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Cultivation of Oil-Producing Cotton Varieties

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Abstract The main purpose of this study is to figure out how to make cottonseeds contain more oil and better oil quality. We started from several aspects, such as genetic improvement, molecular technology, field management and environmental factors. The study found that if we make full use of the genetic differences of different cotton varieties, combined with traditional breeding, gene markers and genetic engineering technology, we can effectively increase the content of cottonseed oil and make the fatty acid composition of the oil more reasonable. The management method in the field is also critical. For example, how much water is irrigated, how much fertilizer is applied, and how dense the cotton is planted, all of which will affect the yield of cottonseed and the quality of oil. We also found that if some specific genes (such as *GhSWEET42*) are expressed more, the cottonseed can grow larger and contain more oil. This is very helpful for future genetic breeding. The interaction between the environment and genes will also affect the stability and genetic effect of oil. This study provides theoretical support and practical methods for the future breeding of high-oil cotton varieties and the realization of large-scale production.

Keywords Cotton breeding; Cottonseed oil; Molecular biology; Cultivation management; Genetic engineering

1 Introduction

Oil cotton (*Gossypium hirsutum* L.) can produce both fiber and oil, and is one of the most valuable crops in the world. Its cotton fiber is mainly used in the textile industry, while cotton seeds can be used to produce edible oil and protein, making it a common source of vegetable oil (Wu et al., 2022). Nowadays, people are paying more and more attention to plant-based oils and fats, and they also pay more attention to green agriculture. Therefore, crops such as oil cotton that can produce both oil and fiber are becoming more and more popular (Yang et al., 2017; Wu et al., 2022).

Cotton is grown in many parts of the world, and South Asia, Africa, East Asia, and the Americas are the main producing areas. Cotton plays an important role in the economies of many countries. For example, in Côte d'Ivoire, cotton cultivation accounts for 1.7% of the country's GDP, 7% of exports are cotton, and it is also particularly critical to farmers' income (Kouakou et al., 2024). However, cotton production and oil production in some places have not increased much, especially in developing countries. This may be due to insufficient water resources, inadequate technology promotion, and the impact of climate change (Fok et al., 1999; Iqbal et al., 2024; Kouakou et al., 2024).

In recent years, the global demand for vegetable oil has been growing. This has also prompted researchers to study cotton varieties with high yields and high oil content, as well as better planting methods (Yang et al., 2017; Wu et al., 2022). Cotton, a crop that can provide both fiber and oil, is particularly suitable for improving land utilization, helping farmers increase their income, and is also beneficial to sustainable agricultural development (Fok et al., 1999; Wu et al., 2022). However, the natural conditions in different regions vary greatly, and current planting techniques cannot be used everywhere. Especially in areas with water shortages and where farmers are mainly smallholders, a new planting method with low input, high returns, and strong resistance is needed (Fok et al., 1999; Iqbal et al., 2024).

This study aims to find out how oil cotton is planted in different regions and how well it is planted. We have reviewed many new field trials and management methods, such as how to water, how much fertilizer to apply, how dense to plant cotton, when to plant, and which new varieties are more effective. We have analyzed and summarized the effects of these practices on cotton yield, oil content, fiber quality, and economic income. This study hopes to provide some theoretical references and practical suggestions for the efficient and sustainable cultivation of oil cotton in the future, help meet the global demand for vegetable oil, and improve the overall benefits of agriculture.

2 Botanical and Agronomic Characteristics of Oil-Producing Cotton Varieties

2.1 Genetic traits linked to oil yield

The fact that oil-producing cotton can produce more oil is closely related to its genetic characteristics. For example, scientists have used SSR molecular markers to identify cotton varieties that are both high-yielding and high-oil (Kusuma et al., 2018). This will help in the future selection of cotton that can produce both good fiber and more oil. In some cottons (such as Pima cotton), a gene called *FAD2-1D* was found to have a mutation. This mutation can increase the oleic acid content in cotton seeds. This is a good target for researchers who want to breed high-oil varieties in the future (Shockey et al., 2017).

2.2 Comparison with fiber-dominant varieties

Compared with cotton that specializes in fiber production, oil-producing cotton has many differences in the amount of seed oil and the composition of the oil. Some oil-producing cotton varieties not only contain more oil, but also have better oil quality due to genetic mutations - for example, more oleic acid and less linoleic acid, which is more suitable for eating and industrial use (Shockey et al., 2017). Fiber-type cotton is mainly for producing good fiber, so less consideration is given to oil, and this part of the trait is often ignored (Kusuma et al., 2018; Shockey et al., 2017).

