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Review Article

A JAUNT THROUGH SUNFLOWER: FROM ITS ORIGIN TO THE DIFFERENT BREEDING APPROACHES FOR ITS IMPROVEMENT

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Abstract: *Helianthus annuus, a large annual herb, is grown for its tasty, fatty seeds. It is also used as a meal or silage plant in residential gardens, as well as cow fodder, bird food, and in some industrial applications. A perennial with several flower heads and branches. The domestic sunflower, in contrast, frequently has a single, large inflorescence (flower head) on top of a straightforward stalk. The seeds of the sunflower plant are used to produce sunflower oil. There is a lot of linoleic acid, and it is a crucial fatty acid. Some sunflowers have undergone genetic modification to increase their oleic acid content. These plants generate sunflower oil, which has high oleic acid content. The polyunsaturated fat in this dish is first-rate. High cholesterol and cardiovascular disease are treated and prevented with sunflower oil. Furthermore, despite the lack of scientific evidence to back up these claims, it is said to treat eczema and a number of other ailments.*

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Keywords:sunflower, cooking oil, *Helianthus annuus*, linoleic acid, oleic acid

Introduction

There is a chance that sunflower in Mexico and the southwestern USA might have independent origins. However, there is no evidence of sunflower origin outside of the USA in historical documents. Molecular analysis specifically showed that Mexican domesticates did not lead to the production of domesticated sunflower germplasm, perhaps a separate origin in the eastern United States (Harter *et al.*, 2004). Wild H. Annus from western America became a North American Indian's food plant. It was then imported into the central part of the world where it was domesticated for the purposes of fruit. Archeological data clearly suggests that Central America was the place of origin of sunflower as early as the first because of the discovery of heads and achenes of domesticated sunflower (Heiser, 1976).

Crop development

Around 3500 BCE, Native Americans in the eastern United States began cultivating sunflowers. They used sunflower seeds to make both food and oil. Sunflower hulls were also employed for colour, pollen, and herbal medicines in religious rites. According to historical records, the Spanish introduced the sunflower to Europe in the early 1600s. It was first grown as an ornamental plant in Europe. Sunflowers were imported from Western Europe to Egypt, Afghanistan, India, China, and Russia in the mid eighteenth century. These seeds were eaten as a snack in this location.

England was the first country to use sunflower oil in 1716 for industrial purposes. Russian scientists then give significant boost to sunflower crop by improving its oil contents up to 40%. Suddenly Russia became the largest producer of sunflower crop in twentieth century with 3-million-hectare area as compared to one half million hectare of Europe. Sunflower open pollinated variety "Russian Mammoth" still sold in North America which was introduced in 1830s. They cultivated sunflower seed for poultry and for livestock silage. Improved Russian varieties having 45–55% oil content were available at second half of the twentieth century. New era of sunflower crop was started in 1970s after the discovery of CMS by the French scientists. Hybrids of sunflower introduced this crop worldwide because of higher yield and oil contents, more uniformity and the disease tolerance(Seiler and TJ Gulya, 2016).

Sunflower in Pakistan

Pakistan is a very agriculturally productive nation that produces a wide variety of crops throughout the year. Pakistan cultivates sunflower as an oilseed crop, among others. The first sunflowers were brought to Pakistan during the 1960s Green Revolution. Currently, the disease has been detected in Attock, Faisalabad, Vehari, district Sialkot, Thattaa, Badin, and Swat, among other cities across the nation. Compared to other crops such as wheat, maize, rice, cotton, and sugarcane, sunflower cultivation requires an exceptionally small amount of land (Okoko et al., 2008).

