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Study on Carbon Reduction Planting Strategy of Cotton Based on Genomic Information

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Abstract Cotton production is a major contributor to agricultural greenhouse gas emissions due to high input requirements and land-use intensity. In response, genomic technologies have emerged as transformative tools for developing sustainable, low-carbon cotton farming systems. This review systematically explores the carbon footprint of conventional cotton cultivation and evaluates how genomic insights can be leveraged to mitigate emissions. We examine gene networks linked to carbon use efficiency, stress tolerance, and nutrient utilization, and discuss the application of marker-assisted selection, genomic prediction, and gene editing to breed low-carbon cultivars. Additionally, the integration of genomics with precision agronomic practices and root microbiome research is addressed for enhancing carbon sequestration. A life cycle assessment (LCA) framework is proposed to align genomic strategies with environmental impact metrics, and a regional case study from Xinjiang demonstrates measurable benefits of such an integrated approach. Ultimately, this review underscores the potential of genomic innovation to guide carbon-reduction planting strategies, paving the way for climate-resilient and environmentally responsible cotton production.
Keywords Cotton genomics; Carbon footprint; Low-carbon breeding; Precision agriculture; Life cycle assessment

1 Introduction

Cotton is not considered "high carbon" by everyone, but it is indeed a source of global carbon emissions that cannot be ignored, especially in the use of fertilizers and water. Many areas still stick to the old high-input routine of planting cotton, spreading more nitrogen fertilizers and irrigating more water. The yield has increased, but the cost is not small-both the environment and the cost are affected (Zhu and Luo, 2024). Excessive use of nitrogen fertilizers is not just a matter of money. Soil degradation and greenhouse gas release are real consequences. But not all cotton varieties are the same. Different genotypes perform very differently in carbon and nitrogen utilization. Some varieties are naturally "saving materials", while others "eat more". This also makes us realize that it is unrealistic to manage all cotton fields with a unified standard. We have to find a way to optimize these metabolic pathways, otherwise it is not enough to just reduce fertilizers (Iqbal et al., 2020; Iqbal et al., 2022).

In fact, in recent years, cotton genome research has made rapid progress. Compared with the past, it is not only possible to sequence, but also to "modify" it (Wang and Zhang, 2024). Through gene editing or functional analysis, researchers can now identify genes that are closely related to carbon and nitrogen metabolism and have ways to regulate them (Yang et al., 2022; Kun et al., 2025). Not only for high yield, but also for the hope that these improved cotton varieties can save resources and have fewer emissions.

This study does not intend to talk about how to grow cotton from beginning to end, but hopes to sort out the current research results around a core issue-"how to grow and manage low-carbon cotton". The focus will be on several aspects: the genetic basis of carbon and nitrogen metabolism, the progress of breeding technology, and the actual planting strategies in the field. We also hope to provide some practical information and inspiration for those engaged in cotton breeding, management and policy research.

2 The Carbon Footprint of Cotton Production

2.1 Sources of greenhouse gas emissions across the cotton cultivation cycle

During cotton production, greenhouse gas (GHG) emissions come mainly from several sources: fertilization, especially nitrogen fertilizer; electricity used during irrigation; and agricultural film used. These links have a significant impact on carbon emissions during the planting phase. In particular, fertilization and irrigation are key causes of increasing emissions (Xiao et al., 2024). In addition, emissions continue to be generated during the post-harvest processing phase of cotton, such as ginning, spinning, dyeing, and post-processing. Dyeing, in particular, accounts for a large portion of the carbon footprint of the entire textile process (Amin et al., 2021). Although cotton can absorb some carbon dioxide through photosynthesis while growing, this absorption is usually not enough to offset emissions from fertilization and electricity use (Singh et al., 2021; Sun et al., 2024).

