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Sulfur cosmos (C.Sulphureus) - A Multifaceted Botanical Treasure: A Review of Ethnobotanical Knowledge and Phytochemical Insights

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Abstract
Ethnopharmacological relevance: Cosmos sulphureus (Sulfur cosmos) has been utilized in traditional medicine and agriculture, highlighting its potential ecological, agricultural, and pharmacological importance.**Aim of the study:**This review aimed to comprehensively examine the life cycle, ecological interactions, ethnobotanical uses, and pharmacological properties of C. sulphureus to understand its multifaceted significance and potential applications.**Materials and methods:**A thorough review of existing literature on C. sulphureus was conducted, focusing on its ecological role, traditional uses, phytochemical composition, and pharmacological activities.**Results:**C. sulphureus plays a crucial role in pollination ecology, adapts to diverse habitats, and has significant floricultural and ethnobotanical value. It possesses hepatoprotective, antidiabetic, nematocidal, antioxidant, and antimicrobial properties, primarily due to its flavonoid and phenolic acid content.**Conclusions**:C. sulphureus is a versatile species with ecological, agricultural, and pharmacological relevance. Further research on its molecular mechanisms, therapeutic potential, and habitat conservation is warranted to fully exploit its benefits for human health, agricultural sustainability, and biodiversity conservation.

Keywords: Cosmos Sulphureus,Asteracae,Schistomicidal,Ethnobotany

1. Introduction

C.Sulphureus, a member of the Asteraceae family**(Classification in Figure 1),** stands out as an annual flower esteemed for its captivating flower shapes and hues (Zhou et al., 2018). Native to Thailand, South and North America, as well as Mexico, its yellow foliage is its distinguishing trait. Belonging to the Compositae family, C.Sulphureus is a short-lived annual herb known for its robust regenerative capabilities and its ability to accumulate cadmium (Wang et al., 2020). It is widespread across the Americas, spanning from South America through Central America to the Caribbean islands. Typically blooming from August to December, it thrives in secondary vegetation areas resulting from tropical deciduous forests, reaching heights of up to two meters. Its vibrant edible blooms, ranging from yellow to orange, are frequently utilized in culinary arts, imparting a tang of bitterness and spice to salads, desserts, and savory dishes (Ortega et al. 2023).

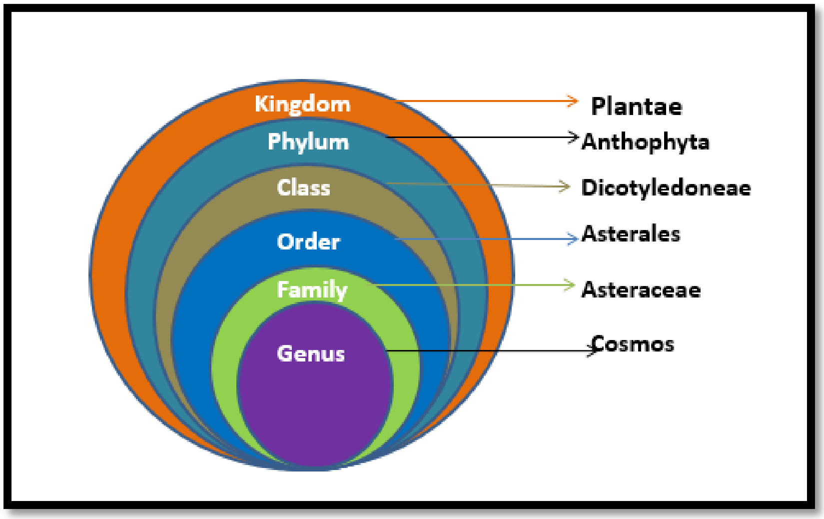
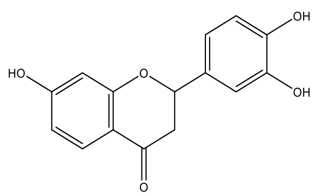


Figure 1: Classification of C.Sulphureus.

C.Sulphureus cav., also known as crest lemon, sunset, cosmic yellow, and cosmic orange, is recognized by its English moniker,Cosmos.Cultivated for its dyeing properties under the name C.Sulphureus cav., this plant is prized for its antibacterial and homeostatic qualities, flourishing in tropical and subtropical regions worldwide (Win et al., 2016). In Mexico, it goes by the names "girasol" or "mirasol amarillo" and finds application in traditional medicine. Various bioactive compounds**(Shown in Figure 2),** including butin, apigenin(6), kaempferol, myricetin(10), rutin(8), and essential oils, have been identified in C.Sulphureus,influencing its bactericidal and antioxidant properties (Andrushchenko et al., 2022). Investigative efforts are underway to explore its potential as a source of biologically active antioxidant compounds (Ortega et al., 2023), primarily focusing on its medicinal applications, biological potentials, and organic synthesis.

Additionally, essential oils extracted from C.Sulphureus leaves have demonstrated schistosomicidal activity against Schistosoma mansoni, the causative agent of schistosomiasis, in vitro (Aguiar et al., 2013). Furthermore, C.Sulphureus is utilized in ethnomedicine as a tonic, hepatoprotector, and malaria support (Lim et al., 2012). In Indonesia, traditional medicine incorporates the use of C.Sulphureus leaves, while in Indonesia and Thailand, the young shoots, leaves, and flowers serve as culinary ingredients (Lim et al., 2012). Its pharmacological properties include antibacterial, anti-inflammatory, and anti-malarial effects, alongside applications in gardening and textile dyeing (Biroki et al., 2021).



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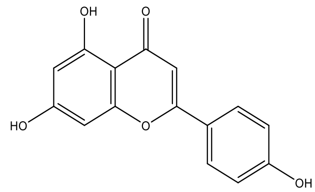

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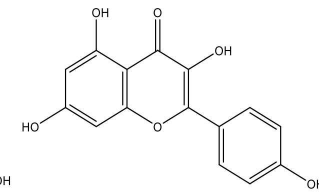

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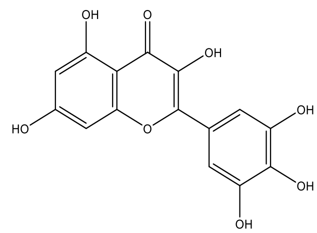

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Figure 2: Some bioactive compounds present in C.Sulphureus.