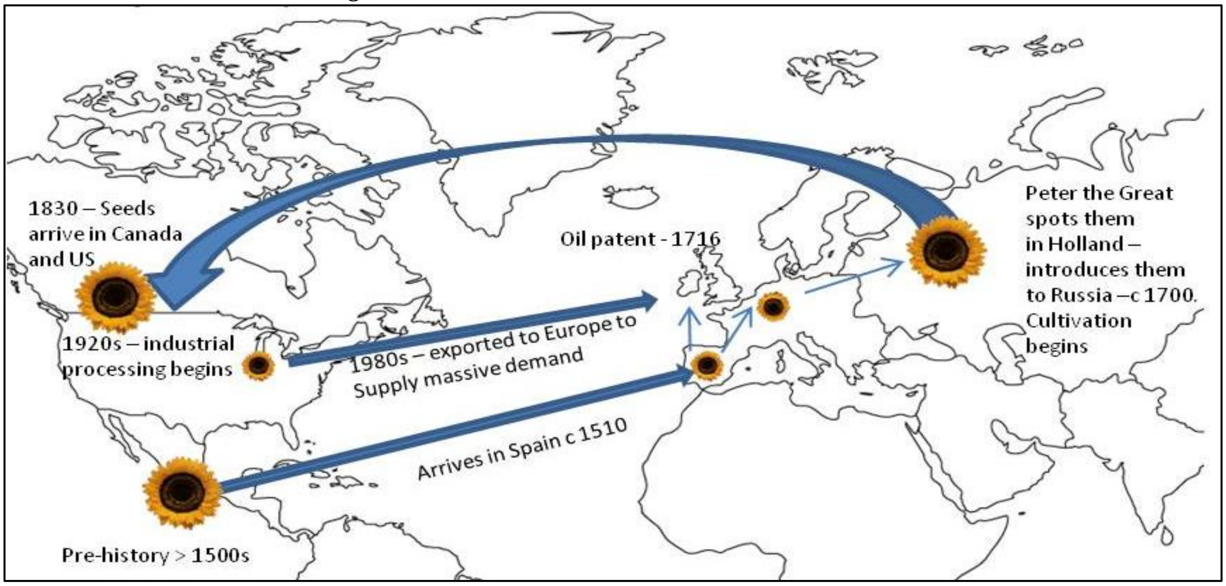

Figure 1: Sunflower development (Source: Kuriositas, 2017)

Introduction of the crop

Family (Asteraceae)

Sunflower belongs to the family Asteraceae (Angiospermae), a large family of flowering plants. This family contains more than 32,000 species, and 13 subfamilies include 1,900 genera. Asteraceae family flowers have thick heads called capitula surrounded by bracts (Panero and Funk 2002).

Genus (Helianthus)

Sunflower belongs to the Genus Helianthus. This genus contains 65 different species. The name Helianthus being derived from Helios meaning "the sun" and Anthos meaning "flower" as they follow the sun during day time. *Helianthus* genus contains 14 annual species. The basic chromosome number of *Helianthus* genus is 17. Diploid, tetraploid and hexaploid species are known.People mostly refer *Helianthus annuus* as sunflower oilseed crop. It is an annual plant having a large inflorescence called flowering head. The plant has a rough and hairy stem, broad, coarsely toothed and rough leaves and also circular heads of flowers (Khaleghizadeh, 2011). Many individual flowers make a sunflower head which then mature into seeds (Seghatoleslami *et al.*, 2012).

Botanical description

Despite their brief growing season, sunflowers are a huge, globally cultivated plant. This annual herb's stem is rough and hairy. The diameters and heights of sunflower stems range from 1.5 to 11 cm and 3.5 to 12.5 feet, respectively. Due of the longer growing season, hybrid sunflowers in the southern hemisphere develop more quickly than those in the northern hemisphere.

