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A comprehensive review on allium cepa

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Abstract
Arcs widely known as Allium Sepal L. is one of the most important and cultivated plant crops in the world. It depends on the family Tamaricaceae and is known for its diverse culinary use, its medicinal properties, and its industrial potential. Onions are a rich source of biologically activated compounds, including compounds containing sulfur, flavonoids, saponins and phenolic acids, providing distinctive taste, aroma and therapeutic benefits. For centuries, allium cepa has been an integral part of human food and traditional medicine, and has played a documented role in the prevention and treatment of a wide range of diseases. Modern scientific research has also identified its pharmacological potential, particularly antioxidant, antibacterial, anti-inflammatory, antidiabetic, cardio protection, and antitumor. The purpose of this review is to provide a detailed overview of CEPA alliums, covering its taxonomy, morphology, culture, phytochemistry, nutrient composition, pharmacological activities, traditional uses, and industrial applications. The journal also highlights recent achievements in the fields of research, security considerations and future prospects, and its role in medicine, nutrition and biotechnology.

Keywords: Allium cepa, onion, phytochemicals, flavonoids, sulfur-containing compound antioxidant activity, anti-inflammatory, antimicrobial, antidiabetic

1. Introduction

Luke (Arisaema L.) is a cultivated culture, consumed worldwide and has been a central role in culinary practice and ethnoscience for thousands of years. Archaeological data show that onion use is over 5, 000 years old, and that its origin is assigned to Central Asia and the Middle East before spreading to the continents of its adaptability and storage potential.[1] Today, onions are one of the best plant crops in terms of global production, India, China and US- managed production [2, 3].

Beyond culinary uses, onions are recognized for their health-benefit properties due to complex phytochemicals such as flavonoids, sulfur compounds, and phenolic acids Epidemiological studies have associated regular onions with reduced risk of chronic diseases such as cardiovascular disorders, diabetes and cancer [5, 6]. The multifaceted use of onions in medicine, nutrition and food technologies highlights their importance in traditional and contemporary contexts. [4]

Fig1: Morphological Characteristics of Onion (*Allium cepa*) at Different Developmental Stages

2. Taxonomy and Botanical Classification

Allium cepa is garlic (A. sativum), A. It belongs to a diverse range of alliums, including over 900 species [7] (A. （A. Schoenoprasum（A。Schoenoprasum） （A。Schoenoprasum） The systematic classification is as follows:

2.1 Kingdom: Plants

2.2 Procedure: Dotted line

2.3 Family: Tamaricaceae Rod: Allium

2.4 Type: Allium Cepa L.

There are morphological and phytochemical differences between onions such as red, white and yellow onions that affect their medicinal and industrial values [8, 9]

