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Sunflower (Helianthus annuus L.) as a Multifunctional Crop - Scope for Edible Oil Security, Bio-Economy Development and Sustainable Agriculture

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ABSTRACT

Sunflower (*Helianthus annuus* L.) is a promising oilseed crop with significant potential to enhance edible oil security and support sustainable agriculture in India. During early 1990s self-sufficiency in oilseed was achieved in India through Yellow Revolution but was not sustained for long. India ranks among the world's leading producers of oilseed crops but it still remains one of the largest importers of edible oils. Sunflower is known for its high-quality oil rich in unsaturated fatty acids and vitamin E additionally multiple value-added products such as sprouts, roasted seeds, oil cake, and bioenergy resources can be obtained. Its by-products can be efficiently utilized in industrial applications, livestock feed, and natural dye production, contributing to a circular bio-economy. Overall, sunflower cultivation can improve cropping intensity, enhance farmer income, and reduce import dependency, it can be used as a significant element in Agro Tourism, making it an important crop for sustainable agricultural development in India.

INTRODUCTION

Sunflower (*Helianthus annuus L.)* is one of the most important oilseed crops in India and is often referred to as the "Champion" among oilseeds due to its wide adaptability and high-quality oil. The oilseed sector has shown steady growth worldwide, expanding at an annual rate of about 4.1 per cent over the past three decades. In India, oilseeds contribute nearly 3 per cent to the Gross Domestic Product (GDP) and about 5.98 per cent to the total value of agricultural output. The country is endowed with diverse agro-ecological conditions, enabling the cultivation of a wide range of oilseed crops. Currently, nine major annual oilseed crops are grown, including seven edible oilseeds groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non-edible oilseeds, castor and linseed.

Despite India being the fourth-largest producer of oilseeds globally, with a production of about 39.67 million tonnes in 2024, the country still depends on imports to meet nearly 60 per cent of its edible oil requirement. This heavy reliance places a significant burden on foreign exchange reserves and highlights the need to enhance domestic oilseed production.

Traditionally, sunflower cultivation has been concentrated in states such as Karnataka, Maharashtra, and Andhra Pradesh. However, in recent years, its cultivation has expanded to non-traditional regions including Haryana, Punjab, Uttar Pradesh, Gujarat, Tamil Nadu, Odisha, Madhya Pradesh, and Rajasthan. Among these, Karnataka remains the leading producer, with an area of about 9.85 lakh hectares, production of 3.62 lakh tonnes, and productivity of around 336 kg per hectare. Sunflower is particularly valued for its short duration (90–110 days), high yield potential, and oil content ranging from 35 to 45 per cent. These characteristics make it highly suitable for resource-constrained farming systems, especially in hill regions. The crop requires relatively less water compared to many other oilseeds and performs well under diverse agro-climatic conditions.

Importantly, sunflower offers a viable solution for utilizing post-monsoon rice fallows, which remain largely underexploited in many parts of India. Its ability to grow on residual soil moisture allows farmers to intensify cropping systems without significant additional investment in irrigation. Thus, promoting sunflower cultivation in rice fallows and non-traditional areas can play a crucial role in improving farmers' income, enhancing cropping intensity, and reducing the country's dependence on imported edible oils.

NUTRITIONAL AND ECONOMIC VALUE

Sunflower oil is rich in vitamin E (tocopherols), a potent lipid-soluble antioxidant that mitigates oxidative stress in cellular membranes. It comprises high levels of unsaturated fatty acids, including polyunsaturated fatty acids (PUFAs, e.g., linoleic acid) and monounsaturated fatty acids (MUFAs, e.g., oleic acid), which lower serum low-density lipoprotein cholesterol and support cardiovascular health. By-products such as seed cake serve as protein-rich (approximately 30–40%) livestock feed, improving milk yield in ruminants.

There are two types of sunflowers seed produced, oilseed and confectionery. About 95% of world production is the oil seed type and only 5% the confectionery type. Sunflower contains appreciable quantities of proteins, vitamins A, B, E & K. It is rich in Vitamin E, a powerful antioxidant that protects cells from oxidative stress. The oil contains a high proportion of unsaturated fatty acids, including polyunsaturated (PUFA) and monounsaturated fatty acids (MUFA), which contribute to heart health by reducing cholesterol levels. Additionally, sunflower oil possesses anti-inflammatory properties and supports overall health and immunity. Sunflower by-products also hold economic value. The residual

cake and thalamus can be effectively utilized as nutritious animal feed, contributing to enhanced milk production in livestock.

