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Agricultural Genetics Strategy as an Innovative Approach to Sustainable Desert Agriculture in Algeria

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Abstract
This study aims to highlight the importance of agricultural genetics as a new approach to sustainable desert agriculture in Algeria, considering this mechanism as one of the most important modern techniques used in the agricultural field. Therefore, the experience of desert agriculture in Algeria, with its positive impact on the national economy, has led the state to adopt modern technologies to promote this type of agriculture, relying primarily on agricultural genetics to ensure its sustainability in the long term.

This research paper sheds light on the reality of desert agriculture in Algeria and the main modern techniques adopted to ensure its sustainability, along with the adoption of agricultural genetics and the main pioneering experiments in this field, as well as the degree of its impact on production and the national economy as a whole.

Keywords:
Agricultural genetics, desert agriculture, sustainability of desert agriculture, modern technologies.

Introduction

Agriculture holds a significant position in the national economy due to its impact on driving economic development and achieving self-sufficiency, ultimately leading to local food security. This is one of the main goals of the Algerian state, and it has become a prevailing international objective, especially after the COVID-19 pandemic, which altered various international balances in the field of food security.

The state's focus on the agricultural sector, particularly desert agriculture, has increased as a fundamental direction within the President's program to promote the desert agricultural sector. Among the notable methods adopted by the state is the reliance on modern techniques, or more precisely, smart agriculture practices, to help crops adapt to the desert climate and to enhance the productivity of agricultural lands despite the challenging natural conditions of those areas. One of the most important approaches in smart agriculture is the use of biological techniques in plant hybridization through what is known as genetic engineering or genetic agriculture.

In light of the above, the question that arises is:

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What is the role of agricultural genetic engineering as a technique of smart agriculture in ensuring the sustainability of desert agriculture in Algeria?
To address this issue, this research paper is divided into three main sections:
1. Theoretical Concepts on Agricultural Genetic Technology
2. The Experience of Desert Agriculture in Algeria – Diagnosis of Reality and Performance Analysis
3. The Role of Agricultural Genetic Technology in the Sustainability of Desert Agriculture in Algeria

Section One: Theoretical Concepts on Agricultural Genetic Technology Concept of Genetic Engineering

In the late twentieth century, the term genetic engineering emerged to refer more specifically to techniques involving recombinant DNA (or gene cloning). This process involves mixing DNA molecules from two or more sources, either within cells or in a laboratory setting. These molecules are then combined and introduced into host organisms, allowing them to replicate[1].
It is worth noting that people have been altering the genomes of animals and plants for many years using traditional breeding techniques. The artificial selection of specific, desirable traits has resulted in a diverse array of organisms, from sweet corn to hairless cats. However, this artificial selection, which involves choosing organisms exhibiting certain characteristics for breeding future generations, was limited to naturally occurring variations[2]. In recent years, advances in genetic engineering have enabled precise control over the genetic changes introduced into living organisms. Today, it is possible to mix new genes from one species into another that is not closely related through genetic engineering, enhancing agricultural performance and facilitating the production of valuable pharmaceutical materials. Crop plants, farm animals, and soil bacteria are clear examples of organisms that have undergone genetic engineering.

Thus, genetic engineering can be defined as a modern branch of life sciences that allows for the removal of undesirable genes from a plant and their replacement with more beneficial genes, or the possibility of taking a gene from one organism and inserting it into another to acquire a desirable trait. Consequently, genetic engineering enables the transfer of genes between genetically distant species. Most genes in living organisms consist of DNA, which can be isolated and rearranged according to human desires, making it possible to obtain superior plants with desirable traits. This involves transferring specific and beneficial parts of the genetic material from one organism to another that is not closely related. From this perspective, genetic engineering can be simply defined as the manipulation of the genetic content of a specific organism to change its hereditary traits[3].

How Genetic Engineering is Performed

The process of genetic engineering is complex and involves modifications to the genetic material of the living organism. Here are the key steps involved:[4]
- Identification of Target Gene: The desired gene that will be modified or transferred is identified.

- Isolation of the Gene: The identified gene is then isolated from the donor organism's DNA.
- Modification of the Gene: The isolated gene may be modified to enhance its function or expression.
- Insertion into a Vector: The modified gene is inserted into a vector (such as a plasmid) that will carry it into the host organism.
- Transformation of the Host Organism: The vector containing the gene is introduced into the host organism's cells.
- Selection and Screening: Cells that successfully incorporate the new gene are selected and screened for desired traits.
- Propagation: The modified cells are allowed to grow and multiply, producing organisms with the new genetic traits.
-**Identification of the Gene**: This refers to the desired trait that is intended to be introduced or modified in the organism under study.

