat possesses traits such as large kernels, heavy spikes, and resistance to new races of Chinese stripe rust. During two years of yield trials, the two varieties derived from synthetic wheat had 20% to 35% higher yields than the commercial check variety (Kazi and Van Ginkel, 2004). In 2003, Spain registered a CIMMYT synthetic wheat derivative under the name Carmona. This fast-growing variety matures and provides seed in a shorter period than most commercial cultivars, which is valuable for wheat growers who often plant late in the year in southern Spain. Carmona has better grain quality and is suited to zero-tillage systems, where it resists foliar diseases and produces higher yields (Kazi and Van Ginkel, 2004).

Synthetics would be an important source of germplasm for escalating element grain concentration, at least in this case for Fe, Mn, K and P (Calderini and Ortiz-Monasterio, 2003a). In addition, previous reports have revealed that synthetic hexaploids have higher concentration of both micro and macronutrients in a single grain than *T. aestivum* (Calderini and Ortiz-Monasterio, 2003b). If synthetic wheat qualities can be incorporated into nowadays' wheat fields, it could give both hardier plants and more nutritious food (Calderini and Ortiz-Monasterio, 2003a).

Utilization of Synthetic Wheat

Resistance to biotic stresses

The prime synthetics have confirmed to be a precious resource of genetic variability for disease resistance (Van Ginkel and Ogbonnaya, 2007). Rust is one of the most damaging diseases of wheat universally Genes for leaf and stripe rust resistance have been reported in synthetic wheat. Synthetic wheat also showed resistance to leaf blotch, glume blotch, crown rot, yellow leaf spot, leaf blight, powdery mildew, karnal bunt (Van Ginkel and Ogbonnaya, 2007). It also showed resistance to certain insect pests such as Green bug and Hessain fly (Van Ginkel and Ogbonnaya, 2007).

Resistance to abiotic stresses

Synthetic wheat showed significant tolerance to various abiotic stresses viz. drought, heat, salinity etc. The synthetic wheat derivatives of primary synthetics showed 8-30% increase in yield over both the Australian parents and local modern check varieties when grown under rain fed conditions in Australia (Ogbonnaya et al., 2007). Globally, synthetic wheat yielded 5-40% more in India, Pakistan, Ecuador and Argentina in addition to Australia under drought stress conditions (Coghlan, 2006). These synthetic varieties had deeper or thicker roots assisting wheat plant in taking handsome amount of water which helped in to survive under water scarcity.

Level of genetic variability for salt tolerance, with the source of their D genome, has been reported limited in elite bread wheat genotypes but additional genetic variation has been reported in synthetic hexaploid wheat cultivars for salt tolerance (Schachtman et al., 1992; Schachtman et al., 1991). At grain filling stage synthetic wheat offers heat tolerance up to 35-40 ^{0}C (Van Ginkel and Ogbonnaya, 2007).

Pre-harvest sprouting

End use quality is greatly reduced by pre harvest sprouting. This occurs particularly in environments having rainfall and high amount humidity during harvesting period resulting in downgrading of wheat (Van Ginkel and Ogbonnaya, 2007). There is an association between seed dormancy and PHS tolerance. Synthetic hexaploid wheat possesses a considerable amount of genetic variation for seed dormancy.

Yield and yield components

Yield trail of synthetic wheat had been carried out in CIMMYT in later half of 1990s showing that synthetic wheat yield was just reached to common wheat yield with no distinguishable difference in yield production. But later on in yield trails of 2001-2003, the synthetic wheat produced yield that exceeded more than those common wheat. These trials showed that synthetic wheat derivative as worldwide competitive and having both particular and broad adaptation (Villareal et al., 1994)

Positive correlation between high grain yield, improved harvest index, improved grain weight and increased above ground biomass has been observed in synthetic wheat (Rattey et al., 2011; Rattey et al., 2009; Shearman et al., 2005). The primary synthetic superior progenies showed their maintained larger seed size and more seed weight along with seed per head and head number attributes (Cooper, 2013; Cooper et al., 2012).

Super wheat

The world requires more wheat to meet the food requirements of increasing population. Although wheat production has been improved, but in the last 15-20 years there is no noticeable increase in wheat per acre yield. Several programs launched worldwide to produce high yielding wheat cultivars; however, a few reported success. A group of scientists working at National Institute of Agricultural Botany (NIAB), Cambridge University reported a breakthrough in the development of high yielding wheat, named as "super wheat". According to NIAB reports, these scientists claimed that this newly developed "super wheat" will have 30% higher yield than existing wheat cultivars. Therefore, this wheat can be regarded as a landmark in the synthetic wheat and would be the first commercialized form of synthetic wheat. This upcoming "super wheat" is expected to be released by 2019 and preliminary tests confirmed its tolerance against various biotic and abiotic stresses (http://www.niab.com/news_and_events/article/281).