Stem, root and leaf morphology

The length of a sunflower leaf ranges from 4 to 12.5 inches and is broad and rough. The quantity and size of internodes impact the stem's length. Internodes are directly proportional to steam thickness; consequently, dense steam has a large number of them. The taproot system of the sunflower is robust and can reach a depth of 280 cm. The lamina of a sunflower leaf resembles a blade, while the petiole resembles a stalk and connects the leaf to the stem. The majority of sunflower leaves are sessile, yet their structure and utility vary widely. As the seedlings break through the surface of the soil and the cotyledons expand, the first pair of true leaves emerge. The length and width of a leaf are influenced by the height of the stem. There are plants with two leaves and plants with eighty leaves. Typically, plants with few leaves mature slowly, indicating a connection problem. It appears that the number of leaves on a plant is linked to the time it takes to ripen(Knowles 1978).

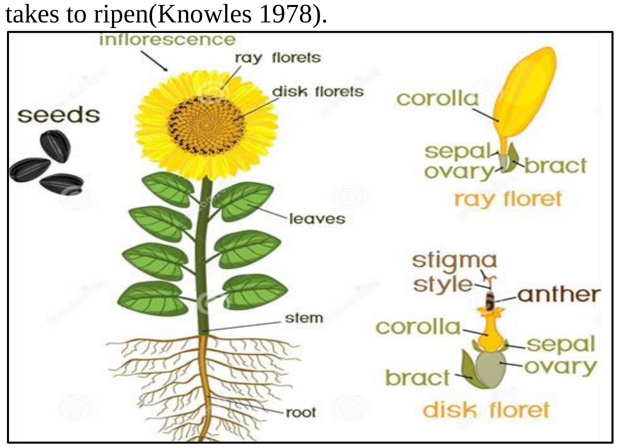

Figure 2: Sunflower morphology(Source: Dreamstime)

Reproductive morphology

Sunflower heads are 4 to 7 inches wide in wild species and a foot long in cultivated varieties. Sunflower heads are composed of many small tubular flowers compactly arranged on a flattish disk. Sunflower head is composed of two types of flowers, ray florets and disk florets. Yellow petals present around the edge of the head are called ray flowers. While the face of the head is composed of 700 to 3,000 of flowers called disk florets, are prefect flowers which then form an achene.

Sunflower seed which oftenly called kernel and its pericarp usually called hull. Seeds mature from the peripheral part of the whorl to the center. At the stage of their attachment, as seed matures, anther,calyx, stigma, corolla tube,and style slip out. The seed size is the highest on the perimeter and the lowest in the middle. The disk flowers produced no seeds in some breeding lines. In the middle of few heads the lack of seed formation is regulated by both genotype and climate. Seed sizes usually vary from 8 to 26 mm long and 5 to 14 mm wide. Sunflower seed colour is usually black.

Sunflower growth stages

The stages of a sunflower's development are largely influenced by its genetic makeup. Throughout the vegetative and reproductive phases of plant development, the major branches or heads of a single head or branching head are recognized. The reproductive phase is classified into nine stages, spanning from flower development to maturity, whilst the vegetative phase is divided into the emerging and mature leaf phases. This technique for expressing sunflower growth stages is efficient, accurate, and reliable (Schneiter and Miller, 1981).

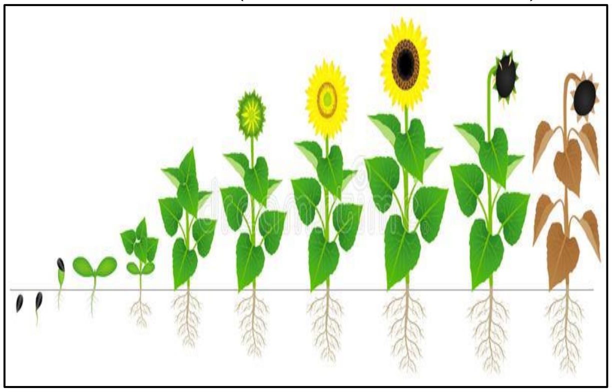

Figure 3 Growth stages of sunflower(Source: Shutterstock)

Economic Importance

The meal's worth remains after the achenes are processed to make sunflower oil, illustrating the plant's economic importance. Because of its greater quality, sunflower oil is significantly more expensive than other vegetable oils such as soybean, rapeseed, cottonseed, and groundnut. This crop is planted in temperate regions all over the world and yields an enormous amount.

