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Rare and Endangered Herbaceous Plants of Yardimli District

Abstract

Botanical Gardens for Plant Conservation (ICBGC), approximately 60,000 higher plant species worldwide or a quarter of the world's flora, may become extinct or be at risk of genetic erosion by the middle of this century. The list of rare and endangered plants found in various regions of the Republic of Azerbaijan is presented in the Red Book of the Republic of Azerbaijan (III edition), published in 2023. Among the rare and endangered species of flora in the III edition, 285 are herbaceous plants. In the III Red Book of Azerbaijan, published in 2023, 7 species of herbaceous plants were listed as rare and endangered in Yardimli region.

Keywords: *extinct, endangered plants, herbs, mesoxerophyte, anthropogenic factor*

Introduction

To expand international cooperation in the field of biodiversity conservation, the Republic of Azerbaijan acceded to the UN Convention on Biological Diversity in 2000. The National Strategy and Action Plan for the implementation of the "National Strategy for the Protection and Sustainable Use of Biological Diversity in the Republic of Azerbaijan for 2017-2020" are aimed at implementing effective measures in this area and achieving concrete results. Therefore, the main reason for this study is to learn about the rare and endangered species of the Azerbaijan Republic (Mammadov, Salakhova, 2020).

Research

In the III Red Book of Azerbaijan, published in 2023, 7 species of herbaceous plants were listed as rare and endangered in the Yardimli region. These plant species are representatives of the families of *Liliaceae (Fritillaria grandiflora* Grossh.), *Iridaceae (Gladiolus halophilus* Boiss. & Heldr., *Iris medwedewii* Fomin, *Iris grossheimii* Woronow ex Grossh.), *Asparagaceae (Ornithogalum hyrcanum* Grossh), *Orchidaceae (Steveniella satyrioides* Schltr.*), Caryophyllaceae (Silene talyschensis* Schishk.) (AR Red Book, 2023; Chase, 2016; APG IV 2013).

Fritillaria grandiflora Grossh - is a perennial bulbous herb. The bulb is not large, compressed, or bulbous. The stem is 35-50 cm high, bare. The leaves are alternate, lanceolate; the lower leaves are up to 1.5 cm wide, the upper ones are narrow. The flowers are very large, single. The inflorescence is wide, bell-shaped, and the leaflets are oblong, sharp, brown-red, and checkered. The capsule is axillary (Flora of Azerbaijan, 1952).

The flowering and fruiting period occurs in May. It reproduces by bulbs and seeds. It is also widespread in forests and rocky places. It is a xeromesophyte.

Found in the village of Daman, Yardimli district (Red Book of the ASSR, 1989). Limiting factors are related to anthropogenic (collection for decorative purposes) and zoogenic (trampling) factors (AR Red Book, 2023).

Iris grossheimii Woronow ex Grossh is a perennial herb, 3-10 cm high. The rhizome is short and creeping. The stem has one large flower spike. The leaves are gray-blue, narrowly linear, 2-3 mm wide, and sickle-shaped. The outer side of the inflorescence is bent down, 3.5-5 cm long, 2 cm wide, oblong, rounded-obtuse, the apex is hollow, bright gray, dark brown veined, the middle part is black, gray spotted, gradually turning into a nail, the surface is covered with dark purple, orange hairs (AR Red Book, 2013).

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It is widespread in the mountains of Nakhchivan (Ordubad district, Soyugdagh and Shikhyurdu mountains), Yardimli district and Deman village (Talibov et al., 2021; Ibrahimov 2022).

The limiting factor is anthropogenic (settlement, intensive grazing, collection, trampling). It is proposed to take control of the distribution areas, conduct regular monitoring, organize reservations in botanical gardens, and collect seeds (AR Red Book, 2023).

Iris medwedewii Fomin is a perennial herb. The rhizome is short, creeping, and the stem is 5-12 cm high, with a single large flower spike. The leaves are gray-blue, narrowly linear, 2-3 mm wide. The spike leaves are lanceolate, pointed. The tube of the inflorescence is shorter than the ovary; the outer parts are linear-scapular, black-purple, 3-4 cm long, 10-13 mm wide; the inner ones are large, obovate, white or blue, with blue-purple veins. The segments of the column are yellowish-brown, spotted, and the segments are blunt, toothed (AR Red Book, 2013).

Flowering is in April, and fruiting is in May. It reproduces by rhizomes and seeds. It is widespread in the middle mountain belt on dry and stony slopes, in steppe meadows. It is a mesoxerophyte. It is an ornamental plant (AR Red Book, 2013).

It is distributed in the village of Gosmalian in the Lerik region and the village of Deman in the Yardimli region (AR Red Book, 2023).

As a result of anthropogenic factors (collection as an ornamental plant, grazing and trampling), its number has sharply decreased. It is proposed to protect its populations as micro-reserves, organize its reservations in botanical gardens, conduct genetic research at the population level, and collect its seeds.

Gladiolus halophilus Boiss. & Heldr is a perennial herb. Its bulbs are ovoid, with reticulate parallel fibers. The stem is 20-25 cm tall, thin, sometimes twisted, and greenish. The leaves are bluish, narrowly linear, pointed and veined. The flower group is a 2-sided, sometimes 1-sided, 4-6-flowered spike. The inflorescence is whitish-blue, wide, open, and the upper side is shorter than the other sides. The stamens are slightly shorter than the stamens (Flora of Azerbaijan, 1952), (AR Red Book, 2023).

Flowering occurs in May and fruiting occurs in June. Propagated by bulbs and seeds. Distributed in the lower mountain belt on dry slopes Xeromesophyte Central Lesser Caucasus, Southern Lesser Caucasus and Nakhchivan Mountains. (Kotam village of Sadarak district and Ordubad district), Yardimli district, Komani plateau (Red Book of the ASSR, 1989; Ibadullayeva 2011, 2021). Limiting factors are anthropogenic and zoogenic factors.

Ornithogalum hyrcanum Grossh is a perennial herb. The bulb is ovoid, 1 cm wide, 2 cm long. The height of the stem is 12-20 (26) cm. The leaves are 2-4 (6), broad, lanceolate, 5-12 (15) mm wide, pointed at the tip, longer than the stem. The flowers are 2-4 (6), densely oval. The inflorescence is lanceolate or ovate, oblong, with a broad light green stripe on the back, and the edges are shiny. The flowers are arranged in a raceme. The stamen is narrow, reaching the middle of the inflorescence. The column is shorter than the ovary. The capsule is wingless, evenly ribbed (Flora of Azerbaijan, 1952). The flowering and fruiting period occurs in May and June. It reproduces by bulbils. It is widespread in forests in the middle mountain belt. It is xerophytic and salt-tolerant (AR Red Book, 2023).

It is widespread in the Lankaran mountains, in the Arvana village of the Yardimli district.

Limiting factors are anthropogenic (gathering, intensive grazing, use of territories for agricultural and settlement purposes) and natural (susceptibility to the negative effects of changing climatic factors) factors. It is proposed to organize individual protection by fencing off the distribution areas, organizing its reservation in botanical gardens, ensuring the collection and restoration of its seeds and searching for new distribution areas.

Steveniella satyrioides Schltr is a perennial herb with an entire rhizome, 1.0-2.5 cm long. The stem is 20-40 cm high, with mostly oblong-oval, brown-green leaves with red-brown spots. The flower cluster is oblong, very dense, 10 (13)-40 cm long, with 5-18 (20) bent flowers. The cap is 7-10 mm long, red-green, and formed by three fused outer leaflets of the calyx. The lip is green-brown, reddish-brown at the base, the lateral lobes are rhomboid, the middle lobe is oblong-linear, 4-4.5 mm long (AR Red Book, 2013).