2.2 Comparative carbon intensity of conventional vs. sustainable practices

Whether cotton yield is high or not is sometimes directly proportional to the amount of input. Especially in the traditional planting model, applying more fertilizer and using more water can indeed maintain the yield, but the cost is also obvious. Data from many cotton-growing areas in China show that carbon emissions per unit area can fluctuate between 2 958 and 6 220 kg of carbon dioxide equivalent per hectare (Yang et al., 2025), with a significant difference. The key lies in the management method and input intensity. Of course, it does not mean that low input will definitely lead to low yield. Some areas have begun to try more energy-saving planting methods, such as reducing the amount of chemical fertilizers, improving irrigation systems, or changing their thinking and using cover crops to help the soil "recover blood" (Figure 1). For example, using February orchids to cover the surface and then appropriately reducing nitrogen fertilizers is said to be able to reduce carbon emissions to less than a quarter of the original. Specifically, some studies say that it has dropped by 76% (Wang et al., 2021). To give another example, traditionally cotton is followed by wheat, which is a common rotation method. However, if cotton and legumes are intercropped and transplanted, carbon emissions can be reduced by almost half (Rajpoot et al., 2021). Don't underestimate this adjustment. The amount of carbon saved is very considerable when it is promoted on a large scale. As for the subsequent processing links, such as dyeing, there is actually room for emission reduction. Especially the new non-water dyeing method, which is not only environmentally friendly, but also much more energy-efficient than traditional dyeing. Some studies have shown that this type of process can reduce the carbon footprint of the textile process by about half (Li et al., 2024). Therefore, from the field to the factory, every link can be optimized.

Figure 1 Cotton field before February orchid turning over (Adopted from Wang et al., 2021)

2.3 Climate change feedbacks and the urgency for carbon reduction

Climate change has already brought many challenges to cotton cultivation, such as affecting yields and water use. Sometimes, more carbon dioxide in the air may lead to higher cotton yields and less water use. But if temperatures continue to rise and climate fluctuations increase, these benefits may be offset, especially in cotton fields that are not irrigated and rely solely on rain (Jans et al., 2021). Carbon emissions from cotton production will in turn exacerbate climate change, and climate change will affect cotton yields. This "interaction" situation makes people more aware that low-carbon measures must be taken now. If traditional high-emission planting methods are not changed immediately, future climate problems will become more and more serious, and cotton yields and the ecological environment will be threatened (Huang et al., 2022).

3 Genomic Insights into Cotton Physiology and Environmental Adaptation

3.1 Identification of genes linked to carbon use efficiency (CUE)

Recent studies have found many key genes and related pathways that control carbon metabolism and resource utilization efficiency through genomic analysis of cotton. With the development of genome sequencing and population genetics research, researchers have discovered many genetic differences, such as some haplotypes and gene loci related to environmental adaptation, as well as traits related to carbon utilization efficiency (Yang et al., 2022). For example, through genome-wide association analysis (GWAS), researchers have located regions on certain chromosomes that are related to environmental adaptability. The genes contained in these regions can be used to breed cotton varieties with higher carbon efficiency (Wang et al., 2017; Dai et al., 2020).

3.2 Functional genomics of drought, heat, and nitrogen-use traits

Scientists now use functional genomics methods, such as transcriptome analysis and gene expression mapping, to find many genes related to drought, high temperature and nitrogen use efficiency. These genes show obvious changes when facing adverse environments. Many pathways involved in stress response are related to secondary metabolite synthesis, plant hormone transmission and defense mechanisms (Dev et al., 2024). Some important transcription factor families, such as ERF, NAC and bZIP, and some key regulatory genes are also considered to play a core role in adapting to stress (Tahmasebi et al., 2019). Through QTL positioning and GWAS methods, scientists have also found gene regions that can improve cotton yield and quality under drought or high temperature environments. These findings will help breed cotton varieties that are both stress-resistant and resource-saving (Saranga et al., 2001).

3.3 Omics-based modeling of growth-carbon allocation dynamics

Studying how cotton grows and how carbon is divided is not as simple as just looking at one gene. Now, scientists no longer work alone, but analyze the genome, transcriptome, and proteome data together to try to piece together a "dynamic panorama" of cotton in various environments. Interestingly, some key genes do not only work alone, but "group" with other genes. Using the method of systems biology, researchers found gene modules that appear together in the expression map when plants are under stress or undergoing cell wall development. These modules are like "operating teams" to respond to environmental changes, and also provide us with a new perspective to understand how carbon is used and how plants grow (Wen et al., 2023). However, the structure of genes is not a monolithic entity. Sometimes, it is not the function of a gene that changes, but its structure-such as the deletion or insertion of a gene segment, or some epigenetic modifications. These differences may not be conspicuous, but they may be the key to cotton's ability to adapt to complex environments and use carbon more efficiently. High-quality genome assembly and alignment allow these subtle but important variations to be found one by one (Lu et al., 2022).