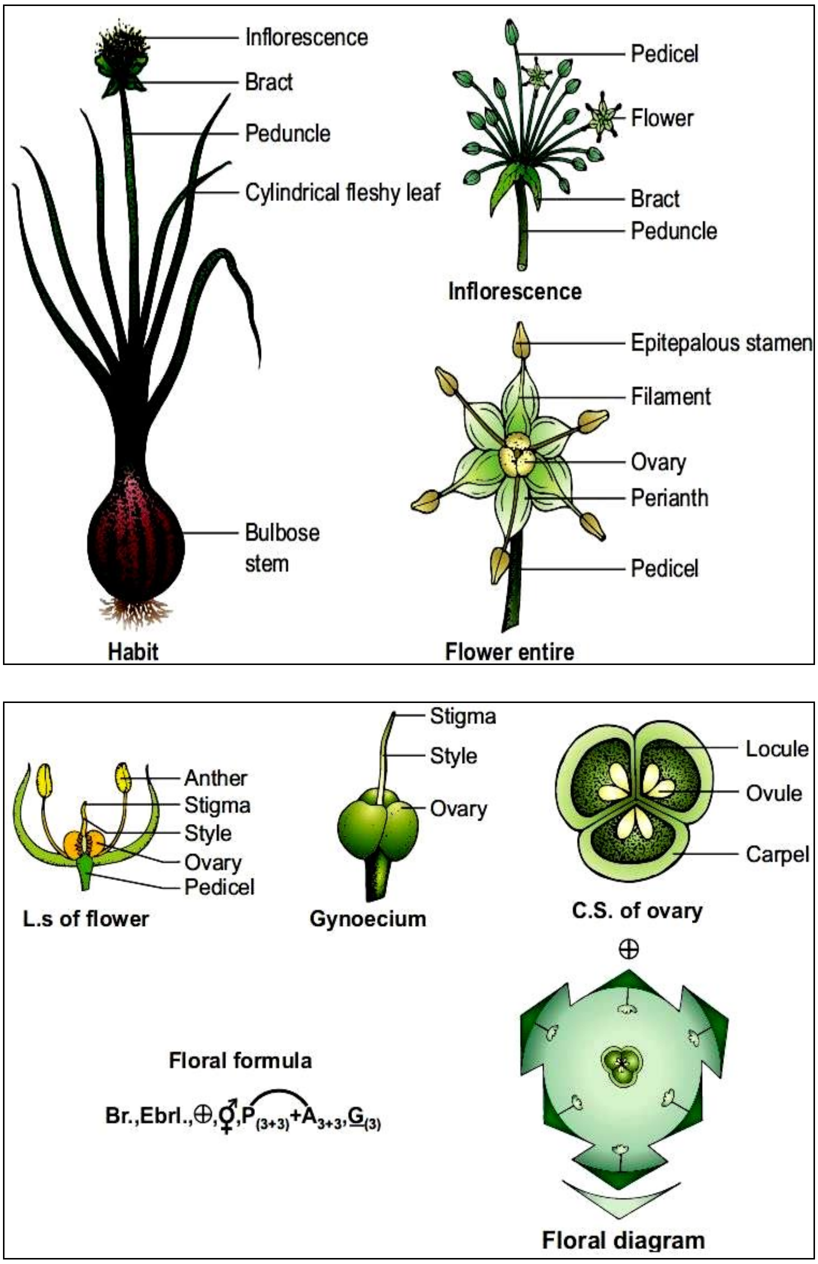

Fig 2: Comprehensive Morphology, Inflorescence, and Floral Characteristics of *Allium cepa* (Onion) [10]

2.5 Leaf [11]

A group of radical sheets flows from a cylindrical, fleshy light bulb in the underground.

Inflorescence: Hot, that is, the axis of the inflorescence from the ground (floral pedicle), on top of it, has a group of flowers. Dogs have the same length from the top of the floral plaid, so they take all flowers to the same level. Flowers: small, white, married, avoderato, pedicel rat, full, slit, actin morphic, and fuck. Flower protection. Pent: Depal 6, White, located in three revolutions, synthesized during continuous valves.

2.6 Androecium [11]

Stamens 6, 3 two revolutions, Epidurals, Apostamand / Free and opposing Teala. Dust is disco, basic, interesting, longitudinal instigation.

2.7 Gynoecium [11]

Synchronized with Tricarpellary. Excellent ovaries, trinocular with two eggs in each trajectory on the placenta of Axia. The style is simple, with a simple stigma and thinner.

2.8 Fruit: A loculicidal capsule.

2.9 Seed: Endo spermous

2.10 Floral Formula.

Floral Formula:

$$Br., Ebrl., \oplus, ⚥, P_{(3+3)}\,A_{3+3}, \underline{G}_{(3)}$$

3. Culture and Agriculture

Onion growth requires specific agricultural practices to maximize performance and quality. It thrives with organic matter and abundant sandy loam in well-drained state. Optimal growth occurs at temperatures ranging from 15 to 25 °C [12]. Culture methods include seeding, bulbs and transplantation. Onion crops require a balanced fertilizer, and nitrogen, phosphorus, and potassium are important nutrients [13, 14]. Pests such as trips and nematodes, as well as diseases such as downy mildew and basal rot, have a major impact on performance (World Health Organization,) [15, 16]. Post-harvest processes such as curing, drying and refrigeration are necessary to extend shelf life and maintain the quality of the bulb [17]

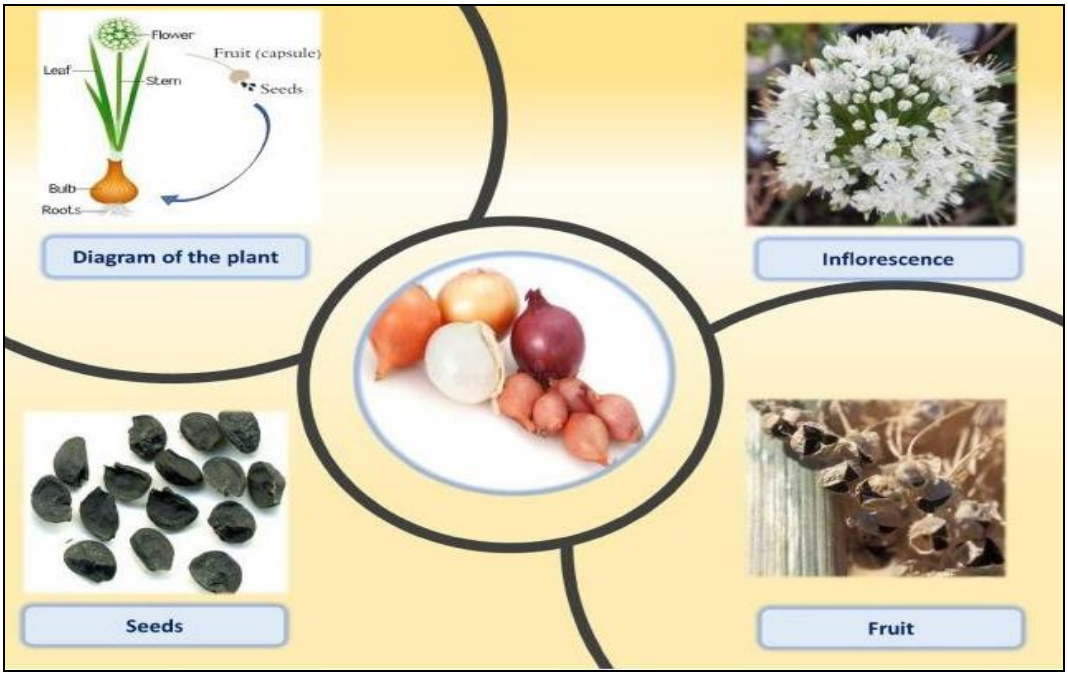

Fig 3: Life Cycle Stages and Products of the Onion Plant (*Allium cepa*)