Flowering is in April, and fruiting is in June. It is widespread in the foothills, lower and middle mountain belts, in forests, forest glades, bushes, and mesophytic mountain meadows that arise after the forest. It is widespread in the Kish village of Sheki region, around Gelarsen-Gorarsen fortress, east of the Greater Caucasus, Lankaran mountains (Astara and Lankaran regions), Shinabend village of Yardimli region, and Lerik region, around Orandchay (AR Red Book, 2023).

The limiting factors are anthropogenic (grazing, trampling and collection) and natural (strong dependence on the habitat and sensitivity to the negative impact of changing climate factors). Partially protected in the Shahdagh National Park. It is proposed to fence off other known habitats, conduct regular monitoring, organize reservations in botanical gardens and create micro-reserves.

Silene talyschensis Schishk. is an annual herb. Its stems are 20-25 cm high. The basal leaves are small, oblong, obovate, blunt, and petiolate. The upper leaves are sessile. The flowers located on the branches are unilateral, sessile, and are horizontally bent during flowering. The calyx is 10-12 mm long, covered with cylindrical hairs. The capsule is 6-7 (8) mm long, broadly ovoid. The seeds are 1.5-2 mm long, black (Flora of Azerbaijan, 1952).

Flowering and fruiting occur in May-July. It reproduces by seeds, is drought-resistant and photophilous. It is a component of mountain-xerophyte groups. It is found on dry, gravelly slopes in the middle mountain belt (AR Red Book, 2023).

Conclusion

It is distributed in the center of the Lesser Caucasus (Garghabazar village, Fuzuli region), Yardimli region, Orand village, Lerik region, Nakhchivan mountains (Bichenak village, Shahbuz region), and Nakhchivan plain (Ordubad region) (Flora of Azerbaijan, 1952; Askerov, 2011). The limiting factor is anthropogenic (trampling, grazing) factors.

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Economic and Biological Importance of Legumes: Industrial and Phytotherapeutic Applications

Abstract

The article discusses the biological and economic benefits of leguminous plants, as well as their role in soil nitrogen enrichment and the utilization of different species. The legume family is a widespread group of plants with a wide range of applications worldwide. Legumes are used in agriculture as fodder and sideral plants, in industry as technical and dyeing raw materials, and in medicine as medicinal plants.

More than 440 species of leguminous plants grow in Azebaijan. Thanks to bacteria of the genus Rhizobium living in their root system, legumes play an important role in increasing the nitrogen content of the soil. The types included in the section, such as *Styphnolobium japonicum* (L.) Schott., *Spartium junceum* L, *Ononis arvensis* L., *Melilotus officinalis* (L.) Pall. and *Glycyrrhiza glabra* L.– have both medicinal and anti-inflammatory properties. Many of these plants contain many colorants, essential oils, vitamins and biologically active substances. They are popular in both industrial production and folk medicine because of their rich chemical composition. Legumes are also known as ornamental plants and honey bees. Thus, legumes have enormous biological and economic potential.

Keywords: *legumes, medicinal plants, nitrogen fixation, forage plants, dye plants, phytotherapy*

Introduction

Fabaceae Lindl. - is one of the largest and most important plant families in the world. Plants of this family are crucial for agriculture, industry, medicine and ecology. They are widely distributed and suitable for multiple uses due to their nitrogen-fixing, melliferous, medicinal and ornamental properties. Numerous representatives of this family are widely distributed in Azerbaijan and used in local medicine in different areas.

Research

Fabaceae Lindl. it is one of the largest and most important plant species in the world. Plants in this family are crucial for agriculture, industry, medicine and ecology. Their widespread and versatile properties include nitrogen-fixing, honey-producing plant, medicinal and ornamental properties. This family has numerous species that are widely distributed in Azerbaijan and used in local medicine in various places.

Scientists have discovered that the legume family is one of the most common and important families on the planet. Members of the legume family are used for a variety of purposes in both agricultural and domestic applications. Legumes are classified according to their applicability: medicinal, technical, fodder, honey-producing plant, food, ornamental, soil strengthening, dyeing, etc.

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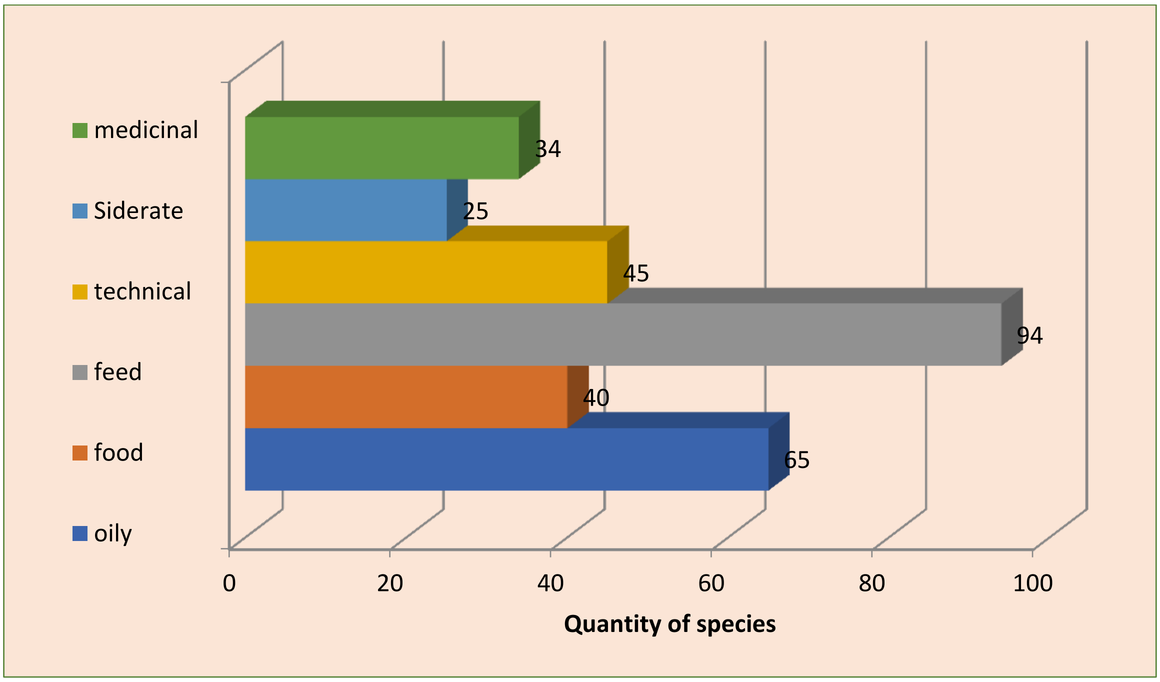

Figure 1. Classification of legumes according to their uses

There are 12,000 species of the legume family worldwide, united in more than 500 genera (Askerov, 2016). In the Caucasus is represented by more than 550 species, in Azerbaijan - 440 (Hajiyev, Musayev, 1996). Among the important genera of the season: *Trifolium* L, *Trigonella* L, *Vicia* L, *Onobrychis* Hill, *Lathyrus* L, *Amoria* C. Presl, C*hrysaspis* Desv. etc. included. Many of them are valuable fodder plants. Also, *Medicago* L., *Onobrychis* Hill, *Vicia* L., *Trifolium* L., *Lathyrus* L., *Melilotus* Hill., etc. are plant species used as siderats. Many species of the legume family are valuable technical and medicinal plants with rich natural resources. In this respect, such species of citrus plants as *Astragalus* L., *Glycyrrhiza glabra* L., *Alhagi* Hill, species of *Melilotus* Hill, *Ononis* L., etc. are more useful. One of the valuable properties of legume crops is their high honey production. Legumes with high honey production include *Melilotus albus* Medik., *Onobrychis cyri* Grossh., *O. transcaucasia* Grossh. and most species of the genus Trifolium can be noted (Abbasova, Ibadullayeva, 2017).