4 Breeding Low-Carbon Cotton Cultivars

4.1 Marker-assisted and genomic selection for carbon-efficient traits

In the past, cotton variety selection relied on some experience of "looking at seedlings to identify seeds". But now it is different. Molecular marker-assisted selection (MAS) and genomic selection are increasingly used in breeding, especially in the matter of improving carbon efficiency. Whether photosynthesis is strong, whether nitrogen fertilizer is used sparingly, whether it can withstand drought-these characteristics can now be judged at the genetic level. Of course, the premise is that there must be a reliable reference genome and genetic markers linked to the target traits. With these "positioning points", breeders can save a lot of time in the test field and directly screen plants at the molecular level (Conaty et al., 2022). To put it bluntly, you don't have to wait for it to grow up to know where its potential is. This method is not only fast, it also improves efficiency, and is particularly suitable for breeding under conditions where resources are not so abundant. Low investment and high hit rate-the selected cotton not only has a stable yield, but also uses nutrients and water more reasonably. For carbon emission control, this is undoubtedly a more realistic breeding path.

4.2 Utilization of gene editing (e.g., CRISPR/Cas9) to reduce carbon cost of growth

Now, gene editing technology, especially the CRISPR/Cas9 system, provides breeders with a way to directly modify genes. These genes are related to carbon metabolism, stress resistance, and the efficiency of fertilizer and pesticide use. Using this type of technology, researchers can precisely improve certain specific functions, such as making photosynthesis more efficient or making cotton less dependent on chemical fertilizers, so that the carbon emissions of the entire planting process can be reduced (Shahzad et al., 2022). The introduction of gene editing makes rapid and accurate genetic improvement possible, and also provides an important supplement to traditional breeding and molecular marker selection.

4.3 Integration of wild relatives and landraces with low-input resilience

Not all cotton is shaped by modern breeding technology. Some old varieties and wild relatives of cotton may look "inconspicuous", but they actually contain a lot of valuable genetic resources. Traits such as drought resistance, insect resistance, and strong nutrient absorption capacity are common in them. They do not rely on high-intensity management, but can survive well under limited conditions. In terms of carbon emission reduction, the value of such varieties is becoming more and more important. Because the investment is not high and the yield is stable, it is naturally more in line with the current planting needs than those "high-consumption" varieties (Sreedasyam et al., 2024). Therefore, many breeding projects are now beginning to re-examine these local species and wild relatives, thinking about how to integrate their advantages into modern cotton lines. Of course, it is not easy to introduce these traits. It takes some technical means such as comparative genomics and gene introgression to introduce characteristics such as stress tolerance and energy saving without destroying the core advantages of the main varieties. The goal is clear: to cultivate cotton varieties that adapt to low investment and support sustainable development, and these resources are just the breakthrough.

5 Optimizing Agronomic Practices Through Genomic Prediction

5.1 Genotype-by-environment (G×E) interaction modeling for site-specific strategies

The performance of cotton is often influenced by the interaction of genes and environment (G×E). Understanding this interaction is necessary to tailor management methods to different locations. Now, the development of environmental omics allows people to use genomic data and environmental information together to use more efficient methods to predict the performance of cotton in different environments. By incorporating the influence of G×E into the prediction model, breeders and agronomists can find the combination of cotton varieties that best suits a certain plot of land, so that higher-yield cotton can be grown locally with fewer resources (Gevartosky et al., 2021; De Coninck et al., 2016). This approach can help develop low-carbon planting methods that are more suitable for local conditions.

5.2 Precision irrigation and fertilization guided by genomic data

Many times, fertilization and irrigation still rely on experience. But in recent years, the situation has changed. More and more studies have begun to try to apply genomic data to field management, especially in the field of precision irrigation and precision fertilization. It is not to say that genes alone can determine how much water to use and how much fertilizer to apply, but they can indeed provide some useful clues. Especially when these data are combined with multi-omics information and machine learning technology, the ability of predictive models has become much stronger. They can not only predict the performance of certain cotton varieties under specific water and fertilizer conditions based on different genotypes, but also take environmental factors into account. For example, deep learning models and multi-trait analysis models can now integrate phenotypic, genetic and climate data to assist decision-making (Bhatta et al., 2020; Tong and Nikoloski, 2020). Of course, this type of method is not a panacea, but it is much more efficient than traditional blind irrigation and fertilization. On the one hand, it helps to stabilize production, and on the other hand, it can reduce waste, especially in the consumption of nitrogen fertilizer and water resources. With less investment, carbon emissions will naturally decrease.

