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Application of Speed Breeding in Wheat

Yali Wang, Qiuxia Sun
Modern Agricultural Research Center, Cuixi Academy of Biotechnology, Zhuji, 311800, Zhejiang, China
Corresponding email: qiuxia.sun@cuixi.org
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Abstract Rapid breeding accelerates generational change by optimizing growth conditions, offering revolutionary potential for overcoming barriers in wheat breeding. This study analyzes the principles, applications, and future prospects of rapid breeding in wheat improvement with case studies, focusing on how it can be combined with emerging technologies to accelerate the development of wheat varieties with improved stress resistance, disease resistance, and nutritional quality. This study found that rapid breeding has promoted the rapid development of wheat varieties with stress resistance, disease resistance, and nutritional quality. Combined with CRISPR/Cas9 gene editing, multi-omics technology, and artificial intelligence optimization, rapid breeding has significantly improved the accuracy and efficiency of breeding. Case studies show that the combination of these technologies has accelerated the variety selection process by verifying key genes and optimizing the selection environment. In addition, projects in Australia, CIMMYT (International Maize and Wheat Improvement Center), and sub-Saharan Africa have demonstrated the large-scale application and impact of rapid breeding technology in addressing local and global wheat production challenges. Rapid breeding represents a paradigm shift in the field of wheat improvement, making it possible to develop more climate-resilient and high-yield varieties. Its combination with advanced biotechnology and precision tools makes it a key strategy to ensure global food security under environmental challenges.
Keywords Wheat; Rapid breeding; Variety improvement; Stress resistance; Genomic integration

1 Introduction

To be honest, it is not easy to grow wheat now. Think about it, the weather is getting hotter and the rain is irregular (Hossain et al., 2021), not to mention the diseases that pop up from time to time. Although some places can still maintain their yields (Cai, 2024), overall, drought and high temperatures have indeed made wheat grow worse than before. But the problem is more than that. Now the global population is rising (Fiyaz et al., 2020), and the demand for food is also increasing. The current yield is definitely not enough (Bhatta et al., 2021). In theory, breeding technology should be able to solve the problem, but in fact, progress is not so fast (Watson et al., 2017). According to this trend, if we don't find a way to improve wheat yield and quality quickly (Watson et al., 2018), the future will be difficult.

Wheat breeding has never been easy, mainly because its genome is too complex. The hexaploid structure, coupled with a large number of gene duplications, makes it very difficult to figure out the genetic mechanism of a certain trait (Li et al., 2021). Sometimes you think you have found a key gene, but it turns out to be just one of them, or it has no practical effect at all. Moreover, the growth cycle of wheat is not short, and it takes a lot of time to breed from generation to generation (Watson et al., 2017; 2018). This pace is difficult to keep up with the demand for rapid iteration of new varieties in modern agriculture. Therefore, the efficiency of breeding using traditional methods is naturally not very high.

Under natural conditions, wheat can only grow two or three generations a year, and it is actually quite difficult to speed up the process (Watson et al., 2017; 2018; Fiyaz et al., 2020). However, there is a method called "speed breeding", which changes the idea: instead of relying on the variety itself, it adjusts its growth environment, such as light, temperature and sunshine time. In a controlled environment, this set of methods can easily produce six generations of wheat a year. It sounds like a radical method, but it actually cooperates well with advanced methods such as high-throughput genotyping, genomic selection, and even gene editing (Watson et al., 2017; 2018; Bhatta et al., 2021). Overall, the speed has increased and the breeding cycle has indeed been shortened a lot.

This study intends to start with actual cases to see how much speed breeding has played a role in wheat, especially its performance in dealing with the old problem of "slowing down progress" in traditional breeding. Now the global demand for wheat is increasing, and the yield must keep up, and the stress resistance must be stronger. This study does not only look at speed breeding itself, but also wants to understand whether it can create new sparks when combined with other technologies, such as combined gene editing and high-throughput screening, hoping to eventually breed wheat varieties that are both high-yielding and resistant, and take a more sustainable path.

2 Principles and Implementation of Speed Breeding

2.1 Definition and concept of speed breeding in controlled environments

In the final analysis, the slow breeding speed is often because the plants themselves "are not in a hurry to grow". But if we change our thinking, can the environment give it a push? This is how speed breeding came about. It is not about changing genes, but adjusting growth conditions such as light and temperature to allow plants to run more rounds in a year. For example, wheat usually has only two or three generations a year in a greenhouse, but under the speed breeding setting, six generations are not a problem (Watson et al., 2018; Amalraj, 2021; Bhatta et al., 2021). This technology is neither new nor simple. The key is whether the breeding time can be shortened so that new varieties can be put into use earlier.

