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BIOLOGICAL, MORPHOLOGICAL AND AGRONOMIC CHARACTERISTICS OF SUNFLOWER CROPS, THEIR ADAPTABILITY TO ENVIRONMENTAL STRESSES, AND THEIR AGRICULTURAL AND ECONOMIC SIGNIFICANCE

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Abstract: Sunflower (Helianthus annuus L.) is an important oilseed crop belonging to the family Asteraceae and the genus Helianthus, which comprises approximately 65 species. The crop has a long history of cultivation, dating back nearly 3,000 years. Sunflower was initially domesticated by Indigenous peoples of eastern North America, who cultivated it as a valuable food and multipurpose plant. Following the arrival of Europeans in the Americas, sunflower cultivation gradually expanded across a wide geographic range, extending from southern Canada to Mexico and subsequently to Europe. Sunflower was introduced into Europe primarily through Spain, where it adapted successfully to local environmental conditions. During the late nineteenth century, the crop spread to Russia, where it demonstrated considerable adaptability to relatively cooler climatic conditions. Russian farmers subsequently made substantial contributions to the development of sunflower cultivation and its transformation into an economically important agricultural crop. At present, sunflower has a wide range of applications. In addition to its primary use as an oilseed crop, it is cultivated as an ornamental, food, medicinal, and fodder plant and is also used as a source of raw materials for various industrial applications, including textile dyes and decorative products. Furthermore, sunflower has attracted considerable scientific interest because of its phytoremediation capacity. Its relatively high tolerance to certain toxic substances enables it to absorb and accumulate contaminants from polluted soils and water, making it a potentially useful crop for the remediation of environmentally contaminated areas.

Key words: Helianthus annuus, Asteraceae, Helianthus tuberosus, oilseed, ornamental plant, medicinal plant, phytoremediation, cotyledon, lateral

1. Introduction. Sunflower (Helianthus annuus L.) is an annual plant belonging to the family Asteraceae. The genus Helianthus derives its name from the Greek words helios, meaning “sun,” and anthos, meaning “flower.” This name reflects the plant’s close association with sunlight and its characteristic tendency to orient its developing structures toward the sun during the day. The genus comprises numerous species exhibiting considerable morphological and ecological diversity, several of which have agricultural, nutritional, fodder, or ornamental importance.

The domestication of sunflower is generally associated with indigenous populations of eastern North America. Archaeological and historical evidence suggests that sunflower was cultivated approximately 3,000–5,000 years ago, primarily for its edible seeds. Subsequently, the crop was introduced into Europe during the early sixteenth century, from where it gradually spread to other regions, including Russia. In Russia, sunflower became increasingly important as an oilseed crop, and its cultivation, breeding, and industrial processing were substantially developed. Improved oilseed forms were later introduced back into North America, particularly during the twentieth century, contributing to the establishment and expansion of commercial sunflower production.

Species of the genus Helianthus have subsequently become distributed across a wide range of geographical and ecological conditions. Among them, Helianthus tuberosus (Jerusalem artichoke) is cultivated in temperate regions and, to a lesser extent, in warmer climates as a food, fodder, and ornamental crop. Its active vegetative development mainly occurs during summer and continues into early autumn, with the most intensive growth generally observed during the middle of the summer season.

The geographical distribution and diversification of Helianthus species are closely associated with their evolutionary history. The genetic variability within the genus has been influenced by natural selection, domestication, hybridization, and deliberate breeding programs aimed at developing cultivars with desirable agronomic characteristics. At the same time, intensive selection for particular production traits, especially high seed and oil yield, may reduce genetic diversity within certain cultivated populations. Consequently, the genetic structure of modern sunflower has been shaped by the interaction between natural evolutionary processes and long-term human selection.

Cultivated sunflower, Helianthus annuus L., is one of the major oilseed crops belonging to the Asteraceae family. The species encompasses a broad range of cultivated forms and varieties, as well as genetically related wild populations. Cultivated forms are primarily selected for agricultural production, whereas wild sunflower populations are important sources of genetic diversity and may contribute valuable traits to breeding programs.

