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Harnessing integrated breeding strategies for high-yielding and climate-resilient varieties in sesame (*Sesamum Indicum* L.)

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Abstract
Sesame (*Sesamum indicum* L.) is one of the oldest oilseed crops cultivated worldwide and is known as the “queen of oilseeds” due to its high-quality oil, nutritional value, and adaptability to diverse agro-climatic conditions. It contains a high percentage of edible oil, protein, antioxidants, and important minerals, making it valuable for human consumption and industrial uses. However, sesame production is constrained by low yield potential, susceptibility to diseases, poor adaptability, and environmental stresses. Therefore, genetic improvement through effective breeding approaches is essential for enhancing productivity and stability.

The major breeding objectives in sesame include increasing seed yield, improving oil content and quality, developing early-maturing varieties, enhancing resistance against diseases and insect pests, and improving tolerance to drought and other abiotic stresses. Various conventional and modern breeding methods are employed for sesame improvement, including selection methods, pedigree breeding, bulk method, single seed descent (SSD), backcross breeding, mutation breeding, and hybridization. Recent approaches such as molecular breeding, marker-assisted selection, and genomic tools are further strengthening sesame improvement programmes. The integration of traditional and advanced breeding techniques can accelerate the development of high-yielding, stress-resistant, and quality-improved sesame varieties. Future breeding efforts should focus on sustainable production and climate-resilient cultivars to meet increasing demands for sesame oil and food security.

Keywords: Sesame (*Sesamum indicum* L.), oilseed crop, genetic improvement, breeding objectives, seed yield, oil content, oil quality, disease resistance

Introduction

Sesame (*Sesamum indicum* L.) is among the most ancient oilseed crops known to mankind and is an important member of the Pedaliaceae family. Owing to its high oil content, nutritional richness, and adaptability to diverse agro-climatic conditions, sesame has been cultivated for thousands of years and continues to play a significant role in global agriculture. It is considered one of the world's major oilseed crops and is extensively grown in tropical and subtropical regions.

Historical evidence indicates that sesame originated in the Indian subcontinent and neighboring regions, where it has been cultivated since ancient times. Over the centuries, the crop spread to various parts of Asia and Africa, becoming an integral component of traditional farming systems and dietary practices. Countries such as India, China, Sudan, Myanmar, and Tanzania are currently among the principal producers of sesame. In recent decades, African countries have experienced substantial growth in sesame cultivation, with Tanzania emerging as a major contributor to global production.

The economic importance of sesame is largely attributed to its seeds, which contain approximately 45–52% oil and 18–25% protein. The oil is highly valued for its stability, pleasant flavor, and resistance to oxidative deterioration, characteristics that are primarily associated with naturally occurring antioxidants present in the seed. Sesame seeds are utilized in a wide range of food products, including edible oils, bakery items, confectionery products, traditional sweets, and nutritional supplements.

Beyond its culinary applications, sesame has attracted considerable scientific attention due to its rich composition of bioactive compounds. The seeds contain lignans such as sesamin, sesamolin, and sesamol, along with vitamins, minerals, phytosterols, and polyunsaturated fatty acids. These compounds have been reported to exhibit numerous biological activities, including antioxidant, anti-inflammatory, antihypertensive, hypocholesterolemia, and cardioprotective effects. Consequently, sesame is increasingly recognized as a functional food with significant health-promoting potential.

In addition to its nutritional and medicinal value, sesame serves as an important cash crop for smallholder farmers in many developing countries, contributing to rural livelihoods, employment generation, and export earnings. The growing demand for healthy vegetable oils and functional foods has further enhanced the commercial significance of sesame in international markets.

Although extensive research has been conducted on various aspects of sesame, including its cultivation practices, chemical composition, and therapeutic properties, there remains a need to consolidate current knowledge regarding its agronomic importance, nutritional attributes, phytochemical constituents, and health benefits. Therefore, a comprehensive review of these aspects is essential to better understand the potential of sesame as a valuable oilseed crop and to promote its sustainable utilization in agriculture, food industries, and human health applications.

Botanical description

Morphologically, sesame is an erect herbaceous plant that may attain a height ranging from 0.5 to 1.50 m, depending upon genotype and environmental conditions. The crop develops a deep and well-branched taproot system, which contributes significantly to its drought avoidance mechanism and efficient utilization of soil moisture. The stem is quadrangular, pubescent, and may be either branched or unbranched. Leaf morphology is highly variable, with lower leaves generally arranged oppositely and upper leaves alternately on the stem.