5.3 Phenotyping and digital tools for carbon-efficient trait expression

No one wants to squat in the fields to measure traits, and the current method of selecting breeding materials by eye has long been out of date. In order to find cotton with high carbon utilization efficiency more quickly, researchers now prefer to use high-throughput phenotyping and digital tools to "do the job for them". These tools can link genotypes and phenotypic performances, use algorithms to make predictions, and no longer rely on repeated field trials (Wang et al., 2022). Efficiency is naturally improved, and the breeding process is more accurate. In particular, those machine learning technologies save a lot of effort when screening target traits. In addition to laboratory analysis, field monitoring is also becoming smart. Some remote sensing platforms and visualization tools can already monitor the growth status of cotton in real time, such as leaf color, plant height, and even photosynthesis intensity. This information can be directly fed back to managers, and the timing of adjusting water and fertilizer strategies will be more accurate (Cooper and Messina, 2021). From a technical point of view, this dynamic monitoring will undoubtedly help to bring carbon efficiency to a higher level.

6 Microbiome and Root-Associated Traits in Carbon Sequestration

6.1 Genomic basis of cotton-root architecture and its role in soil carbon dynamics

Roots are not only used to see whether cotton is stable, they also have an impact on how much soil carbon can be retained. For example, the deeper the roots grow and the more they spread, the more contact they have with the soil. How organic matter is decomposed and how carbon sinks are all inseparable from the participation of roots. Details such as root length, thickness, and branching structure may seem insignificant, but they are actually becoming more and more important in breeding (Rossi et al., 2020). Now many studies are also trying to "pick" out varieties with better root characteristics. Some are identified through genomic means, while others are directly modified by genetic engineering. The purpose is actually the same-to let cotton leave more carbon in the soil, not only will it grow well, but the land will also be able to support it (Srivastava and Yetgin, 2024).

6.2 Breeding for microbiome compatibility to promote carbon fixation

In addition to the characteristics of the roots themselves, its "friends around" are also critical. Especially the fungi and bacteria living around the roots of cotton, they sometimes work harder than the plants themselves to help fix carbon. Some fungi, such as mycorrhizal fungi, and certain specific bacterial groups promote organic carbon accumulation by interacting with roots or root secretions (Wang et al., 2024). But there are problems. Not all cotton gets along with these microorganisms. If we can make cotton roots more attractive to these "good bacteria" through breeding, the carbon sequestration effect may be further improved. Of course, it's easier said than done. If we really want to "regulate" the microbiome, we still have to rely on a large number of experiments to verify the feasibility and stability, otherwise it is easy to have a situation where the ideal is very beautiful but the effect is unstable (Clemmensen et al., 2013; Song et al., 2020).

6.3 Integration of rhizosphere functional genomics into cotton selection programs

In recent years, functional genomic methods have also begun to be used in cotton breeding. Researchers no longer focus on gene sequences, but begin to study what the roots secrete, what the microbial communities in the soil look like, and how these data correspond to plant traits (Panchal et al., 2022; Liu et al., 2022). These seemingly fragmented studies are actually pieced together a roadmap for "carbon sequestration cotton" bit by bit. If this information can be integrated into the breeding process, in the future it may be possible to select varieties that have a tacit understanding between roots and microorganisms, high yields, and low carbon. This is not only for yield, but also to allow agriculture itself to contribute to emission reduction (Fierer and Walsh, 2023).