Based on their morphological and biological characteristics, cultivated sunflower forms can generally be classified into field or oilseed sunflower and ornamental sunflower groups. Field sunflower is predominantly cultivated for seed production and extraction of vegetable oil, making it an economically important agricultural crop. Ornamental forms, in contrast, are characterized by considerable diversity in the size, shape, color, and structure of their flower heads and are mainly grown for decorative purposes.

The sunflower possesses an erect, robust, and coarsely pubescent stem. Depending on the genotype, environmental conditions, and cultivation practices, plant height can vary considerably and may reach approximately 1–4.5 m. The leaves are relatively large, rough-textured, and characterized by serrated margins. They are arranged alternately or spirally along the stem. The inflorescence is a characteristic capitulum (head) consisting of numerous individual flowers. In wild forms, the flower head commonly measures approximately 7.5–15 cm in diameter, whereas cultivated varieties may produce considerably larger heads, frequently reaching 30 cm or more.

These morphological characteristics are determined not only by the genetic properties of individual sunflower varieties but also by environmental factors, including temperature, soil conditions, water availability, and agricultural management practices. Therefore, the morphological development of sunflower can serve as an important indicator for assessing plant growth and productivity under different agroecological conditions. [3].



Figure 1. Sunflower*:*

The leaves are large, banded, 20-40 cm long, oval-heart-shaped, with a sharp tip, thickly covered with hairs. The edges of the leaves are serrated. The lower two or three pairs of leaves are opposite the stem, the rest are solitary. The leaves in the middle are the largest. The number of leaves per plant can range from 14 to 50 and more. Early maturing varieties produce fewer leaves and late-maturing varieties produce more leaves.

Vegetation period.

The sunflower is a broad-leaved plant that emerges from the soil with two large seed pods (cotyledons). Appears when planted at a depth of 2–3 cm in warm soil, it takes four to five days, but in colder soils or when planted deeper, it takes a few more days. Sunflowers grow quickly and form large and broad leaves. Currently, sunflower varieties reach an average height of 183 cm, varying between 153 cm and 213 cm depending on the date of planting and soil conditions. The growth of the sunflower is directly related to its genetic composition [6]. In addition, the planting season affects its development; these seasons usually occur in mid-summer and early fall. The development of the sunflower is divided into vegetative and reproductive stages, which can be identified by identifying the heads or main branches of a single or branched head. After reaching full height and flowering, the heads of the sunflower are turned down to make it difficult for the birds to eat the seeds. Sunflowers have self-sustaining flowers for pollination, meaning they do not require pollinating insects, but some studies have shown that bee pollinators slightly increase productivity Sunflower is an annual, erect, broadleaf plant with a strong taproot and prolific lateral spread of surface roots. Stems are usually round early in the season, angular and woody later in the season, and normally unbranched. Sunflower leaves are phototropic and will follow the sun's rays with a lag of 120 behind the sun's azimuth. This property has been shown to increase light

interception and, possibly, photosynthesis. In temperate regions, sunflower requires approximately 11 days from planting to emergence, 33 days from emergence to head visibility, 27 days from head visibility to the first anther, 8 days from first to last another, and 30 days from the last anther to maturity. Cultivar differences in maturity are usually associated with changes in the vegetative period before the head is visible. Its total growing period ranges from 125 to 130 days. The sunflower head is not a single flower (as the name implies) but is made up of 1,000 to 2,000 individual flowers joined at a mutual receptacle. The flowers around the circumference are ligulae ray flowers without stamens or pistils; the remaining flowers are perfect (with stamens and pistils). Anthesis (pollen shedding) begins at the periphery and proceeds to the center of the head. As many sunflower varieties have a degree of self-incompatibility, pollen movement among plants by insects is important, and bee colonies have generally increased yields. [2].

2. Methods. Choosing the right variety is one way to ensure high profits at a low cost. Since sunflowers are not prone to major diseases and pests, the varietal selection is usually based on yield and yield reliability. The effectiveness of varieties tested in several environments is the best basis for selecting sunflower hybrids. The selection should take into account the yield, high-fat percentage, seed size (for non-fat markets) and habitat, and resistance to birds.

The sunflower is an annual, erect, broad-leaved plant with strong roots and many lateral roots. The stem is usually round at the beginning of the season, angular and woody at the end of the season, and is usually unbranched.