World Production Area

Sunflower production in 65 countries reached 27,51 million hectares in 2019-20. (USDA 2019-20). In terms of edible oil production, it is the second-largest hybrid crop after maize, trailing only soybean, rapeseed, and cottonseed. France, Spain, Bulgaria, Hungary, Italy, and Romania produce the most sunflower seeds (4,35 Mha), followed by the Russian Federation (9,10 Mha), Ukraine (7,10 MHA), and Ukraine. (USDA 2019-20). Argentina was second with 1.60 Mha, and China was third with 1.31 Mha. In 2019, Turkey and the United States both produced 1.19 Mha.Ukraine produced the most sunflowers in 2019-20, with an output of 2.70 Mt/ha. Pakistan recorded the lowest output (0.15 Mt/ha). In compared to some of the world's top sunflower-producing countries, the average sunflower yield in other regions of the world was 0.59 Mt/ha.

Oil and Oil Quality

The value of a sunflower is determined by the amount of remaining grain and oil that can be extracted. Sunflower seeds are often dark in colour. The oil extracted from sunflower seeds accounts for 79% of the crop's value. The two most essential parameters in determining oil content are the amount of hull and the amount of oil in the kernel. The hull percentage is thought to vary by genotype, ranging from 11 to 61%. The oil content of the kernel varies between 250 and 710 g/kg. The percentage of achenes in the hull and the oil content of modern high oil cultivars varies from 21-26% and 569-668 g/kg, respectively. Sunflower oil is a high-quality edible oil due to its high concentration of linoleic acid, a necessary unsaturated fatty acid, and low concentration of linolenic acid. Its oil contains no potentially harmful elements and has a high nutritional value (Dorrell and Vick 1997).

Uses of Sunflower Oil

Sunflower is the world's fourth-largest oil seed crop. Sunflower oil is used in both cooking and salad dressings (Kunduraci et al., 2010). Along with shortening, this is an important ingredient in many margarine compositions. Sunflower oil can be used to make modified resins, polyester prints, lacquers, copolymers, and plasticizers. Iodine sunflowers have a diameter of 119 to 139 mm. Because of its high linoleic acid concentration and unusually low linolenic acid level, sunflower oil has excellent drying qualities without becoming yellow (Dorrell and Vick 1997). It can also be used to manufacture soap and detergent (Suslov 1968). In 1968, Suslov Emulsifiers and surfactants derived from fats and oils can be used to create insecticides (Pryde and Rothfus 1989).

As fuel, a dried sunflower stem is utilized. Sunflowers have also historically been utilized in rituals as an attractive plant (Muller et al., 2011). Sunflower has been discovered to provide some medical benefits for respiratory disorders. Body art, textile colours, and other embellishments are made from plant resources. Sunflower oil is also used in cosmetics and industrial paint. The remaining seed cake is fed to cattle after oil extraction. In the Soviet Union, hulls are used to create ethyl alcohol, yeast, and plywood padding. The dry stems were frequently used as fuel. Sunflower stems can be composted and used as fertilizer since they are high in phosphate and potassium. Because of their high nutritional content and lack of anti-nutritional additives, sunflower meals are a superb source of protein (Fozia et al., 2008).