7 Life Cycle Assessment (LCA) and Genomic Strategy Integration

7.1 Genomics-informed LCA models for cotton systems

At present, there are not many studies that specifically combine genomic strategies with cotton life cycle assessment (LCA), which can almost be said to be blank. But then again, it is not completely clueless. In other fields, such as corn or grain crops, some people have tried to enrich LCA models with genetic data, which provides a lot of ideas for cotton. For example, integrating new data such as genomics into LCA is not necessarily for "seeing further", but for "seeing more closely"-more realistic and closer to the situation in the field. Once the data source is updated, the transparency and traceability of the model will follow. In fact, some studies have significantly improved the reliability of LCA models by introducing new data streams (Löwgren et al., 2025). Therefore, although it has not really been implemented in the cotton field yet, this method can be used as a reference. In the future, if you want to evaluate the carbon efficiency of a cotton variety from seed sowing to harvesting and then to post-processing, genomic data will sooner or later be pulled in.

7.2 Environmental impact metrics aligned with carbon footprint reduction goals

In the past, when we talked about LCA of cotton, we always focused on how much energy was used and how much material was invested. These are indeed important, but now it seems that these alone are obviously not enough. Emissions, waste, and even the treatment methods at the end of the entire life cycle should actually be taken into account (Löwgren et al., 2025). Especially if you want to evaluate new varieties bred using genomic methods, the indicators must be more specific. It is not enough to just look at inputs and outputs. You also have to ask: Can this cotton help the soil lock in more carbon? Can you use less nitrogen fertilizer? Can greenhouse gas emissions be lower than before? These are the measurements that are truly linked to carbon reduction goals. In the final analysis, what we need is a more practical environmental indicator system that can reflect the real environmental effects of different breeding strategies, rather than just the input-output ratio on paper.

7.3 Data integration for decision support in sustainable cotton farming

If we talk about LCA now, it seems that we are "out of touch" if we don't mention data integration. Many systems are already using blockchain to track the entire life cycle of agricultural products. This approach is quite advanced and has indeed improved the transparency and credibility of the data. But on the other hand, genomic data is often "put aside." In fact, it shouldn't be like this. If cotton cultivation wants to become more environmentally friendly and low-carbon, it is far from enough to rely solely on the tracking process. Genetic information must also be integrated. As long as the data is well pieced together, the basis for both on-site decision-making and macro policies will be more solid. For farmers, this is a tool to help them make more timely adjustments; for policymakers, it is a yardstick for measuring green planting performance. In the final analysis, data integration must be deep enough to allow these gene-driven strategies to truly be implemented.

8 Case Study: Carbon-Reduced Cotton Cultivation in the Xinjiang Region

8.1 Application of carbon-efficient genotypes and molecular breeding tools

Xinjiang does lack "hard evidence" in carbon-efficient molecular breeding. But this does not mean that the technology is backward. On the contrary, Xinjiang's planting system has been quietly changing, and the changes are not small. From the early optimization of light and heat utilization, to the later large-scale drip irrigation system, to the current mature efficient and simplified planting system, this "three-stage" development path has long been running (Feng et al., 2024). As for molecular breeding technology, it is now more of a supplementary means of intervention. Once combined with existing field technologies, such as selecting cotton varieties that perform well in water and fertilizer utilization and are easy to grow, overall carbon emissions may be further reduced. In other words, although technology is a piece of the puzzle, don't ignore the space behind it and the traditional agronomic methods.

8.2 Agronomic modifications based on genomic-environmental fit

In the past, cotton planting required “experience” and “adaptability”, but now it is different. Xinjiang’s planting planning has begun to gradually introduce climate and environmental data, trying to plant each variety in the most suitable plot. It is not to say that changing the location will save resources, but if the combination is good, a lot of waste can actually be avoided (Figure 2) (Zhu et al., 2023). Methods such as drip irrigation, water-fertilizer integration, and mulching are already being used in many cotton-growing areas in Xinjiang, and the efficiency of water and fertilizer utilization has indeed increased. Moreover, once such methods become popular, it will not only be a matter of increasing production, but energy conservation and emission reduction will also become a “by the way" thing. More importantly, if these agronomic methods can be combined with the information related to environmental adaptability in the genome, such as predicting in advance which soil and climate a certain variety performs better in, then cotton planting will no longer be a matter of "trying it out", but "seeking it before planting", and the carbon reduction effect will naturally be more stable.