2.3 Growth habits, flowering/fruiting characteristics

In terms of growth, flowering, and fruiting, oil-producing cotton is actually similar to ordinary cotton. However, there may be some differences when the grains mature and oil accumulates. Different cotton varieties have very different performances, whether in appearance or at the molecular level. These differences are actually advantages, because they can help us select new varieties that are both oil-rich and grow well, and provide a lot of useful genetic resources (Kusuma et al., 2018).

2.4 Optimal environmental conditions and stress tolerance

The yield and oil content of oil-producing cotton are affected by the environment. Studies have found that the growth regulation mechanism of cotton is quite complex, whether in normal weather or when encountering stress such as drought and salinity. Varieties with drought and salt resistance can produce oil more stably (Gupta et al., 2023). Now, scientists have used genetic engineering and molecular breeding to improve these stress resistance capabilities, hoping to enable cotton to grow well and produce the same amount of oil even in less than ideal environments.

3 Breeding and Selection of Oil-Rich Varieties

3.1 History and evolution of breeding programs

In the beginning, cotton breeding was mainly aimed at improving the quantity and quality of fiber, and few people paid attention to oil content. However, in recent years, as people's demand for edible oil and biodiesel has increased, cottonseed oil content has become a new breeding target. Studies have found that different cotton germplasm resources vary greatly in oil content. This shows that we can select varieties with more oil through breeding (De Faria et al., 2013; Sharif et al., 2019; Eldessouky et al., 2021; Wu et al., 2022). Recently, breeders have begun to systematically select varieties with high oil content, and through hybridization and generational breeding methods, the oil content of cottonseed has been significantly increased.

3.2 Key traits selected: oil content, seed size, disease resistance

When breeding oil cotton, the most important goal is to increase the oil content of cottonseed. The oil content of different cotton varieties varies greatly, and many of these differences are determined by genetics. This means that through multiple generations of breeding, varieties with high oil content can be slowly selected (De Faria et al., 2013; Eldessouky et al., 2021; Malalha et al., 2023). In addition to oil content, grain size is also critical. Indicators such as seed index and endosperm index are closely related to oil content and are often used as references (Eldessouky et al., 2021). Disease resistance and adaptability cannot be ignored. Some varieties have high oil content but are not disease-resistant and difficult to grow, which is not acceptable. When breeding, it is necessary to ensure that they can grow and produce oil normally under different environments (Malalha et al., 2023; Yang et al., 2022).

3.3 Notable high-oil cultivars (e.g., 'Sicot 189', 'H1220')

Currently, some cotton varieties with high oil content have been screened out. For example, BRS Aroeira, Acala 1.13-3-1 and 149 FURRS have high oil content and can be hybridized with fiber-rich lines to breed new varieties (De Faria et al., 2013). In Egyptian cotton, genotypes 13, 15 and 8 have high endosperm oil content and good oil index, making them very suitable for improving oil content (Eldessouky et al., 2021). There are also two varieties in Cameroon, Irma Q302 and Irma A2249, which are stable and high in oil content when planted in different regions (Malalha et al., 2023).

3.4 Advances in genomic selection and hybridization

Now, with the development of molecular breeding and genomics technology, the speed of breeding high-oil cotton has also accelerated. Researchers have found many key genes and QTL loci that control oil content and fatty acid composition. They also used gene editing (such as CRISPR/Cas9) and transgenic technologies to make the improvement more precise (Ashokkumar and Ravikesavan, 2011; Sharif et al., 2019; Zhu et al., 2020; Wu et al., 2022; Yang et al., 2022). There is a gene called GhDGAT1. If the expression is enhanced, the oil content of cotton seeds will increase significantly (Wu et al., 2021). Some people also use different types of cotton such as sea island cotton for hybridization and chromosome segment replacement, which can increase the source of useful genes and make the variety better (Zhu et al., 2020). Now, methods such as genomic selection and molecular marker-assisted selection (MAS) are becoming more and more commonly used, which make breeding faster and more efficient (Ashokkumar and Ravikesavan, 2011; Yang et al., 2022).