Isolation of the Desired Gene
This involves using special enzymes known as "restriction enzymes" to cut the DNA at specific sites and isolate the desired gene. These enzymes function like "molecular scissors." Additionally, separation techniques are employed to isolate DNA fragments based on their size, aiding in the isolation of the gene.

Construction of the Gene Vector
A vector is used to carry the new gene into the target cell, linking the gene to the new vector.

Introduction of the Vector into the Target Cell
There are several methods for introducing the vector into the target cell, which vary depending on the type of cell:
- In plant cells, the process is done using a gene gun.
- In animal cells, it is done via microinjection.
- In bacteria, it is achieved through heat shock or electroporation.

Selection of Genetically Modified Cells
This step involves the identification and selection of cells that have successfully incorporated the desired gene.

Gene Expression and Verification of Results
This includes confirming that the desired gene is expressed correctly in the modified organism.

Propagation and Production (in the case of living organisms Genetic Engineering in Agriculture
Since its inception, agriculture has relied on modifications to the genetic structures of both plants and animals through selective breeding. Generations of countless crops and livestock have been selectively cultivated to enhance traits beneficial to humans. However, since the early twentieth century, scientific discoveries have revealed many techniques that have accelerated innovation in agriculture, leading to the widespread use of genetically modified organisms (GMOs) and foods.

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Applications of Genetic Engineering in Agriculture:
Some of the most important applications of genetic engineering in agriculture include:[5]
- Development of Pest-Resistant Crops: Crops engineered to resist pests, reducing the need for chemical pesticides.
- Drought-Resistant Varieties: Plants modified to withstand drought conditions, enhancing food security in arid regions.
- Nutrient-Enriched Crops: Crops that have been genetically enhanced to contain higher levels of essential nutrients.
- Herbicide-Resistant Crops: Varieties that can tolerate specific herbicides, making weed control more efficient.
- Improved Shelf Life: Fruits and vegetables modified to have extended shelf life, reducing waste.

Applications of Genetic Engineering in Agriculture:
- Faster Plant Growth: Through genetic engineering, plants have been developed to grow at a faster rate.
- Increased Crop Yield and Productivity: This is one of the most important applications of genetic engineering aimed at increasing food reserves.
- Improved Taste: Genetic modifications can enhance the flavor of crops, making peppers hotter and corn sweeter.
- Reduced Need for Pesticides: By applying genetic engineering, several plants have been modified to produce their own pest-resistant compounds, reducing reliance on chemical pesticides[6].
- Production of Improved Seeds: Changes in the DNA of seeds can lead to the creation of plants that are more resistant to harsh climates, while also extending the shelf life of seeds during safe and reliable transportation to distant areas.
- Production of High-Quality Wood: The technique of gene insertion and transfer can also play a significant role in producing a new and improved variety of wood sourced from trees[7].
- Production of Disease-Resistant Plants: Many microorganisms have been developed that can break down toxic chemicals and can be used to target harmful pests and diseases[8].

Development of High Tolerance Crops
Genetic engineering enables the development of plants that can withstand salt, boron, aluminum, frost, drought, and other environmental stress factors. This allows plants to grow in conditions where they might not thrive otherwise. Through genetic modification, plants can also exhibit resistance to humidity, heat, and diseases.

Production of Fertilizer-Efficient Plants
Several varieties have been produced that can directly fix atmospheric nitrogen, reducing reliance on fertilizers. Additionally, some plants have been developed to enhance their own nutrient uptake.

Development of Nutrient-Rich Plants

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Genetically modified plants can include added vitamins and minerals, providing significant health benefits to people.

How Crops are Developed Through Genetic Engineering

Significant efforts are made to advance agriculture through genetic engineering and genetic modifications of crops. The following outlines how crops are developed using genetic engineering:

- Enhancing the Quantity and Quality of Proteins in Seeds
- Introducing Nitrogen-Fixing Genes from Legumes into Cereals
- Improving Photosynthetic Efficiency by Modifying Genes in Chloroplasts
- Transferring Pest and Pathogen Resistance Genes from Wild Plants to Crop Plants

Section Two: The Experience of Desert Agriculture in Algeria – Diagnosis of Reality and Performance Analysis

1. Components of Desert Agriculture in Algeria

The desert regions of Algeria are rich in resources and potential capable of meeting local needs for job opportunities and food requirements. They play a significant role in improving food security. The climatic conditions in areas like the Saharan Atlas, the lower Sahara (Biskra and El Oued), and even in the central Sahara (Ouargla and Ghardaïa) offer opportunities for developing off-season production sectors. These sectors can enhance the supply of vegetables, including potatoes, to major urban centers in the north.