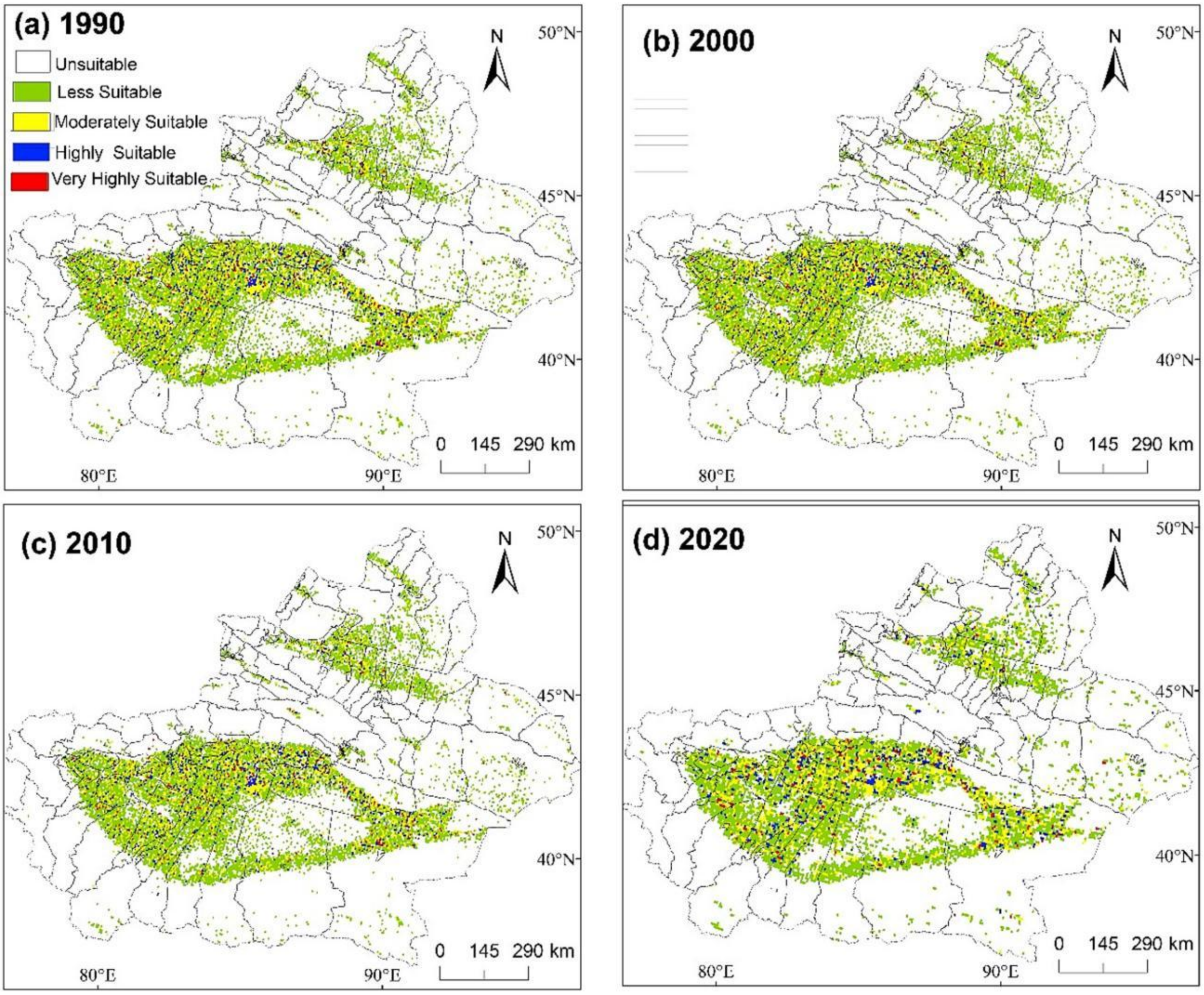

Figure 2 Suitability zoning maps for cotton cultivation in Xinjiang during 1990-2020 (Adopted from Zhu et al., 2023)

8.3 Measurable outcomes: reduced emissions, improved yield, and economic viability

According to the results of life cycle assessment, cotton in Xinjiang has higher carbon emissions per mu of land and per kilogram of output than wheat and corn, mainly because more fertilizers and energy are used (Yang et al., 2025). However, in terms of economic benefits, cotton is still the most profitable of all major crops. Even in the process of trying to reduce emissions, cotton can still maintain a high level of profitability. Field measurements have found that if advanced irrigation methods and covering technologies are used, cotton fields can even become net carbon sinks during the critical growth period, that is, more carbon is absorbed than emitted, which is very helpful for carbon reduction goals (Bai et al., 2015). In order to make Xinjiang's cotton industry sustainable both environmentally and economically, it is necessary to continue to promote the combination of planting technology, agronomic improvement and genomic breeding.