2.2 Core technologies of speed breeding

In speed breeding, a common trick is to extend the light duration. Not all plants can adapt to it, but crops such as wheat respond well. Generally, plants are exposed to light for 22 hours a day, leaving them with only 2 hours of darkness. This arrangement is actually quite particular. On the one hand, it promotes photosynthesis, and on the other hand, it does not completely disrupt their biological rhythms (Watson, 2019; Raju and Sagar, 2020; Amalraj, 2021). Interestingly, this long-term lighting not only makes plants grow faster, but also activates some genes related to the biological clock, and the entire development rhythm is brought up.

Not all growing environments are suitable for speed breeding. If there is a slight deviation in temperature and humidity, the plants will easily have problems. For common crops such as wheat and barley, the daytime temperature is generally controlled at 22 °C, and the night temperature is reduced to 17 °C, and the humidity is maintained between 60% and 70% (Raju and Sagar, 2020; Bayhan et al., 2022). This sounds very specific, but it is actually to prevent the plants from being too "tired"-neither too hot nor too dry. Through these settings, plants can be less stressed by the environment in the growth room or greenhouse and grow more robustly.

Sometimes, temperature and humidity control alone is not enough, and speed breeding also needs some "hardware" support. For example, hydroponics, which is slow to grow in soil and difficult to control water and nutrients, can directly provide nutrient solution to the root system, so plants absorb it quickly and grow quickly. In addition, LED lights can save energy on the one hand, but more importantly, they can adjust the wavelength and extend the duration of lighting, making them much more flexible to use than traditional lights (Ghosh et al., 2018; Watson et al., 2018; Fiyaz et al., 2019). These technologies are not new when taken alone, but when used together, they can push plants forward from generation to generation, and the efficiency will be improved.

2.3 Establishment of speed breeding platforms

To achieve speed breeding, it is not enough to have technical ideas, the environment must keep up. Therefore, building a platform has become a key step. Generally speaking, such platforms are some fully equipped growth rooms or greenhouses, which can adjust things like light, temperature, and humidity, and when necessary, add technology to promote plant growth. Not all crops adapt in the same way, but some crops like wheat, barley, and rapeseed respond quite well (Bhatta et al., 2021; Song et al., 2021; Bayhan et al., 2022). According to research, it is not uncommon for this system to produce six generations a year, and it has indeed significantly promoted the progress of breeding.

3 Application of Speed Breeding in Wheat

3.1 Integration of genomic selection with speed breeding

To achieve speed breeding, it is not enough to have technical ideas, the environment must keep up. Therefore, building a platform has become a key step. Generally speaking, such platforms are some fully equipped growth rooms or greenhouses, which can adjust things like light, temperature, and humidity, and when necessary, add technology to promote plant growth. Not all crops adapt in the same way, but some crops like wheat, barley, and rapeseed respond quite well (Bhatta et al., 2021; Song et al., 2021). According to research, it is not uncommon for this system to produce six generations a year, and it has indeed significantly promoted the progress of breeding.

3.2 Development of stress-tolerant wheat varieties

Speed breeding is indeed quite good at breeding stress-tolerant varieties, especially when faced with abiotic stresses such as drought and high temperature. Interestingly, this method does not wait for natural disasters to occur before testing, but directly "artificially creates difficulties" in a controlled environment, such as limiting water to simulate drought. In this way, it is clear at a glance which wheat genotypes can withstand it (Fiyaz et al., 2020; Bayhan et al., 2022). Of course, not every genotype reacts equally quickly, so with the high-frequency generation update of speed breeding, the outstanding ones can be screened out in a short period of time. Compared with traditional methods, this pace is obviously much faster, and it also makes the development and testing of new varieties more flexible and closer to actual environmental needs (Watson et al., 2017; 2018).