In addition, nodules that absorb and fix atmospheric nitrogen are present on the roots of about 70% of legumes. *Rhizobium* Frank is a type of root nodule that is formed by the outgrowth of root parenchyma cells and has different shapes. provides endogenous reproduction of related bacteria. As a result of interaction between legumes and bacteria, legumes return 100-140 kg of nitrogen per hectare of soil per year.

Woody representatives of legumes are used to produce high quality furniture. *Pericopsis elata* (Harms) Meeuwen is the most valuable legume in the world for wood.

Ornamental plants such as *Albizia* Durazza, *Acacia* Hill, *Robinia* L., *Laburnum* Medik., *Spartium junceum* and *Gleditsia caspia* Desf. are of great importance.

Representatives of legumes are rich in B vitamins, fiber and protein. Since ancient times, many species have been grown for food and used for oil production (*Glycine* Willd., *Arachis* L., *Cicer* L., *Pisum* L., *Phaseolus* L., *Vicia* L., etc.) (Isayev, 2008).

Spartium junceum L. is an unpretentious ornamental shrub that is drought and light tolerant. During the flowering period, which lasts from May to July, the outside of the shrub is covered with fragrant, densely-waved yellow flowers resembling a large golden ball, which bloom for more than a month. Medium quality ropes, sacks, and paper are made from the saricol rod. Its flowers have essential oil and important coloring agents flavonoids. This substance can create a dyeing solution that can dye woolen yarn yellow or any other color such as yellow, green, brown, beige, etc. This can be dyed in several colors.

There are up to 50 species of *Styphnolobium japonicum* (L.) Schott. In the Caucasus, including Azerbaijan, 1 species is cultivated: *Styphnolobium japonicum* (L.) Schott. *Styphnolobium japonicum* (L.) Schott. is both an ornamental and a valuable medicinal and dye plant (Nasibova, 2018). It is widely used in Azerbaijan as a decorative plant in parks and gardens. During the flowering period of Safflower (approximately from the second half of July to the end of August), its large yellow flowers are striking in their beauty (Gahramanova, Ibadullayeva, 2017).

Because of its healing properties, sapora was considered mysterious and sacred in ancient times in Japan and China. Various extracts from the shoots and flowers of the plant are used to treat eczema and skin diseases.

The method of treatment with safflower alcohol in folk medicine has been passed down from generation to generation and has survived to this day. The patient does not feel any harm from the alcohol, because it is easily digested by him. Alcoholic essences accelerate the healing of hard-to-heal purulent wounds and burns of the first and second degree. It is also used to treat hair loss, dry pleurisy and skin rashes.

Coloring agents such as rutin, sophorin and quercetin are found in various above-ground parts of Japanese saphora. Acquired dyes can be used to apply millet, golden yellow, orange, brown and other colors to wool and silk.

Ononis arvensis L. - up to 70-80 species of the genus Ononis live around the world. Five species are found in the Caucasus, including Azerbaijan.

People since ancient times have known about the medicinal properties of the Ononis arvenis. The root of the plant is used as a medicine. From the root part of the Ononis arvensis was prepared infusions, which were used to treat edema, diuretic and styptic diseases. Its extract eliminates kidney and bladder stones, stops bleeding in acute hemorrhoids and relieves chronic constipation.

Astragalus L. The genus Astragalus includes 1600 to 2000 species worldwide. Of these, 150 species are distributed throughout the Caucasus, including Azerbaijan.

Herbs harvested between May and June are used for medicinal purposes. Collection should start at the end of May and continue until the sowing phase. However, the plant cannot be harvested by hand. because the shoot may be damaged. As a tonic and immunostimulant, astragalus preparations are used to increase the body's resistance. It also lowers blood pressure, improves blood circulation, increases sexual activity and is very good for chronic heart failure (Nasibova, Ibadullayeva, 2018).

Arachis hypogaea L. Up to thirty species of the genus peanut are found worldwide. Up to 53% of oil is contained in peanut seeds.

Since it contains a high amount of fiber, peanuts satisfy hunger. It is also considered a plant with medicinal properties. In his works, French professor Boudreau noted that peanut consumption led to improved health of hemophilia patients. The plant is also used to improve sexual function and improve the functioning of the liver and other organs (Mammadova, Nasibova, Ibadullayeva, 2023).

Melilotus officinalis L.- This medicinal plant is highly prized. This aromatic plant is also useful for fodder and honeydew. Coumarin is the substance that gives khashanbul a sweet flavor. The amount of coumarin increases during the flowering period. Coumarin is used as a flavoring agent in soaps, tobacco and perfumes. Hashambul is used in both scientific and folk medicine for treatment. A decoction of the dried herb is drunk for colds, to reduce suppuration, and to treat pain and malaria. For the treatment of respiratory diseases it is used as an expectorant and chest emollient (Mammadov, 2010).

Galega officinalis L.- It is used in scientific and folk medicine because it improves heart function, reduces blood clotting, improves diuresis and increases lactation. It is used to treat minor cases of diabetes mellitus. It is done by using the above-ground part of the plant. It exists in forested areas of the lower and middle mountain ranges and in open areas.

Lotus corniculatus L. is used as a medicinal remedy. It mainly contains bioactive substances that help dissolve, crush and remove kidney stones from the body. It has a pleasant odor, so it can be used in the perfume and cosmetic industry.

Glycyrrhiza glabra L.- Roots and roots of the plant are used to treat stomach ulcers, whooping cough, pulmonary tuberculosis, dry bronchitis, meat and mushroom poisoning, eczema and other inflammatory diseases (Aliyev, 2016). Animals greatly appreciate the above-ground part of licorice bare. Its roots contain valuable dyes that can create up to fifty different colors.

The extract from the root of licorice bare root is of great importance in mechanics for coating metals, hardening steel alloys and extinguishing fires. The trunk and roots impregnated with soundproof cardboard, rope, shoe polish and other materials The waste material is used to make fertilizer.

Indigofera L.- It is a valuable plant that can be obtained from nature. It is cultivated in many countries because its leaves contain the famous dye ingo. Its fruits can also have gray, brown and beige shades. The resulting colors are very resistant to various chemical attacks.

The most common natural source of vitamin C is indigofera. It is widely used in folk medicine in the form of decoction for scurvy, rickets, choleretic and diuretic treatment, as well as for tuberculosis and jaundice.

Conclusion

Members of the legume family have many useful properties and, because they are widely used in agriculture, industry and medicine, they are of vital importance. Their value is increasing because of their ability to increase soil fertility, their use as medicinal and industrial plants, and as honeybees and ornamental plants. Legumes are of strategic importance for food security and the development of alternative medicine as demonstrated by the species studied.

Thus, much attention should be paid to the diversity of leguminous grasses that are useful and productive in various industries and agriculture in both summer and winter pastures. In addition, leguminous grasses are widely used in grassland reclamation and grassland farming.