4 Cultivation Practices

4.1 Soil preparation and fertility management: Best soil types, pH, organic matter

It is best to choose fertile and well-drained soil for oil cotton. If there is enough organic matter and nutrients in the soil, cotton will grow better, and the yield and quality will also be improved. Before planting, if you can apply basal fertilizer properly and water well before sowing, not only will the root system grow more developed, but the leaves will also be larger. In this way, the aboveground part and the fruiting part of the cotton can accumulate more nutrients, and the distribution of oil and protein will be more reasonable in the end (Chen et al., 2017). Spraying some foliar fertilizers such as potassium nitrate and magnesium sulfate can also help improve the quality of fiber and the composition of oil (Kaur et al., 2025).

4.2 Sowing techniques and timing: Row spacing, seed rate, mechanized vs. manual

The selection of cotton planting row spacing and density has a great impact on yield. Generally speaking, medium density (such as 9.0 plants/square meter) plus early sowing (such as late May) will increase the yield of seed cotton and lint cotton. This is mainly because the growth period has become longer and the weight of the fruiting part of cotton has increased (Khan et al., 2017). Reasonable density can also make the use of land and fertilizer more efficient, and can help cotton absorb more potassium and promote flowering and fruiting. Machine sowing is efficient and can be planted more evenly, but some places still rely on manual sowing.

4.3 Irrigation management: Requirements across growth stages

Oil-producing cotton is more afraid of water shortage, especially during the flowering and fruiting period. If water resources are limited, you can try underground drip irrigation technology, such as irrigating at 80% of the crop water requirement (ETc). This method can achieve a relatively good level of cotton yield, oil and protein, while saving water, and cotton is more drought-resistant (Kaur et al., 2025). Another method is to plant on wide ridges and high ridges, and then irrigate at a moderate amount (for example, water at 1.0 times the evaporation Ep), which can also obtain good yields and oil content (Moursi and Yehia, 2016). If you irrigate enough water before planting, and then combine it with reasonable fertilization, it can also make the roots and leaves grow better, laying the foundation for flowering and seeding (Chen et al., 2017).

4.4 Weed and pest control: Integrated Pest Management (IPM) strategies

If you want to achieve stable and high cotton yields, pests and weeds must be managed well. Integrated management strategies (IPM) are quite effective. For example, planting less densely, rotating crops properly, and managing fertilizers and water scientifically can enhance cotton resistance and reduce the occurrence of pests and diseases (Yang et al., 2017). Laying mulch or covering with wheat straw or cotton stalks can also suppress the growth of weeds and improve the microclimate in the field, which helps cotton grow better and increases economic benefits (Iqbal et al., 2024).

5 Oil Content Determination and Influencing Factors

5.1 Analytical methods (e.g., Soxhlet extraction, NIR spectroscopy)

If you want to measure the oil content in cottonseed, Soxhlet extraction is generally used. This method uses organic solvents to extract oil, which is more accurate and the results are stable, so many studies use it as a standard method (Malalha et al., 2023). In addition to it, some people now use near-infrared spectroscopy (NIR) to measure oil. This method is fast and does not destroy the sample, which is very suitable for large-scale screening. However, from the current literature, Soxhlet extraction is still the most commonly used.

5.2 Influence of genotype, environment, and cultivation method

The amount of oil in cottonseed depends not only on the variety, but also on where and how it is planted. Studies have found that both variety (genotype) and environment have a great influence on oil accumulation, and the effects are almost the same (Gōng et al., 2022; Malalha et al., 2023). Different cotton varieties have different oil content and fatty acid ratios (Ju, 2015; Amer et al., 2020; Eldessouky et al., 2021). Some varieties are naturally high in oil, which has a lot to do with their genes. For example, some studies have found that the heritability of oil content is very high (H^2 can reach 96.6%), and key genes such as GhDGAT1 and Gh_A03G0701 have been found, which are involved in the synthesis and regulation of oil (Zhao et al., 2019; Liu et al., 2020; Zhu et al., 2020; Wu et al., 2021). The environment is also very important. The climate and geographical location of a region will affect the variation of cottonseed oil content, which can explain about 38% of the difference. If the daily average rainfall is high, the oil content will increase; but if the total rainfall is too high, the oil will easily decrease (Gōng et al., 2022) (Figure 1). The way of planting also has an impact. Things like the sowing time and how to manage the field can affect the amount and stability of oil (Awais et al., 2021; Malalha et al., 2023). Moreover, if the variety and environment are properly matched, the oil content of cottonseed can be stable and high (Gōng et al., 2022; Malalha et al., 2023).