C.Sulphureus known colloquially as Kenikir Jawa blossoms, serves as a source of natural yellow colorants (Rahayuningsih et al., 2016). Moreover, it can be harnessed for bioherbicidal purposes, with its flowers acting as a natural source of bioherbicide chemicals effective against various weeds (Respatie et al., 2019). Its non-edibility makes it ideal for soil remediation, effectively absorbing hazardous heavy metals (Aftab et al., 2021). Despite its scientific name's association with sulfur, the yellow pigment in C.sulphureusflowers, known as sulphuretin, does not contain sulfur in its chemical composition. Instead, flavonoids such as 5-deoxy and 5-hydroxyflavonoids, along with chalcone and aurone glycosides, contribute to the vibrant orange-yellow hue of the petals (Akers et al, 1986.; Wallert et al., 1985).

C.Sulphureus holds paramount significance owing to its wealth of ethno-botanical knowledge and phytochemical insights. With a historical lineage deeply rooted in traditional medicine, this botanical species has long been employed in the treatment of diverse ailments, spanning from digestive maladies to dermatological conditions, underscoring its promising therapeutic utility. Phytochemical analyses unveil a diverse array of compounds, including flavonoids and terpenoids, indicative of potential antioxidant and antimicrobial properties. Such findings present avenues for the development of novel drugs and therapeutic interventions. Beyond its medicinal implications, Sulfur cosmos contributes to ecosystem dynamics, fostering biodiversity and potentially influencing the growth patterns of surrounding flora. Moreover, culturally, it carries symbolic significance, embodying notions of beauty and vitality while safeguarding traditional customs and cultural heritage. The review aims to explore the traditional uses, cultural significance, and indigenous knowledge surrounding C.Sulphureus. This entails investigating its historical utilization in traditional medicine, rituals, ceremonies, and cultural practices across diverse communities. The article will explore into the phytochemical composition of C.Sulphureus, examining the array of bioactive compounds present, including alkaloids, flavonoids, terpenoids, and phenolic compounds, and their potential pharmacological activities. Furthermore, it will highlight the plant's ecological role, morphological characteristics, genetic diversity, and potential applications beyond traditional medicine, such as in agriculture, horticulture, landscaping, and conservation efforts.

2. Cosmos Profile: Botanical and Cultural Perspectives

2.1Taxonomy

The preferred scientific name for this plant is C.Sulphureus Cav., commonly known as sulphur cosmos. It also goes by various other scientific names such as Bidens artemisiifolia (Jacq.) Kuntze, Bidens artemisiifoliavar.sulphurea (Cav.) Kuntze, Bidens sulphurea (Cav.) Sch. Bip., Coreopsis artemisiifolia Jacq., Cosmos artemisiifolius(Jacq.) M.R.Almeida, and Cosmos aurantiacus Klatt. Internationally, it is referred to by different common names in various languages and regions. In English, it is known as cosmos, orange cosmos, and yellow cosmos. In Spanish-speaking regions, it may be called cempualcho, chopa, ligirasolamarillo, mirasol amarillo, San Miguel, sochipal, or suchipate. French speakers may refer to it as cosmos soufré, while in Chinese, it is known as liuhuangju.

Locally, it carries different common names in different countries and regions. In Brazil, it may be called beijo de moça, cosmoamarelo, klondike cosmos, picão de florgrande, or picãogrande. In Costa Rica, it is known as cambray, while in Cuba, it goes by the name estrella del norte. In the Dominican Republic, it is referred to as cyemita, and in El Salvador, it is called botón de oro or flor de muerto. In Germany, it is known as gelbesSchmuckkörbchen, and in Honduras, it may be called clavel de muerto. In Japan, it is referred to as kibana-kosumosu, and in Mexico, it carries names such as axal-xóchitl, caxtlieh, caxtlimirasol yellow, shinul, xinul, or xochipal. In Micronesia, Federated States of, it is known as barungpurang or purangpalap, while in Myanmar, it may be called paw-me-tar or sein-chai-ka. In Nicaragua, it is referred to as chambray, and in Portugal, it is known as cosmos-amarelo. In Puerto Rico, it goes by the name panchita, and in the Russian Federation, it is called kosmoszelyj. Lastly, in Sweden, it is known as gullskara. These diverse names reflect the widespread distribution and cultural significance of this plant across different regions of the world (Lim et al., 2013).

2.2 Description

C. sulphureus Cav. stands out as an annual herbaceous plant renowned for its dazzling and remarkable blossoms. Belonging to the Asteraceae family, commonly known as the aster, daisy, or sunflower family, Sulphur cosmos typically reaches heights ranging from 0.3 to 2 meters, although variations are observed based on environmental factors and cultivar types. This plant boasts an erect growth habit, featuring robust stems that frequently branch out. Stem texture varies, ranging from smooth (glabrous) to sparsely covered with fine hairs, termed pilose to hispid. Sulphur cosmos leaves are cauline**(Shown in figure 3),** meaning they arise directly from the stem, and are arranged alternately along it. These leaves are deeply lobed, imparting a delicate and intricate appearance. Petioles, the leaf stalks, measure between 10 and 70 mm in length, providing support to the expansive leaf blades. The blades themselves are ovate to lanceolate, spanning from 50 to 250 mm in length. Narrow ultimate lobes, measuring 2 to 5 mm wide, adorn the leaves' margins, often featuring sparse spinulose-ciliate structures, with their apices terminating in sharp points known as apiculate. Sulphur cosmos produces showy inflorescences, known as synflorescences, extending from 100 to 200 mm in length and ascending in spread. Each inflorescence comprises multiple small flower heads, or capitula, clustered together. Surrounding the capitula are bractlets that are linear-subulate, measuring 5 to 10 mm long, with acute apices. The capitula themselves are relatively diminutive, typically ranging from 6 to 10 mm in diameter. Involucral bracts, encircling the individual florets within the capitulum, are erect and oblong-lanceolate, varying from 9 to 18 mm in length, often featuring acute to rounded-obtuse apices. The flowers of sulphur cosmos exhibit a diverse array of colors, ranging from golden yellow to red-orange. The ray florets, forming the outer ring of the capitulum, are the most prominent and colorful portion of the flower. These ray florets possess obovate laminae measuring 18 to 30 mm long, with truncate, denticulate apices. Disc florets, located at the capitulum's center, are smaller and less conspicuous, typically measuring 6 to 7 mm in length. Post-flowering, sulphur cosmos produces fruits known as cypselae. These fruits are light brown, flattened, and measure 1.5 to 3 mm in length. Often adorned with fine hairs, some variations may be glabrous. Unlike many of its counterparts in the Asteraceae family, sulphur cosmos lacks a pappus, the tuft of hairs or scales attached to the fruit aiding in dispersal. However, remnants of the pappus structure may be observed in some instances, with two or three widely divergent awns, measuring 1 to 7 mm long.