3.3 Breeding for disease resistance

Diseases have always been a headache in wheat breeding, especially diseases like rust and wilt. Once they break out, the yield will drop immediately. But then again, the pace of traditional breeding is too slow and it is difficult to keep up with the speed of pathogen mutation. Speed breeding is particularly practical in this regard. It can greatly speed up the replacement of generations and introduce disease-resistant genes into new strains as quickly as possible. Moreover, under controlled conditions, a large number of materials can be tested for disease resistance at one time, so the efficiency of screening resistant genotypes is also improved (Watson, 2019; Fiyaz et al., 2020; Bhatta et al., 2021). Furthermore, once speed breeding is used in conjunction with technologies such as genomic selection and MAS, not only the breeding pace is accelerated, but also the aggregation of resistance genes is more accurate. Watson (2019) mentioned that after combining rapid breeding and genomic selection, the entire breeding process is more than a little faster. After the introduction of PCA, trait evaluation becomes more intuitive; and multivariate GS can also take into account the relationship between multiple traits to improve genetic gain (Figure 1). This set of methods can indeed help select wheat varieties with strong disease resistance and stable performance more quickly (Amalraj, 2021; Song et al., 2021).

3.4 Quality improvement and functional breeding

Speed breeding is a very useful method for wheat breeding now, especially when you want to improve wheat quality. Think about it, traditional breeding takes several years, but speed breeding can shorten the cycle and screen out wheat with high protein content and good baking performance more quickly (Watson et al., 2017). Of course, speed alone is not enough. The key is that it can accurately adjust the growth conditions under a controlled environment, which makes it easier to study which genes determine quality. But then again, speed breeding alone may not be enough, so it is often combined with gene editing and high-throughput phenotyping analysis (Watson et al., 2018), so that genetic modification is more targeted and more efficient. The ultimate goal is nothing more than to breed wheat that better meets the needs of food processing and consumer tastes (Fiyaz et al., 2020). After all, the market is the hard truth.

4 Potential of Combining Speed Breeding with Emerging Technologies

4.1 Speed breeding and CRISPR/Cas9 gene editing

CRISPR/Cas9 gene editing is indeed a good thing for wheat breeding now. Chen et al. (2019) said that this technology is fast and accurate, much better than traditional hybrid breeding. Think about it, in the past, hybridization or mutagenesis was not only time-consuming, but also the modified traits were random. Now it is much easier to edit genes directly, and it will not bring in messy linked traits (Figure 2). However, gene editing alone is not enough. It must be combined with a speed breeding platform to quickly verify the editing effect. In this way, good traits such as high yield and stress resistance can be stabilized faster, and the most important thing is that there is no need for genetic modification (Liang et al., 2017). Of course, the final cultivated varieties must be able to adapt to different environments, which is the key point (Li et al., 2021; Bonea, 2022).