5.3 Harvest timing and post-harvest handling impact on oil quality

When cotton is harvested and how it is handled after harvesting also has a great impact on the quality of the oil. Studies have found that in the late stage of cottonseed development, such as around the 25th day, some oil-related genes will begin to express in large quantities. At this time, the harvest will have more oil and better fatty acid composition (Zhu et al., 2020). If harvested too early or too late, both oil content and yield may be affected. Therefore, arranging the harvest time is a key point to increase oil content (Awais et al., 2021). How to handle cottonseed after harvest is also very important. Steps such as drying and storage will affect the stability and quality of oil. However, most of the current research is still focused on varieties and environment, and not much is known about the specific impacts of post-harvest processing.

6 Economic Analysis

6.1 Input costs (seed, fertilizer, water, pest control)

The money spent on growing oil cotton is mainly used in several aspects: good seeds, fertilizers, water, and pest control. High-yield cotton varieties consume fertilizers more, for example, they absorb about 384 kg of nitrogen and potassium, 83 kg of phosphorus per hectare, and consume about 10.7 trillion liters of water (Constable and Bange, 2015). Therefore, the input of fertilizer and watering is the key. To save money, you can try underground drip irrigation with reasonable fertilization, such as irrigating with 80% of the crop's water requirement, and spraying foliar fertilizer. This approach not only saves water and fertilizer, but also increases yield and quality

(Kaur et al., 2025). Planting cotton more densely and mastering the sowing time can also reduce the cost per kilogram of output (Khan et al., 2017).