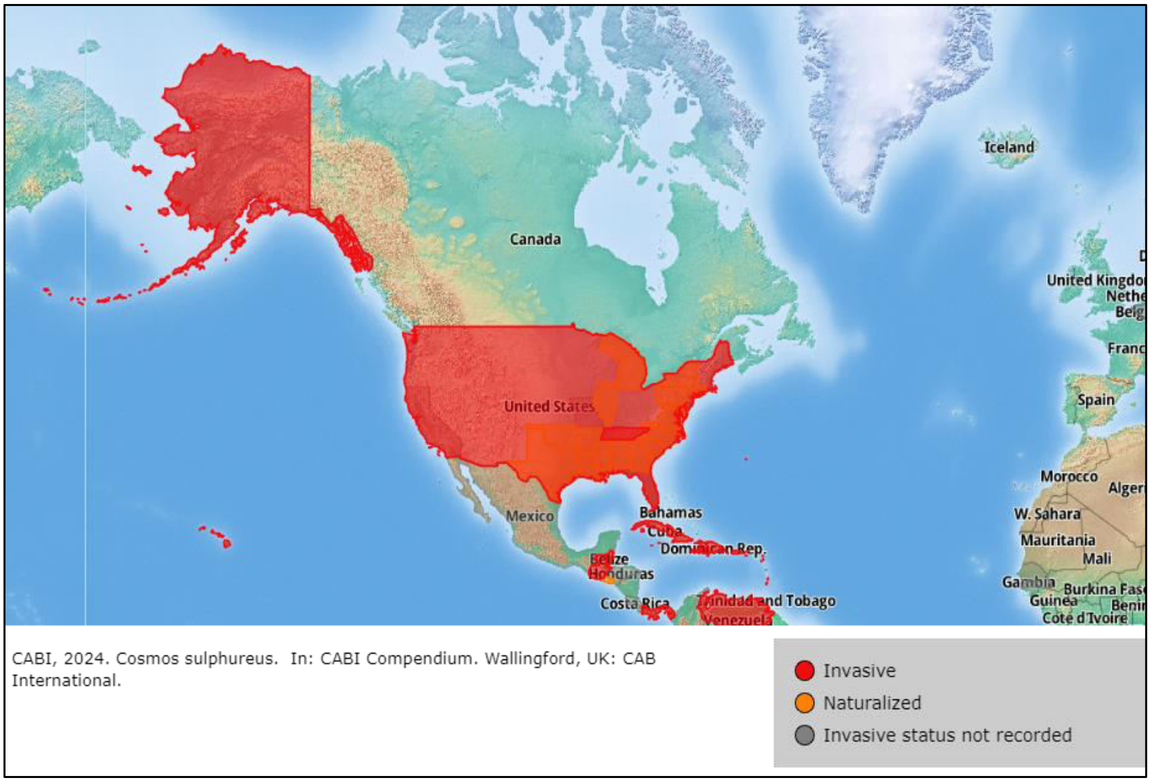
Sulphur cosmos is esteemed for its alluring foliage and vibrant, enduring flowers, rendering it a favored selection for ornamental gardens, landscaping, and cut flower arrangements. Its adaptability to diverse soil types and climates, coupled with its straightforward cultivation from seed, renders it a versatile and widely cultivated plant across various global regions. This description is compiled from various sources (Chen et al.,2011; Pandey et al.,1986; Beentje et al., 2005).

Figure 3:Different plant parts of C.Sulphureus.

2.3 Distribution

C.Sulphureus originates from Mexico and possibly northwestern South America(USDA-ARS, et al., 2016) Despite its origins, it has become extensively cultivated and sporadically naturalized in various temperate and tropical regions worldwide (Villaseñor et al., 1998). Both intentional and unintentional introductions have occurred, particularly notable in the southern USA (Strother, J. L., 1999), where cultivation and occasional wild occurrences are observed. In regions like Chiapas, Mexico, it undergoes extensive cultivation and may escape into nearby natural habitats. Similarly, in Central America, it displays ruderal growth patterns, flourishing along roadsides and occasionally escaping from cultivated gardens. Puerto Rico also witnesses common occurrences along roadsides and sporadic cultivation. Escaping cultivation has led to invasive tendencies in parts of Florida, the Caribbean, and South America (Randall, R. P., 2012); Liogier, A. H., & Martorell, L. F., 2000)). While some records suggest its native status in Peru (Peru Checklist, 2016), Ecuador (Vascular Plants of Ecuador, 2016), and Colombia (Vascular Plants of Antioquia, 2016), conflicting reports classify it as naturalized(USDA-ARS, 2016; Mondin CA, 2014 ; Robinson, H. E., 2006)). Cosmos sulphureus is reported as naturalized and weedy in sections of the USA, New Zealand, and Australia (Randall, R. P., 2012), as well as across parts of Africa and Asia. Although not officially listed in the European alien species database (DAISIE, 2017), reports indicate its adventive occurrences in Belgium and Poland (USDA-ARS, 2016). In the Pacific, cultivation occurs in places like French Polynesia and Micronesia but is absent from Hawaii.

The distribution of C.Sulphureus extends across multiple continents and regions, showcasing its adaptability and potential ecological impact**(Shown in Figure 4 and Table 1).** In Africa, it thrives in countries such as Cameroon, Eswatini, Kenya, Malawi, Mauritius, Mozambique, Réunion, Senegal, South Africa, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe, where it has been introduced and demonstrates invasive behavior in certain areas. In Asia, it has been sighted in Bhutan, China, India, Japan, Myanmar, North Korea, the Philippines, Singapore, South Korea, and Sri Lanka, exhibiting signs of naturalization and invasive tendencies, especially in China and South Korea.