Current edible oil scenario in Pakistan

Pakistan is primarily an agricultural nation. Agriculture employs 39% of the labour force and contributes 19% to the nation's gross domestic product (GDP). Despite this substantial contribution, the demand-consumption imbalance for edible oil widens annually. The average annual intake of edible oil in Pakistan has surpassed 18 kg, a worrying trend for the nation. Due to a number of obstacles, including a lack of high-quality seed, a lack of research on oilseed crops, an unequal marketing structure, and the high cost of local hybrid seed, our local production of edible oil is rather low. Pakistan spends a significant portion of its annual budget on the importation of edible oil to meet the needs of its population. During the 2019-20 fiscal year (July-March), 3.26 million tonnes of cooking oil were consumed, whereas 0.507,000 tonnes were produced locally. The remaining 2.75 million tonnes of cooking oil were obtained at a cost of Rs 321.6 billion (US$ 2.1 billion) from other nations (Govt. of Pakistan, 2019-20).

Importance of Sunflower as an oil seed crop

Sunflower has the potential to fill a gap in crop consumption and production due to its high yield potential, an adjustment in current cropping patterns, early maturity, and drought resistance. Sunflower cultivation covers 0.27 million acres in Pakistan, yielding 0.15 million tonnes of seeds and 55000 tonnes of edible oil. Sunflower seed yield is 1.4 tons/hectare on average, but it has the potential to produce up to 4.5 tons/hectare.

Need of Hybrid development

In 1944, Canadian scientists firstly studied hybrids development in sunflower and observed remarkable results of increasing yield upto 62% as compared to open pollinated varieties (Unrau and White 1944). Some hybrid varieties like "Advance" was developed at that time using self-sterility method to facilitate crosses between parental lines. But the ratio of hybrid plants was limited as it was impossible to use highly self-sterile parents, since they could not be multiplied.

Leclercq (1969) discovered a cytoplasmic male sterility (CMS) source from a cross between *H. petiolaris* and *H. annuus,* a hybrid production in which all female plants are male sterile. Anthers of male sterile plants carry no pollen at flowering period. After that restorer genes were found in progenies from the same cross and also in wild *H. annuus* and some other annual *Helianthus* species (Kinman 1970). In 1974, first hybrids (FRANSOL and RELAX) were registered in France. After that cytoplasmic hybrid have been developed worldwide, are now almost the sole type of variety.

Breeding strategies for oil and yield related traits in sunflower

Combining ability analysis

Combining ability is defined as estimation of the value of genotypes on the basis of their progeny performance in a reliable mating design. (Sprague and Tatum, 1942).General combining ability (GCA) is the average inbred value in all cross combinations whereas specific combining ability (SCA) is a line value in a desired cross (Sprague and Tatum, 1942).

Bhoite *et al.* (2018) used 3 CMS inbred and 14 male testers in a mating design Line × Tester to describe the extent of heterosis, combining ability, genotype × environment interactions in sunflower. 42 crosses were developed. Days to seed yield/plant, physiological maturity, time to 50% flowering, head wideness, biological yield/plant, 100 grain mass, plant height, seed filling percentage, hull quantity, oil proportion and harvest index were observed. SCA variance was observed highest then variance of GCA, which specified the occurrence of gene action called non-additive. The testers R-348 x R-274, KOP-I×15 NB-7, IB-19×R-274, 3376-R, HAM-183, KOP-I×RHA-856 and RHA-6D-1×R-272-4 and the line CMS-17A showed remarkable GCA for head wideness, seed yield/plant, and percent seed filling. It is reported that the crosses CMS-234A x (R-348 x R-274), CMS-17A× (RHA-6D-1×R-272-4), CMS-234A× (KOP-I×RHA-856), CMS-17A×3376-R and ND-2A× (RHA-6D-1 × R-272-4) were good crosses based on the heterosis, SCA effects and has good seed yield/plant.

Aghdam *et al.* (2019) reported genetic interpretation of sunflower morphological and physiological traits. In a line × tester study, five CMS lines and four tests were crossed to achieve 20 F_1 crosses. Important findings for plant height, head diameter, catalase enzyme, superoxide dismutase enzyme, proline, chlorophyll a, chlorophyll b, number of seeds per head, weight of 1000 seeds have been identified. AGHK30 line was the best line for general combining ability under stress conditions and RGHK50 was the best tester. Cross RGHK56 x AGHK44 was observed as the best hybrid in optimum and stress conditions.