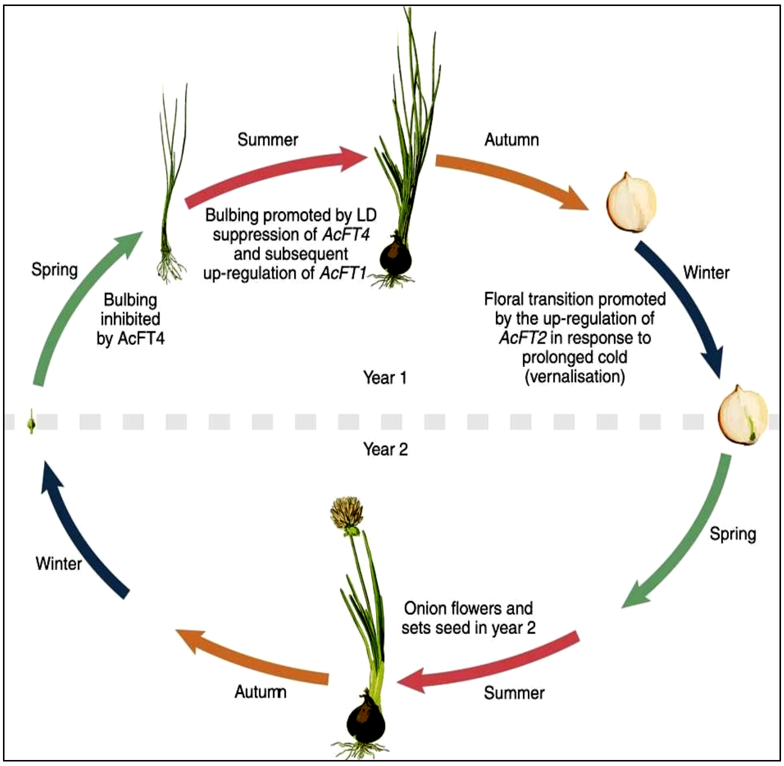

Fig 4: Biennial Life Cycle of Onion (*Allium cepa*) and Regulation of Bulbing and Flowering by *AcFT* Genes

3.1 Onion Life Cycle

The provided image depicts the biennial life cycle of the onion, Allium cepa, with a focus on the seasonal developmental phases and the genetic regulation of flowering and bulb formation.[18] Although onions usually take two years to complete their life cycle, they are frequently grown as annuals in order to produce bulbs.[18]

3.2 Year 1: Vegetative Growth and Bluing

Spring (Early Growth): Onion seedlings emerge during spring. At this stage, the gene AcFT4 inhibits bulb formation, allowing the plant to focus on vegetative leaf development. [19, 20]

Summer (Bulb Initiation): Bulb formation begins in response to long-day (LD) photoperiods. This is regulated by the suppression of AcFT4 and subsequent up-regulation of AcFT1, which promotes bulb swelling and storage tissue accumulation. The bulb serves as an energy reservoir for overwintering. [19, 20]

Autumn (Bulb Maturation): The bulb reaches maturity by autumn. Growth slows as the plant prepares for dormancy [18].

Winter (Vernalization Phase): During prolonged cold exposure, a process known as vernalization, the gene AcFT2 is upregulated. This genetic switch promotes the floral transition, preparing the plant for reproductive growth in the second year. [19, 20]

3.3 Year 2

Seed Production and Reproductive Growth Spring (Floral Initiation): The onion begins to grow actively again after vernalization. According to Brewster (2008), the bulb's stored energy facilitates the growth of flower stalks. Small white flowers form an umbel inflorescence on the plant during the summer (flowering and seed set). Within the umbels, pollination takes place and seeds are planted). Harvesting viable seeds for further cultivation is the final stage of the onion plant's life cycle, which occurs in the autumn (see seed maturation) [21, 22]

In order to prioritize leaf development, genetic regulation AcFT4 inhibits bulbing during early growth stages. (AcFT1: Encourages bulbing in reaction to extended daylight hours Initiating floral development in the second year, AcFT2 is activated during extended cold (vernalization) [19, 20, 21].

4. Harvesting of onion

Onion harvesting is a combined operation consisting four critical steps, viz., (de)topping, lifting, curing and transporting from field to warehouse. [22] Harvesting of onion decides the quality and storage life of the bulbs. In general, onions are harvested after 70-90 days after transplantation process and in some varieties up to 110-120 days [23].

The harvesting time is indicated when the onion leaf turns yellow from green on the top and simultaneously collapse just above the top of the bulb. In the case of large-scale harvesting, harvesting is done after half of the tops are fallen down but when the leaves are still green. Sometimes the bulbs are picked after the leaves turn yellow, but the tops do not fall off, as is the case with onions grown in the fall. Harvesting is usually done a week later, when half of the tops have dropped, for winter varieties. Poor harvesting practices, such as collecting bulbs too soon, cause them to sprout, yet picking bulbs later causes their roots to develop more during storage [23].

Furthermore, post-harvest onion bulb quality and storability are significantly influenced by irrigation. Since onions have shallow roots, frequent yet mild watering is necessary to ensure ideal soil moisture and bulb growth.

When the bulbs are ready, which is two weeks (12-15 days) prior to harvest, irrigation is often halted. Before harvest, excessive watering (two or more times a week) may result in larger bulbs, but it also decreases their storability because of an increase in moisture content that causes microbial contamination and other post-harvest losses like sprouting. [23]

4.1 Topping

Detopping, lifting, and curing are the three main processes in onion harvesting, as previously mentioned. Lifting and topping are interchangeable processes.