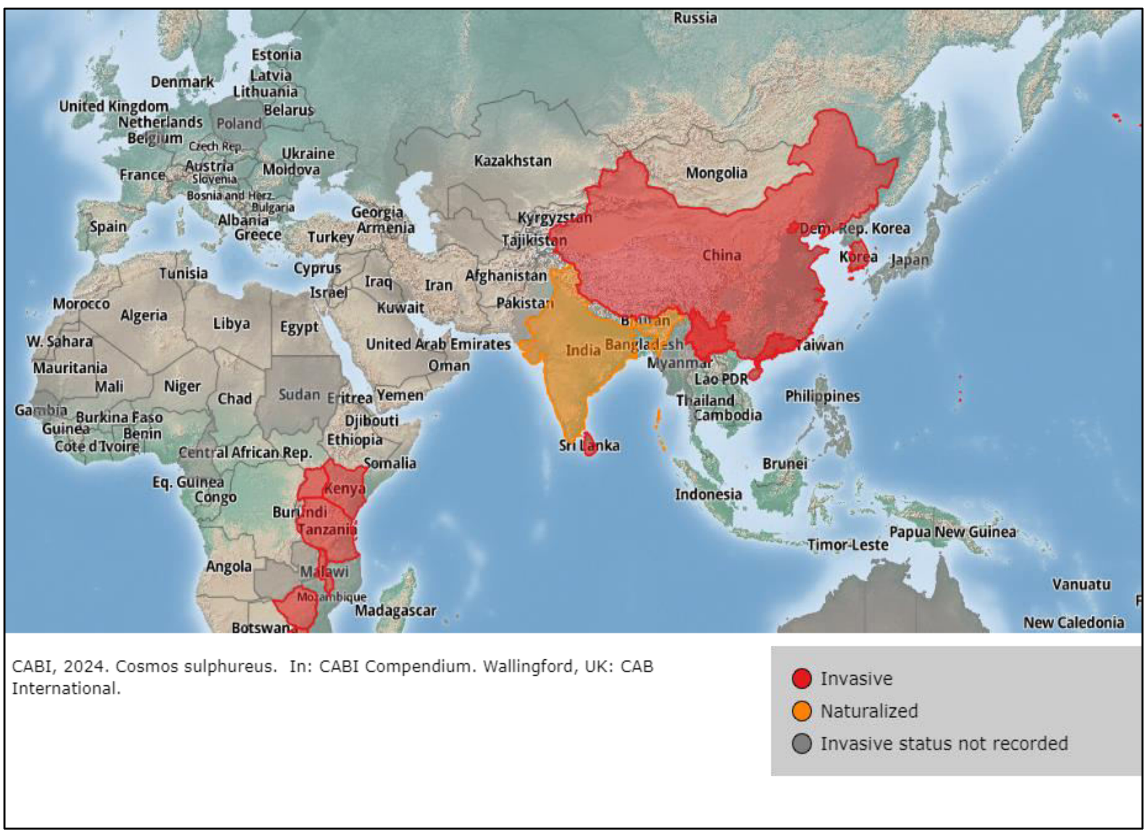


Figure 4:Distribution of C.Sulphureusaround the world and India

Throughout Europe, including Belgium and Poland, it has been reported as adventive. In North America, its presence is noted in countries such as Antigua and Barbuda, Belize, Bermuda, Costa Rica, Cuba, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Puerto Rico, and the United States, where it often becomes invasive or naturalized. Oceania hosts this species in Australia, French Polynesia, Guam, New Zealand, and the Northern Mariana Islands, where reports indicate naturalization and invasive behavior.

Finally, in South America, it inhabits regions such as Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, and Venezuela, with both native and introduced statuses observed across various regions. This widespread distribution underscores the ecological significance and potential impact of C.sulphureus across diverse ecosystems globally.

Country	Origin	Invasive	Distribution	References
Antigua and Barbuda	Introduced	Invasive	Present	Acevedo-Rodríguez, P., & Strong, M. T., 2012
Argentina	Introduced	-	Present	Zuloaga, F. O., Morrone, O., & Belgrano, M. J., 2008
Australia	Introduced	-	Present	Cosmos sulphureus, 2017
Belgium	Introduced	-	Present	USDA-ARS, 2016
Belize	Introduced	Invasive	Present	Balick, M. J., Nee, M., & Atha, D. E., 2000
Bermuda	Introduced	Invasive	Present	Robinson, H. E., 2006
Bhutan	Introduced	-	Present	Cosmos sulphureus, 2017
Bolivia	Introduced	-	Present	Bolivia Catalogue, 2016
Brazil	Introduced	Naturalized	Present	USDA-ARS,

				2016
Cameroon	Introduced	-	Present	Jansen, P. C. M. 2005
Chile	Introduced	Naturalized	Present	USDA-ARS, 2016
China	Introduced	-	Present	Cosmos sulphureus, 2017
Colombia	Native	-	Present	Vascular Plants of Antioquia, 2016
Costa Rica	Introduced	-	Present	USDA-ARS, 2016
Cuba	Introduced	Invasive	Present	Acevedo-Rodríguez, P., & Strong, M. T. 2012
Dominica	Introduced	-	Present	Nicolson, D. H., 1988
Dominican Republic	Introduced	Invasive	Present	Acevedo-Rodríguez, P., & Strong, M. T., 2012
Ecuador	Native	-	Present	Vascular Plants of Antioquia, 2016
El Salvador	Introduced	Naturalized	Present	USDA-ARS, 2016
Eswatini	Introduced	-	Present	Swaziland National Trust Commission, 2016.
Guatemala	Introduced	Invasive	Present	Nash, D. L., & Williams, L. O., 1976
Haiti	Introduced	Invasive	Present	Nicolson, D. H., 1988
Honduras	Introduced	-	Present	Garden, M. B., 2016

India	Introduced	Naturalized	Present	USDA-ARS, 2016
Japan	Introduced	-	Present	Quattrocchi, U., 2012
Kenya	Introduced	-	Present	Beentje, H. J., & Hind, D. J. N., 2005
Malawi	Introduced	-	Present	Beentje, H. J., & Hind, D. J. N., 2005
Mauritius	Introduced	-	Present	Jansen, P. C. M., 2005
Mexico	Native	-	Present	USDA-ARS, 2016
Micronesia (Federated States of)	Introduced	-	Present	Cosmos sulphureus, 2017
Mozambique	Introduced	-	Present	Jansen, P. C. M., 2005
Myanmar		-	Present	Kress et al., 2003
New Zealand	Introduced	-	Present	Randall, R. P., 2012
Panama	Introduced		Present	Flora of Panama, 2016
Paraguay	Introduced	Invasive	Present	Cosmos sulphureus, 2017
Peru	Native	-	Present	Cosmos sulphureus, 2017
Philippines	Introduced	-	Present	Merrill, E. D., 1908.
Poland	Introduced	-	Present	USDA-ARS, 2016

Saint Lucia	Introduced	Invasive	Present	Acevedo-Rodríguez, P., & Strong, M. T., 2012
Saint Vincent and the Grenadines	Introduced	Invasive	Present	Acevedo-Rodríguez, P., & Strong, M. T., 2012.
Senegal	Introduced	-	Present	Jansen, P. C. M., 2005
Singapore	Introduced	-	Present, Only in captivity/cultivation	Chong, K. Y., Tan, H. T., &Corlett, R. T., 2009
South Africa	Introduced	Invasive	Present	Pruski, J. F G., &Meyer, N., 2003
Sri Lanka	Introduced	Invasive	Present	Pruski, J. F., & Robinson, H. E., 1997.
Sudan	Introduced	-	Present	Jansen, P. C. M., 2005
Uganda	Introduced	Invasive	Present	Beentje, H. J., & Hind, D. J. N., 2005
United Republic of Tanzania	Introduced	Invasive	Present	Jansen, P. C. M. 2005
United States of America	Introduced	Invasive	Present	Cosmos sulphureus, 2017
Venezuela	Introduced	Invasive	Present	Pruski, J. F., & Robinson, H. E., 1997
Zambia	Introduced	-	Present	Jansen, P. C. M., 2005

Zimbabwe	Introduced	Invasive	Present	Beentje, H. J., & Hind, D. J. N., 2005

Table 1 : Distribution of C.Sulphureus around different countries.