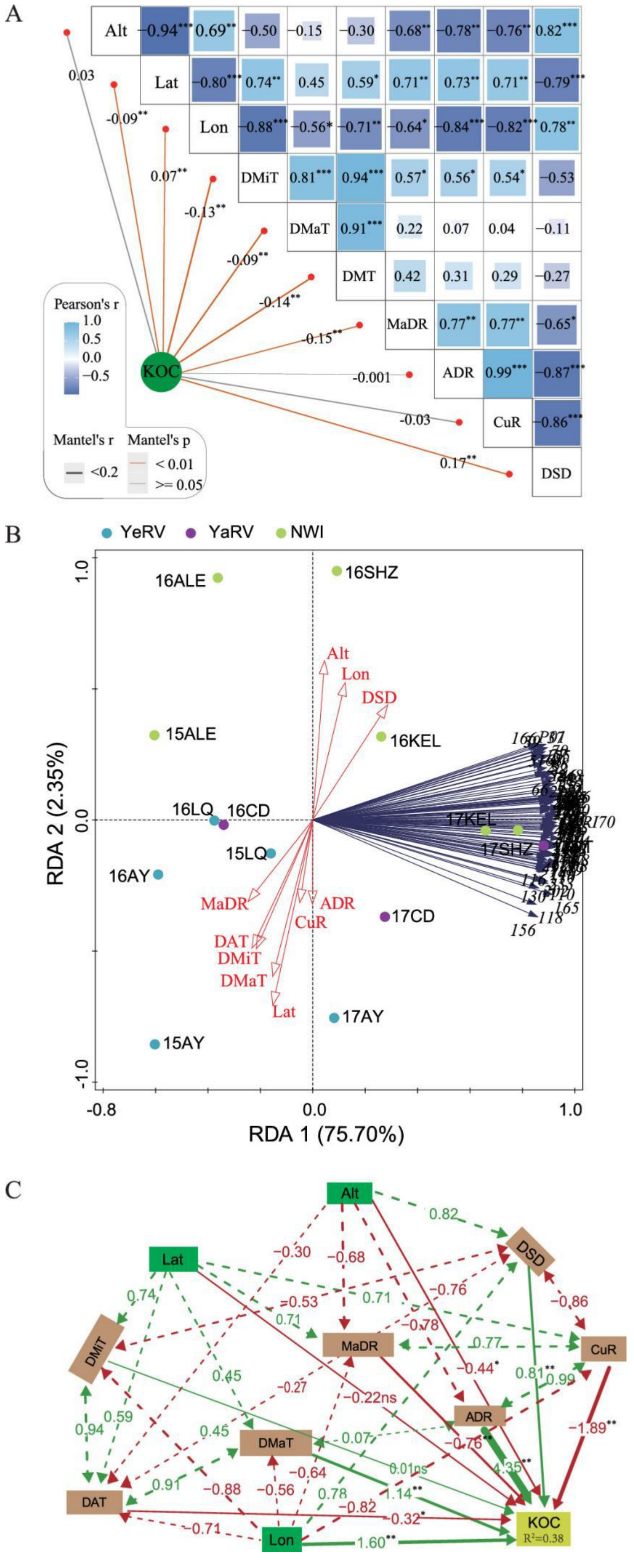

Figure 1 Interaction network between geographical and meteorological factors and their impacts on KOC. (A) Correlation analysis between the KOC of 253 genotypes across 14 environments and the geographical and meteorological factors from May to September. (B) RDA bisequential graph of the KOC of cottonseed and the geographical and meteorological factors. (C) SEM of the causal relationship between geographical and meteorological factors and KOC. The solid and dashed lines indicate direct and indirect acting modes, respectively. Double-headed arrows indicate mutual impacts between factors, and single-headed arrows indicate one-way impacts. The significance levels were *** P < 0.001, ** P < 0.01, * P < 0.05 (Adopted from Gōng et al., 2022)

6.2 Yield metrics (fiber yield, seed yield, oil recovery)

The yield of cotton is generally considered from three aspects: how much fiber there is, how good the seed cotton harvest is, and how much oil can be squeezed out. The average yield of lint cotton in the world is about 800 kg per hectare. If irrigation is used, it can reach up to 3 500 kg, and theoretically even 5,000 kg (Constable and Bange, 2015). Different varieties, planting methods and environments are also different, so the yield fluctuates greatly. Choosing the right density and sowing time can increase the yield of seed cotton and lint cotton by 29% and 26% respectively (Khan et al., 2017). The oil content is also closely related to the variety, generally between 33.4% and 40.28%. The more oil is squeezed, the higher the seed cotton yield is (Eldessouky et al., 2021). If comprehensive management measures are used, not only will the oil be more, but the protein and seed cotton yields can also be increased together (Yang et al., 2017).

6.3 Profitability compared to conventional cotton

Compared with ordinary cotton, oil-producing cotton has greater room for profit because of its higher oil yield. If some comprehensive planting strategies are adopted, such as reasonable use of nitrogen fertilizer, not too sparse planting, and selection of good varieties, fiber and oil yields can be increased at the same time without much investment (Khan et al., 2017; Yang et al., 2017). Drip irrigation combined with scientific fertilization not only increases the harvest, but also makes cotton planting more sustainable, especially suitable for water-scarce areas (Kaur et al., 2025).

6.4 Market demand for cottonseed oil and value-added byproducts

Cottonseed oil is the second largest source of edible vegetable oil in the world and plays a very important role in ensuring people's oil and grain supply (Sharif et al., 2019). Although it is not as common as soybean oil or rapeseed oil, it is actually nutritious and functional, and market demand is slowly increasing. In addition to oil, cottonseed can also be squeezed into by-products such as protein and cottonseed meal, which can be used as feed and biofuel, with a certain added value (Yang et al., 2017). If the yield of cottonseed oil and by-products can be increased by improving varieties and planting methods, the competitiveness of the entire cotton industry chain will also be enhanced.

7 Environmental and Sustainability Considerations

The cultivation of oil cotton is not only for high yield, but also for environmental protection and sustainable development. This section mainly discusses its impact and performance from four aspects: how to use soil and water, how to rotate crops, what impact it has on biodiversity, and its carbon emissions.

7.1 Soil and water resource use efficiency

Oil cotton varieties are similar to ordinary cotton, and both have high requirements for water and soil fertility. But now many planting methods can use water and nutrients more efficiently. Methods such as water-deficient irrigation, conservation tillage and precision fertilization can make resources more economical. Studies have found that some genetically modified cotton varieties have more developed root systems and higher water absorption efficiency. For example, drip irrigation plus fertilization during irrigation can reduce water waste by up to 40%, while allowing cotton to better absorb nitrogen fertilizer and avoid nutrient loss. Some farmers also grow legumes (such as mung beans and cowpeas) in cotton fields, which not only increases soil organic matter, but also uses less chemical fertilizers, which is good for the soil (He et al., 2021).

7.2 Contribution to crop rotation and land use optimization

Oil-bearing cotton can be well arranged in crop rotation plans to make land use more efficient. In Central Asia, southern Africa, southern India and other places, farmers rotate oil-bearing cotton with legumes. This can maintain soil fertility and reduce pests and diseases. Oil-bearing cotton can also bring double benefits - it produces both fiber and oil, so farmers can earn more per piece of land and be more motivated to plant. This rotation also allows farmers to plant more crops without occupying more land, which can protect forests and prevent land degradation.