Onions are traditionally picked by hand using forked tools to loosen the soil, then lifting also known as de-topping the process of removing the leaves. [24] In India, women are often involved in this labor- and time-intensive operation. The dried leaves are detopped using a sickle, and it was anticipated that 12.5-woman hours would be needed to depot 1 tone of material (onion bulbs).

As an alternative, crop raising machines and de topping (field toppers) have been used recently to pull the bulbs out of the ground and remove the dried leaves. For lifting and detopping, a number of machine designs have been put forth and used. [24, 25].

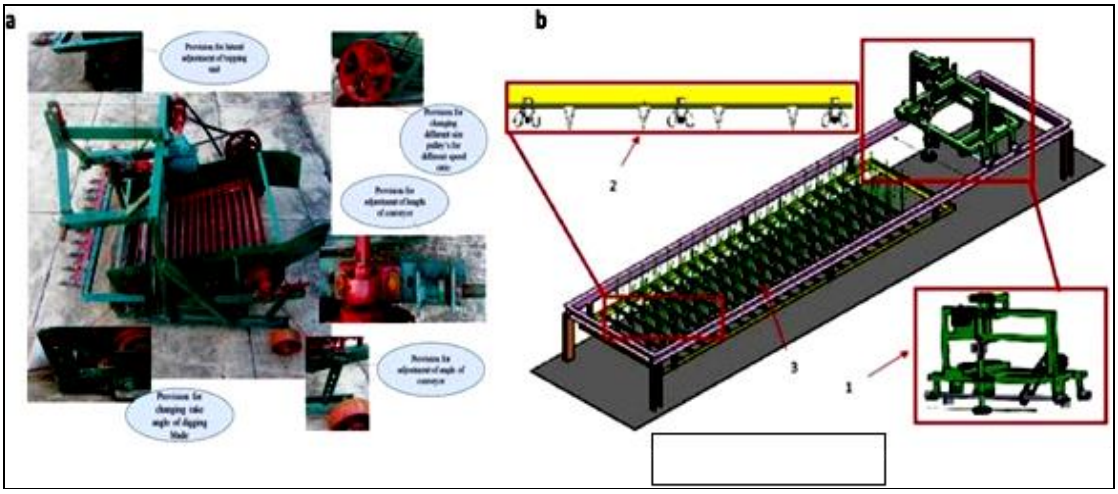

Fig 5: Design and Implementation of the Automatic Onion Planter

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4.2 De topping
To top the leaves, created a machine. Onion plant holding units, a guide rail, and a rotary cutting unit in a processing trolley made up the design. The cutting unit was made up of two nylon ropes fastened to a rotating drum. An onion harvester powered by a tractor or power tiller could be equipped with the leaf topping unit. The cutting unit's speed and the forward speed could be adjusted by the processing unit. The authors noted that in order to attain good topping efficiency, the cutting speed should be below 1800 RPM and the processing trolley's forward speed should be less than 1 point 2 km h−1Between 250 and 300 W of power was needed on average to top onion leaves. [29].

4.3 Lifting
Lifting is another important step that affects the onion bulbs' storability, as was previously mentioned. The bulbs must be dug up from the ground in order to be lifted. When 60 to 80 percent of the tops are down or the foliage has collapsed, lifting is frequently done. They are occasionally lifted late, more than 90 percent tops-down, or earlier, between 10 and 50 percent tops-down [26]. In comparison to early lifting, late lifting has been found to improve the nutritional quality of onions, as evidenced by a 45 percent increase in the concentration of quercetin and its derivatives [30]. By preventing the bulbs from absorbing too much moisture from the soil and hastening the drying of the top and neck, lifting at the right time accelerates the curing process. Immature bulb lifting, i.e. When only 25% of the leaves have fallen, lifting too soon causes too much moisture and prolongs the curing period, which raises the risk of microbial diseases like neck rot [26].

4.4 Curing
The process of curing involves drying out the harvested onion bulbs' outer skins, roots, and neck tissues to eliminate extra moisture. When 50 to 80 percent of the tops fall off and the leaves have dried and withered, onions are typically harvested. [31] Curing improves the onions' ability to be stored and lowers the risk of microbial infection. Curing causes the bulb's surface skin to dry out because moisture is only eliminated from the outer scales. According to Garapata et al., the dried outer or surface skin of onions serves as a mechanical barrier to prevent water loss, a defense against microbial attack, and a cosmetic enhancement. Onions are deemed cured when their necks are taut and their outer scales have dried after consuming 3-5% of their body weight [31, 32]

4.5 Major problems associated with onion cultivation and storage
- Rotting:
- Black mold
- Fusarium basal plate rot
- Neck rot
- Neck rot
- Neck rot
- White rot
- White rot [33]

5. Phytochemical Composition of Onions
5.1 Sulfur-Containing Compounds
Onions' unique pungency, aroma, and many of their medicinal qualities are primarily attributed to compounds that contain sulfur. These substances are created when the tissues of onions are disturbed (e.g. A. Crushing or chopping), which causes the enzyme alliinase to become active. S-all (en)yl- L-cysteine sulfoxides (ACSOs) are catalyzed to transform into volatile thiosulfates by alliinase, which gives them their distinctive scent [34]. Similar in structure to the allicin in garlic, thiosulfates are short-lived but extremely bioactive compounds.
Onions medicinal potential is enhanced by their antimicrobial, antioxidant, and antithrombotic properties [35]. Sulfoxides are abundant in intact bulbs and function as precursors of aroma. Compounds like diallyl disulfide and allyl methyl sulfide, which are produced when sulfoxides are broken down by enzymes, are what give off the odor and may also have detoxifying and cholesterol-lowering effects [36]. content.