Various programs have been initiated by the relevant ministry to develop the southern regions, meeting the necessary conditions to create job opportunities and improve living standards and incomes for rural populations.

Among the key indicators demonstrating the importance of utilizing the desert for agricultural purposes in the national economy are:

1. Identification of Several States, Municipalities, and Administrative Divisions for the promotion of desert agriculture[9].

Table 2-1: States and Municipalities Scheduled for Investment in Desert Agriculture

Source: Prepared by the Researchers Based on Data from the National Office of Desert Agriculture

Relevant Provinces	Tindouf	Tamanrasset	Ouargla	Laghouat	Illizi	Ghardaïa	El Oued	Biskra	Béchar	Adrar
Municipalities				**Rural: 141 Regions**	**Municipality: 188**	**Municipal**				
Associated Administrative Districts	Tindouf	- Ain Salah - AinGuezzam	- Touggourt	- Laghouat	- Djaneet	- Menia	- Mghair	- Ouled Jalal	- Béni Abbes	- BordjBadji Mokhtar - Timimoun

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In addition, there are 14 natural regions: El Sayah, Ziban, OuedRigh, WadiM'zab, The Kasours, Ouargla, Gourara, Saoura, Touat, Tassili, Tidalcat.
From the previous table, it is evident that the state has established a diverse strategy that encompasses most of the desert states and their various administrative divisions for agricultural investment in desert areas. This is all aimed at ensuring local food security primarily.
The area designated for investment is estimated at **18,181,839 hectares** with a border belt of 5,000 km The total active population is estimated at **12,033,725** individuals, including 465,177 farmers.
Additionally, the state has recently identified another land area of **163,999 hectares** allocated for desert investment across several states. The following table illustrates this:

Table 2-2: Areas Included in the Fourth Investment Package to Support Desert Agriculture in Southern Algeria

Number	Area	Allocated Area	Perimeters	Provinces
01	Adrar	- 8250 hectares distributed over 3 perimeters	An Tiliya	- 5500 hectares
			Kebratane06	- 1000 hectares
			Adrar Ouled	- 1750 hectares
02	Ouargla	- 44503 hectares distributed over 6 perimeters	HassiLhad	- 13500 hectares
			MahadiFajet El Bajel	- 532 hectares
			Plate 01	- 2790 hectares
			Plate 02	- 6393 hectares
			Hassi El Hajar	- 18232 hectares
			Rabia	- 3056 hectares
03	Timimoun	- 20273 hectares in one perimeter	HogbaOqroub	- 3750 hectares
04	Touggourt	- 3369 hectares distributed over 4 perimeters	Arouq El Ziyar	- 500 hectares
			Taya Ali Ben Tumi	- 1602 hectares
			Dzioura	- 850 hectares
			Marakh El Na'am	- 417 hectares
05	Menia	- 21540 hectares distributed over 3 perimeters	eurayqatalmislan	- 1082 hectares
			Kilometer Point 154	- 19000 hectares
			El Wafila 02	- 1458 hectares
06	Djaneet	- 13698 hectares distributed over 3 perimeters	Mughiyaw	- 9401 hectares
			Tafsast	- 3993 hectares
			Tiska	- 304 hectares
07	Illizi	- 45260 hectares distributed over 7 perimeters	Aghragar	- 647 hectares
			Faj Ben Marah	- 4321 hectares
			Rod El Chouf	- 14231 hectares
			Rod El Nas 01	- 9467 hectares

			Rod El Nas 02	- 15342 hectares
			Tinsboka	- 588 hectares
			Tintoura	- 664 hectares
08	Laghouat	- 7481 hectares distributed over 2 perimeters	Hwayta Road	- 314 hectares
			Mhuqen	- 7167 hectares
09	Ghardaïa	- In one perimeter with an area of 16148 hectares	Shabriqa	- 16148 hectares

Source: Data from the National Office of Desert Agriculture
02 - Available Resources for Agricultural Investment in the Algerian Desert Regions

First - Area and Workforce:
- The area suitable for agricultural exploitation is approximately **1.4 million hectares**, distributed across large regions that have been the subject of previous studies in ancient palm oases, including: El Oued, RehirTouat, GouraraTidalcat, as well as the perimeters of Qasi Tall, HassiMessaoud, AinAmnas, and Abadla.