Sunflower leaves are phototropic, observing sunlight at 1200 azimuth. This property has been shown to retain light and possibly enhance photosynthesis. Sunflower seeds germinate at 5 ° C, but a temperature of at least 14 to 21 ° C is required for satisfactory germination [9]. Sunflower grows in a wide variety of fertile soils with a pH of 6.0 to 7.5. The planting density of sunflowers varies from 25,000 to 35,000 plants per hectare, depending on the yield of the area. Row width can range from 90 to -100 cm, compared to grain crops, sunflower makes very good use of soil nutrients. The main reason for this is a thinly branched and broad root system. The roots come in contact with nutrients that are not used by other crops. The method of irrigation will depend on the availability of water and the available irrigation equipment. The pH of irrigation water should be slightly neutral [10].

In most cases, South African sunflower is cultivated under dry land during the summer rainfall season (November to March). In areas with low rainfall, water supply can be supplemented with irrigation to increase yield. The method of irrigation will depend on the water availability and the available irrigation pieces of equipment. The pH of the irrigation water should be

slightly neutral.

Mechanical weed control can be very effective, provided it is done in time and with care not to damage the crop. Chemical weed control can be applied successfully together with mechanical methods and cultivation practices to bring about better weed control. The following tips are given

for mechanical control:

- Cultivate before the sunflower is too tall for equipment, or the plants will be damaged easily.
- To prevent damaging the sunflower roots, cultivation should be shallow (less than 75 mm).
- Throw loose soil onto the row—this will assist in suffocating weeds that sprout in the row.
- Smaller weeds die off easily when dry soil is hoed.
- Hoe during the hottest part of the day when the sunflowers are wilted—this reduces stem damage.

The use of herbicides has many advantages, of which the most important is that effective weed control can be applied during wet periods when mechanical weed control is impossible. If

sunflower is cultivated in crop rotation with maize, weeds can be controlled more effectively in both crops as grass and broadleaf herbicides can be used in continuous succession.

These potential risks require that growers follow integrated pest management (IPM) practices. IPM means using a combination of pest control methods to maintain pest populations below levels that result in unacceptable losses to crop quality or yield. IPM includes biological, cultural,

physical, and chemical control. Resistance to insects can be improved by the presence of a dark-colored “armor” layer on the seed coats.

Resistance to midges has been suggested, however, it is not presently effective. Only currently approved insecticides should be used for the control of insects. Birds can be major pests in sunflowers, especially blackbirds, goldfinches, doves, grosbeaks, and sparrows. Many approaches to feed

disruption have been tried, including scarecrows, fright owls, aluminum strips that flutter in the wind, and carbide exploders. No technique is 100% effective, as birds will adapt to many of these techniques. Currently, no chemicals are approved for bird control in sunflowers.

3. Results.

1) Effective control of weeds is a prerequisite for high yields of sunflowers. This is achieved through a combination of mechanical and chemical operations. Young plants are very sensitive to strong weed competition and cannot grow fast enough to form a complete shady cover that can suppress weed seedlings. Therefore, the first 6 weeks after planting is a very important period for the harvest. During this time, weeding the fields can significantly increase yields.

2) The most serious diseases of sunflower are caused by fungi. The main diseases include Rust, Verticillium, Sclerotinia, Phoma, head rot, black stem, and leaf spot.

In Brazil, a unique production system called the sunflower system is used: first sunflowers are planted, then soybean crops reduce idle time and increase the overall production and profitability of the sunflower. sunflowers are usually planted in the extreme southern or northern regions of the country. Often in the southern regions, sunflowers are grown at the beginning of the rainy season, and then in the summer can be planted in the shade [7]. Researchers have found that changing the use of fertilizers can improve the shade of sunflowers. The current method has been shown to have a positive effect on the environment [8].

In temperate regions, the overall growth period is 125 to 130 days [11]. The head of a sunflower is not a single flower (as the name suggests), it consists of 1000 to 2000 individual flowers combined in a reciprocal pot. Because many sunflower varieties have a degree of spontaneous incompatibility, pollen movement between plants by insects is important, and bee colonies typically have increased yields. Below are the incomplete names of the available varieties.

