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Future of Wheat Breeding is Driven by Hybrid Wheat and Efficient Strategies for Pre-Breeding on Quantitative Traits

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Short Communication

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The world wheat production has to be doubled until 2050 to meet the increased demand arising from the continuing population growth, rising meat and dairy consumption, and expanding use of biofuel and biogas [1]. The most sustainable and environmental friendly approach to reach this goal is to increase crop yields per area, but yield growths in wheat are stagnating in many parts of the world [2]. Hybrid breeding has been proposed as a potential strategy to boost yields in selfing species and to enhance yield stability [3,4]. Wheat hybrids are currently cultivated on only <1% of the global acreage but large research efforts have been launched to increase this acreage.

For instance, in a vast experimental project in Germany, we have elaborated with four breeding companies that heterosis for grain yield in wheat is about 10% and yield stability is higher for hybrids than for lines [5,6]. Moreover, hybrids could be identified with grain yield considerably higher than all commercial checks, although the parental lines have never been selected for hybrid combinations [5]. This year, the first hybrids with very good baking quality have been registered by the respective Federal Offices underlining the future potential of hybrid wheat breeding.

Nevertheless, important draw-backs for hybrid wheat have to be addressed by the scientific community. First, the hybrid seed production must be facilitated by improving cross pollination and developing easy, cheap and environmental stable hybridization systems. Main research efforts should target screening methods for pollen traits, like anther extrusion, pollen spread and vitality, and female receptivity. In addition, fine-mapping of potential cytoplasmic male sterility systems, identification of alternative sterility systems and their development for routine use in breeding must intensively be pushed. Second, high yielding heterotic patterns have to be generated by intensive hybrid field tests and prediction methods based on high-dense genotyping [7]. Interestingly, these authors emphasized that an initial size of 15 lines per heterotic group might be sufficient warranting short- and long-term success of hybrid wheat breeding. A central point in the development of heterotic patterns will be the establishment and connectivity of these patterns across different climate zones, like Central Europe pattern versus Asian pattern and others, to warrant long-term gene flow by possible line exchanges across patterns. In order to keep these patterns as open as possible, strong efforts from public research are required ideally orientating new approaches at the already ongoing efforts in Central Europe or at CIMMYT.

Efficient Exploitation of Genetic Resources

Besides hybrid wheat, a further crucial point averting future food shortage is the efficient use of genetic resources in breeding. More than 560,000 wheat accessions are frozen in about 40 gene banks globally, but wheat breeding is yet exploiting a very small sample of this genetic diversity [8,9]. A three-stage strategy has been proposed based on (1) genotyping and (2) phenotyping of gene bank accessions as well as (3) making these data public available [10]. The tremendous improvements in marker technology and biodiversity information facilities (cf. http://www.wheatinitiative.org/ research/databases) warrant the feasibility of stage one and three. In contrast, high-throughput phenotyping of this plethora remains yet a challenge.

Phenotyping on adaptation traits and disease resistances might be implementable on a larger scale due to their high heritability and the possibility to phenotype in small observation plots. However, for quantitative inherited traits like grain yield, the low heritability requires field trials in large plots at multiple locations. Furthermore, the trait of interest might be hidden due to few negative major genes, like tall plant height or heavy disease infection. An innovative approach has been recently proposed to uncover this hidden breeding value of genetic resources by making use of the recently developed hybrid seed production tools [11].

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Crossing an elite tester, which is fixed for the positive dominant alleles for short plant height, disease resistance and other genes, to the genetic resources and testing their F1 generation in large field trial series uncovers breeding values of genetic resources for quantitative inherited traits. These breeding values can then be used to exploit the most promising genetic resources for pre-breeding activities. As yet quite rarely used, large efforts of the scientific community should rapidly be started to mine the plethora of genetic resources with this concept for most important quantitative traits. Ideally, new initiatives will orientate at the few running projects in order to maximize comparability and warranting open access of data.

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