The flowers are solitary, axillary, and zygomorphic, typically exhibiting white, pink, or pale violet coloration. Sesame is predominantly self-pollinated; however, varying degrees of natural cross-pollination may occur through insect-mediated pollen transfer. The fruit is a dehiscent capsule containing numerous small seeds whose color ranges from white and cream to brown and black, depending on the genotypes.

Research Gaps and Emerging Priorities in Sesame Improvement

1. Limited Genomic Resources and Marker-Assisted Breeding Approaches

Despite advancements in plant genomics, the availability of validated QTLs, high-density genetic maps, and trait-linked molecular markers in sesame remains inadequate. The integration of next-generation sequencing technologies, SNP/other markers, transcriptomics, and genomic selection into breeding programs is still limited.

2. Constraints in plant architecture and agronomic trait improvement

The development of ideotype-based sesame cultivars suitable for modern production systems remains a major breeding challenge. Particular emphasis is required on traits such as capsule indehiscence, synchronized maturity, reduced plant height, and suitability for mechanized harvesting.

3. Genetic enhancement for abiotic and biotic stress tolerance

The identification and incorporation of genes conferring resistance to environmental stresses and major diseases remain insufficient. Developing cultivars with durable resistance to drought, waterlogging, stem rot, root rot, and other production constraints is a critical research priority.

4. Exploration and strategic utilization of genetic resources

Although extensive sesame germplasm collections are available worldwide, their systematic phenotypic and molecular characterization remains incomplete. Effective exploitation of genetic diversity for the identification of superior alleles and donor genotypes is essential for broadening the breeding base.

5. Improvement of seed quality and nutritional attributes

Simultaneous enhancement of oil content, protein concentration, lignin composition, antioxidant potential, fatty acid profile, and market-preferred seed coat color remains a significant challenge. Advanced breeding strategies are needed to optimize these quality traits without compromising yield performance.

6. Integration of advanced breeding technologies

The application of modern breeding approaches, including genomics-assisted selection, genome-wide association studies (GWAS), genomic prediction, gene editing, and high-throughput phenotyping, offers significant opportunities for accelerating genetic gain in sesame.

7. Prospects for climate-resilient and market-oriented cultivar development

Future breeding efforts should focus on developing high-yielding, climate-resilient, nutritionally enriched, and mechanization-compatible cultivars capable of meeting the evolving demands of farmers, consumers, and global markets.

Major Breeding Objectives in Sesame

1. Enhancement of seed yield potential

Increasing seed yield remains the foremost objective of sesame breeding programs. This can be achieved through the improvement of yield-contributing traits such as number of capsules per plant, seeds per capsule, branching pattern, biomass production, and seed size. The development of high-yielding cultivars with stable performance across diverse environments is essential for improving crop productivity.

2. Development of ideal plant architecture

Breeding efforts are focused on the development of desirable plant types possessing erect growth habit, optimum plant height, reduced lodging susceptibility, and efficient resource utilization. Special emphasis is placed on the incorporation of indehiscent capsules, determinate growth habit, and uniform maturity to facilitate mechanized harvesting and minimize seed losses.

3. Improvement of resistance to diseases and insect pests

The development of cultivars with durable resistance to major diseases and insect pests is a key objective in sesame improvement. Breeding programs aim to incorporate resistance against important pathogens and insect pests to ensure stable yield performance and reduce dependence on chemical control measures.

4. Enhancement of abiotic stress tolerance

Improving tolerance to environmental stresses such as drought, high temperature, salinity, and waterlogging is essential for sustaining sesame production under changing climatic conditions. The development of stress-resilient genotypes capable of maintaining productivity under adverse environments remains a major breeding priority.

5. Improvement of seed quality and oil content

Breeding strategies are directed toward increasing seed oil content and improving oil quality. Emphasis is placed on enhancing desirable fatty acid composition, antioxidant content, lignin concentration, and nutritional value to meet the requirements of consumers and the edible oil industry.

6. Development of superior seed characteristics

The improvement of seed traits such as seed size, seed weight, seed coat color, uniformity, and dehulling efficiency constitutes an important breeding objective. These attributes significantly influence market acceptance, processing quality, and export potential.