2.4 Life cycle

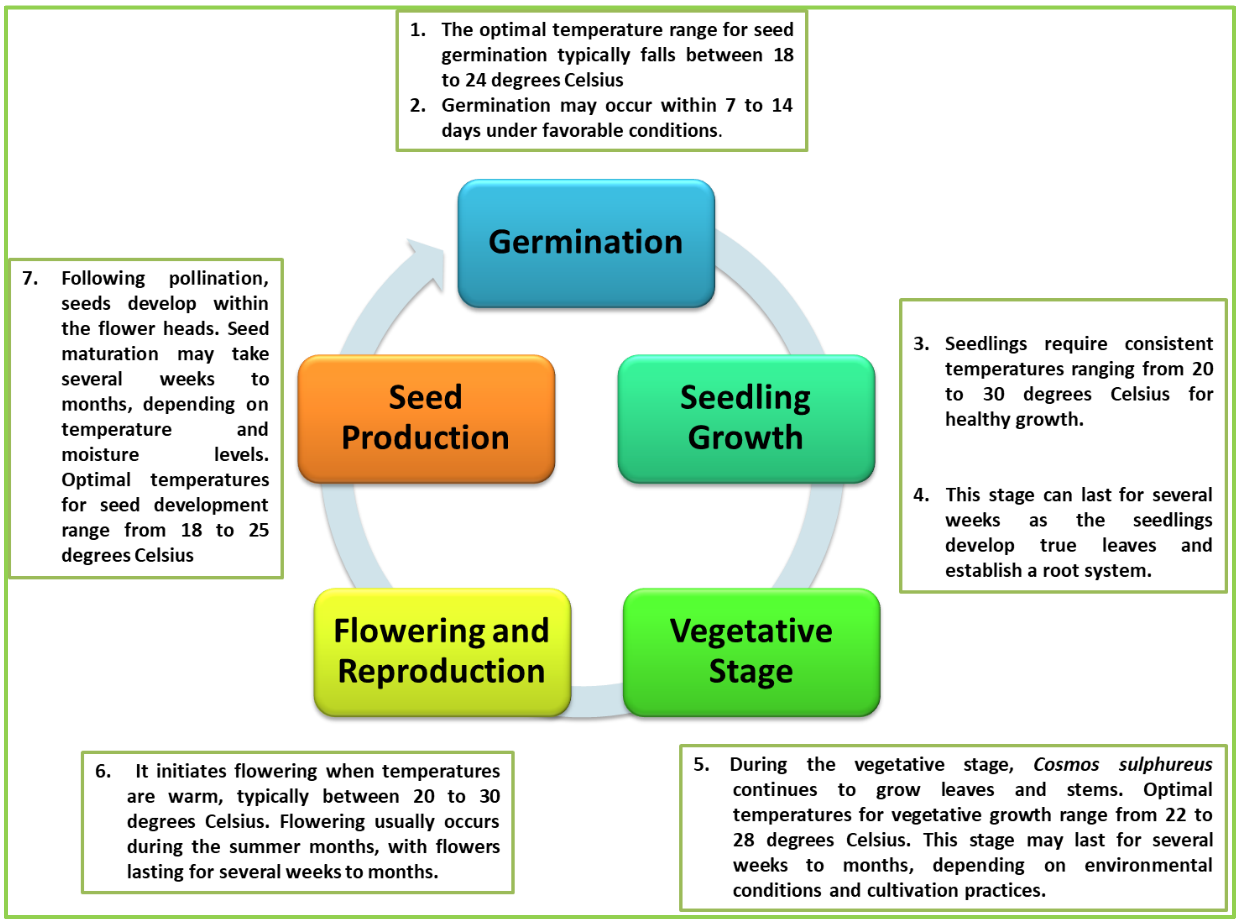


Figure 5 Different stages ofC.Sulphureusgrowth.

As an annual botanical specimen, C.Sulphureus undergoes its entire life cycle within a singular year. Within this timeframe, the plant progresses from the germination of its seeds to full maturity, culminating in the production of flowers and seeds before reaching the end of its life cycle. The lifecycle of C.Sulphureus can be delineated into distinct stages, including seed germination, vegetative growth, flowering, and seed maturation **(shown in Figure 5).** During the late summer to autumn period, C.Sulphureus adorns itself with resplendent yellow or orange flowers, with seed dispersal facilitated by natural processes such as wind dispersal. However, the germination of seeds typically occurs in the subsequent growing season following the natural senescence of the plant during the autumn or winter months (Wang et al., 2019).

In tropical regions, environmental factors such as temperature, light exposure, and the spatial distribution of seeds within the soil play pivotal roles in influencing the germination and emergence of C.Sulphureus seeds. These factors can either promote or inhibit dormancy in seeds. Seed banks serve as primary reservoirs for the resurgence and potential expansion of C.Sulphureus in agricultural settings. Generally, seeds exhibit germination across a wide temperature range, with optimal temperatures yielding the most favorable results. Furthermore, extreme temperature thresholds define the geographic and climatic regions conducive to the collection of seeds or fruits (de Souza et al., 2013).

The fundamental chromosome count in Cosmos species is estimated to be approximately 12, inferred from the observations of chromosome pairing dynamics during cellular division processes (Sugiura, T., (1940)). The initial root structure of C.Sulphureus is characterized by a diminutive radicle with early branching. Meanwhile, the hypocotyl elongates prominently beneath the cotyledons. The cotyledons themselves are smooth and linear, directly attached to the stem, with subsequent emergence of ovate leaves. The germination process of C.Sulphureus is distinguished by its rapid pace and robust energy reserves during this critical phase (Ifrim, C., &Gaţu, I., 2018).

Tetrarch radial steles, defined by distinctive radial configurations, are a notable feature observed in the primary roots of C.Sulphureus. These steles feature primary phloem bundles interspersed among positions housing the protoxylem, a feature that sets C.Sulphureus apart from other species which typically exhibit diarch roots. The transition from root to shoot in C. Sulphureus initiates slightly below the external base, coinciding with the emergence of the root's central pith. At this juncture, the xylem forms a continuous circular band encircling the pith, presenting four distinct regions with outwardly projecting initial xylem vessels [51].