9 Future Prospects and Research Directions

9.1 Advances in pan-genomics and multi-omics integration

At present, the modeling method for studying cotton carbon balance is much more complicated than before. It is not just as simple as how much carbon is measured in the field and how much cotton is produced. Satellite images, environmental parameters, and even information about how farmers manage the land are all pulled in to calculate (Qin et al., 2025). The integration of these data makes the results look more realistic. But then again, most of the current research is still centered around yield and carbon flux. As for new data such as pan-genomics and multi-omics, although there is a lot of discussion, not many of them are actually integrated into the model. However, this is not difficult to understand. No matter how big the data is, how to use it is the key. If these genetic-level data can work well with the existing system, there is a chance to screen out those cotton varieties that are "naturally low-carbon and highly adaptable". This direction may be more efficient than simply adjusting the management method. Especially in the face of an increasingly unstable climate, it is far from enough to rely on feelings to control, and it is necessary to rely on data to "target" and make changes. In the final analysis, future breeding and management are more like "precision customization" rather than a one-size-fits-all approach.

9.2 Global collaboration for open-source carbon data in cotton

If cotton production is to become greener and more sustainable, comprehensive, transparent, and accessible carbon footprint data is needed. Studies in China and the United States have shown that large-scale carbon accounting using life cycle assessment and statistical models is valuable (Huang et al., 2022). If more countries can work together to develop unified data collection methods, modeling steps, and reporting standards in the future, it will be easier to compare different regions and promote good low-carbon planting methods more quickly.

9.3 Policy implications and incentives for genomic-guided low-carbon farming

In terms of policy, we should also encourage people to adopt more energy-saving and environmentally friendly planting methods, such as using genomics to select varieties, or carefully managing fertilizer and water resources. Many studies have shown that reasonably reducing the use of fertilizers and energy while improving efficiency is an effective way to reduce cotton carbon emissions (Singh et al., 2021). Policymakers can encourage farmers and companies to participate by funding relevant research, promoting data sharing, and establishing some low-carbon planting reward certification mechanisms.

10 Concluding Remarks

Genomic technology is really hot now, especially tools like CRISPR/Cas that can "move genes", which have set off quite a wave in cotton breeding. To be honest, breeding a new cotton variety in the past was not only slow, but also easy to hit a wall. But the situation has begun to change. Especially with the transformation method that does not rely on genotypes, the efficiency has been improved all of a sudden, and many of the original stuck places have also loosened. However, editing technology alone is not enough. Researchers now simply integrate the data of genomes, transcriptomes, and metabolomes at once, with the goal of finding those "excellent" genes that are both carbon-saving and resistant to stress. With these clues, the direction of breeding is also clearer-breeding "all-rounder" cotton that can do things and has strong adaptability is no longer just an ideal (although it is still a little far from being fully realized).

In addition to CRISPR, new tools such as base editing and primary editing have also been gradually added, and the breeding toolbox is getting fuller and fuller. Although it is a bit "dazzling", it is indeed practical, especially in improving carbon utilization efficiency and climate adaptability. These new technologies, together with the research on functional genomics and regulatory networks, are also gradually revealing the complex mechanisms behind cotton-such as how fibers develop, how to resist drought, how to save resources, etc. These basic knowledge are the roots of supporting "low-carbon and high-yield" cotton.

Of course, to make these technologies truly come into play, it is not enough to rely on the scientific research circle alone. There must also be policy support, corporate participation, and data sharing. In recent years, sequencing, editing, and multi-omics technologies have indeed developed rapidly, but "fast technology" does not mean "smooth implementation". In the future, if you want to breed "climate-smart" cotton that can truly adapt to the future environment and emit less carbon, it will definitely not work alone. Scientific research, industry, and government must all work together to make this happen.

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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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