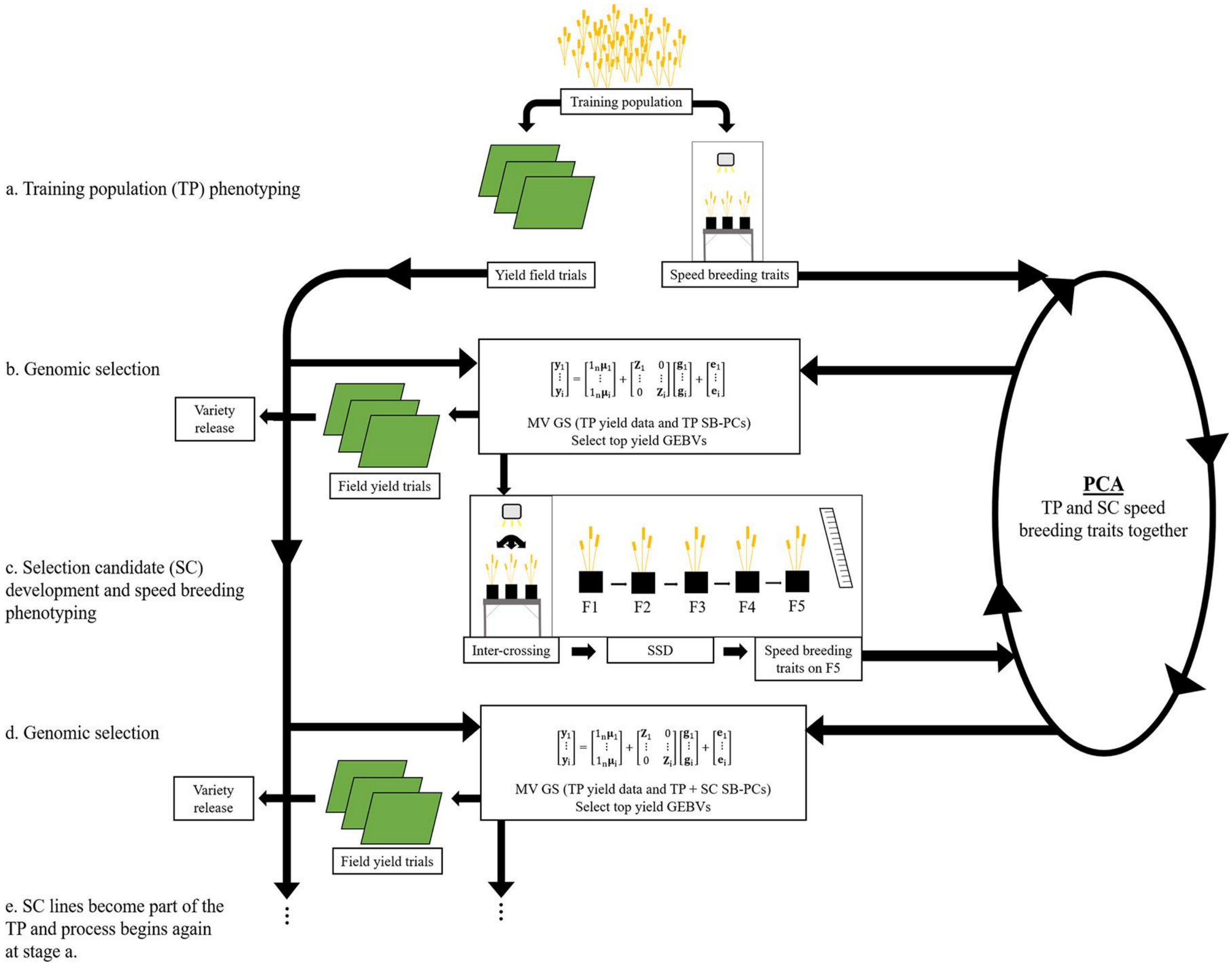

Figure 1 Breeding strategy incorporating speed breeding (SB), selection candidate (SC) population development, and multivariate genomic selection (GS) (Adopted from Watson, 2019)

Image caption: (a) Training population (TP) phenotyping for yield and SB traits is followed by principal component analysis (PCA) to derive SB principal components (SB-PCs). These are then used in (b) multivariate GS (based on own phenotypes) to select parents for SC population development and advanced yield trials. (c) Combined intercrossing of selected lines, single seed descent (SSD) from F1 to F5, and phenotyping of the F5 plants under SB conditions. The SB traits undergo PCA with the SB traits of the TP to derive the SB-PCs, and (d) multivariate GS is performed to determine which F5 lines will go into field trials. (e) The selected SC lines become part of the TP for the next cycle, beginning with the first stage. GEBV, genomic estimated breeding value; MV, multivariate (Adopted from Watson, 2019)

When it comes to wheat breeding, there is now an interesting combination-CRISPR/Cas9 plus speed breeding. Did you know that using CRISPR/Cas9's ribonucleoproteins (RNPs) to edit wheat genes can produce non-transgenic mutants in as fast as 7 to 9 weeks (Liang et al., 2017), and basically no other genes will be harmed by mistake? This is much faster than traditional methods! Of course, speed alone is not enough, the key is that this speed just matches the rhythm of speed breeding. To put it bluntly, the precise editing ability of CRISPR/Cas9, coupled with the rapid verification characteristics of speed breeding, is simply a match made in heaven.

Speaking of wheat breeding, there was a very interesting experiment recently-they used CRISPR/Cas9 technology to tinker with the FT1 flowering gene of wheat. This gene is very critical. If modified, it can regulate the flowering time of wheat (Chen et al., 2019), allowing wheat to adapt to different seasons and climates. Of course, just modifying the gene is not enough, and the actual effect must be seen. But then again, this kind of precise editing is indeed much faster than traditional methods (Li et al., 2021), and the effect is more controllable.