- As for the workforce in agriculture, thanks to state efforts,it is continuously increasing according to an upward trend. The following table shows the total workforce ratios as well as those allocated to agriculture, in addition to the total agricultural land from 2019 to 2022:

Table 3-2: Total Workforce and Total Agricultural Land from 2019 to 2022

Unit: Thousands of people for the workforce / Thousands of hectares for agricultural and geographical area.

Years / Indicators	2019	2020	2021	2022
Total Workforc	12700	12102.76	12260.83	
Agricultural Workforce	2693.55	2650	2650	12480.90
Total Arable Land	43968.80	41358.85	41358.85	2890
Cultivated Area	5724.78	8509.57	8509.57	44278.28
Geographic Area	238174.10	238174.10	238174.10	9001.25

Source: Prepared by the Researchers Based on Data from the Arab Organization for Agricultural Development, Annual Statistics Book 2022

From the previous statistics, we observe that the workforce is continuously increasing since 2019, when the total workforce was estimated at 12,700 thousand individuals, of which approximately 2,693 thousand were related to agricultural labor, representing 21.21% of the

total agricultural land exploited. This percentage increased to around 23.16%of the total workforce by 2022, reflecting a 1.95% increase. This indicates a growing trend of individuals moving towards work in the agricultural sector and investing in it.

Second: Water Resources

The water resources are estimated to reach approximately 1.6 billion cubic meters by 2050, according to the numerical model of the groundwater system. The available water and soil resources will allow for the consolidation of current production areas and the establishment of new regions, potentially increasing production by 30% in the medium to long term.

Third: Renewable Energies

Renewable energy sources include solar energy with a capacity of 9 terawatt-hours/year, wind energy with a capacity of 35 terawatt-hours/year, and geothermal energy[10].

Fourth: Tax Incentives Granted Under the Investment Law

Under Investment Law No. 22-18, agricultural investors operating as Algerian companies benefit from tax incentives ranging from **3 to 10 years**, depending on the adopted incentives system. Financial support is also provided through low-interest loans, including:

- Seasonal loans (Al-Rafiq) and investment loans (Al-Tahadi) offered by the Agricultural and Rural Development Bank.
- Financial aids and grants provided in the form of production means.
- Incentive grants offered as cash amounts to producers and operators as motivation[11].

3 - Key State Institutions Supporting Agricultural Investment in the Algerian Desert

To enhance state support for desert agriculture, several institutions have been established, along with legislation and laws to promote investment in desert agricultural land. Notable examples include:[12]

3-1 Governorate for the Development of Agriculture in Desert Regions

This is a regional public institution established under Decree No. 86-222 dated September 2, 1986. Its intervention scope covers southern states with multiple tasks across the 2 million square kilometers of desert territory.

3-2 Technical Institute for Desert Agriculture Development

This public administrative institution was established under Decree No. 86-117 dated May 6, 1986, and amended by Decree No. 87-55 dated February 24, 1987. It was inaugurated in 1993 by the Minister of Agriculture, Mr. Mohamed ElyasMesli, and is located in Ain Ben Noui, Biskra Province.

3-3 National Office for the Development of Industrial Agriculture in Desert Lands

This public institution has an industrial and commercial nature, enjoys legal personality and financial independence, and operates under the authority of the Minister of Agriculture. Established by Executive Decree No. 20-265 dated September 22, 2020, the office is equipped with a one-stop shop to facilitate all administrative operations, along with a technical evaluation committee responsible for studying candidate applications and supporting

them. This office is a tool for implementing national policy aimed at promoting and developing strategic industrial agriculture in desert areas.

To further encourage agricultural investors to focus on strategic crops in the southern states, the government, on December 1, 2023, identified another agricultural land area of approximately 163,999 hectares designated for investors across 9states.including 30 perimeters as follows:[13]

- adrar Province: 8,250 hectares distributed across three perimeters.
- Ouargla Province: 44,503 hectares distributed across six perimeters.
- Timimoun Provinces: 3,750 hectares in one perimeter.
- Touggourt Province: 3,369 hectares.
- El Menia Province: 21,540 hectares distributed across three perimeters.
- Gant Province: 13,698 hectares distributed across three perimeters.
-illizi Province: 4,260 hectares distributed across seven perimeters.
- Laghouat Province: 7,481 hectares distributed across two perimeters.
- Ghardaïa Province:16,148 hectares in one perimeter.

