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Mini review

Research progress on marker-assisted selection pyramiding breeding of disease resistance genes in wheat

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Abstract

Marker-Assisted Selection (MAS) pyramiding breeding combined with traditional breeding techniques has become an important method for molecular breeding in wheat. In recent years, with the continuous discovery of disease-resistance genes and the development of molecular markers associated with related genes in wheat, the research of MAS pyramiding disease-resistance genes has made great progress. The progress on the study of MAS pyramiding resistance genes in wheat powdery mildew, rust, and Fusarium head blight (Fhb) was reviewed. The aims of pyramiding breeding were discussed in order to promote the research on MAS pyramiding breeding in wheat.

More Information

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Introduction

Wheat is one of the important food crops in the world. With global warming, wheat disease occurs severely in wheat plant areas worldwide. The major diseases affecting wheat production include wheat powdery mildew, rust and Fusarium head blight, et al. Over time, the fungi themselves mutate with changing wheat varieties. At present, wheat varieties containing a single resistance gene are easy to lose disease resistance, and various pathogenic microorganisms are prone to produce variations. These factors aggravate the risk of greater disease occurrence. Therefore, cultivating varieties with durable and comprehensive disease resistance is the best strategy, and polymerizing multiple resistance genes in wheat by MAS pyramiding breeding is an important technique for wheat breeding.

Pyramiding breeding is a means to aggregate multiple genes scattered in different parents into the same genome by traditional hybrid, backcrossing, and recrossing. MAS is a new technology produced with the rapid development of modern molecular biology, which can quickly and accurately analyze the genetic composition of individuals from the molecular level and realize the direct selection of genotypes. MAS can greatly promote the molecular breeding process. MAS can reduce selection blindness, shorten breeding life, and improve selection efficiency. The combination of MAS with traditional breeding techniques has become an effective method for wheat genetic improvement.

MAS pyramiding breeding of wheat powdery mildew resistance genes

Wheat powdery mildew is caused by *Blumeria graminis*. f. sp. *tritici*, which is a destructive disease that seriously affects the yield and quality of wheat. To date, 68 powdery mildew resistance genes (*Pm*) have been identified in wheat [1]. These powdery mildew resistance genes provide a sufficient genetic resource for the pyramiding breeding of wheat. Cultivating disease resistance plants polymerizing multiple genes is of great significance for wheat powdery mildew resistance work.

Using MAS combined with traditional breeding techniques, several combinations of powdery mildew resistance genes were polymerized into wheat varieties. The *Pm8* and *Pm21* pyramiding, the *Pm2* and *Pm4b* pyramiding, and the *Pm4a* and *Pm21* pyramiding improved the disease resistance in high-generation hybrid materials of wheat to some extent [2]. The *Pm4b*, *Pm2,* and *Pm13* pyramiding, the *Pm4b* and *Pm13* pyramiding, the *Pm13* and *Pm21* pyramiding, and the *Pm4b* and *Pm21* pyramiding were acquired in wheat disease

resistance breeding [3]. Wheat hybrid materials polymerizing *Pm2*, *Pm4*, *Pm13,* and *Pm21* genes increased disease resistance to powdery mildew [4]. Wheat line AL69 has two types of resistant genes to powdery mildew, *Pm4b,* and *Pm7* and showed all-stage resistance [5]. The *Pm21*, *Pm35,* and *Pm52* pyramiding were immune to powdery mildew [6]. Wheat varieties and hybrid materials pyramided multiple *Pm* genes can improve wheat resistance to powdery mildew, which showed that pyramiding is helpful to increase the disease resistance of wheat.