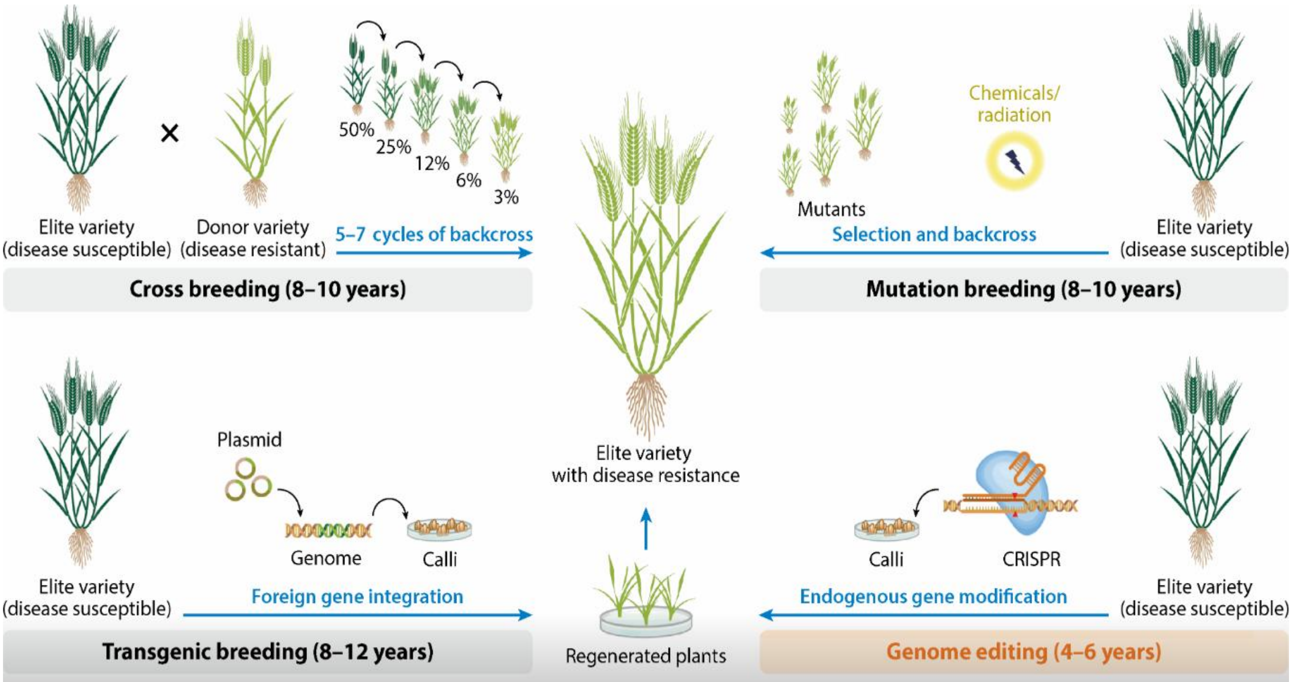

Figure 2 Comparison of breeding methods used in modern agriculture (Adopted from Chen et al., 2019)

Image caption: Cross breeding: improving a trait (e.g., disease resistance) through crossing an elite recipient line with a donor line and selecting outstanding progeny with the desired trait. To introduce the desired trait from the donor line into the elite recipient line, the selected progeny must be backcrossed with the recipient line for several generations to eliminate unexpected linked traits. Mutation breeding: improving a trait using chemical or physical mutagens to treat plant materials (such as seeds) and generate mutants via random mutagenesis. Transgenic breeding: improving a trait by purposefully transferring exogenous genes into elite varieties. Genome editing: improving a trait by precisely modifying the target genes or regulatory elements or rearranging chromosomes in elite varieties (Adopted from Chen et al., 2019)

4.2 Application of multi-omics technologies

Nowadays, it is a bit difficult to keep up with the pace of crop breeding by relying solely on traditional methods. In fact, new technologies such as transcriptomics and metabolomics are quite useful (Bortesi and Fischer, 2015). Although they may seem complicated at first, they can help us see clearly what is going on with important traits such as crop stress resistance. To put it bluntly, these technologies can be used to find key genes and metabolic pathways (Zhang et al., 2016), so that when doing speed breeding, you can take fewer detours and the efficiency will naturally increase. Of course, the specific operation depends on the actual situation, but it is indeed much better than breeding blindly.

When it comes to studying crop stress resistance, a single method is not enough. You see, transcriptomics can tell us which genes are "active" under different environments, but this is only part of the story. In fact, metabolomics and proteomics are more practical, and they directly find out the metabolites and proteins that really work (Bhowmik et al., 2018). Although these technologies have their own focuses, using them together can make complex traits clear. Just like a puzzle, each piece may not be interesting when viewed separately, but only when they are put together can you know what the complete picture looks like.