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Effect of Spring Fertilization on Early Blooming in Almond Trees: A Case Study from the Absheron Peninsula

Abstract

Almond cultivation is highly vulnerable to early spring frosts, particularly in climates where warming trends and sudden cold snaps coincide with flowering. Among several agronomic factors influencing almond phenology, spring fertilization—especially nitrogen input—has emerged as a potentially critical determinant of bloom timing. This three-year study (2023–2025) conducted on the Absheron Peninsula investigates how foliar-applied nitrogen fertilizers affect the flowering onset of the early-blooming Guara cultivar of *Prunus dulcis*. Trees receiving nitrogen in early March bloomed 7–11 days earlier than untreated controls. In 2025, a striking early bloom was observed just 12 days after nitrogen application. However, this advancement coincided with frost events that caused 20–40% yield losses. These findings underscore the dual role of nitrogen as both a growth stimulant and a potential risk enhancer. In frost-prone regions, nitrogen fertilization should be carefully timed to avoid ecological and economic losses. This paper integrates field data, comparative analyses, and a comprehensive review of the physiological mechanisms linking nitrogen to bud development and bloom induction.

Keywords: *Prunus dulcis, nitrogen fertilization, phenological shift, bloom advance, spring frost, Guara cultivar, Absheron Peninsula, climate risk management*

Introduction

Almond (*Prunus dulcis*) is one of the most economically important nut crops globally, with rising interest in cultivation extending beyond traditional Mediterranean zones into semi-arid and continental climates. Due to its inherently early phenological development, almond is particularly susceptible to spring frost damage, a leading cause of yield instability (Rodrigo, 2000; Egea et al., 2003).

Traditionally, bloom timing has been attributed to genetic and climatic factors—mainly the fulfillment of chilling and heat requirements (Campoy et al., 2011; Tabuenca, 1964). However, emerging evidence points to the significant impact of agronomic practices such as fertilization, irrigation, and pruning on bud development and floral timing (Fernandez-Escobar et al., 2004; Dag et al., 2010). Nitrogen, a key macronutrient for cell division and hormonal activity, has been particularly associated with the acceleration of bud break and bloom in temperate fruit crops (Marschner, 2012; Tromp, 1984).

Research

This study investigates how early-spring nitrogen fertilization affects bloom advancement in almonds grown in the unique microclimate of Azerbaijan's Absheron Peninsula. The 'Guara' cultivar, known for its earliness and self-fertility, was selected due to its increasing use in local orchards.

2. Materials and Methods

2.1 Experimental Site

The trial was conducted at the Absheron Experimental Station (40.453866 N, 50.085366 E), located in a semi-arid zone with highly variable spring weather. The site has low annual precipitation (200–300 mm), a high summer evapotranspiration rate and poor organic matter content—conditions typical of the Absheron Peninsula.

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2.2 Orchard Design and Tree Selection

A 600 m² high-density orchard was established in 2021 with 45 *Guara* almond trees, spaced at 3 × 3 m. Eighteen trees were selected for this study and randomly assigned to three groups (6 each):

- **T1 – Main group** (early spring nitrogen fertilization)
- **T2 – Replicate group** (identical treatment for validation)
- **C – Control group** (no nitrogen until post-bloom)

2.3 Soil Characteristics

The soil was gray calcareous with the following parameters:

- pH: 6.3
- Organic matter: 2.6%
- Lime content: 26.4%
- Electrical conductivity: 0.38 dS/m
- Available nitrogen: Low
- Texture: Silty-clay

2.4 Fertilization Protocol

Fertilizers were applied foliarly on dry days:

- **March 5**: 32-2.5-32 (N: 32%, SO_3 : 32%)
- **April 4**: 13-0-46 (N: 13%, K_2O: 46%)
- **May 22**: 11-0-0 (N: 11%, MgO: 15.4%)
- **June 25**: 13-40-13 (N: 13%, P_2O_5 : 40%, K_2O: 13%)

Soil nitrogen content was monitored pre- and post-treatment using standard Kjeldahl analysis.

Conclusion

3.1 Flowering Phenology

In all three years, trees treated with nitrogen on March 5 entered bloom approximately 7–11 days earlier than untreated trees. The most dramatic result was observed in 2025: all nitrogen-treated trees bloomed by March 17, while untreated controls remained dormant until March 27–30.

3.2 Frost Damage and Yield Impact

In 2023 and 2025, frost events (March 18–21) occurred shortly after bloom initiation in nitrogen-treated trees. These trees exhibited visible floral damage (necrosis, abscission) and reduced fruit set. Estimated yield loss ranged between **20–40%**, depending on bud stage at frost time. Control trees, blooming later, escaped this damage and showed more uniform kernel development at harvest.

3.3 Bud Morphology and Growth Dynamics

Microscopic dissection revealed more advanced floral organ development in treated trees by mid-March, including faster ovule maturation and elongation of flower parts. This correlates with studies by Rodrigo and Herrero (2002), showing nitrogen's involvement in primordia expansion through hormonal pathways.

4. Discussion

4.1 Mechanism of Bloom Advancement

Nitrogen promotes rapid cell expansion and the synthesis of growth-regulating hormones, including cytokinins and gibberellins. These compounds have been linked to earlier and more vigorous bud development in almond and other Rosaceae (Sanchez-Perez et al., 2012; Tromp, 1984). Gibberellins, in particular, are known to reduce dormancy depth and hasten phenophase transitions (Dennis, 1994).

Furthermore, high nitrogen availability alters the carbon/nitrogen balance in tissues, promoting shoot elongation and reducing dormancy persistence (Blanke & Lenz, 1989). These biochemical processes likely explain the bloom acceleration observed in treated trees.

4.2 Risk Trade-Offs in Spring Fertilization

While nitrogen-induced early blooming may be beneficial under frost-free conditions, it poses a significant threat in regions like Absheron where late frosts are unpredictable. A similar dilemma

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has been noted in cherry, apricot, and plum production across Eastern Europe and Central Asia (Stoev et al., 2021).

Additionally, early blooming can lead to phenological desynchronization with pollinators, potentially affecting fruit set even in self-fertile cultivars like Guara (Martinez-Gomez et al., 2009).

4.3 Strategic Recommendations

To mitigate risks, nitrogen fertilization should be aligned with local chill-hour models and thermal time forecasts. Several decision-support models—such as Utah Model, Dynamic Model, or CHU accumulators—can help growers adapt nutrient schedules to local conditions (Fishman et al., 1987; Luedeling et al., 2009).

5. Conclusion and Recommendations

This study confirms that spring nitrogen fertilization significantly accelerates blooming in *Prunus dulcis*, particularly in the early-flowering Guara cultivar. However, this phenological shift comes at a cost: increased vulnerability to frost and potential yield reductions.

Recommendations for frost-prone regions:

1. **Delay nitrogen fertilization** until late April or after chill and heat thresholds are met.
2. **Adopt split nitrogen applications** to reduce hormonal spikes and avoid stress induction.
3. **Use phenology forecasting models** to adjust fertilization in line with bloom safety windows.
4. **Monitor bud development microscopically** to fine-tune timing in high-risk years.
5. **Experiment with low-nitrogen early-season alternatives** (e.g., micronutrients, seaweed extracts).

These recommendations are particularly relevant for almond-growing regions in Central Asia, Iran, Turkey and the Caucasus, where frost threats coincide with economic dependence on stable yields.

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Analysis of a Smart Agriculture System Based on the Internet of Things

Abstract

The article highlights the interplay between the smart agricultural Internet of Things system and innovation-driven approaches in promoting harmonious coexistence between society and nature and promoting high-quality economic growth. The article discusses the methods of using IoT-based green technologies, which provide new ideas for the development of green innovations and the digital economy. To illustrate the effectiveness of the use of various digital technologies, we consider examples of digital, green and innovative development in agriculture. The article presents a comprehensive analysis based on existing research and paves the way for future in-depth research. The conclusions of this article have both theoretical and practical significance and suggest practical approaches to achieve sustainable development in various sectors.