REFERENCES

Calderini DF and Ortiz-Monasterio I, 2003a. Are synthetic hexaploids a means of increasing grain element concentrations in wheat? Euphytica. 134:169-178.

Calderini DF and Ortiz-Monasterio I, 2003b. Grain position affects grain macronutrient and micronutrient concentrations in wheat. Crop Sci. 43:141-151.

Coghlan A, 2006. Synthetic wheat offers hope to the world. New Scientist Print Edition.

Cooper JK, 2013. Synthetic hexaploid wheat as a source of improvement for winter wheat (*Triticum aestivum* L.) in texas. Texas A&M University.

Cooper JK, Ibrahim A, Rudd J, Malla S, Hays DB and Baker J, 2012. Increasing hard winter wheat yield potential via synthetic wheat: I. Path-coefficient analysis of yield and its components. Crop Sci. 52:2014-2022.

Gollin D, Morris M and Byerlee D, 2005. Technology adoption in intensive post-green revolution systems. Am. J .Agri. Econ. 87:1310-1316.

Kazi M and Van Ginkel M, 2004. Wild wheat relatives help boost genetic diversity. CIMMYT News

Lage J, Skovmand B and Andersen S, 2004. Field evaluation of emmer wheat-derived synthetic hexaploid wheat for resistance to russian wheat aphid (homoptera: *Aphididae*). J. Econ. Ent. 97:1065-1070.

Lange W and Jochemsen G, 1992. Use of the gene pools of triticum turgidum ssp. Dicoccoides and aegilops squarrosa for the breeding of common wheat (*T. aestivum*), through chromosome-doubled hybrids. Euphytica. 59:197-212.

Ogbonnaya FC, Ye G, Trethowan R, Dreccer F, Lush D, Shepperd J and Van Ginkel M, 2007. Yield of synthetic backcross-derived lines in rainfed environments of australia. Euphytica. 157:321-336.

Rana RM, Rehman SU, Ahmed J and Bilal M, 2013. A comprehensive overview of recent advances in drought stress tolerance research in wheat (*Triticum aestivum* L.). Asian J. Agri. Biol. 1:29-37.

Rattey A, Shorter R and Chapman S, 2011. Evaluation of CIMMYT conventional and synthetic spring wheat germplasm in rainfed sub-tropical environments. I. Grain yield components and physiological traits. Field Crop Res. 124:195-204.

Rattey A, Shorter R, Chapman S, Dreccer F and Van Herwaarden A, 2009. Variation for and relationships among biomass and grain yield component traits conferring improved yield and grain weight in an elite wheat population grown in variable yield environments. Crop Pasture Sci. 60:717-729.

Reynolds M and Borlaug N, 2006. Impacts of breeding on international collaborative wheat improvement. J. Agri. Sci. 144:3.

Schachtman D, Lagudah E and Munns R, 1992. The expression of salt tolerance from *Triticum tauschii* in hexaploid wheat. Theor. Appl. Genet. 84:714-719.

Schachtman D, Munns R and Whitecross M, 1991. Variation in sodium exclusion and salt tolerance in *Triticum tauschii*. Crop Sci. 31:992-997.

Shearman V, Sylvester-Bradley R, Scott R and Foulkes M, 2005. Physiological processes associated with wheat yield progress in the UK. Crop Sci. 45:175-185.

Shiva V, 1992. The violence of green revolution: Third world agriculture, ecology and politics. Zed Books.

Talbot SJ, 2011. Introgression of genetic material from primary synthetic hexaploids into an australian bread wheat (*Triticum aestivum* L.), School of Agriculture, Food and Wine. The University of Adelaide.

Trethowan R and Mujeeb-Kazi A, 2008. Novel germplasm resources for improving environmental stress tolerance of hexaploid wheat. Crop Sci. 48:1255-1265.

Van Ginkel M and Ogbonnaya F, 2007. Novel genetic diversity from synthetic wheats in breeding cultivars for changing production conditions. Field Crop Res. 104:86-94.

Villareal R, Mujeeb-Kazi A, Toro ED, Crossa J and Rajaram S, 1994. Agronomic variability in selected *Triticum turgidum* x *T. tauschii* synthetic hexaploid wheats. J. Agron. Crop Sci. 173:307-317.

Weigand C, 2011. Wheat import projections towards 2050. US Wheat Associates, USA.