In C.Sulphureus, the black pigment phytomelanin is localized within the subepidermal sclerenchyma, positioned adjacent to the epidermal layer, analogous to its presence in plants characterized by tri-layered mesocarp. Noteworthy distinctions of C.Sulphureus include its larger spore size, thicker spore walls, and the unique ability to generate an additional developmental stage termed the anamorphic stage, distinguishing it from other species within its genus (da Silva Santos et al,2014); Batista, M. F., & de Souza, L. A.,2017); Lutz, M., & Piątek, M., 2016).

C.Sulphureus (2n=2x=24) boasts desirable traits such as disease resistance and adaptability to hot, humid conditions, complemented by its trichromatic floral display featuring yellow, orange, and red hues. Consequently, this species emerges as a promising genetic resource for the improvement of C.atrosanguineus(Mii, 2023).

2.5 Ecological Interactions

2.5.1Pollinator Relationships

Within its ecological niche, C.Sulphureus engages in intricate relationships with various organisms, particularly pollinators. Studies have elucidated associations between C.Sulphureus and spider families such as Araneidae,Eutichuridae,Oxyopidae,and Thomisidae,underscoring the complexity of its ecological network. Moreover, a diverse array of approximately 257 insects, spanning 12 species, have been documented to frequent C.Sulphureus, with pollinators demonstrating a pronounced preference for its vibrant flowers (Amrulloh et al, 2023). Notably, the morphology of C.Sulphureus flowers, offering ample landing support, attracts butterflies, particularly larger species, enhancing its role as a pollinator-attracting floral resource (Vinithashri, G., & Kennedy, J. S., 2021).

2.5.2 Contributions to Pollination Ecology

Pollination ecology is pivotal for the reproductive success and genetic diversity of plant populations. In the context of C.Sulphureus, its interactions with pollinators play a vital role in ensuring effective pollination and subsequent seed production. The floral morphology of C. Sulphureus, coupled with its nectar rewards, facilitates pollinator visits, contributing to the transfer of pollen grains between flowers (Vinithashri, G., & Kennedy, J. S., 2021). This interaction underscores the significance of floral traits in mediating pollination dynamics and reproductive outcomes in plant communities.

2.5.3 Influence on Native Flora and Fauna

The presence of C.Sulphureuswithin ecosystems exerts influence on native flora and fauna, shaping community dynamics and ecological processes. Experimental investigations have revealed that C.Sulphureusaccounts for a notable proportion of variation in plant varieties observed in controlled settings (Burkle, L. A., & Belote, R. T., 2015). Such findings suggest that C.Sulphureusmay play a role in structuring plant communities and influencing species composition. Additionally, the unique seed morphology of C.Sulphureus, characterized by elongated awn attachments, affects seed dispersal dynamics, potentially impacting seed bank composition and plant regeneration processes (Hall, J. T., 1998).

2.5.4 Ecological Niche Adaptations

Understanding the ecological niche adaptations of C.Sulphureusprovides insights into its physiological responses and adaptive strategies in diverse environmental conditions. Research indicates that C.Sulphureusexhibits heightened cytokinin concentrations during flower development, implicating hormonal regulation in flowering processes (Roberts, N. J., Menary, R. C., & Hofman, P. J., 1991). Moreover, the plant demonstrates enhanced growth under suboptimal conditions when thiamin is present, highlighting the role of nutrient availability in mediating plant performance (Bora, P. C., & Selman, I. W., 1969). These adaptations underscores the ecological versatility of C.Sulphureusand its capacity to thrive across a range of environmental gradients, contributing to its ecological success and widespread distribution.

2.5.5 Sulfur cosmos as a Floricultural Resource

C.Sulphureus emerges as an intriguing subject for floricultural study, given its alluring blossoms and potential economic significance. The rich presence of phenolic acids within its flowers contributes significantly to their vivid hues and may also harbor herbicidal properties (Aldini, G. M., Martono, E., &Trisyono, Y. A. 2019). This distinctive feature has propelled C. Sulphureusinto prominence within the floriculture sector, positioning it as a desirable option for ornamental purposes in various settings such as gardens, parks, and landscaping projects.

2.5.6Ecological Dynamics with Predators

C.Sulphureusflowers exhibit an ecological magnetism, drawing an array of predators into their midst, particularly insects like Coccinellidae (ladybirds) and Syrphidae (hoverflies) (Barros et al., 2022). Renowned for their prowess in biological pest regulation, these predators flock to the abundant nectar and pollen stores offered by C.Sulphureusblooms. This symbiotic relationship plays a pivotal role in curbing pest populations within both agricultural and natural ecosystems. Moreover, spiders hailing from families such as Lycosidae and Linyphiidae are also enticed by the allure of C.Sulphureus, amplifying the ecosystem's pest management capabilities through their predation efforts.

2.6. Ethnobotany

Ethnobotany encompasses the traditional medical practices employed by indigenous communities to address human health concerns. Ancient Indian medical systems, including Ayurveda, Siddha, Unani, and Amchi, rely extensively on plant-based remedies. These systems, alongside regional health practices, provide a robust framework for the safe and effective management of various ailments (Kaur et al., 2021).

The utilization of C.Sulphureus flowers in the extraction of infused oil presents promising therapeutic potential. When applied topically, it demonstrates notable efficacy in treating dermatological conditions and alleviating muscular discomfort. This botanical remedy exhibits potential anti-inflammatory and analgesic properties, providing supportive evidence for its traditional use in managing skin disorders and muscular pain (Phuse, S. S., & Khan, Z. H., 2018). A thorough exploration of the diverse applications and contributions of C.Sulphureus can be found across traditional, agricultural, genetic, and scientific domains.

2.6.1 Traditional and Medicinal Uses

Cosmos sulphureus showcases a diverse array of pharmacological attributes, including antibacterial, anti-inflammatory, anti-malarial, anti-ulcer, anti-allergic, anti-cancer, and anti-diabetic properties**(Shown in Table 2)** (RAUF, T., & PERVEEN, A., 2024))**.**Additionally, it demonstrates efficacy in addressing fungal-induced earaches (Sharma, S., & Lata, S., 2021)). Initially identified through ethnobotanical studies for its potential antimalarial properties, this species has been documented alongside various other plant species for its medicinal implications against malaria (Botsaris, A. S., 2007).

Table 2:Traditional uses of Cosmos Sulphureus.