Keywords: *smart agriculture***,** *IoT*, *agriculture*, *green technology*, *Python*, *aeroponic*

Introduction

To resolve the contradiction between the environment and socio-economic development, digital, green and innovation are key issues for sustainable economic development. The transition to a digital economy is a step towards rapid resource optimization and high-quality economic development. At the technical level, the digital economy includes emerging technologies such as big data, cloud computing, the Internet of Things (IoT), blockchain, artificial intelligence (AI) and 5G communication (Saiz-Rubio & Rovira-Más, 2020).

Green economy a new economic form that is developed with a market orientation, based on the traditional industrial economy. And aims to achieve the interrelationship between the economy and the environment. (Pearce,1989).

A recent report published by Allied Market Research – titled “Green Technology and Sustainability Market by Technology and Application: Opportunity Analysis and Industry Forecast, 2020–2027” – confirms, that large corporations or small and medium-sized enterprises have begun to integrate environmental policies into their business models (Tian, 2021).

In recent years, some manufacturing enterprises have begun to develop and produce green products with environmental efficiency, in order to increase market share and product competitiveness. In this context, the green supply chain has emerged, providing a new mode of operation for enterprises. The adoption of green supply chain management greatly contributes to the long-term viability of businesses and serves as an effective operational plan for the growth of modern businesses (Tseng et al, 2019).

Western countries have increased their funding for “green projects.” For example, in 2021-2023, the European Union allocated 22.8 billion euros for the development of “green” activities, while the US allocated 94.4 billion dollars. South Korea and China are leading in this regard: Korea invested 38.1 billion dollars, 3% of the country’s GDP; China invested 215 billion dollars, 3% of the country’s GDP (Green Economics Institute, 2022).

With the widespread use of “global things” and artificial intelligence, the digital economy is also developing rapidly. Many new technologies and business models have emerged in agriculture. These innovations have changed the process of value creation (Pan et al., 2022).

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Research

The theoretical basis of the study is the work of researchers on innovative development and innovation management, journals, own research, research results of local and international organizations and Internet resources, on the basis of which the discussion and conclusions are illustrated.

The methodological basis of the study is both general scientific and economic research methods, namely: descriptive, analytical and explanatory methods, functional analysis and synthesis, systematic and logical approaches, grouping, comparison, evaluation and statistical analysis methods, on the basis of which important research issues are identified.

Smart Agriculture IoT System Example Using Python Programming

The Internet of Things is a technology that connects devices to a computing network and allows them to collect, analyze, process, and transmit data to other objects through software and hardware. For the most part, devices operate without human intervention, although humans can interact with them. IoT systems typically consist of a network of smart devices and a cloud platform to which these devices are connected (Yan et al, 2024).

We will discuss the use of powerful IoT technology to simulate a smart agriculture IoT system and solve this problem.

In order for computers to communicate with the Internet, it is necessary to define communication protocols (Gorli & G. Yamini, 2017).

For its ease of use, we have developed a Python library called *SmartAgro*, which aims to communicate with the server and facilitate the transmission of messages through Python software. The Python standard library is very extensive and provides a wide range of functionality.

If both enabling the *SmartAgro* service and connecting sensors to detect data are done on the same *UNIHIKER*, then it functions as both a client and a server.

The *SmartAgro* IoT system is used to determine the moisture value of an external soil moisture sensor, display the data on the screen, and simultaneously send it to the *SmartAgro* IoT platform for viewing on the platform's web interface.

After connecting remotely to Rowboard web menu, post entries for the topic "Smart Agriculture IoT System/Soil_Moisture_Value" will appear on the platform's website. (Figure 1).

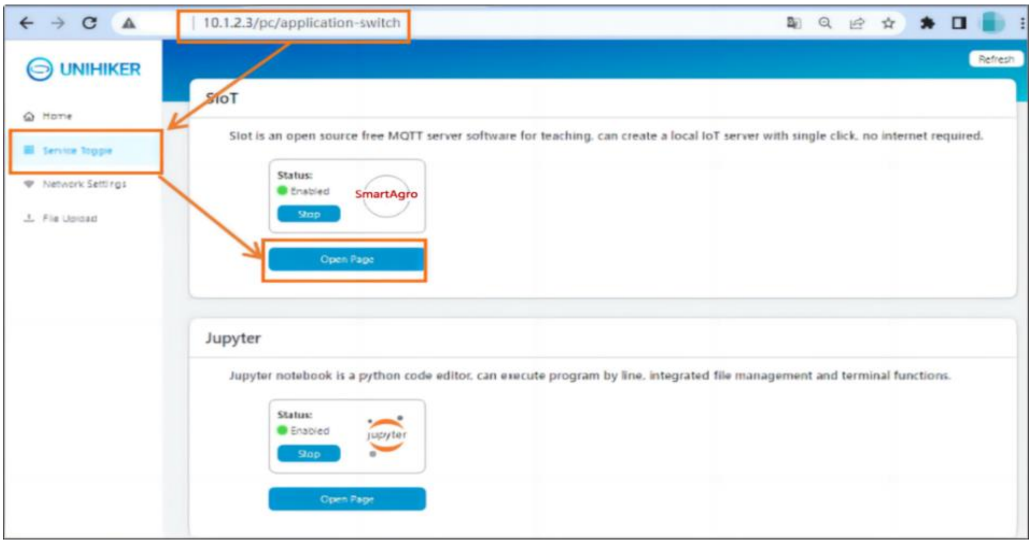

Figure 1. Sending Humidity Data to SmartAgro IoT Platform.

Adding the platform notification subscription function to the dashboard allows irrigation to be controlled via the *SmartAgro* IoT platform web page when the soil is dry. The complete example program is as follows:

ISSN: 2707-1146
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```
from unihiker import GUI  # Import GUI module from unihiker library
from pinpong. board import Board, Pin  # Import Board and Pin modules from pinpong library
import time  # Import time library
import siot  # Import siot library for SIoT communication
 gui = GUI()  # Instantiate the GUI object
 Board().begin()  # Initialize the UniHiker board
adc0 = Pin(Pin.P21, Pin.ANALOG)  # Initialize pin 21 as analog input mode
 SERVER = "10.1.2.3"  # MQTT server IP, enter your actual IP
CLIENT_ID = ""  # On the SIoT platform, CLIENT_ID can be left empty
IOT_UserName = 'siot'  # Username
IOT_PassWord = 'dfrobot'  # Password
IOT_pubTopic = 'Smart Agriculture IoT System/Soil_moisture_value'  # Moisture topic, "Project name/Device name"
 siot.init(CLIENT_ID, SERVER, user=IOT_UserName, password=IOT_PassWord)  # Initialize SIoT with the provided credentials
siot.connect()  # Connect to the SIoT platform
  # Display background image
img = gui.draw_image(w=240, h=320, image='img/stop1.png')
 gui.fill_rect(x=45, y=35, w=95, h=30, color="white")  # Draw a rectangle for humidity
gui.fill_rect(x=148, y=35, w=55, h=30, color="white")  # Draw a rectangle to display the humidity value
 text_1 = gui.draw_text(x=48, y=36, color="orange", text='humidity:')  # Display humidity
text_value = gui.draw_text(x=155, y=36, color="orange", text="")  # Display the humidity value
 while True:
    Soil_moisture_value = adc0.read_analog()  # Read the analog value
    print(Soil_moisture_value)  # Print the humidity value
    siot.publish(IOT_pubTopic, Soil_moisture_value)  # Publish the information to the SIoT platform
    text_value.config(text=Soil_moisture_value)  # Update the humidity value
    time.sleep(1)  # Delay for 1 second
```

Figure 2. Complete program in Python.

After connecting remotely to *UNIHIKER* and the results will be displayed. The dashboard shows that the temperature and humidity values are constantly updated and displayed in real time on the screen.

In this example, we discussed the use of remote methods on crops, combined with an IoT platform.

Innovative Technologies in Agriculture and Economic Challenges (Using Aeroponics on the Example of Georgia)

Along with the growth of the world population, the demand for clean and healthy agricultural products is increasing. It is necessary to develop and implement innovative methods in agriculture. In this regard, one of the most effective and new methods is aeroponics, which allows the cultivation of a 3-dimensional greenhouse in a minimal area, in the absence of soil, using a small amount of water. In this regard, Georgian companies are not lagging behind the processes taking place in the world and are actively involved in the improvement and development of the aeroponics system. We believe that the introduction of aeroponics will make a positive contribution to improving food security (Hamilton, 2000).

We will consider one of the Georgian startups “GSA Technologies”, which aims to develop a 100% environmentally friendly greenhouse. To achieve this goal, the company used an unconventional, innovative method of plant vegetation, namely aeroponics.

The term aeroponics means working in the air. More specifically, aeroponics refers to the vegetation of plants without soil, in an artificially created controlled environment. According to Osvald, all the necessary nutrients and minerals are supplied to the plant by spraying them on the roots. Typically, the plants are equipped with spectral lighting to accelerate the vegetation process with maximum efficiency (Osvald et al., 2015). As a rule, spectral lighting is arranged above the plants to accelerate the vegetation process with maximum efficiency.

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Under aeroponic conditions, the roots of the plant were clearly visible and allowed the researcher to study its structure. Since then, many researchers have used this method to study various plants (Zobel et al., 1993).

Since the plant roots are in a controlled, oxygen-rich environment, one of the main advantages of aeroponics is its high yield. The development of modern technologies has further simplified this process. The availability of various measuring devices (including pH, humidity, and temperature meters), as well as the emergence of various mobile applications that simplify the control process, are increasingly strengthening the advantages of aeroponics over other traditional methods (Koghuashvili & Mamukelashvili, 2020).

Future trends in the integration of digital, green and innovative development include: the integration of digital technology and green technology, such as 5G, artificial intelligence, the Internet of Things, the Industrial Internet, big data and green and low-carbon industries, promotes the construction of smart cities through the integration of two-way scenarios of digital technology and green technology.

Conclusion

At the intersection of the digital, green and innovative economies, new trends in sustainable development are emerging, shaping the pursuit of sustainability and economic growth.

We discussed, “Smart Agriculture IoT System Example Using Python Programming” Smart Agriculture IoT System“. We have developed a software framework in the Python environment that allows agricultural crops to be controlled via an IoT platform website.

In these examples, we have shown the effectiveness of using remote methods on agricultural crops in conjunction with an IoT platform. Thus, the use of digital technologies is a prerequisite for promoting innovative development in agriculture.

Finally, the convergence of digital, green and innovation in the economy is shaping new trends in sustainable development.

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The Role of Genetically Engineered Animals in Modern Biotechnology

Abstract

This article provides a comprehensive overview of the growing significance of genetically engineered animals in the field of modern biotechnology. Beginning with the historical development and foundational breakthroughs in genetic engineering, the paper traces the evolution of transgenic animal technologies and their expanding applications across multiple sectors. In the field of biomedical research, genetically modified animals serve as critical models for studying complex human diseases such as cancer, neurodegenerative disorders, and metabolic syndromes. In agriculture, transgenic livestock and poultry are utilized to enhance productivity, disease resistance, and nutritional content. Additionally, environmental biotechnology benefits from genetically engineered species designed for pollution detection and bioremediation, while industrial biotechnology employs such animals as bioreactors for the cost-effective production of therapeutic proteins, enzymes, and monoclonal antibodies. The article further explores the ethical concerns surrounding animal welfare, biodiversity, and the long-term ecological impact of releasing genetically modified organisms. It examines the evolving regulatory frameworks that govern the use of transgenic animals in research and industry, highlighting both national policies and international guidelines. Finally, the article discusses current challenges and emerging trends, including advancements in genome editing technologies like CRISPR/Cas9, which promise greater precision and efficiency in the creation of genetically engineered animals. By analyzing both the benefits and risks, this article aims to provide a balanced perspective on the present and future role of transgenic animals in science and society.

Keywords: *animals, genetically engineered, biotechnology*

Introduction

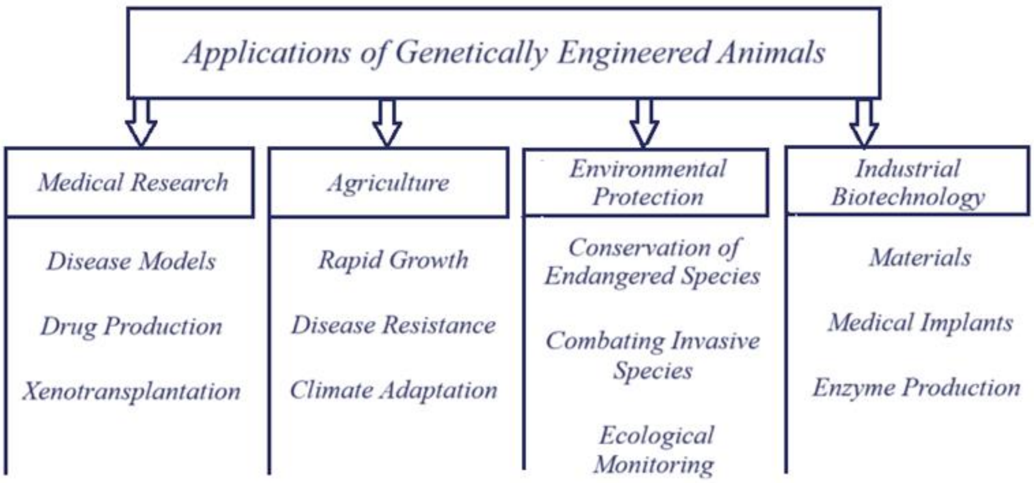
Since the dawn of humanity, food has been a vital resource essential for human survival. Ensuring food security, storing it under optimal conditions, and producing it in sufficient quantities are fundamental to sustaining human life. Nowadays, consumers are increasingly concerned about the quality and safety of food, and sensitivity toward the consumption of healthy and safe food is steadily growing (Sevim, et.al., 2021; Çağlar, Mustafa, 2018).

The food supply chain encompasses the entire journey of food from farm to table, with consumers representing the final point of contact. Food safety plays a crucial role in protecting both the health and the economic interests of consumers and food service professionals worldwide. While regulatory authorities are tasked with overseeing food safety within the food-service industry, maintaining proper food safety practices at home falls under the responsibility of consumers. Therefore, knowledge and application of food safety principles significantly influence the occurrence of foodborne illnesses (Çiğdem, et al., 2021).

Genetic engineering is a collection of biotechnological methods used to modify or manipulate the genetic material of organisms. In recent decades, especially with the development of widely used genome editing technologies such as CRISPR-Cas9, genetically engineered animals have become an integral part of modern biotechnology (Doudna, Charpentier, 2014). These animals are used to model diseases, test drugs, increase food production, and even protect the environment.