4. Discussion. A wide range of sunflower varieties and hybrids are cultivated under different climatic and soil conditions across the world. The selection of an appropriate variety is an important factor determining the growth, development, productivity, and quality of sunflower crops. Varieties and hybrids differ considerably in their biological characteristics, duration of the growing season, resistance to environmental stresses, yield potential, oil content, and ability to adapt to specific soil and climatic conditions.

One of the important characteristics used to distinguish sunflower varieties is **earliness or maturity period**. Early-maturing varieties generally complete their vegetative and reproductive development within a shorter period and can therefore be advantageous in regions characterized by a relatively short growing season or high temperatures occurring during the later stages of plant development. Medium- and late-maturing varieties usually have a longer vegetation period and

may demonstrate greater biomass accumulation and yield potential when sufficient moisture, nutrients, and favorable temperatures are available throughout the growing season.

Sunflower varieties also differ in their **yield potential and yield components**. Important productivity-related characteristics include plant height, number and size of leaves, diameter of the capitulum, number of seeds per head, thousand-seed weight, seed yield per plant, and overall yield per hectare. These characteristics are strongly influenced by the interaction between genotype and environmental conditions. Consequently, a variety that demonstrates high productivity under one set of agroecological conditions may not necessarily show the same performance when cultivated in another region.

Soil conditions also play a significant role in determining the suitability of sunflower varieties. Different genotypes may exhibit varying levels of tolerance to soil salinity, drought, limited soil moisture, nutrient deficiencies, and other unfavorable soil properties. Varieties with greater tolerance to salinity and water deficit are particularly important for cultivation in arid and semi-arid regions, where irrigation water is limited and soil salinization can negatively affect plant growth and productivity.

Climatic adaptation is another essential criterion in the selection of sunflower varieties. Temperature, precipitation, atmospheric humidity, solar radiation, and the duration of the growing season can significantly affect sunflower development. Varieties adapted to warm and dry conditions may maintain relatively stable productivity under high-temperature and water-limited environments, whereas other varieties may perform better under cooler or more humid climatic conditions. Therefore, the choice of sunflower variety should be based on a comprehensive assessment of its **maturity period, yield potential, drought and salinity tolerance, soil adaptability, and regional climatic suitability**. Matching the biological characteristics of a variety with the prevailing agroecological conditions can contribute to more efficient use of water and soil resources, stable crop development, and increased seed yield. This is particularly relevant for sunflower production in arid regions, where environmental stresses can strongly influence the duration of the growing season and final crop productivity.

5. Conclusion. Sunflower is one of the most economically important crops with a wide range of agricultural and industrial applications. Although it is widely recognized as a major oilseed crop, sunflower is also cultivated for ornamental, food, medicinal, fodder, and industrial purposes. Its seeds are particularly valuable because they contain a high proportion of edible vegetable oil, which is widely used in the food industry and serves as an important source of plant-based dietary fat. In addition to oil production, sunflower seeds and other plant residues can be utilized as valuable sources of animal feed and raw materials for various processing industries. Sunflower cultivation is widespread across different regions of the world, particularly in areas where climatic and soil conditions are suitable for its growth. The crop is primarily grown on agricultural lands for the production of vegetable oil; however, its high biomass productivity also makes it useful as a forage crop. The green aerial biomass can be used for silage and other livestock feed preparations, providing an additional economic benefit to farmers.

An important biological characteristic of sunflower is its relatively high adaptability to unfavorable environmental conditions. The crop demonstrates considerable tolerance to soil salinity and can maintain satisfactory growth and biomass production under moderately saline conditions. This characteristic is particularly significant for irrigated agricultural systems in arid and semi-arid regions, where secondary soil salinization is a major constraint to crop production. The ability of sunflower to produce substantial amounts of green biomass under such conditions increases its

potential as an alternative crop for the productive utilization of saline and marginal agricultural lands.

Furthermore, sunflower can contribute to the diversification of crop rotations and the efficient utilization of agricultural resources. Its comparatively strong root system allows the plant to explore deeper soil layers for available water and nutrients, which may support its development under conditions of limited soil moisture. Consequently, sunflower has considerable agricultural potential in regions affected by drought, salinity, and water scarcity.

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