Sunflower seeds are a rich nutritional source, boasting high levels of protein, fiber, minerals, and phenolic compounds [3]. Sunflower crops are drought tolerant and can be cultivated late in the rainy season. They are also utilized in farming systems for crop rotation, alternating with rice, beans, or corn. Additionally, sunflower products like sunflower butter provide an alternative for consumers with nut allergies

AGRO-TECHNIQUES AND SOWING PERIODS

Sunflower (Helianthus annuus L.) is a highly adaptable crop that can be cultivated across a wide range of agro-climatic conditions and seasons. However, for optimum productivity, it is essential to ensure that the flowering stage does not coincide with periods of heavy rainfall or extreme temperatures exceeding 38°C, as these conditions adversely affect pollination and seed setting.

The sowing window varies across regions and soil types. In traditional sunflower-growing areas, the crop is sown during the kharif season from the second fortnight of June to mid-July in light soils, while in heavy soils sowing can be extended up to the second fortnight of August. During the rabi season, sowing is generally carried out from September to the end of November. In non-traditional regions, sunflower can also be successfully cultivated as a spring crop, with sowing undertaken from January to the end of February.

Soil reaction plays a critical role in determining crop performance. Sunflower grows best in slightly acidic to neutral soils, with an optimum pH range of 6.8 to 7.5. Soil acidity is a major limiting factor, and yields may decline by 10 per cent or more under highly acidic conditions (pH 4.7–5.3). Therefore, appropriate soil amendments, such as liming in acidic soils, are essential to ensure optimal nutrient availability and crop growth.

Although sunflower develops a deep root system, nearly 60 per cent of the roots are concentrated within the top 0–40 cm soil layer. Hence, proper land preparation is crucial. Deep ploughing to a depth of 30–35 cm is recommended to facilitate root penetration and improve soil aeration. In areas prone to waterlogging, the formation of raised beds enhances drainage and prevents root damage. Prior incorporation of well-decomposed farmyard manure or compost further improves soil structure and nutrient status, supporting better crop establishment.

Sunflower is a self-incompatible crop, and successful seed set depends largely on cross-pollination mediated by insects, particularly bees. Therefore, maintaining a conducive environment for pollinators is essential for achieving higher yields.

The crop duration generally ranges from 90 to 100 days, depending on environmental conditions such as temperature, relative humidity, soil fertility, and the cultivar used. Physiological maturity is indicated when the back of the capitulum (flower head) changes from green to yellow, while harvest maturity is reached when the flower heads turn brown. At this stage, the seed moisture content typically ranges between 12 and 14 per cent, which is considered ideal for safe storage.
Harvesting is usually carried out by cutting the mature flower heads using a knife or sickle. The harvested heads are then sun-dried to reduce moisture content, followed by threshing or shelling to separate the seeds. Proper post-harvest handling ensures better seed quality and storage longevity.

SUNFLOWER SPROUTS

Sunflower sprouts derived from *Helianthus annuus* L. are increasingly recognized as a nutrient-dense functional food, particularly among health-conscious consumers. Compared to mature seeds, these sprouts exhibit enhanced antioxidant capacity, making them a valuable addition to health-oriented diets.

They are rich in diverse bioactive phytochemicals, including phenolic acids such as caffeic acid, chlorogenic acid, caffeoylquinic acid, cynarine, and gallic acid. Sunflower sprouts also contain significant levels of flavonoids including heliannone, quercetin, luteolin, and kaempferol that contribute to their potent antioxidant activity. In addition, they provide natural pigments such as chlorophyll, carotenoids, and xanthophylls, along with essential vitamins A, B-complex, C, and E.

Nutritionally, sunflower sprouts supply key minerals including calcium, iron, magnesium, and phosphorus. The presence of niacin and other antioxidants further enhances their nutritional and therapeutic value.

The array of phytochemicals in sunflower sprouts confers multiple bioactive properties, including antioxidant, antimicrobial, anti-inflammatory, and antibacterial effects. Moreover, certain compounds exhibit potential antihypertensive activity that supports blood pressure regulation, with effects comparable to those of some medicinal plants.

SEEDS

Roasted seeds of Sunflower are widely consumed as a nutritious snack. Sunflower seeds are characterized by a high oil content, typically ranging from 44 to 52 per cent, along with a substantial protein content of about 28 to 32 per cent. The lipid fraction is predominantly composed of unsaturated fatty acids, mainly linoleic acid (approximately 62–69%) and oleic acid (20–25%), which are considered beneficial for human health. In addition to their lipid and protein content, sunflower seeds are a rich source of bioactive compounds, including tocopherols (vitamin E), betaine, lignans, arginine, and various phenolic acids. They also contain essential micronutrients that contribute to their nutritional and functional value.