4- Barriers and Challenges of Desert Agriculture in Algeria

4-1Barriers

The government is committed to promoting desert agriculture as an alternative to the rentier economy, especially after agricultural exports reached **$1 billion** in the early months of 2020, and approximately **$397 billion** in 2023, despite the barriers hindering the revitalization of desert agriculture, as recognized by experts.

The state is working to enhance desert agriculture through the National Office of Desert Agriculture, acting as a link between the north and south. The issue with exporting is not just about containers, but also about transportation costs between the north and south. Additionally, there is a problem with the connection between this office and the Ministry of Agriculture, which affects its role as a direct exporter of desert agricultural products.
Despite Algeria's vast natural resources that could make the agricultural sector a leader in wealth creation and economic development, particularly in desert areas, certain conditions and criteria must be met for this to happen.

The barriers to desert agriculture in Algeria mainly include:[14]
- Lack of Infrastructure: There is a significant absence of infrastructure and storage facilities, particularly with increasing investments in the sector. For example, potato producers faced storage issues despite a surplus in production, highlighting the inadequacy of storage mechanisms.

- Disconnection Between North and South: This is one of the main barriers, as it is crucial for management, marketing, and exporting Algerian products. The agricultural sector has achieved substantial export volumes outside of hydrocarbons.
- Lack of Modern Technologies: There is a deficiency in modern agricultural technologies, particularly the reliance on renewable energies such as wind and solar power, which are

essential for supporting agriculture in desert regions. Additionally, techniques for extracting groundwater are underutilized, despite Algeria having significant groundwater reserves.
- Bureaucratic Hurdles: Bureaucratic processes and issues related to farmers, support mechanisms, and inadequate infrastructure hinder progress, affecting exporters trying to sell surplus production.

-Inadequate Technology for Groundwater Utilization: There is a shortage of modern technologies to exploit groundwater efficiently and at lower costs.

4-2 - Challenges

The agricultural sector aims to export a larger percentage of products, especially after achieving self-sufficiency. Algeria exported 50,000 tons of agricultural products in the first quarter of the current year, while the sector's exports exceeded 100,000 tons of vegetables and fruits last year, despite the challenges posed by the COVID-19 pandemic.
The government aspires to utilize all available resources and capacities to strengthen access to foreign markets and enhance the agricultural sector's contribution to the national GDP, which exceeds 12.4% and is valued at $25 billion in 2022.

Notably, the fifth edition of the National Desert Agriculture Salon (Agrosov) was organized, a collaboration between Al-Fahd Exhibition Company, the Agricultural Chamber, and the General Confederation of Algerian Enterprises in El Oued, from December 20 to 23, 2021. This salon aims to showcase local agricultural products, packaging capabilities, and new technologies in desert agriculture[15].

Among the successful investment experiences in Algeria's desert agriculture is that of Ms. Halima Khaled, an agricultural engineer in the Wilaya of M'ghair. Through her dedication to cultivating the land, she has pioneered desert agriculture by developing quinoa cultivation, achieving encouraging results that have gained widespread recognition among farmers[16].

She successfully adapted quinoa, a non-native plant originally from the Andes mountains in Latin America, to the Algerian desert, transforming a region known for date production into green oases with a diverse food basket.

Given the prominent role of the agricultural sector in the economies of most countries, it contributes to the growth of GDP and the provision of jobs, thus reducing unemployment. Therefore, it is considered one of the strategic sectors vital for ensuring sustainable agricultural development. Like other countries, Algeria is striving to implement economic strategies aimed at diversifying its resources beyond the hydrocarbon sector to achieve development.

Agriculture is among the most important sectors that can contribute to this diversification, aligning with both economic and social activities, and the conditions required for development, particularly in desert areas. These regions have unique economic and natural characteristics that enable them to drive contemporary economic growth. Some southern provinces, such as El Oued, Adrar, Ouargla, and Biskra, are experiencing a qualitative shift in

the agricultural sector, transforming from limited subsistence farming to extensive agricultural areas. This indicates their potential to become significant agricultural hubs in the future if all necessary resources, particularly modern agricultural technologies—including advanced irrigation systems and soil improvement—are deployed.