Country	**Uses**	**Ref**
Mexico	Stomatitis	(Martinez, Maximino., 1969)
Mexico	Sore	(Martinez, Maximino., 1969)
Mexico	Scorpion sting	(Martinez, Maximino., 1969)
India	Plant is grown by tribal as ornamental plants in garden and flower heads are used in worship	(Sharma, S., & Lata, S., 2022)
Native American culture	As dye	(Sabatini,, 2020)
Asia	As ornamental	(Andrushchenko, O., & Levon, V., 2021)
Thailand	Preparation of salads and flower teas	Kaisoon, O., Konczak, I., &Siriamornpun, S., 2012)
-	Flavoring agent	(de Morais, 2020)

Brazil	In malaria	(Botsaris, A. S., 2007)
-	Jaundice, intermittent fever, splenomegaly. Tonic, hepatic, hepatoprotective.	(Botsaris, A. S., 2007)

2.6.2 Agricultural and Environmental Contributions

In agricultural landscapes, Cosmos serves as a vital refuge for beneficial entomofauna, crucial components of natural pest control mechanisms (Respatie et al, 2019). These organisms, acting as predators to insect pests, seek shelter and sustenance within Cosmos, contributing significantly to ecological equilibrium within agricultural ecosystems.

Farmers in regions such as Yogyakarta and Central Java have strategically integrated Cosmos sulphureus into rice fields to create an environment conducive to cultivated crops (Sugiharti, 2018). This practice supports the protection and adaptation of rice plants to their specific agroecological conditions, capitalizing on the adaptability and compatibility of C. sulphureus within these settings.

Moreover, the incorporation of C.Sulphureus into wheat dough, at concentrations not exceeding 10%, yields notable improvements in bread characteristics (Osokina, 2017). Resulting bread products exhibit uniform pigmentation, robust crust integrity, resilient crumb structure with discrete aerations, and enhanced organoleptic properties, particularly taste and aroma. This underscores the potential of C.Sulphureusas a functional ingredient in food applications.

2.6.3 Genetic Studies and Industrial Applications

Studies focusing on C.Sulphureusencompass a range of investigations, including hybridization, gene expression analysis, and genetic modification, with diverse objectives such as enhancing disease resistance and isolating specific genes. Notably, heightened activity of C. Sulphureus's chalcone 3-hydroxylase (CH3H) enzyme results in increased production of 3-hydroxyphlorizin, thereby reducing the susceptibility of M. domestica cv. Pinova apples to diseases such as scab and fire blight (Zhou et al, 2017).

Moreover, recent research efforts have led to the identification of the gene responsible for encoding the chalcone 3-hydroxylase enzyme in C.Sulphureus. This gene plays a crucial role in the conversion of trihydroxychalcone into butein (Ohno et al, 2011). The hybrids derived from this method are currently being commercialized as specific cultivated varieties in Japan. Additionally, plants treated with colchicine to induce doubled sets of chromosomes have demonstrated successful back-crossing ability with C.Sulphureus(Shaw, J. M., 2015).

Furthermore, beyond its antimicrobial and anti-inflammatory properties, the flower heads of C.Sulphureusare utilized in the production of environmentally friendly natural dyes, particularly in the wool industry (Kumari, S. 2012). This multifaceted plant showcases promising applications across various fields, from agriculture to textiles, highlighting its versatility and potential for sustainable utilization.

3. Phytochemistry

The phytochemical analysis of C.Sulphureusreveals a spectrum of compounds, including flavonoids, phenolic acids, antioxidants, and chalcones/aurones.These constituents collectively contribute to the plant's medicinal attributes and potential health-promoting effects. Flavonoids and phenolic acids are renowned for their antioxidant properties, pivotal in shielding cells from oxidative stress induced by free radicals. The presence of antioxidants holds significant implications for mitigating the risk of chronic ailments and fostering overall well-being. Furthermore, chalcones and aurones, also present in C.Sulphureus, exhibit bioactive properties, potentially encompassing anti-inflammatory and antioxidant activities (Kumari, S., 2012).

3.1 Flavonoids

The floristic characterization of the vibrant "Orange Flare" variant within C.Sulphureusis intricately defined by a consortium of key chemical components. Specifically, coreopsin is localized within the floral rays, while luteolin(7) permeates the entire blossom. Additionally, a quercetin(5) glycoside, likely isoquercitrin, manifests in various anatomical regions, notably the disk-florets and involucral bracts. An intriguing revelation surfaces regarding coreopsin, previously identified as a constituent, now recognized as a butein glycoside. Notably, ongoing scientific exploration aims to elucidate the precise structural features and linkage patterns of the sugar moiety associated with coreopsin, a facet yet to be fully clarified within the context of this resplendent floral specimen (Roth, W. L., & Rollefson, G. K., 1942).

C.Sulphureushouses a diverse spectrum of constituents, prominently featuring flavonoids, quercetin(5), and dimethoxychalcone, among other bioactive elements. These compounds exhibit therapeutic potential in addressing ailments such as fibromyalgia and eczema, while also demonstrating promising antiviral attributes. Furthermore, the presence of butein within this botanical specimen enhances its pharmacological profile, renowned for its discernible anti-inflammatory properties and antioxidative capacities. Collectively, these constituents underscore the plant's therapeutic significance across various health conditions, particularly in modulating inflammatory responses (Phuse, S. S., & Khan, Z. H., 2018).

In Mexico City, the prevailing constituents identified within C.Sulphureusare luteolin(7) and sulphuretin (Garcia-Bucio et al, (2019)). Additionally, fustin(20), categorized as a flavonoid and specifically a flavonol, has been identified within the C.Sulphureus flower extract. This compound has been detected and isolated from the extract obtained from the flowers of C. Sulphureus(Vankar, P. S., & Shukla, D., 2018).

3.2Phenolic acids

The phenolic constituents present in C. Sulphureus encompass a diverse array of compounds, notably including phenolic acids, which demonstrate remarkable versatility. These phenolic acids hold significant promise, serving as promising precursors for the development of both biopesticides, offering environmentally friendly solutions for insect control, and biopharmaceuticals, contributing to advancements in medicine. The identification of gallic acid(27) within C.Sulphureuspresents an intriguing opportunity for its potential utilization as a herbicidal agent, potentially serving as a natural deterrent against weeds. Therefore, the presence of phenolic acids within this floral specimen signifies substantial potential for the pharmaceutical industry and the exploration of sustainable strategies for weed and insect management (Irsyadi, M. B., Sawitri, W. D., & Purwantoro, A. 2022).

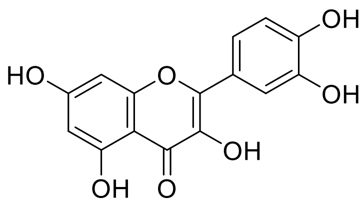
In a comprehensive investigation involving multiple plant extracts, C.Sulphureus exhibited a notable abundance of phenolic compounds and demonstrated moderate antioxidant efficacy (Wangkiri, 2021). In experimental settings, Cosmos flowers showcased the most significant accumulation of phenolic compounds, demonstrating notable prominence both before and after in vitro analyses. Among these compounds, rutin(8) and hesperidin were notably prominent, exhibiting a pronounced correlation with the flower's antioxidative potential. Moreover, within the floral spectrum analyzed, Cosmos flowers distinguished themselves by containing the highest concentration of hesperidin, a representative flavonoid, with the exception of begonias among the flowers examined. Notably, among the array of compounds scrutinized, rutin(8), classified as a flavonol, exhibited the highest levels within the yellow Cosmos blossoms (de Morais, (2020)).