7. Broadening the genetic base

The utilization of diverse germplasm resources and wild relatives is essential for expanding the genetic variability available to breeders. Broadening the genetic base facilitates the identification and incorporation of novel genes governing yield, quality, and stress tolerance traits.

8. Development of climate-smart cultivars

A long-term objective of sesame breeding is the development of climate-resilient cultivars combining high yield potential, stress tolerance, superior quality, and wide adaptability. Such cultivars will contribute to sustainable sesame production under future climatic scenarios.

9. Development of varieties suitable for modern production systems

The breeding of cultivars compatible with intensive and mechanized farming systems is becoming increasingly important. Such varieties should possess uniform growth, synchronized maturity, non-shattering capsules, and high harvest efficiency to reduce production costs and improve profitability.

Breeding methods for sesame improvement

1. Conventional breeding approaches:

Conventional breeding methods have contributed significantly to the development of improved sesame varieties worldwide. Among these methods, pure line selection, mass selection, pedigree breeding, hybridization, backcross breeding, and mutation breeding have been most extensively utilized. Despite the emergence of molecular and genomic tools, conventional breeding remains the foundation of sesame improvement programs because of its effectiveness, simplicity, and ability to exploit existing genetic variability. The integration of conventional approaches with modern breeding technologies offers considerable potential for developing high-yielding, stress-tolerant, and nutritionally superior sesame cultivars.

Introduction and Selection

Selection is the oldest and simplest breeding method used in sesame improvement. Superior plants are identified from existing populations based on desirable characteristics such as high yield, early maturity, disease resistance, and seed quality.

(a) Mass Selection

In mass selection, a large number of phenotypically superior plants are selected from a heterogeneous population, and their seeds are bulked to raise the next generation. It is simple and economical, effective for improving highly heritable traits and maintains broad genetic variability.

(b) Pure Line Selection

Pure line selection involves selecting superior individual plants from local landraces or heterogeneous populations and evaluating their progenies over several generations. Produces genetically uniform cultivars. Improves yield and quality traits. Widely used in self-pollinated crops like sesame.

2. Hybridization Breeding

Hybridization is the deliberate crossing of genetically diverse parents to combine desirable traits into a single genotype. It combines high yield with superior oil quality. Incorporate resistance to diseases and pests. And to develop varieties with improved plant architecture and stress tolerance.

Types of Hybridization

(a) Inter-varietal Hybridization

Crossing between different varieties of *Sesamum indicum*.

(b) Inter-specific Hybridization

Crossing cultivated sesame with related wild species to transfer useful genes such as disease resistance and stress tolerance. Creates new genetic variability. Facilitates the combination of multiple desirable traits.

3. Pedigree Method

The pedigree method is a conventional breeding method mainly used in self-pollinated crops for the development of improved varieties. In this method, two genetically diverse parents having desirable traits are crossed to generate variability. The F_1 generation obtained from the cross is self-pollinated to produce the F_2 generation, where segregation of characters occurs. Superior individual plants are selected from the F_2 generation based on desirable traits such as higher yield, disease resistance, maturity, and better plant type. The selected plants are grown as separate progeny rows in subsequent generations (F_3, F_4, F_5), and selection is practiced both among and within families while maintaining a record of the ancestry or pedigree of each selected plant.

4. Bulk Method

The bulk method is a conventional breeding method mainly used in self-pollinated crops for developing improved varieties. In this method, two genetically diverse parents with desirable traits are crossed to create variability. The F_1 generation is self-pollinated, and the resulting F_2 seeds are harvested and grown together as a bulk population without individual plant selection. The segregating generations (F_2 to F_5 or F_6) are advanced by growing the population in bulk, allowing natural selection to act on plants under field conditions. After several generations, when the population becomes more homozygous, individual superior plants are selected and evaluated for desirable traits such as high yield, disease resistance, maturity, and quality.

5. Single Seed Descent (SSD)

The Single Seed Descent (SSD) method is a breeding approach mainly used in self-pollinated crops to rapidly advance generations while maintaining maximum genetic variability. In this method, plants from the segregating generations are advanced by selecting one seed from each plant and using it to grow the next generation. The process is continued from F_2 to F_5 or F_6 generations without selection for desirable traits, allowing rapid attainment of homozygosity. After reaching a highly inbred stage, individual plants or lines are selected and evaluated for important traits such as yield, quality, disease resistance, and stress tolerance.