Leading Provinces in Agriculture:

Certain provinces, especially El Oued, have taken a leading position nationally in various agricultural fields due to a clear policy implemented by the Algerian state and the exploitation of local resources to invigorate the sector. Given the challenges faced by Algeria and the government's commitment to developing and modernizing the sector, particularly in the desert areas, there is a focus on reducing import burdens and achieving self-sufficiency, especially in widely consumed staples like hard and soft wheat. This focus is expected to revitalize the national economy and enable desert agriculture in Algeria to achieve sustainable agricultural development, aimed at increasing national income through production multiplication, food provision, reducing unemployment rates, and enhancing soil fertility while maintaining its quality in the long term[17].

Programs to Promote Desert AgricultureVarious programs and initiatives implemented in the desert agricultural sector have had significant positive impacts on improving the sector's performance. These include expanding cultivated agricultural areas, attracting private investors, establishing factories and storage facilities, and developing agricultural equipment and infrastructure, such as rural electricity and road construction. Agricultural production has advanced across various sectors.

Additionally, the support programs established by the Algerian government for desert agriculture, particularly reclamation and incentive programs, along with modern irrigation techniques, have strengthened production and positioned the desert as an agricultural market with reach from the depths of the desert to the Algerian coastline, relying on the quality and volume of its production. This necessitates further governmental support, especially regarding the factors that attract settlement in the south, focusing on seed and fertilizer quality, and providing essential agricultural technologies, particularly in high-quality agricultural equipment and irrigation systems, while expanding the use of alternative and renewable energy sources.

International Agreements in Agriculture

One of the key strategies employed by the state to promote the agricultural sector as a whole, particularly in southern Algeria, is the establishment of international agreements. Notably, a partnership agreement with Qatar was signed on April 24, 2024 to establish a comprehensive project for producing powdered milk in southern Algeria, specifically in Adrar Province. This agreement aims to create an integrated agricultural-industrial system for cattle breeding and the production of powdered milk and its derivatives.

The project occupies a total area of 117,000 hectares, consisting of three hubs, each featuring a farm for cattle breeding and milk and meat production, a farm for grain and fodder production, and a milk powder production factory. The project's cost is estimated at $3 billion, with a capacity to create 5,000 direct jobs. It is expected to fulfill **50%** of the

[17]- Same previous reference.

national needs for milk powder, supply the local market with red meat, and contribute to increasing the national cattle herd.

Partnership Agreement with Italy:
An additional partnership agreement with Italy was signed on July 7, 2024, which outlines the implementation of an agricultural project covering 36,000 hectares aimed at creating a complete production chain for grains and legumes. The total project cost is estimated at €420 million in Timimoun Province. This project will focus on producing wheat, lentils, dried beans, and chickpeas, alongside establishing processing units for food pasta, storage silos, and other vital structures. The project will also incorporate other strategic crops into the agricultural cycle, particularly oilseeds like soybeans, and is set to span over four years[18].

The third axis: The Role of Agricultural Genetics Technology in Sustainable Desert Agriculture in Algeria
Agricultural genetics technology is one of the most significant modern technologies contributing to the sustainability of desert agriculture. This technology helps plants adapt to harsh desert environmental conditions while improving the quality of agricultural products and enhancing their genetic diversity.

1. Importance of Effective Biodiversity Supporting Desert Agriculture Sustainability:
Agricultural genetics is fundamental in preserving the genetic diversity of crops, contributing to the maintenance of various plant varieties adapted to surrounding conditions. Preserving genetic diversity requires the documentation and physical conservation of different plant varieties in seed banks or genetic farms. It is also crucial to raise awareness among farmers and local communities about the importance of preserving genetic diversity and encouraging them to grow ancient and distinctive plant varieties to ensure the sustainability of desert agriculture[19].

Preserving genetic diversity is vital for the sustainability of desert agriculture, as it enhances agricultural production efficiency and crop resilience to harsh environmental conditions. The significance of preserving genetic diversity includes maintaining traditional plant varieties that possess unique traits, such as drought resistance or adaptation to sandy soils. Diverse plant varieties can address various challenges faced by agriculture in desert environments, making them essential for achieving food and agricultural security in these regions.
Contributions of BiodiversityBiodiversity contributes to:[20]

Improving Soil Health
Diverse living organisms in the soil, such as bacteria, fungi, and earthworms, help improve its physical, chemical, and biological properties. They contribute to the decomposition of organic matter, enhance soil aeration, and fix nitrogen, which promotes plant growth and improves productivity.

Pest and Disease Resistance

Biodiversity aids in combating pests and diseases by providing habitats for predatory insects and birds that feed on pests, as well as microorganisms that produce natural compounds to resist diseases.