MAS pyramiding breeding of wheat rust resistance genes

Wheat rust mainly has stripe rust, leaf rust, and stem rust. Stripe rust is caused by *Puccinia striiformis* f. sp. *tritici*, which is one of the most devastating diseases of wheat worldwide. The disease occurs frequently in areas where climatic conditions are favorable for stripe rust, which can decrease wheat yield from 3% to 90% [7]. Leaf rust is caused by *Puccinia triticina* Eriks. & E. Henn and stem rust are caused by *Puccinia graminis* f. SP. *tritici*. Leaf rust and stem rust can cause significant yield losses up to > 50% or > 75 respectively [8,9]. Because of the continuous variation of pathogens and single resistance source, wheat varieties with a single resistance gene are prone to lose disease resistance. At present, more than 60 stripe rust resistance genes (*Yr*), 70 leaf rust resistance genes (*Lr*) and 60 stem rust resistance genes (*Sr*) [10-12] were discovered. Searches showed that the pyramiding of multiple resistant genes can improve disease resistance to rust.

Based on MAS combined with traditional breeding, some pyramids were aggregated into cultivars to improve resistance to stripe rust, leaf rust, and stem rust. Two stripe rust-resistant genes, *YrSM139-1B* and *YrSM139-2D* were pyramided into cultivar Shaanmai 139 [13]. Wheat lines pyramided with *Yr15* and *Yr64* both on chromosome 1BS provided high resistance to stripe rust [7]. Disease resistance of wheat cultivars aggregated *Lr16* and *Lr34* was higher than that of wheat cultivars possessing *Lr16* or *Lr34* [14]. Wheat cultivar HD2733 pyramided with two effective leaf rust resistance genes, *Lr19* and *Lr24* derived from Thinopyurm, improved resistance to leaf rust [15]. Resistance genes *Lr24* and *Lr28* were aggregated in wheat cultivar PBW343 resurrected the rust resistance of wheat [16]. The spring wheat line L503/W3534//L503 carrying *Sr22* and *Sr25* was highly effective for resistance to stem rust [17]. All the research suggested that pyramiding rust resistance genes into one cultivar can increase resistance to rust in wheat.

MAS pyramiding breeding of Fusarium head blight resistance genes

Wheat Fusarium head blight, also called scab, is caused by *Fusarium spp*. (FHB). To date, only seven FHB resistance genes have been named, from *Fhb1* to *Fhb7* [18]. Several combinations were studied by MAS combined with traditional breeding techniques. Wheat lines pyramiding *Fhb1* and *Fhb7* presented improved FHB resistance [18]. The *Fhb1*, *Fhb4* and *Fhb5* pyramiding could significantly reduce the FHB severity [19]. These studies showed that MAS has efficiently displayed the potential in improving FHB resistance breeding.

MAS pyramiding of various disease-resistance genes

Pyramiding various disease-resistance genes by MAS combined with traditional breeding techniques is an effective way to improve wheat disease resistance. Wheat cultivar Shannong 20 presented excellent disease resistance, which possesses 6 resistance genes to powdery mildew (*Pm12*, *Pm24*, *Pm30*, *Pm31*, *Pm35*, *Pm36*), 6 resistance genes to stripe rust (*Yr5*, *Yr9*, *Yr15*, *Yr24*, *Yr26*, *YrTp1*) and 2 resistance genes to leaf rust (*Lr21*, *Lr26*) [20]. Pyramiding of *Yr15*, *Yr40,* and *Lr57* in wheat cultivars can improve wheat resistance to rust [21]. Simultaneously aggregated 3 stripe rust resistance genes (*Yr5*, *Yr18*, *Yr20*) and 4 stem rust resistance genes (*Sr33*, *Sr36*, *Sr-cad*, *Sr43*) into Plateau 448 increased its stripe rust and stem rust resistance [22]. All these researches demonstrated that MAS combined with traditional breeding techniques is a new means to modify wheat disease resistance.

Conclusion

Because of the continuous variation of pathogens and single resistance sources, wheat varieties are threatened by loss of resistance. The combination of MAS with traditional breeding techniques has become a new idea in wheat disease resistance breeding. There are few instances of successfully pyramiding multiple disease resistance genes in a single material by molecular breeding means, and most studies remain in the laboratory stage. The pyramiding of various disease resistance genes into a variety is an important goal of breeding work, which requires continuous painstaking exploration by researchers.

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