7.3 Biodiversity implications of intensive cotton cultivation
If only one cotton variety is planted on a large area, especially oil-bearing cotton, it may damage biodiversity. If the variety is too single, farmland will become more susceptible to pests and diseases. In addition, in the past, cotton fields used a lot of pesticides to prevent insects, which also harmed many beneficial insects. However, there are some new practices to improve this problem, such as planting Bt cotton (cotton with insect-resistant genes), which can reduce the use of pesticides and cause less damage to the ecology. Planting "refuges", setting up insect corridors, and integrated pest management (IPM) can also help maintain ecological balance. In this way, the yield of oil cotton can be guaranteed while retaining useful insects (Altieri, 1999; Lu et al., 2012).

7.4 Carbon footprint and lifecycle assessments
From planting to harvest, the carbon emissions of oil cotton are both good and bad. If it is planted in a more extensive way, with a lot of fertilizers and pesticides, and frequent tillage, greenhouse gas emissions will be quite high. But if no-tillage, organic fertilizers and clean energy are used for irrigation, carbon emissions can be reduced, up to 30% less carbon dioxide than traditional methods. Cotton seeds can produce both oil and fiber, and these two products can "share" carbon costs and use resources more efficiently. What's more interesting is that some cottonseed oil ingredients can also replace palm oil or soybean oil. This can reduce the deforestation of tropical rainforests and indirectly help reduce the pressure of global warming.

8 Case Study: Region or Farm Name
8.1 Geographical and climatic background
The northern part of Cameroon belongs to the tropical semi-arid region, where there is not much rain and the weather is relatively hot. This climatic condition is very suitable for growing crops that require little water, such as cotton (Malalha et al., 2023). There are many types of soils in this area, and some plots have good drainage, and cotton roots can grow better in this type of soil.

8.2 Selected cotton variety and rationale
Two varieties of *Gossypium hirsutum* were used in this case: Irma Q302 and Irma A2249. These two varieties have shown relatively high and stable seed cotton oil content of 26.61% and 26.40% in trials in several places and several seasons. They are very suitable for local cultivation in Cameroon and can also meet the needs of cottonseed oil production (Malalha et al., 2023).

8.3 Cultivation timeline and method
The study adopted a completely randomized block design. Cotton was sown in spring, and the entire growing period coincided with the local main rainy season. Field management mainly involves moderate irrigation and pest and disease control, which ensures that cotton gets enough water and nutrients during the critical growth stage (Malalha et al., 2023).

8.4 Observed outcomes
8.4.1 Agronomic performance (growth rate, disease incidence).
Different varieties grow differently in different plots. Irma Q302 grows well in places with good conditions and has fewer diseases, indicating that it is more adapted to the local environment (Malalha et al., 2023).

8.4.2 Oil yield and quality
The oil content of cotton seeds varies greatly in different locations, generally ranging from 20.34% to 26.08%. Irma Q302 and Irma A2249 have high overall oil content. The oil extracted is also of good quality and can be eaten or used as industrial oil (Tak et al., 2020; Malalha et al., 2023).

8.4.3 Farmer economics and community impact
After planting these high-oil cotton varieties, farmers' incomes increased. Selling cottonseed oil became an additional source of income, which was a good benefit for farmers and made the local community's economy and food and oil supply more stable (Malalha et al., 2023; Khalid et al., 2022).

8.5 Challenges encountered and local adaptations

The main problems faced by this region are erratic rainfall and high temperatures. Sometimes there are droughts, which are not conducive to cotton growth. To cope with these problems, local farmers chose more drought-tolerant varieties, adjusted sowing times, and strengthened irrigation management. This improved cotton yields and oil stability (Malalha et al., 2023; Khalid et al., 2022). Pests and diseases are also a major problem. Farmers have successfully reduced losses by using highly resistant varieties and comprehensive prevention and control measures.

9 Challenges and Knowledge Gaps

9.1 Limited awareness and market channels for oil-cotton

Although cottonseed oil is a very useful byproduct with a global market, cotton varieties specifically used for oil extraction are not well known. Many people do not know the value of these varieties and do not know how to promote them. The current policy and market system do not support oil-producing cotton enough, resulting in farmers and companies not paying much attention to this type of cotton. Market development has not kept up, and it is not easy to sell the product (Keller et al., 2024).