There was a very interesting study recently, in which they used a multi-omics approach to study wheat salt tolerance. To be honest, looking at gene expression alone may not be enough, but when the transcriptome, metabolome, and proteome data are analyzed together (Bhowmik et al., 2018), things become much clearer. They not only found the key salt-tolerant genes, but also figured out the related metabolic pathways. Although it is quite complicated in practice, these findings are really helpful-now breeders can use this information to more specifically select salt-tolerant wheat varieties (Cui et al., 2019). Of course, there is still a way to go from the laboratory to the field, but at least the direction is clear.

4.3 Integration of artificial intelligence (AI) with speed breeding

AI has really helped a lot in speed breeding now. Think about it, breeding experiments often generate massive amounts of data, and it would be exhausting for humans to analyze them, but AI algorithms can handle these much more easily. Although it may seem unreliable at first, in actual use, AI can not only find the best conditions such as light and temperature (Biswas et al., 2021), but also predict the success rate of breeding. Of course, predictions are predictions, and in the end it depends on the actual situation. But then again, using machine learning models to analyze historical data (Fang, 2024) can at least avoid a lot of detours, save time and resources.

Recently, there has been an interesting attempt to use AI to adjust the lighting conditions of wheat. Think about it, traditional breeding basically relies on experience in lighting control, but the AI system can adjust the light intensity and duration in real time (Ansari et al., 2020), which makes things much simpler. Although you may feel that high technology is not grounded at first, it can help breeders lock in high-yield wheat more quickly in actual use. Of course, light is only one of the influencing factors, but this case at least proves that AI can indeed come in handy in speed breeding.

5 Advantages and Limitations of Speed Breeding in Wheat

5.1 Advantages of speed breeding

Speed breeding (SB) is really a good thing for wheat breeding now. Just think about it, ordinary greenhouses can only produce two or three generations a year, but with SB technology, spring wheat can be grown up to six generations. This mainly relies on adjusting light and temperature, which is to make wheat grow faster (Fiyaz et al., 2020). However, speed alone is not enough. The key is that it can be used in conjunction with new technologies such as genomic selection (GS) (Bhatta et al., 2021). For example, when combined with GS, it can not only improve the accuracy of yield prediction, but also screen out good varieties earlier (Watson, 2019). Although it takes some effort to operate, it is indeed much more efficient than traditional methods (Watson et al., 2019).

When it comes to the benefits of speed breeding (SB), saving money is a real deal. Think about it, using LED lighting not only makes wheat grow faster (Watson et al., 2017), but the electricity bill is also much cheaper than traditional lighting (Watson et al., 2018). Of course, saving money is not enough. The key is that SB can handle large-scale phenotypic and genotypic testing at the same time. Although it takes some effort to operate, rapid cycle generations can indeed accumulate more data (Samantara et al., 2022), and you will have a better idea when selecting varieties. Especially for studies such as QTL positioning (Song et al., 2021), the controlled environment advantage of SB comes out-the temperature and light can be adjusted as you want, which makes it much easier to find excellent alleles.

5.2 Technical and infrastructural limitations

Although speed breeding is useful, it is not a panacea. The first is the equipment problem-you need a special growth chamber that can precisely control light and temperature, which is not cheap and puts a lot of pressure on small breeding units (Fiyaz et al., 2020). Another troublesome thing is that rapid reproduction can easily lead to inbreeding. Although it has a quick effect in the short term, it may narrow the gene pool in the long run. So now some teams are starting to try to do more random hybridization in the early stages, but the specific effect remains to be seen.

When it comes to the application of speed breeding (SB), the effects may vary greatly depending on the crop type. For example, long-day crops such as wheat are easy to use, but if you switch to short-day or perennial crops, you have to readjust the plan (Samantara et al., 2022), which is really troublesome. There is also a practical problem-environmental pressures such as water shortage (Bayhan et al., 2020), which may reduce the yield. Although SB runs fast in the laboratory, new varieties have to wait for slow processes such as field testing and approval to be truly implemented (Watson, 2019), and it is also a headache if the pace of the two sides is not in sync.