Improving Pollination
The diversity of pollinators, such as bees, butterflies, and birds, contributes to improved pollination and increased crop productivity.

Increasing Ecosystem Resilience
Biodiversity helps ecosystems adapt to environmental changes, such as climate change and the emergence of new pests and diseases.

Supporting Water Resource Sustainability
Biodiversity contributes to conserving water resources by improving water filtration and reducing evaporation.
Examples of the Importance of Biodiversity for Desert Agriculture:
- Drought-Resistant Trees: Such as acacia and tamarisk, help stabilize the soil and provide shade for other plants, as well as a source of fodder for animals[21].
- Ground-Covering Plants: Such as sagebrush and couch grass, help maintain soil moisture and reduce evaporation.
-Soil Microorganisms : Contribute to improving soil fertility and fixing nitrogen.
- Predatory Insects: Such as ladybugs, help in combating agricultural pests.

2. Practical Applications of Agricultural Genetics in Algerian Desert Areas
Algeria, like other countries, is focused on its agricultural sector due to its significant importance in achieving food security. The country has adopted a strategy to utilize desert areas and encourage agricultural investments to promote the sector as a whole. Among the methods implemented is the introduction of modern technologies in agriculture, including agricultural genetics, which helps sustain farming in desert areas by enabling plants to acquire genetic traits resistant to desert climates.

Key scientific efforts by the state include research studies in universities to improve crop quality, as well as the National Center for Agricultural Research's efforts to use agricultural genetics techniques to develop drought-resistant plant varieties. Additionally, international collaboration through global research centers and Algeria's cooperation with FAO.

Successful Studies in Agricultural Genetics Technology Applications in Algerian Desert Areas

StudyTopics	Study Objectives	Implementing Agencies	Results	Observations

- Development of Drought-Resistant Wheat Varieties	-Genetic Modifications in Wheat Seeds: To develop wheat varieties that can withstand drought and water scarcity.	- National Center for Agricultural Research in collaboration with University of Oran	- Development of Two New Wheat Varieties : P01 and P02 - 20% Increase in Production in Arid Regions - 30% Reduction in Water Consumption	- The new varieties were planted in Adrar and Beshar achieving an average yield of 2.5 tons per hectare.
- Development of Barley Varieties Resistant to Soil and Water Salinity	-New Barley Variety: To obtain a new type of barley that can resist soil and water salinity.	- Technical Institute for Agricultural Development in Arid Regions in collaboration with FAO	- Development of a Salt-Tolerant Barley Variety that withstands salinity up to 12 meters compared to traditional varieties - 25% Increase in Productivity in Highly Saline Areas	- The new varieties were cultivated in the OuarglaandTimimounregions, with production increasing to 3 tons per hectare.
- Use of Drip Irrigation Technology with Genetically Improved Varieties	-Water Use Efficiency: To enhance water use efficiency in desert areas.	- Ministry of Agriculture and Rural Development in collaboration with University of Constantine	- Reduction in Production Costs - 40% Decrease in Water Consumption - 30% Increase in Overall Production - Improvemention Soil Quality due to reduced salt accumulation	- The project was implemented in the Biskra and Ghardaïa provinces. - Yield rates rose to 4 tons per hectare.
- Development of High-Quality Date Varieties Resistant to Pests and Diseases	-Quality and Productivity of Dates: To improve the quality and productivity of dates in desert regions.	- National Institute for Agricultural Research in collaboration with University of Algiers	- Production of an Improved Date Variety (DagalaNour) that is pest-resistant and has a high yield - Increase in Yield to 8 Tons	- This variety was planted in BiskraandOuedsouf resulting in an annual productivity increase of 20%.

			per	
- Genetic Modification of Tomatoes Using CRISPR Technology for Fungal Pest Resistance	-Tomato Genetic Enhancement: To enhance tomato genes to increase shelf life while improving resistance to pests and fungi.	- French Agricultural Research Institute in collaboration with University of Tlemcen	Hectare, enhancing the economic return for farmers - 50% Increase in Shelf Life with a 15% rise in productivity	- Cultivation occurred in Mascara andTlemcen, with the average yield rising to 10 tons per hectar.