5.2 Flavonoids
Onions contain a large number of non-sulfur phytochemicals called flavonoids, especially flavanols. Of these, quercetin is the most prevalent and well-researched substance.
Glycosides are its most common form (e.g. 3. both quercetin-3, 4′-O- Di glucoside and quercetin-4′-O-glucoside) in onion tissues [37]. Strong anti- inflammatory, cardioprotective, and antioxidant qualities are possessed by quercetin. According to epidemiological research, eating a lot of foods high in quercetin lowers your risk of developing heart disease and some types of cancer [38]. Onions also contain kaempferol, another flavanol that has been shown to have anti-proliferative and antioxidant properties in smaller amounts [39]. Peeling techniques appear to have a significant impact on the overall flavonoid intake, as the flavonoid content is concentrated primarily in the bulb's outer fleshy layers and dry skins [40].

5.3 Phenolic Compounds
Onions are rich in flavonoids and phenolic acids, such as p-coumaric acid, ferulic acid, and gallic acid. These substances reduce oxidative stress and scavenge free radicals as natural antioxidants [41]. Phenolic acids give onions their bitter and astringent flavor and are involved in plant defense mechanisms. Particularly well-known for its capacity to counteract reactive oxygen species and prevent lipid peroxidation, ferulic acid helps prevent chronic illnesses like diabetes and cancer [42]. Onions' total antioxidant capacity is boosted by gallic acid, while p-coumaric acid has demonstrated antimicrobial activity [43].

5.4 Saponins and Steroidal Compounds
Steroid saponins, a type of glycosides with surfactant qualities and possible medicinal us es, are also found in onions.
Onions' saponins reduce serum cholesterol levels by binding to bile acids and encouraging g their excretion, which has hypocholesterolemia effects [44].
Furthermore, saponins are significant elements of the onion phytochemical profile due to their immunomodulatory, antifungal, and anticancer characteristics [16].
Saponin- derived steroidal chemicals have demonstrated promise in enhancing gut health and regulating immunological responses. Their biological activity may be enhanced by their synergistic effect with sulfur compound ds and flavonoids, despite the fact that their concentration in onions is lower than that of some other Allium species [45].

5.5 Vitamins and Minerals
Onions offer vital vitamins and minerals in addition to secondary metabolites, which add to t heir nutritional and health-promoting benefits.
Vitamin C, an important antioxidant that promotes collagen production, immune system function, and defense against oxidative stress, is abundant in them [50]. B-complex vitamins including pyridoxine and folate, which are critical for neurological and energy metabolism, are also found in onions.
Potassium is the most prevalent mineral and is essential for preserving electrolyte balance and cardiovascular health.
Significant amounts of calcium, magnesium, and selenium are also present [51].
To strengthen antioxidant defense mechanisms, selenium, in particular, works in concert with sulfur compounds.
Onions' designation as functional foods are supported by the presence of several micronutrient nets and phytochemicals.

6. Pharmacological and Biological Activities of Onions
6.1 Antioxidant Activity
Onions' powerful antioxidant potential is one of its best-known qualities.
The main flavonoid in onions, quercetin, and sulfur compounds like thiosulfates are important for scavenging free radicals and minimizing oxidative damage [52]
This antioxidant defense aids in preventing cellular damage that fuels chronic illnesses including diabetes, heart disease, and neurological disorders.
In support of their protective function, studies have demonstrated that onion extracts can increase se the activity of natural antioxidant enzymes such as catalase and superoxide dismutase (SOD) [53].

6.2 Anti-inflammatory Properties
By modifying important inflammatory pathways, onions have strong anti- inflammatory properties. Onions contain bioactive substances that prevent the release of pro-inflammatory mediators like cyclooxygenase enzymes, interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α) [3]. Specifically, quercetin inhibits NF-dB signaling, a key route in inflammation, and suppresses the production of inflammatory genes [54].
Therefore, chronic inflammatory diseases like arthritis, asthma, and metabolic syndrome may be lessened by regular eating or therapeutic use of onion extracts.

6.3 Antimicrobial Effects
A wide range of bacteria and fungi are susceptible to the broad- spectrum antibacterial action of onions. This activity is caused by sulfur- containing chemicals, particularly thiosulfates.
Onion extracts have been shown in lab experiments to be effective against infections such h Candida albicans, Escherichia coli, and Staphylococcus aureus [55].
Onions are a potential supplemental ingredient for food preservation and infection man agreement because of their antibacterial properties.

6.4 Antidiabetic Effects
Additionally, onions show promise as an antidiabetic.
The bioactive substances limit intestinal glucose absorption, increase insulin sensitivity, and encourage peripheral tissue glucose uptake [56].
Supplementing with onion extract has been demonstrated to significantly lower fasting blood glucose levels and enhance glycemic control in both human and animal models [57]. Key enzymes involved in glucose metabolism are thought to be modulated by quercetin, and sulfur compounds help shield

6.5 Anticancer Potential
Onions have important anticancer capabilities, according to recent studies.
Phenolic acids, quercetin, and organosulfur compounds work together to inhibit tumor growth and cause cancer cells to undergo apoptosis [58].
Onion extracts have been demonstrated in experiments to stop the growth of prostate, breast, and colon cancer cells [59].
Modification of cell signaling pathways, reduction of angiogenesis, and protection of DN A damage are some of the causes of these effects. Consuming onions is also associated with a lower risk of developing some types of cancer r, according to epidemiological research [60].