5.3 Genetic diversity and environmental adaptability

Speed breeding (SB) can really help a lot in wheat breeding now. Think about it, it takes several years for traditional breeding to accumulate genetic variation, but SB can quickly accumulate these variations (Watson et al., 2019), so that the varieties bred in this way are more adaptable (Bhatta et al., 2021). However, SB alone may not be enough. It would be better if it is combined with genomic selection-directly select those traits that perform well in the field (Watson, 2019), and the ability of new varieties to adapt to different environments will naturally increase. Although it takes some effort to operate, it is better than waiting slowly.

Speed breeding (SB) is fast, but if it is not done properly, it will narrow the gene pool. If you select too hard and change generations too quickly, it is easy to make the varieties "inbreeding". However, there are ways to deal with this (Jighly et al., 2019), such as finding a few more varieties with different "parents" to breed, or specifically adding traits with strong adaptability. Although it takes more effort, it is better than having a bunch of "twin brothers" in the end, don't you think?

6 Case Studies of Speed Breeding in Global Wheat Breeding

6.1 The australian speed breeding program

Australia is quite good at breeding drought-resistant wheat. They transferred the drought-resistant gene *TaDREB3* into different varieties of wheat, and the effect was good-it not only improved drought resistance, but also did not delay normal growth. Of course, genetic modification alone is not enough. They also combined traditional breeding methods, such as genetic analysis and trait screening (Mwadzingeni et al., 2016), and slowly "accumulated" drought resistance (Khadka et al., 2020). Although the process was quite troublesome, in the end, several good varieties that are drought-resistant and high-yielding were indeed produced (Langridge and Reynolds, 2021).

The drought-resistant wheat varieties recently introduced by Australia are indeed quite effective. Take the variety with the *TaDREB3* gene (Shavrukov et al., 2016), which can withstand 21.5% more yield than ordinary wheat in severe drought (Figure 3). Although there are always people who grumble about genetically modified crops, the actual data is there-the survival rate in drought-prone areas is high. Of course, not all drought-resistant varieties are so effective, but this case at least proves that speed breeding for drought-resistant wheat is indeed effective.

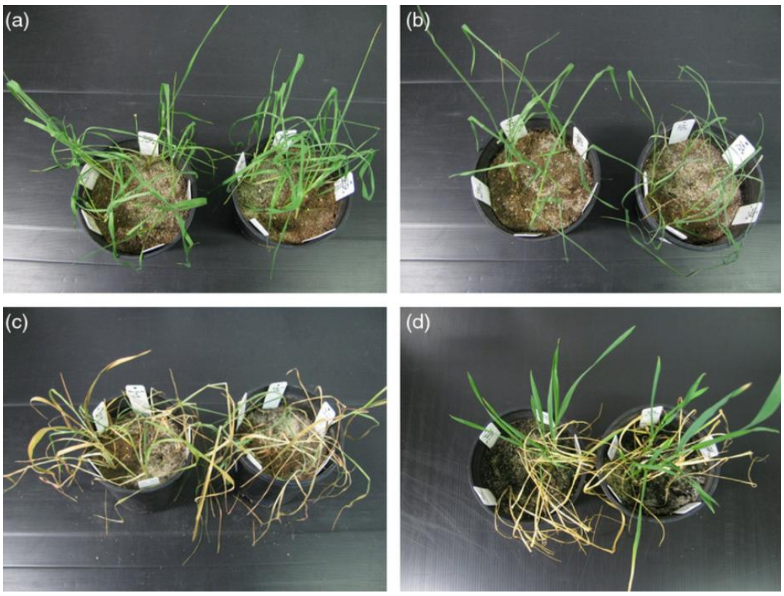

Figure 3 Images of plants at different stages of the drought survival test (Adopted from Shavrukov et al., 2016)

Image caption: (a) the day on watering was withheld, (b) day six of drought, (c) day 12 of drought, immediately before re-watering, (d) 1 week after re-watering. Each pot contained five plants including WT, a null-segregant and three plants from each of three randomly selected independent F2BC3 transgenic lines (Adopted from Shavrukov et al., 2016)

6.2 CIMMYT speed breeding facilities

CIMMYT (International Maize and Wheat Improvement Center) has been doing some interesting wheat breeding recently. They used speed breeding, mainly in growth chambers that can precisely control the environment (Ahmad et al., 2022). Although it may seem too technical at first, the actual effect is quite good-especially for wheat rust, the breeding cycle has been significantly shortened. Of course, they may not be able to do it alone, so they have also brought in partners from all over the world to work together. This not only speeds up the screening of disease-resistant varieties, but also improves the nutritional value of wheat, which is a two-pronged approach.