The history of genetic engineering began in the 1970s with the discovery of recombinant DNA technology. The first transgenic mouse was created in 1974, but the first patented transgenic animal - the "oncomouse" - was only created by Harvard University in 1988 (Sherkow, Greely, 2015). This significant scientific achievement laid the foundation for the large-scale development of genetically modified animals in subsequent decades.

Among modern genome editing technologies, Zinc Finger Nucleases (ZFNs), TALENs, and especially CRISPR-Cas9 systems hold significant importance. The CRISPR-Cas9 system has revolutionized genome editing. This system consists of guide RNA that recognizes the target DNA sequence and the Cas9 enzyme that cuts DNA. The simplicity, efficiency, and affordability of the technology make it suitable for widespread application (Doudna, Charpentier, 2014). In recent years, improved versions of CRISPR technology, such as Base Editing and Prime Editing, have been developed to create more precise mutations.



Scheme1: Applications of Geneticall Engineered Animals (Li, et al., 2019)

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2. Materials and Methods

2.1. Genetically Engineered Animals in Medical Research

In the field of medical research, genetically engineered animals, especially mice, have become indispensable tools for studying many human diseases (Whitelaw, et al., 2016). Transgenic mice are widely used in oncology research to study the growth and metastasis of cancer cells. Such models allow for better understanding of cancer cell behavior and response to treatment methods (Whitelaw, et al., 2016; Brian, et al., 2018).

Genetically modified animals also play an important role in studying neurodegenerative diseases, including Alzheimer's, Parkinson's, and Huntington's diseases (Whitelaw, et al., 2016; Michael, et al., 2024). For example, transgenic mice modeling Alzheimer's disease demonstrate the formation of beta-amyloid plaques in brain tissue and the development of neurological symptoms. These models create valuable opportunities for developing and testing potential treatments.

Genetically engineered animals are also widely used in the research of metabolic diseases, including diabetes, obesity, and metabolic syndrome (Wang, et al., 2014). For instance, genetically modified mice that overexpress or deactivate insulin receptors have been created for diabetes research. These models are used to study the basic mechanisms of diabetes and test new treatment methods.

In the field of drug production, genetically engineered animals are used as "bioreactors." They can produce important proteins that are produced in the human body (e.g., insulin, coagulation factors) in their milk or blood (Ran Zhang, et al., 2018). This method allows for cheaper and more effective production of natural human proteins. At the same time, transgenic animals are also used for the production of monoclonal antibodies. These antibodies are used to treat various diseases, including cancer, arthritis, and multiple other diseases (Ran Zhang, et al., 2018; Chojnacka-Puchta, Sawicka, 2020).

In the field of xenotransplantation, genetically engineered animals, especially pigs, are considered as a potential solution to the problem of human organ shortage (Cooper, et al., 2016). Special genetic modifications are made for the human immune system to accept pig organs. For example, pig antigens recognized by the human immune system are deleted, and genes that regulate the defense mechanisms of the human immune system are added (Cooper, et al., 2016). Additionally, it is possible to reduce the risk of infection by deleting endogenous retroviruses from the pig genome. Research in this area is approaching a solution to the problem of organ shortage for transplantation.

2.2. GMO Animals in Agriculture

The main purpose of genetically engineered animals in agriculture is to increase food production, enhance disease resistance, and provide adaptability to climate change (Van Eenennaam, 2017). Creating animals with rapid growth characteristics is one of the main directions in this field. For example, AquAdvantage salmon - a transgenic fish that produces growth hormone excessively and grows twice as fast as ordinary salmon (Van Eenennaam AL.,2017, Ledford H.,2015). Such animals allow for the production of more food with the same resources. Feed conversion efficiency is also an important factor in agriculture. Genetically modified animals can produce more meat, milk, or eggs with less feed (Cooper, et al., 2016). This is both economically efficient and reduces environmental impact. Additionally, genetic engineering is also used to change the composition of food products. For example, transgenic animals are created that produce healthier fatty acids or additional nutrients (Van Eenennaam, 2017; Alexandr, et al., 2024).

Disease resistance is also an important issue in agriculture. Genetic engineering allows for the creation of animals resistant to specific pathogens (Van Eenennaam, 2017, Lillico, et al., 2016). For example, work is being done on creating pigs resistant to the African Swine Fever virus. Such modifications both improve animal welfare and help farmers minimize disease-related losses. At the same time, it is also possible to reduce the spread of zoonotic diseases, i.e., diseases that can be transmitted from animals to humans.

In the context of climate change, the adaptability of animals to changing conditions is becoming increasingly important. Genetic engineering allows for the creation of animals that are resistant to

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heat stress and require less water and food (Kiplangat, 2023). Such animals can help form sustainable agricultural systems in the context of global warming.

2.3. The Role of Transgenic Animals in Environmental Protection

In the field of environmental protection, genetic engineering is used to save endangered species, combat invasive species, and monitor environmental pollution (Robert Costanza & Shuang Liu, 2014, Frankham, 2015). For saving endangered species, genetic engineering is used to increase genetic diversity and enhance the sustainability of populations. For example, the problem of low genetic diversity in small and isolated populations can be solved by adding genetic material from other populations of the same species (Frankham, 2015). A more radical approach is de-extinction attempts - i.e., creating genetic similars of extinct species (Shapiro, 2017). This approach is implemented by modifying the genome of the extinct species' closest relative. For example, work is being done on "resurrecting" mammoths by adding specific genetic characteristics of mammoths to modern elephants. Gene drive systems can play a significant role in combating invasive species (Esvelt, et al., 2014). This technology, using the CRISPR-Cas9 system, reduces the reproductive ability of invasive species or allows for the rapid spread of certain genetic characteristics throughout the population (Doudna, Charpentier, 2014; Esvelt, et al., 2014). For example, experiments are being conducted on gene drive systems to reduce populations of malaria-carrying mosquitoes. For monitoring environmental pollution, transgenic animals that respond to pollutants in natural conditions are created (Garcia-Reyero, 2015). Such "biosensor animals," for example, zebrafish that change color when certain toxic substances are present in water or soil, can be significant tools for ecological monitoring.

3. Results

3.1. Applications in Industrial Biotechnology

In industrial biotechnology, transgenic animals are used for the production of new materials and chemicals. In the field of fiber and material production, transgenic silkworms that produce higher quality silk are created (Xiangping Dai, 2024). Natural silk is a very valuable material, but its production is complex and expensive. Genetic engineering allows for increasing the quality of silk and production efficiency. Additionally, transgenic animals are also used in the production of new biomaterials for medical implants and tissue engineering (Ran Zhang, et al., 2018, Saif AL-Hafedh, et al., 2024). For example, transgenic goats carrying the human collagen gene can secrete human collagen with milk for medical applications. Such approaches allow for more efficient production of new biomaterials and biologically active substances. The production of enzymes and industrial chemicals is also one of the industrial applications of transgenic animals (Ran Zhang,et al., 2018). Transgenic animals that produce enzymes used in various industrial processes allow for cheaper and more environmentally friendly production of these substances.

3.2. Ethical Issues and Public Acceptance