Roasted sunflower seeds are produced through a series of processing steps involving dehulling (if required), brining, and thermal treatment. Typically, cleaned seeds are soaked in a saline solution and subsequently subjected to controlled roasting or baking.

For safe storage and quality maintenance, the moisture content of roasted sunflower seeds should be maintained below 5 per cent. The characteristic aroma and flavour of roasted sunflower seeds are attributed to the formation of a complex mixture of volatile compounds during the roasting process. These include terpenes (such as α-pinene and β-pinene), heterocyclic compounds (including various pyrazines and pyridine derivatives), aldehydes (e.g., hexanal and phenylacetaldehyde), hydrocarbons, and alcohols. Among these, compounds like γ-butyrolactone contribute significantly to the distinctive sensory profile.

SUNFLOWER SEED OIL

Sunflower seed oil's fatty acid composition includes approximately 85% unsaturated fatty acids. Of these, oleic acid is most prevalent, followed by 4–8% linoleic acid, less than 2% linolenic acid, and approximately 15% saturated fatty acids. Refined sunflower-seed oil is obtained by removing contaminants from the fats or oils extracted from the seeds.

SUNFLOWER OIL CAKE

Sunflower oil cake, a byproduct of sunflower-seed oil extraction, has gained considerable attention due to its versatile applications. It is utilized as a high-protein and high-fat feed source for livestock, as well as a substrate in the production of enzymes, antibiotics, and biosurfactants. There are studies on sunflower-meal supplementation as a complementary protein source in the diet of laying hens, focusing on productive performance, egg quality, and nutrient digestibility.

BIODIESEL

Sunflower oil serves as a suitable feedstock for biodiesel production, which is a renewable liquid fuel derived from vegetable oils and animal fats. The conversion process involves transesterification, wherein the oil reacts with methanol in the presence of a catalyst to produce fatty acid methyl esters (biodiesel) with properties comparable to conventional diesel fuel.

Seed husks residue after processing can be hydrolysed to produce fermentable sugars, which can subsequently be utilized for ethanol production. Furthermore, sunflower husks can be converted into charcoal briquettes, providing an alternative and sustainable energy source. Such by-products can also be incorporated into animal feed formulations.

FIBER

The stalks of Sunflower. represent an important source of lignocellulosic biomass with considerable industrial and environmental significance. Structurally, the sunflower stem is composed of two distinct components: the outer bark and the inner core. The bark is relatively rich in structural polymers, containing approximately 48 per cent cellulose and 14 per cent lignin, whereas the core consists of about 31.5 per cent cellulose and a lower lignin content of around 2.5 per cent. This compositional variation influences their suitability for different applications. Crushed sunflower stalks can be processed into natural fibres suitable for the development of engineered bio-composites. These materials demonstrate favourable mechanical properties and can be used in applications such as thermal insulation panels in buildings. Their use not only reduces dependence on synthetic materials but also supports waste valorization and circular economy principles.

DYE

The extraction of pigments from sunflower petals can be carried out using different polar solvents such as water, methanol, and dilute alkaline solutions (e.g., 1% NaOH). Studies have shown that methanol extraction typically produces a yellow shade, aqueous extraction results in a lighter yellow hue, while alkaline extraction using sodium hydroxide can yield darker shades, including black, when applied to cotton fabrics.

SILAGE

Sunflower biomass also holds promise in the livestock sector. Studies have shown that increasing the proportion of sunflower silage in the diet of lactating goats can enhance the profile of beneficial fatty acids, including oleic acid, conjugated linoleic acid and linolenic acids, thereby improving the nutritional quality of animal products.

CONCLUSION

Sunflower is a versatile crop poised to address India's edible oil import dependence through high-quality oil, adaptability to diverse agro-climatic zones (including marginal lands and rice fallows), low water needs, and short duration. It has the potentiality to enhance the bio-economy via value-added products like nutrient-rich sprouts, roasted seeds, biodiesel, fibre, dyes, and livestock feed

minimizing waste and promoting circularity. Sunflower cultivation can foster rural entrepreneurship and development through sunflower based Agrotourism. Sunflower based aAro tourism can boosts farmer incomes, enhance nutritional security, and supports sustainable practices, especially in regions like Northeast India.

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