CIMMYT is working on wheat rust resistance breeding, and speed breeding has really helped a lot. Think about it, it used to take several years to screen disease-resistant genotypes, but now with high-throughput phenotyping and genomic selection, the efficiency is much higher. Although the equipment investment is not small, the rust-resistant varieties produced in this way can be delivered to farmers faster. Of course, technology alone is not enough, the key is that they cooperate with various places to speed up the entire process.

6.3 Implementation in developing countries

It is a bit contradictory to do speed breeding in low-income countries. On the one hand, this technology can indeed speed up breeding (Watson et al., 2018), but the reality is that the equipment is expensive, the electricity bill is high, and many places do not even have basic laboratories. But then again, if the plan can be adjusted according to local conditions and international organizations can be brought in to help, it may really be possible. Although there are many difficulties, it is better than waiting.

Wheat breeding in sub-Saharan Africa is not easy, as water shortages and droughts are commonplace. However, they have made a name for themselves by using speed breeding-they specifically select varieties that are water-saving and drought-resistant (Chowdhury et al., 2021). Although advanced breeding equipment is not available whenever you want, they have relied on existing conditions to develop several wheat varieties that can withstand the harsh local climate (Shahid et al., 2022). This is a simple matter, just focus on the most critical traits such as water use efficiency, and the effect is better than those fancy ones.

7 Future Directions and Research Priorities

7.1 Integration of speed breeding with precision breeding

In crop breeding, the combination of new technologies such as speed breeding and genomic selection has really worked well. Take wheat breeding for example. This combination not only shortens the breeding cycle, but also increases the genetic progress achieved each year (Voss-Fels et al., 2019). Although the initial investment may be relatively large, high-throughput phenotyping in a controlled environment (Fiyaz et al., 2020) does make it more accurate to select traits (Bhat et al., 2023). In the final analysis, we need to cope with both population growth and climate change. It is really necessary to develop new varieties that are high-yield and resistant to stress (Bhatta et al., 2021). Of course, every link needs to be closely monitored in the specific operation, but it is better than fighting alone.

7.2 Environmentally friendly speed breeding technologies

When it comes to speed breeding, everyone is now thinking about how to make it more environmentally friendly. In fact, using LED lights is a good way (Watson et al., 2017)-saving both electricity and money (Watson et al., 2018), killing two birds with one stone. However, just changing the light bulb is not enough. Recently, some people have tried to adjust parameters such as lighting time, temperature and humidity (Raju and Sagar, 2020) to make the indoor environment closer to the natural state. Although the effect remains to be seen, at least the direction is right. After all, we must ensure breeding efficiency and reduce the impact on the environment (Song et al., 2021). This matter still needs to be explored.

7.3 Speed breeding strategies for climate change adaptation

Speed breeding is indeed a good helper in crop breeding, especially in dealing with climate change. Think about it, traditional breeding takes five or six years to see results (Watson, 2019), but now speed breeding may produce new varieties that are drought-resistant and salt-tolerant in two or three years (Bhatta et al., 2021). Of course, speed alone is not enough, it must be accompanied by technologies such as genomic selection and phenotypic analysis (Samantara et al., 2022), so that good traits can be found more accurately. But then again, climate conditions vary from place to place, and special plans will have to be developed for different regions in the future (Voss-Fels et al., 2019). After all, varieties that work well in India may not be suitable for Africa (Fiyaz et al., 2020). Although there are many challenges, someone has to do it, right?

7.4 Multidisciplinary collaboration and international cooperation

When it comes to speed breeding, you can't do it alone. If you look at the projects that have been done well, they are all the work of geneticists and agronomists. To be honest, laboratory data alone is not enough. Field trials and big data experts must be involved (Bhat et al., 2023) to make the plan more reliable. International cooperation is also crucial. Last year, we exchanged a batch of wheat germplasm resources with India, and the effect was better than expected. However, this kind of cooperation must be maintained for a long time (Song et al., 2021). After all, climate change is not something that any country can solve on its own. In the final analysis, to deal with major issues such as food security, experts from all over the world must work together to find solutions. Although coordination is troublesome, looking at the progress made in recent years, the effort is worth it.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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