The use of genetically engineered animals raises a number of ethical issues (Ishii, Araki, 2016; Thompson, 2018). Animal welfare problems are one of the main concerns in this area. Can genetic modifications negatively affect animal welfare? How should the ethical status of genetically engineered animals be determined? These questions are actively discussed both in the scientific community and in public debates (Thompson, 2018). Various religious and cultural perspectives also shape attitudes toward genetically engineered animals (Mohd Izhar, et al., 2018). Islam, Christianity, Judaism, and other religions have different attitudes toward GMO animals. According to some religious views, genetic modifications are seen as "playing with nature" or "interfering with the divine order." Other religious perspectives evaluate these technologies as the use of knowledge and skills given by God to humans to improve human welfare.

Cultural acceptance and rejection also differ in different societies (Ishii T. and Araki M.,2016). Some countries have strong public resistance to GMO products, while in others these technologies are more accepted. These differences depend on both historical and cultural context, as well as the level of information and education (Ishii, Araki, 2016, Kübra Sinem, et al., 2023). Risk assessment and safety are also important issues. The potential impacts of releasing genetically modified animals into the natural ecosystem should be seriously investigated (Kübra Sinem, et al., 2023). There is a

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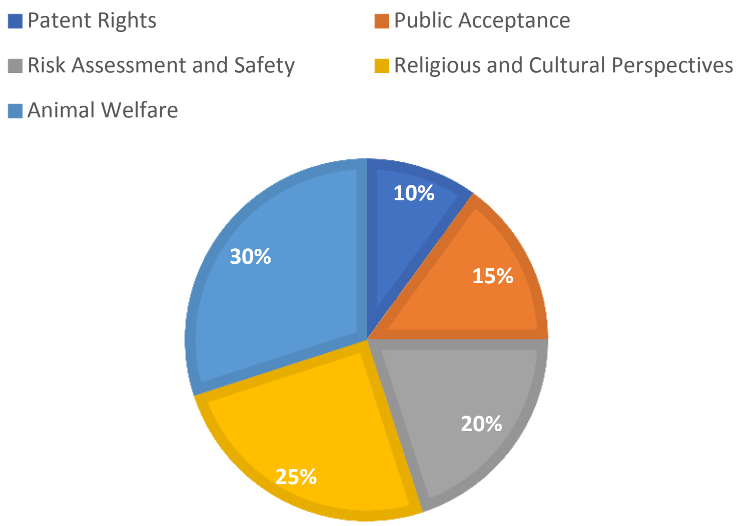
risk of transgenic genes transferring to wild populations and causing unexpected ecological consequences. At the same time, the potential effects of consuming GMO animal products on human health should also be carefully studied (Michael, et al., 2024, National Academies Press (US), 2016).



Scheme 2: Ethical Issues (Ormandy, et al., 2011).

3.3. Regulatory Frameworks

Various international, regional, and national frameworks exist to regulate the use of genetically engineered animals (Yunus, Yilmaz, 2019). At the international level, the Cartagena Protocol is one of the main agreements on biosafety. This protocol regulates the international movement of "living modified organisms" and establishes rules to ensure their safe use.

CODEX Alimentarius provides international standards for food safety. These standards establish guidelines for assessing the safety and labeling of GMO food products (Codex Alimentarius Commission, 2003). These international standards play an important role in the international trade of genetically engineered food products.

Various regulatory mechanisms also exist at regional and national levels. In the USA, the FDA (Food and Drug Administration), USDA (United States Department of Agriculture), and EPA (Environmental Protection Agency) play a role in regulating genetically engineered organisms (Carter, et al., 2014). In the USA, the evaluation of GMO products is carried out on the basis of the principle of "substantial equivalence" - i.e., the GMO product is compared with its traditional analog. Regulation of GMOs in the European Union is stricter (Norio, 2016). Here, the "precautionary principle" is applied, and comprehensive safety assessment is required before permitting the use of GMO products. At the same time, labeling of GMO products is mandatory in the European Union, which allows consumers to make informed choices (Norio, 2016).

Regulatory approaches in Asian countries differ (Robert Costanza & Shuang Liu, 2014). For example, China actively conducts research in the field of genetic engineering and supports GMO products at the level of official policy. Japan applies strict rules for the evaluation and labeling of GMOs. The differences in these approaches stem from both scientific and political and public factors (Robert Costanza & Shuang Liu, 2014; Zhang, Guo, & Zhu, 2016).

4. Discussion

4.1. Future Perspectives and Trends

A number of new technologies and approaches are being developed in the field of genetic engineering. Single-cell Genomics, i.e., genetic analysis and modification technologies at the single-cell level, enable more precise and effective genetic changes (Wang, Navin, 2015). This technology creates new opportunities for studying and modifying the genetic profiles of individual cell types in complex organisms. The creation of artificial chromosomes is also one of the

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promising directions for the future (Boeke, et al., 2016). Fully artificial chromosomes could allow for the addition of new genetic functions not present in natural organisms. This approach opens new possibilities for creating and studying complex biological systems. Epigenetic modifications are used to regulate gene activity without changing the DNA sequence (Stricker, et al., 2017). This approach allows for changing the expression of genetic material without touching the material itself. Epigenetic modifications offer less invasive and more precise genetic regulation possibilities.

New application areas are also rapidly developing. In the field of neurobiology, transgenic animals are used to study brain functions and the mechanisms of neurological diseases (Wang, et al., 2014; Kim, et al., 2015). For example, transgenic animals expressing fluorescent proteins to visualize brain activity help to better understand brain functions. Genetic engineering also plays an important role in aging research (Tian-Yi Zhu, et al., 2025). Work is being done on genetic modifications to slow down aging processes and increase longevity. For example, activation of the telomerase gene in mice can reduce signs of aging. Genetic engineering also has potential applications in space biology (Arora, & Mishra, 2016). Organisms modified for long-term space missions can be adapted to the specific conditions of the space environment (e.g., radiation, weightlessness). Such organisms can be used both for food and oxygen production on space stations, and for interplanetary missions and terraforming of exoplanets.

Social and economic impacts are also among the factors that will determine the future of the field of genetic engineering (Van Eenennaam, 2017; Herrero, et al., 2017). GMO animals can have a significant impact on global food security. More efficient and sustainable food production can help solve the food supply problem for the growing population. At the same time, economic issues related to GMO technologies, such as patent issues, market sharing, and the situation of small farmers, should also be considered (Herrero, et al., 2017).

Food safety remains a major concern for consumers and continues to be a central focus for food producers and regulatory authorities overseeing food safety (Tosun, Demirbaş, 2021; Aydan, 2013). In addition to the practical benefits that biotechnological applications and, specifically, genetically modified organisms (GMOs) can offer, protecting human and environmental health as well as socio-economic systems from the potential risks of these applications and products forms the foundation of related policies. At this point, alongside technical and legal measures, establishing a mechanism for "public oversight" plays a critical role (Oğuz, Meltem, 2010).

Conclusion

Genetically engineered animals have become an integral part of modern biotechnology. They play an important role in various fields from medical research to agriculture and environmental protection. In the medical field, genetically engineered animals are used for creating disease models, drug production, and xenotransplantation. In agriculture, they are used to increase food production, enhance disease resistance, and adapt to climate change. In the field of environmental protection, genetic engineering offers new opportunities for saving endangered species and combating invasive species.

However, the development of this technology requires constant consideration of ethical, safety, and regulatory aspects. Animal welfare problems, religious and cultural perspectives, as well as risk assessment and safety issues should be seriously investigated. Existing international, regional, and national frameworks for regulating the use of genetically engineered animals should be continuously improved.

In the future, further improvement of genetic engineering technologies, more precise genome modifications, and the emergence of new application areas are expected. New technologies such as Single-cell Genomics, artificial chromosomes, and epigenetic modifications will enable more precise and effective genetic changes. Genetic engineering will find wide application opportunities in new fields such as neurobiology, aging research, and space biology. These developments can potentially lead to significant advances in human health, food security, and environmental protection. However, along with these, society must use these technologies responsibly and in

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accordance with ethical principles. Genetic engineering offers great opportunities and potential benefits, but to properly use these opportunities, a balance must be found between science, politics, ethics, and public opinion.

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