6. Backcross Breeding

The backcross method is a conventional breeding technique used to transfer one or more desirable traits from a donor parent into a superior variety (recurrent parent) while retaining most of the desirable characters of the recurrent parent. In this method, the initial cross is made between the recurrent parent and the donor parent possessing the desired trait. The F_1 hybrid is then repeatedly crossed back with the recurrent parent for several generations. In each backcross generation, plants carrying the desired trait are selected and again crossed with the recurrent parent. After several backcrosses, the selected plants are self-pollinated to obtain a stable pure line containing the target trait along with the genetic background of the recurrent parent.

7. Mutation Breeding

Mutation breeding is a plant improvement method in which artificial mutations are induced in plants to create new genetic variation for the development of improved varieties. In this method, seeds or plant materials are treated with physical mutagens such as gamma rays, X-rays, and ionizing radiation or chemical mutagens such as EMS (Ethyl Methane Sulphonate) to produce useful genetic changes. The treated materials are grown and evaluated in subsequent generations to identify desirable mutants with improved traits. Mutation breeding is used to enhance characters like higher yield, early maturity, dwarf plant type, disease resistance, stress tolerance, improved oil quality, and better seed characteristics.

Advanced Breeding Strategies and Emerging Technologies for Sesame Improvement

1. Marker-Assisted Breeding for Trait-Specific Genetic Improvement

Marker-assisted breeding (MAB) utilizes DNA markers tightly linked to genes or quantitative trait loci (QTLs) controlling economically important traits. Unlike conventional selection, which relies solely on phenotypic performance, marker-assisted selection enables breeders to identify desirable genotypes at the seedling stage, thereby increasing selection efficiency and reducing breeding time.

In sesame, molecular markers such as SSRs, SNPs, AFLPs, RAPDs, and others have been employed for genetic diversity analysis, linkage mapping, and trait identification. Marker-assisted breeding is particularly useful for traits that are difficult, expensive, or time-consuming to evaluate phenotypically, such as disease resistance, drought tolerance, oil quality, and seed shattering resistance. The integration of molecular markers into breeding programs facilitates the rapid development of improved cultivars with enhanced productivity and stress resilience.

2. Genomics-Enabled Approaches for Sesame Improvement

Advances in next-generation sequencing technologies have significantly accelerated genomic research in sesame. The availability of whole-genome sequence information and high-density molecular markers has provided valuable insights into genome organization, gene function, and genetic variation. Genomics-assisted breeding involves the identification of genes and genomic regions associated with target traits and their subsequent utilization in cultivar development. Whole-genome resequencing, comparative genomics, and pan-genome analyses enable the discovery of novel alleles governing yield, quality, and stress tolerance. These approaches facilitate the efficient exploitation of genetic diversity and enhance the precision of breeding programs.

3. Genome-Wide Association Mapping for Trait Discovery

Genome-Wide Association Studies (GWAS) represent a powerful approach for identifying genetic loci associated with complex quantitative traits. Unlike traditional linkage mapping, GWAS exploits natural genetic variation present within diverse germplasm collections and provides higher mapping resolution.

In sesame, GWAS has been employed to identify marker-trait associations related to seed yield, capsule characteristics, flowering time, plant architecture, oil content, fatty acid composition, and stress tolerance. The identification of significant genomic regions through GWAS contributes to the discovery of candidate genes and supports marker-assisted breeding strategies.

4. Predictive Genomics and Genomic Selection Strategies

Genomic selection (GS) is an advanced breeding methodology that predicts the breeding value of individuals using genome-wide marker information. Rather than focusing on individual genes or QTLs, GS simultaneously incorporates the effects of thousands of markers distributed across the genome.This approach is particularly effective for complex traits controlled by numerous genes with small effects, such as yield, drought tolerance, and oil content. By enabling early and accurate selection, genomic selection shortens breeding cycles and increases the rate of genetic gain. As genomic resources expand, GS is expected to become a cornerstone of future sesame improvement programs.