9.2 Climate risks and varietal stability

The yield and oil content of oil-producing cotton are greatly affected by weather and environment. Different varieties perform significantly differently in different places. Some varieties produce more in one place, but not in another place. The interaction between genes and the environment (also called GEI) makes this instability more obvious. Climate change, extreme heat or low rainfall also make it more difficult to breed varieties with strong adaptability. In addition, there are still many technical difficulties in improving both stress resistance and high oil content at the same time (Gupta et al., 2023; Malalha et al., 2023; Thangaraj et al., 2024; Saleem et al., 2024) (Figure 2).

9.3 Seed availability and quality control

The seed supply of high-oil cotton is still unstable, and good seeds are hard to find. Farmers want to plant, but sometimes the seeds they get are of different quality, some are impure, some have low germination rates, and some have poor adaptability. These problems affect farmers' enthusiasm and the progress of promotion (Wu et al., 2022; Sapkota et al., 2023). What's more serious is that the current seed quality standards are not unified, and key indicators such as purity and germination rate mostly lack systematic testing and management methods (Wu et al., 2022).

9.4 Gaps in mechanization and post-processing infrastructure

The planting and processing of oil cotton are not mechanized enough. The planting and harvesting links in the field mainly rely on manpower, which is not efficient. Most of the existing cotton machinery is designed for fiber cotton, and there are not many special machines for oil cotton. Cottonseed oil extraction equipment is also relatively backward, and processing technology cannot keep up. This makes the entire industry inefficient and costly, which is not conducive to the expansion and strengthening of oil cotton, and also limits farmers' income (Keller et al., 2024; Thangaraj et al., 2024).

10 Conclusion and Future Perspectives

Breeding and planting of oil cotton have made a lot of progress in recent years. Studies have found that the content and fatty acid composition of cottonseed oil are affected by varieties, environment and management methods. Different cotton genotypes and environmental combinations will have different performances, and there is still a lot of potential to be exploited. Varieties such as Irma Q302 and Irma A2249 are not only high in oil content, but also stable in performance. If combined with reasonable irrigation methods (such as underground drip irrigation with 80% ETc), scientific fertilization and foliar nutrient spraying, cotton yield, oil and protein content can be further improved, and the fatty acid structure can be more ideal and have higher nutritional value. Planting more densely and choosing the right sowing time can also improve yield and benefits.