7. Industrial and Food Applications of Onions
7.1 Food Industry
Onions are mostly utilized in the food sector as natural preservatives, sauces, and flavorings
Products including dehydrated onion pastes, flakes, and powder are frequently used in ready-to-eat meals, sauces, snacks, soups, and processed goods [61].
They are perfect for large- scale production and distribution since dehydration extends their shelf life while preserving a sizable amount of their bioactive ingredients [62].
Because of their antibacterial qualities, onion extracts are also being investigated as natural preservatives, offering a clean-label substitute for artificial additives [63].

7.2 Pharmaceutical Industry
Onions are prized in medicine for their antibacterial and antioxidant properties.
Formulations that address oxidative stress, metabolic problems, and microbial infections include extracts high in sulfur compounds and flavonoids [64].
These characteristics justify their use in dietary supplements and nutraceuticals that enhance immune system function, glycemic control, and cardiovascular health [65].

7.3 Cosmetics Industry

Onion extracts are used in cosmetic products for skin-whitening, anti-aging, and scar- reducing properties.

Onions' phenolic chemicals and sulfur derivatives are known to promote collagen synthesis and suppress the development of melanin, improving the tone and texture of skin [66]. Hair growth serums and skin rejuvenation treatments also contain formulations based on onions [67].

8. Future Research Directions on Allium cepa:

8.1 Advanced Methods of Breeding:

The creation of onion cultivars resistant to pests and diseases while increasing the phytochemical content should be the main focus of future research. CRISPR/Cas-based gene editing, genomic selection, and marker-assisted selection are examples of contemporary breeding methods that can hasten the development of cultivars with increased yield, stress tolerance, and concentrations of advantageous substances like flavonoids and organosulfur compounds [68]

8.2 Pharmacological Validation via Clinical Trials

Onions' anti-inflammatory, anti-cancer, antidiabetic, and antioxidant qualities are supported by a large body of in vitro and in vivo research, but thorough clinical trials are required to verify their effectiveness in people. For the use of extracts from onions in nutraceuticals and complementary medicine, such research would aid in the establishment of dosage, safety, and therapeutic guidelines [69].

8.3 Methods of Sustainable Cultivation

In order to lessen environmental effects such soil erosion, water use, and chemical inputs, sustainability in onion farming is becoming more and more crucial. To guarantee long-term productivity while reducing ecological footprint, research should concentrate on integrated pest management, organic farming practices, and environmentally friendly fertilizer approaches [70].

Increased Use in Industry

Future research should examine new industrial uses for onions, such as their incorporation into functional foods, biodegradable packaging, and cosmetic compositions. Furthermore, the transport, stability, and bioavailability of onion bio actives in functional goods can be improved by the development of nano- and microencapsulation methods [71].

Conclusion

Many species with notable morphological, physiological, genetic,

and phytochemical diversity are found in the genus Allium, especially Allium cepa L.

Allium cepa species are now among the most economically significant vegetable groups due to their ability to adapt to v arious agroclimatic zones across the globe. Various species, including A. cepa var. aggregatum (shallots), A. fistulous (Welsh onion), A. sphenogram (chives), and A. prolife rum (Egyptian walking onion), differ in their growth habits, bulb characteristics, day-length responses, and ecological adaptations.

The Allium cepa species exhibit significant genetic diversity, which is beneficial for breeding and enhancing crops. The use of molecular techniques, including DNA markers and genomic sequencing, has facilitated more accurate classification and identification of species, contributing to the creation of improved cultivars that possess qualities such as disease resistance, tolerance to stress, and increased yield. These developments are essential for sustainable production, particularly in light of climate change and the challenges posed by new pest threats.

Phytochemically, various species exhibit different concentrations of organosulfur compounds, flavonoids, phenolics, and anthocyanins. These compounds impact the taste, scent, and health advantages of onions. For instance, red and purple varieties are abundant in quercetin and anthocyanins, enhancing their antioxidant properties, while shallots are richer in sulfur compounds, providing a stronger flavor and health benefits. This signifies that Allium cepa species are significant not just as food crops but also as functional foods with medicinal qualities.