5. Transcriptome-Based Approaches for Functional Gene Discovery

Transcriptomics involves the comprehensive analysis of gene expression under different developmental stages and environmental conditions. RNA sequencing (RNA-seq) has emerged as a powerful tool for identifying differentially expressed genes and understanding molecular mechanisms underlying important agronomic traits. In sesame, transcriptomic studies have provided valuable insights into pathways involved in oil biosynthesis, seed development, drought tolerance, salinity tolerance, and disease resistance. Identification of stress-responsive and quality-related genes enhances the understanding of genotype–phenotype relationships and facilitates the development of improved cultivars through molecular breeding.

6. Precision Breeding through Genome Editing Technologies

Genome editing technologies have revolutionized crop improvement by enabling precise modification of target genes. Among these technologies, CRISPR-Cas systems have emerged as the most efficient and versatile tools for plant genome engineering. In sesame, genome editing offers significant potential for improving traits such as non-shattering capsules, determinate growth habit, enhanced oil quality, disease resistance, and abiotic stress tolerance. Unlike conventional breeding, genome editing allows targeted genetic modifications without introducing large segments of foreign DNA, thereby accelerating the development of superior cultivars.

7. Accelerated Crop Improvement through Speed Breeding

Speed breeding refers to the manipulation of environmental conditions such as light intensity, photoperiod, and temperature to accelerate plant growth and reproductive development. This technique enables the production of multiple generations within a single year, thereby reducing the time required for variety development. The integration of speed breeding with molecular breeding and genomic selection can substantially increase breeding efficiency in sesame. Rapid generation advancement facilitates the faster fixation of desirable alleles and accelerates the release of improved cultivars.

8. Advanced Phenomics and High-Throughput Trait Evaluation

Phenotyping has traditionally been a major bottleneck in crop improvement programs. High-throughput phenotyping (HTP) utilizes advanced imaging technologies, sensors, drones, and remote sensing platforms to collect large-scale phenotypic data rapidly and accurately.

These technologies enable precise assessment of plant growth, canopy architecture, biomass accumulation, disease severity, water-use efficiency, and stress responses. The integration of phenomics with genomics facilitates a deeper understanding of complex traits and enhances the effectiveness of breeding decisions.

9. Haplotype-Guided Breeding Approaches

A haplotype represents a group of linked genetic variants inherited together. Haplotype-based breeding focuses on identifying favorable combinations of alleles associated with superior agronomic performance and utilizing them in breeding programs. This approach provides greater accuracy than single-marker analysis because it captures the combined effects of multiple linked loci. Haplotype-guided breeding enables the efficient selection and pyramiding of desirable alleles controlling yield, quality, and stress tolerance traits in sesame.

10. Multi-Omics Integration for Crop Improvement

The complexity of biological systems often requires the integration of multiple layers of information. Multi-omics approaches combine genomics, transcriptomics, proteomics, metabolomics, and phenomics to provide a comprehensive understanding of plant growth and development.

In sesame, multi-omics studies facilitate the identification of molecular networks governing oil accumulation, stress adaptation, and nutrient metabolism. Such integrated approaches accelerate gene discovery and support the development of cultivars with improved productivity and nutritional quality.

11. Artificial Intelligence-Assisted Breeding and Decision Support Systems

Artificial intelligence (AI) and machine learning (ML) technologies are increasingly being incorporated into crop breeding programs. These computational approaches can analyze large genomic, phenotypic, and environmental datasets to identify patterns and predict breeding outcomes. Applications in sesame include yield prediction, genomic selection modeling, disease diagnosis, trait prioritization, and optimization of breeding strategies. AI-driven tools improve selection accuracy, reduce breeding costs, and support data-driven decision-making.

12. Climate-Resilient Breeding for Sustainable Sesame Production

Climate change poses significant challenges to sesame cultivation through increased frequency of droughts, heat waves, erratic rainfall, and emerging pest and disease pressures. Climate-resilient breeding aims to develop cultivars capable of maintaining stable productivity under variable environmental conditions.

Conclusion

The enhancement of sesame (*Sesamum indicum* L.) productivity remains a major objective of contemporary breeding programs due to the crop's relatively low yield potential compared with other major oilseed crops. Breeding efforts have traditionally focused on improving seed yield, oil content, seed quality, resistance to biotic and abiotic stresses, and adaptation to diverse agro-climatic conditions. Conventional breeding approaches such as selection, hybridization, pedigree breeding, backcross breeding, and mutation breeding have contributed significantly to the development of improved sesame cultivars and continue to serve as the foundation of genetic improvement programs.