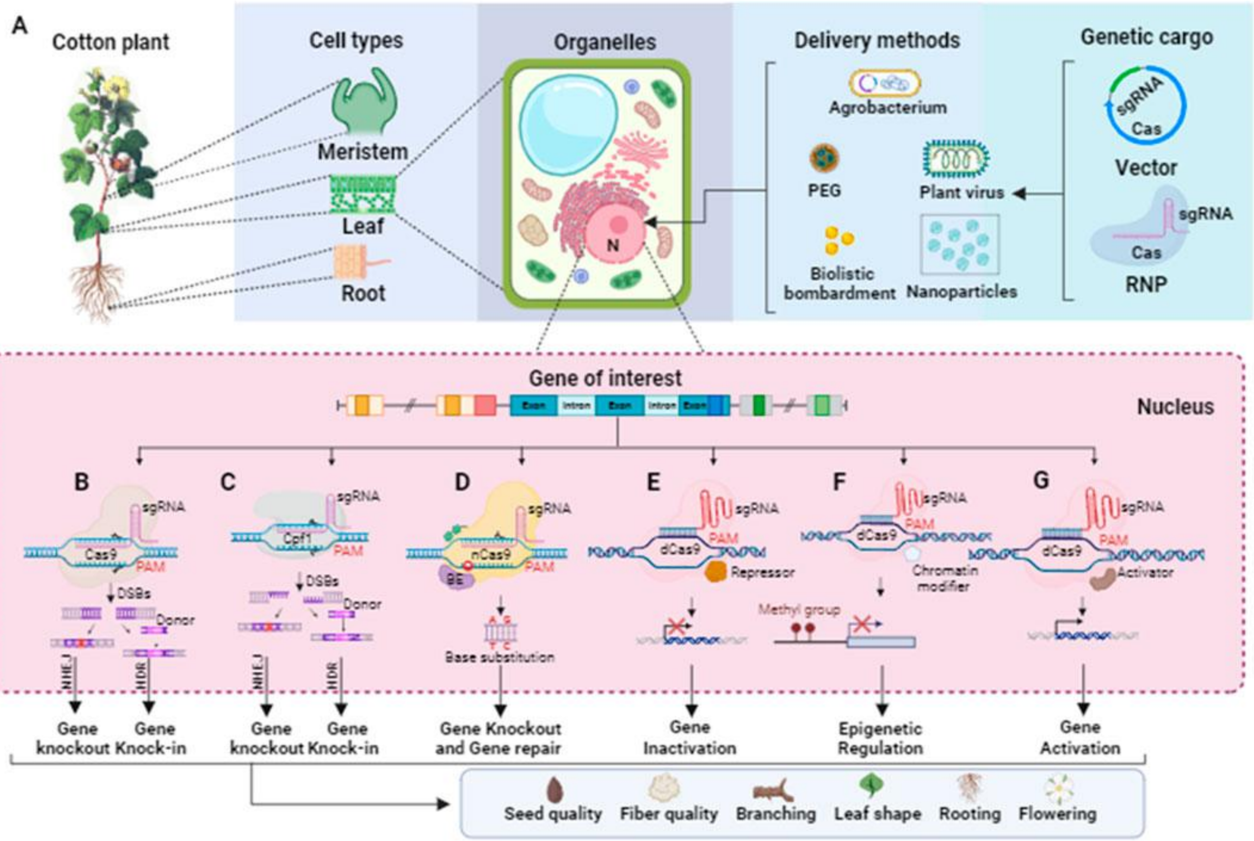

Figure 2 Schematic representation of CRISPR/Cas-based editing tools for targeting the genes related to seed quality, fiber quality, and architecture of the cotton plant. (A) DNA or RNA that encode Cas and sgRNAs or CRISPR – Cas – sgRNA ribonucleoprotein (RNP) can be transformed into the nucleus of the meristem, leaf, and root cells of a cotton plant using an appropriate delivery method such as Agrobacterium, plant viruses, polyethylene glycol (PEG), nanoparticles, and biolistic bombardment. (B) CRISPR/Cas9 comprises Cas9 endonuclease and a sgRNA complex, and a PAM site (NGG) is present downstream of the targeted DNA sequence. DSBs (blunt-ended) produced by CRISPR/Cas9 fixed by NHEJ or HDR, resulting in gene knock-out or knock-in. (C) CRISPR/Cpf1 consists of Cpf1 endonuclease and a sgRNA to bind with targeted DNA which is present upstream of a PAM site (NTT). Similarly, the DSBs (sticky-ended) generated by CRISPR/Cpf1 fix by NHEJ or HDR to gene knock out or knock-in. (D) In base editing, a base editor like adenine deaminases or cytidine deaminases is fused with nickase Cas9 (nCas9), which can lead to a base substitution in the targeted DNA sequence for gene knock-out and repair. (E) The dead Cas9 (dCas9) fused with a transcriptional repressor to regulate the targeted cotton genes associated with desired traits. (F) Epigenome editing at the target genomic site can be executed via Cas9-chromatin modifier fusion protein. (G) The dead Cas9 (dCas9) fused with the activator protein can be employed for regulating the expression of the desired genes (Adopted from Saleem et al., 2024)

Current molecular breeding and genetic engineering technologies have brought new ways to improve the quality of oil cotton. Technologies such as genomics, QTL mapping, transgenics and CRISPR/Cas9 have helped us find some key functional genes, such as GhSWEET42, which plays an important role in oil synthesis and grain development. These achievements have laid the foundation for subsequent molecular design breeding and the development of new high-oil varieties. If agricultural management technologies such as precision irrigation, optimized fertilization and foliar nutrition are also combined, it will not only save resources but also improve the sustainability of cotton cultivation.

It is recommended that the government invest more support in this regard, especially in basic research and new variety breeding. Consider increasing the construction of molecular breeding platforms, encouraging multidisciplinary research, and promoting the sharing and innovation of genetic resources. At the same time, it is also necessary to support the cooperation between enterprises and research institutions, and jointly promote green technologies such as water-saving irrigation and precision fertilization to enhance the competitiveness and environmental protection capabilities of the entire cotton industry chain. In the face of the challenges brought by climate change, we must also focus on those varieties that are more drought-resistant and more adaptable. In order to truly implement these new varieties and new technologies, it is necessary to carry out multi-point and continuous field trials in different ecological regions for several years to systematically evaluate how these planting methods and varieties perform. At the same time, it is also necessary to strengthen agricultural technology promotion and training services so that farmers can learn to use and dare to grow high-oil cotton, and truly turn scientific and technological achievements into output and income. If we want to make oil-bearing cotton develop rapidly and steadily, we must rely on the in-depth integration of genetic breeding and modern agricultural technology, and we also need the joint support of policies, funds and promotion systems.

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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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