Lakshman *et al.* (2019) reported combining ability and gene action in sunflower. They used 9 testers and 4 lines for the development of 36 hybrids through Line × Tester breeding scheme. Lines R-138-2, EC-601978, R-104, and Pet-89-1A revealed significant GCA for oil content and lines R-104, EC-601978, Pet-2-7-1A, R-12-96, R-630, and CMS-107A exhibited significant GCA effects for yield of seed. Crosses showed non-additive gene action for oil %, head widness, 100 kernel mass, volume weight, 100 seed mass, seed yield/plant and hull content. Five parents i.e. EC-601978, R-104, R-12-96, P-2-7-1A and EC-601958 reported good general combiners because positive and high GCA effect for volume weight, head widness, oil percentage and 100 seed mass were reported in it.

Rizwan *et al.* (2019) described the combining ability to assess the breeding potential of sunflower. They crossed 20 lines and 3 testers to develop 60 crosses by using Line × Tester breeding scheme. Data of various traits were estimated viz., 100 achene mass, head diameter, oil %, fatty acid profile and achene yield/plant. Positive GCA for oil contents, achene yield/plant and oleic acid indicated in lines L11 and L6 while 100 achene weight showed positive GCA for lines L7 and L6. Negative GCA was observed for linoleic acid. Cross L11×T2 showed significant SCA for traits such as achene yield/plant and head diameter while the crosses L6×T1, L17×T1, L5×T3 and L20×T3 showed significant SCA for oil contents, linoleic acid, 100 achene mass, and oleic acid respectively. Variance of SCA was reported greater than GCA variance which indicates dominant gene action for parameters.

Heterosis breeding

In hybrid development, heterosis is a key role in identification of superior hybrids. It is a process in which the F_1 cross has superior performance as compared to its parents in term of one or more desired traits.Kanwal *et al.* (2019) stated that the knowledge about heterosis breeding of the genetic components of achene yield and seed quality traits is limited in sunflower. They detertmine the combining abilities, maternal and paternal gene actions for achene yield and seed quality traits in 21 crosses through Line × Tester design. Significant mean differences were observed for achene yield and seed quality traits. Traits achene weight, achene length, achene thickness, head diameter, plant height, protein content, leaf area and oil content contributed 35.6% variation to achene yield. Significant GCA was observed in parental inbred lines for emergence percentage, head diameter, plant height, 100 achene weight and achene yield per plant, while hybrids demonstrated positive SCA for emergence percentage, head diameter, plant height, 100 achene weight, flowering days, maturity days, oil content and achene yield per plant.Heterosis, heterobeltosis and commercial heterosis was observed in the hybrid H5. Genetic exploitation of H5 in future breeding programme to map QTL genes in arid and semi-arid zones and to boost up yield and seed quality traits is highly desirable.

Telangre *et al.* (2019) analyzed the magnitude of heterosis as well as combining ability effects in sunflower. They developed 40 crosses by crossing 4 CMS inbred and 10 testers via Line × Tester breeding scheme. Data regarding different yield-related traits were observed. CMS lines PET 89-1A and PET 2-7-1 A reported significant and positive GCA for oil amount and kernel yield respectively whereas restorers EC 601957 and RHA138-2 showed good GCA for yield-related traits. High significant SCA was observed in crosses CMS 234A × EC 601924, PET 2-7-1A × EC 601957, PET 2-7-1 A×R-16 and ARM 249A×R 271-1 for yield of seed in a plant.

Conclusion

Sunflower is important oilseed crop. It can fulfil the requirement of cooking oil in Pakistan if researchers focus on this crop. Good quality cooking oil can be obtain from this crop which fulfil the requirement of healthy diet and it will lower down the import of cooking oil.

Conflict of interest

The authors declared absence of conflict of interest.

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