However, the increasing demand for high-yielding, climate-resilient, and nutritionally superior varieties necessitates the adoption of advanced breeding technologies. Modern approaches including marker-assisted selection, genomic selection, genome-wide association studies, transcriptomics, genome editing, speed breeding, and high-throughput phenotyping have enhanced the precision and efficiency of selection for complex traits. These technologies facilitate the identification and utilization of favorable alleles governing yield, capsule characteristics, oil quality, stress tolerance, and disease resistance.

Particular emphasis should be placed on the development of cultivars possessing high seed yield, indehiscent capsules, synchronized maturity, superior oil quality, and resilience to environmental stresses. Furthermore, the effective utilization of diverse germplasm resources and integration of conventional and molecular breeding strategies will broaden the genetic base and accelerate genetic gain in sesame improvement programs.

In the present era of climate change and increasing food and nutritional security concerns, an integrated breeding approach combining conventional methodologies with genomics-assisted and precision breeding technologies offers the most promising pathway for developing next-generation sesame cultivars. Such cultivars will contribute to sustainable production, enhanced farmer profitability, improved oil quality, and greater adaptability to future agricultural challenges.

Table 1: State wise recommendations of sesame varieties

Gujarat	Gujarat Til-3, RT-346, RT-351, Guj. til-4, Gujarat Junagadh Til-5 (GJT-5)
Haryana	RT-346, RT-351
Himachal Pradesh	RT-346
Karnataka	DSS-9, DSS-9, DS-5
Madhya Pradesh	Jawahar Til –12 (PKDS-12), Jawahar Til –14 (PKDS-8), TKG-308
Maharashtra	RT-346, PKV-NT-11, JLT-408, JLT-408, RT-351
Odisha	Shubra, Smarak, Subhra (OSC-2007), Smarak (OSC 560)
Rajasthan	RT-346, RT-351
Uttar Pradesh	RT-346, RT-351
West Bengal	SWB-32-10-1(Savitri)
North Eastern Hill States	RT-351

Table 2: Sesame varieties along with their specific characteristics

Variety	Released center	Oil content (%)	Yield potential (Kg/ha)	Characteristics
SWB-32-10-1 (Savitri)	ORS, Berhampore (WB)	48-52	1200-1500	Duration 84-88 days, Light brown seed, Tolerant to Macrophomina
Jawahar Til –12 (PKDS-12)	ZARS, JNKVV, Powarkheda (MP)	48-52	700-750	Duration 82-85 days, White seed, moderately resistant to Macrophomina stem/root rot
Jawahar Til –14 (PKDS-8)	ZARS, JNKVV, Powarkheda (MP)	50-53	700-750	Duration 82-85 days
Gujarat Til-3	ARS, GAU, Amreli (Gujrat)	48-52	750-800	Duration 84-88 days, White bold seed
RT-346	BAU, Bikaner	49-51	750-850	Duration 82-86 days, White seed, Resistant to leaf curl, moderately resistant to Macrophomina, Alternaria, Cercospora
PKV-NT-11	PDKV, Agril. College, Nagpur	50-53	800-850	Duration 88-92 days, White seed, Moderaterly resistant to root rot, bacterial blight
DSS-9	UAS, Dharwad	48-50	600-650	Duration 85-90 days, White bold seed, early maturing
JLT-408	Oil Seeds Research Station MPKV Jalgaon	51-53	700-800	Duration 80-85 days, White seed
RT-351	ARS, RAU, MAnodre (Raj)	48-50	700-800	Resistant to Macrophomia, Leaf curl, Phillody, moderately resistant to cercospora & capsule borer
Gujarat Til-4 (GTil-4) (AT-159)	ARS, GAU, Amreli	48-52	750-800	White seed, early maturing and multicapsular
HT 9713 (HT 2)	CCSHAU Hisar	48-50	650-750	White seed, tolerant to phyllody & leaf curl
SMARAK (OSC 560)	OUAT, Bhuvaneswar	48-52	800-900	Golden yellow bold seed, tolerant to Macrophomina
SUBHRA (OSC 207)	OUAT, Bhuvaneswar	48-52	800-900	White Seeded Variety
VRI 3	Vridhachlam	50-52	850-950	MR to Macrophomina

Source: Directorate of Oilseed Development, Ministry of Agriculture & farmer Welfare, Government of India, Seed Division, seednet.gov.in & ICAR Institutes.

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