Source: National Institute of Agricultural Research of Algeria, https://inraa.dz/

Based on the aforementioned data, Algeria is making significant efforts in genetic agriculture to adapt farming to the desert environment and ensure its sustainability, as this technology is one of the most effective tools for that purpose. Numerous initiatives in various desert provinces have been the subject of study and research, where the National Institute of Agricultural Research of Algeria, in collaboration with various local scientific research and higher education institutions and international bodies, has worked in this field. This is evident through the development of drought-resistant and salt-tolerant crops via hybridization and genetic modification, resulting in the production of new strains resistant to water scarcity and soil salinity. This has reflected an increase in production of about 30%, with average yields rising from approximately 3 tons to 10 tons per hectare

Additionally, the use of modern irrigation techniques has led to reduced water consumption and better utilization, with a decrease of 40% in consumption alongside a 30% increase in production and improved soil quality. As for nutrient-efficient crops and those resistant to diseases and pests, studies have also focused on developing high-quality date varieties resistant to pests and modifying tomato genes to resist fungi, both contributing to a 15% increase in production and quality.

Consequently, agricultural genetics significantly contributes to enhancing sustainable use of natural resources, achieving food security, and improving the livelihoods of populations in these areas. Algeria must invest in research and development in agricultural genetics and effectively apply these technologies to leverage agricultural potential in its desert regions.

3. Challenges Facing the Implementation of Agricultural Genetics in the Algerian Desert

Technical and Scientific Challenges

- Lack of Research Infrastructure: Insufficient advanced laboratories and modern equipment necessary for conducting research in biotechnology.
- Shortage of Qualified Personnel: A lack of skilled professionals in agricultural genetics and genetic modification.
- Technology Transfer Difficulties: Challenges in transferring modern technologies from developed countries due to technological and logistical barriers.
- Unsuitable Technology: Lack of appropriate technology for harsh desert conditions.
- Lack of Scientific Data: Few field studies and research on the application of agricultural genetics in desert environments[22].

Economic Challenges:[23]
- High Costs: The cost of developing and applying agricultural genetics techniques is high, particularly with limited budgets for agricultural research.
- import Costs: High costs associated with importing modern equipment and technologies.
- Funding Shortages: Limited financial support from the government and private sector for agricultural research; difficulties in obtaining international funding for research projects.

Social and Cultural Challenges
- Resistance to Change: Farmers' reluctance to accept modern technology due to a lack of awareness of its benefits.
- Fear of Risks: Concerns about the potential risks associated with genetic modification techniques.
- Lack of Awareness: Insufficient awareness of the importance of agricultural genetics in improving agricultural productivity; absence of educational programs to inform farmers about the benefits of these technologies.

Environmental Challenges:
- Harsh Climate Conditions: High temperatures, water scarcity, and soil salinity make the application of modern techniques more difficult.
- Productivity Instability: Challenges in achieving stable productivity due to recurring climate changes.
- Limited Biodiversity: Low biodiversity in desert areas restricts the development of adapted plant varieties.

Legal and Ethical Challenges
- Absence of Legal Framework: Lack of clear laws regulating the use of genetically modified organisms (GMOs) in agriculture; difficulties in obtaining licenses for genetic modification techniques.
- Ethical Concerns: Fears regarding the impact of GMOs on human health and the environment; insufficient community discussion on the ethical aspects of agricultural genetics.

Logistical Challenges
- Access to Remote Areas: Difficulties in transporting equipment and modern technologies to remote desert regions.

- Infrastructure Shortcomings: Inadequate infrastructure necessary for applying modern techniques (such as roads, electricity, and communications).
- Lack of Supporting Services: Unavailability of technical support and training services for farmers in desert areas[24].

Challenges Related to Agricultural Policies

- Lack of Clear Strategy: Absence of a national plan to integrate agricultural genetics techniques into desert agriculture; insufficient coordination among government agencies, research centers, and universities.
-Focus on Traditional Agriculture: Continued reliance on traditional agricultural methods instead of adopting modern techniques[25].

Challenges Related to International Cooperation

- Difficulties in Cooperation with Developed Countries: Political and economic barriers that limit technology transfer from developed nations.
- Lack of International Partnerships: Insufficient international collaborations in agricultural research.

Conclusion

Desert agriculture is one of the most important alternatives for achieving sustainable development and economic growth instead of relying solely on hydrocarbons. Therefore, the Algerian government places significant emphasis on it through modern development programs. This is evidenced by the efforts made by the government that benefit desert agriculture in general. Furthermore, smart agriculture strategies, including agricultural genetic engineering, are among the most effective means to ensure the sustainability of crops and plants, allowing them to adapt to the harsh desert climate.

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