References

26. Griffiths G, Trueman L, Crowther T, Thomas B, Smith B, et al. Onions—a global benefit to health. Phytother Res. 2002;16(7):603-615.
27. Bose TK, Kabir J, Maity TK. *Vegetable crops.* Calcutta: Naya Prokash; 2003.
28. Food and Agriculture Organization of the United Nations (FAO). FAOSTAT statistical database. 2020 [cited 2025 Oct 10]. Available from: https://www.fao.org/faostat/en/
29. Lanzotti V. The analysis of onion and garlic. J Chromatogr A. 2006;1112(1-2):3-22.
30. Nuutila AM, Puupponen-Pimiä R, Aarni M, Oksman-Caldentey KM. Comparison of antioxidant activities of onion and garlic extracts by inhibition of lipid peroxidation and radical scavenging activity. Food Chem. 2003;81(4):485-493.
31. Slimestad R, Fossen T, Vågen IM. Onions: a source of unique dietary flavonoids. J Agric Food Chem. 2007;55(25):10067-10080.
32. Fritsch RM, Friesen N. Evolution, domestication and taxonomy. In: Rabinowitch HD, Currah L, editors. *Allium crop science: recent advances.* Wallingford: CAB International; 2002. p. 5-30.
33. Prakash D, Singh BN. Onion (*Allium cepa* L.)—a potential source of antioxidants. Indian J Agric Biochem. 2007;20(1):1-5.
34. Lee EJ, Yoo KS, Patil BS. Phytochemical profiles of 15 onion cultivars and their relationships with pungency, color and antioxidant activity. Food Chem. 2015;188:628-637.
35. McClements DJ. Nanoparticle- and microparticle-based delivery systems: encapsulation, protection and release of bioactive compounds. Crit Rev Food Sci Nutr. 2017;57(8):1301-1352.
36. Fahn A. *Plant anatomy.* 4th ed. Oxford: Pergamon Press; 1990. p. 320-324.
37. Bose TK, Kabir J, Maity TK. *Vegetable crops.* Calcutta: Naya Prokash; 2003.
38. Sharma RP, Sharma R, Kaur A. Effect of nitrogen and phosphorus fertilization on growth and bulb yield of onion (*Allium cepa* L.). Indian J Agric Sci. 2016;86(4):567-572.
39. Brewster JL. *Onions and other vegetable alliums.* 2nd ed. Wallingford: CABI Publishing; 2008.
40. World Health Organization. *Pesticide residues in food - 1999 evaluations.* Geneva: WHO; 1999.

41. Schwartz HF, Mohan SK. *Compendium of onion and garlic diseases and insects.* St. Paul (MN): APS Press; 2007.
42. Griffiths G, Trueman L, Crowther T, Thomas B, Smith B, et al. Onions—a global benefit to health. Phytother Res. 2002;16(7):603-615.
43. Brewster JL. *Onions and other vegetable alliums.* 2nd ed. Wallingford: CABI Publishing; 2008.
44. Lee R, Baldwin S, Kenel F, McCallum J, Macknight R. FLOWERING LOCUS T genes control onion bulb formation and flowering. Nat Commun. 2013;4:2884.
45. Lee R, McCallum J, Macknight R. The genetic control of flowering and bulb formation in onion. Sci Hortic. 2013;157:1-8.
46. Brewster JL. The physiology of onion seed production. In: *Onions and other vegetable alliums.* 2nd ed. Wallingford: CABI; 2008. p. 215-240.
47. Rashid MH, Inden H. Onion seed production and quality: a review. J Fac Agric Kyushu Univ. 2012;57(1):1-10.
48. Lee R, et al. Onion bulb formation and flowering are regulated by FT gene family members. Sci Hortic. 2025 [cited 2025 Oct 10]. Available from: https://www.sciencedirect.com/science/article/pii/S0304423825002018
49. Wright CJ, Triggs CM. Postharvest handling of onions. New Zeal J Crop Hortic Sci. 2005;33(4):335-343.
50. Kumawat A, Raheman H. Development of an onion topper-cum-lifter for efficient harvesting. Eng Agric Environ Food. 2022;15(1):69-78.
51. Rathinakumari R. Labour requirements for onion de-topping in India. Agric Eng Today. 2022;46(2):22-27.
52. Wright CJ. Mechanization in onion harvesting: current practices and future prospects. Acta Hortic. 2005;688:309-316.
53. Wright CJ, Triggs CM. Postharvest handling of onions. N Z J Crop Hortic Sci. 2005;33(4):335-343.
54. Rathinakumari R. Labour requirements for onion de-topping in India. Agric Eng Today. 2022;46(2):22-27.
55. Kumawat A, Raheman H. Design and development of an onion leaf topper. Eng Agric Environ Food. 2022;15(1):69-78.
56. Kumawat A, Raheman H. Development of a tractor-operated onion topper-cum-lifter. Agric Mech Asia Afr Lat Am. 2022;53(3):19-26.
57. Ren F, Zhou Q. Effects of lifting time on flavonoid content and storage quality of onion bulbs. Postharvest Biol Technol. 2021;175:111483.
58. Petropoulos SA, Ntatsi G, Ferreira ICFR. Onions: a source of flavonoids and phenolics. Food Chem. 2017;231:88-97.
59. Gorreapti A, Rao P, Srivastava B. Role of curing in improving onion storage quality. J Food Sci Technol. 2018;55(9):3795-3803.
60. Rani S. Post-harvest management and storage of onions. Indian J Hortic Sci. 2016;73(4):567-572.
61. Block E. The chemistry of garlic and onions. Sci Am. 1985;252(3):114-119.
62. Amagase H, Petesch BL, Matsuura H, Kasuga S, Itakura Y. Intake of garlic and its bioactive components. J Nutr. 2001;131(3 Suppl):955S-962S.
63. Rose P, Whiteman M, Moore PK, Zhu YZ. Bioactive S-alk(en)yl cysteine sulfoxide metabolites in the genus *Allium*. Nat Prod Rep. 2005;22(3):351-368.
64. Imai S, Tsuge N, Tomotake M, Nagatome Y, Sawada H, Nagata T, et al. An onion enzyme that makes the eyes water. Nature. 2002;419(6908):685-689.
65. Bonaccorsi P, Caristi C, Gargiulli C, Leuzzi U. Flavonol glucosides in *Allium* species: a comparative study by means of HPLC-DAD-ESI-MS. Food Chem. 2005;95(2):240-247.
66. Hollman PCH, Katan MB. Dietary flavonoids: intake, health effects and bioavailability. Food Chem Toxicol. 1999;37(9-10):937-942.
67. Middleton E, Kandaswami C, Theoharides TC. The effects of plant flavonoids on mammalian cells. Pharmacol Rev. 2000;52(4):673-751.
68. Price KR, Rhodes MJC. Analysis of the major flavonol glycosides present in four varieties of onion. J Sci Food Agric. 1997;74(3):331-339.
69. Slimestad R, Fossen T, Vågen IM. Onions: a source of unique dietary flavonoids. J Agric Food Chem. 2007;55(25):10067-10080.
70. Rodríguez G, Olivas GI, Rojas R, Sepulveda DR. Effect of processing techniques on phenolic compounds and antioxidant activity of onions. Food Chem. 2015;188:537-544.
71. Srinivasan M, Sudheer AR, Menon VP. Ferulic acid: therapeutic potential through its antioxidant property. J Clin Biochem Nutr. 2007;40(2):92-100.
72. Heleno SA, Martins A, Queiroz MJRP, Ferreira ICFR. Bioactivity of phenolic acids: metabolites versus parent compounds. Food Chem. 2015;173:501-513.
73. Oakenfull D, Sidhu GS. Saponins and human health: a review of the evidence. Nutr Res. 1989;9(4):1065-1078.
74. Man S, Gao W, Zhang Y, Huang L, Liu C. Chemical study and medical application of saponins as anticancer agents. Fitoterapia. 2010;81(7):703-714.
75. Augusti KT. Therapeutic values of onion and garlic. Indian J Exp Biol. 1996;34(7):634-640.
76. Levine M, Rumsey SC, Daruwala R, Park JB, Wang Y. Criteria and recommendations for vitamin C intake. JAMA. 1999;281(15):1415-1423.
77. United States Department of Agriculture (USDA). FoodData Central: Onion, raw. Washington (DC): USDA; 2023.
78. Griffiths G, Trueman L, Crowther T, Thomas B, Smith B. Onions—A global benefit to health. Phytother Res. 2002;16(7):603-15.
79. Lee EJ, Yoo KS, Patil BS. Functional properties of onion and garlic. Food Sci Biotechnol. 2010;19(3):519-29.
80. Ebisawa K, Yamada M, Sasaki T, Nakajima T. Anti-inflammatory effects of onion extract. Int J Mol Med. 2015;35(5):1421-6.
81. Boots AW, Haenen GRMM, Bast A. Health effects of quercetin: from antioxidant to nutraceutical. Eur J Pharmacol. 2008;585(2-3):325-37.
82. Ankri S, Mirelman D. Antimicrobial properties of allicin from garlic. Microbes Infect. 1999;1(2):125-9.
83. Kumari K, Augusti KT. Antidiabetic and antioxidant effects of onion (*Allium cepa*) extract. Indian J Exp Biol. 2002;40(7):791-3.
84. Olaokun OO, McGaw LJ, Eloff JN, Naidoo V. Evaluation of onion extracts in diabetic rats. J Ethnopharmacol. 2013;150(3):841-8.

85. Auger C, Teissedre PL. Dietary polyphenols and cardiovascular protection. Curr Opin Lipidol. 2010;21(1):59-67.
86. Edwards RL, Lyon T, Litwin SE, Rabovsky A, Symons JD, Jalili T. Quercetin reduces blood pressure in hypertensive subjects. J Nutr. 2007;137(11):2405-11.
87. Sengupta A, Ghosh S, Bhattacharjee S. Onion extract suppresses growth of cancer cells. Eur J Cancer Prev. 2004;13(6):419-26.
88. Hsing AW, Chokkalingam AP, Gao YT, Madigan MP, Deng J, Gridley G, et al. *Allium* vegetables and risk of prostate cancer. J Natl Cancer Inst. 2002;94(21):1648-51.
89. Galeone C, Pelucchi C, Levi F, Negri E, Franceschi S, Talamini R, et al. Onion and garlic use and human cancer. Am J Clin Nutr. 2006;84(5):1027-32.
90. Sharma K, Assefa AD, Kim S, Ko EY, Lee ET, Park SW. Evaluation of onion cultivars for functional food ingredients. Food Chem. 2015;167:91-9.
91. Benkeblia N. Dehydration technology and antioxidant activity of onion. LWT Food Sci Technol. 2004;37(8):789-95.
92. Nascimento GGF, Locatelli J, Freitas PC, Silva GL. Antibacterial activity of plant extracts and phytochemicals on antibiotic-resistant bacteria. Braz J Microbiol. 2000;31(4):247-56.
93. Lee EJ, Yoo KS, Patil BS. Functional properties of onion and garlic. Food Sci Biotechnol. 2010;19(3):519-29.
94. Kumari K, Augusti KT. Antidiabetic and antioxidant effects of onion (*Allium cepa*) extract. Indian J Exp Biol. 2002;40(7):791-3.
95. Saitta M, Lo Turco V, Salvo F, Di Bella G, Dugo G. Cosmetic applications of onion extracts. J Cosmet Dermatol. 2012;11(3):193-9.
96. Kenel F, Prouteau M, Drouet A, Macheix JJ. Genetic transformation and disease resistance in onion. Plant Sci. 1995;110(1):43-52.
97. Griffiths G, Trueman L, Crowther T, Thomas B, Smith B. Onions—A global benefit to health. Phytother Res. 2002;16(7):603-15.
98. Kumari K, Augusti KT. Antidiabetic and antioxidant effects of onion (*Allium cepa*) extract. Indian J Exp Biol. 2002;40(7):791-3.