3.3 Antioxidants

Within the Asteraceae family,C.Sulphureusstands out for its rich composition of phenolic compounds,rendering it a coveted ornamental species within Indonesia (Respatie et al, 2019). Researchers have identified these compounds as potential candidates for natural herbicidal applications, accentuating the plant's multifaceted utility. Particularly noteworthy is the prevalence of natural antioxidants across various plant parts, with phenolic compounds notably abundant. Comparative analysis spanning leaves, roots, and stems has revealed the leaves to host the highest concentration of these beneficial compounds. However, it is the flowers that boast a remarkable array of antioxidants, comprising phenolic acids, anthocyanins(18), and flavonoids, distinguishing them from other vegetative components.

In a comprehensive study exploring the nutritional benefits of diverse edible flowers, C. Sulphureusflowers have emerged as promising candidates due to their exceptional antioxidant properties Chensom, S., Okumura, H., & Mishima, T., 2019). Comparative assessments have showcased these flowers' elevated levels of antioxidants, notably beta-cryptoxanthin, surpassing counterparts in other floral varieties. Evaluation employing the HORAC value has underscored the superior antioxidant potency of yellow Cosmos flowers among the samples examined. This robust antioxidant profile owes to the presence of beneficial compounds such as gallic acid(27), ferulic acid, caffeic acid(26), chlorogenic acid(24), and myricetin(10). Overall, yellow Cosmos flowers exhibit significant potential for promoting health, serving as a rich source of polyphenols and antioxidants among the surveyed edible flowers.

Hesperidin and rutin(8), prominent constituents within these flowers, play pivotal roles in their antioxidant capacity, particularly as measured by ORAC activity (Cornea-Cipcigan et al, 2022). These molecules actively contribute to counteracting the adverse effects of harmful substances within the body, offering protective benefits against oxidative stress. Recent scientific endeavours have shed light on the specific molecules responsible for the vibrant hues exhibited by flowers like C. sulphureusand Butea frondosa (Palas) (Kumar, M. M., &Kachhara, N. L). Identified as chalcones and aurones, these compounds contribute to the vivid and rich colouration observed in these floral specimens.



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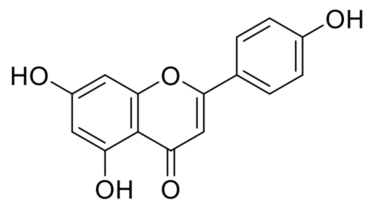

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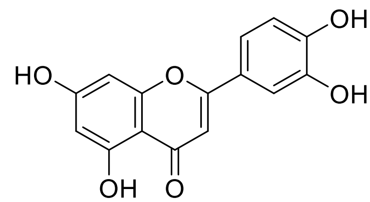

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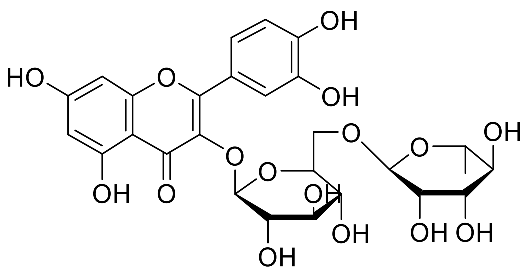

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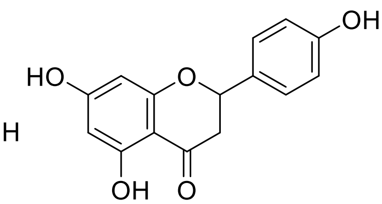

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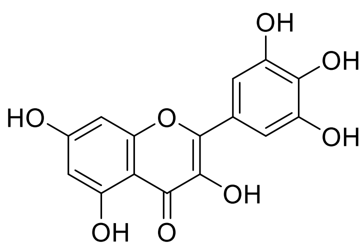

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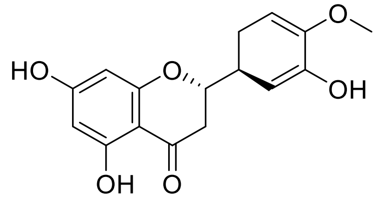

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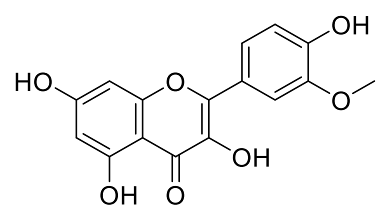

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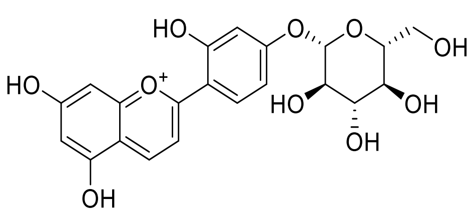

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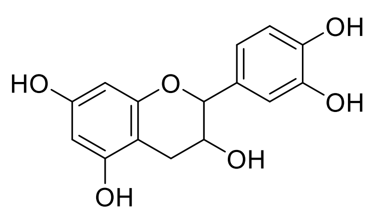

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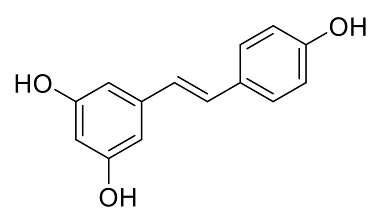

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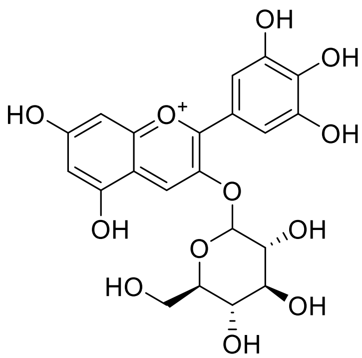

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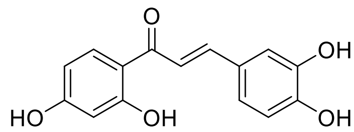

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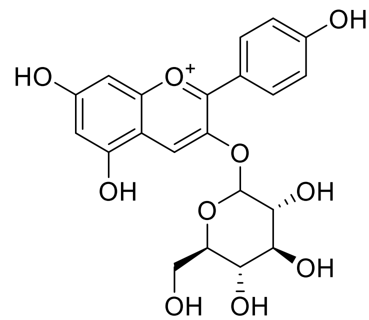

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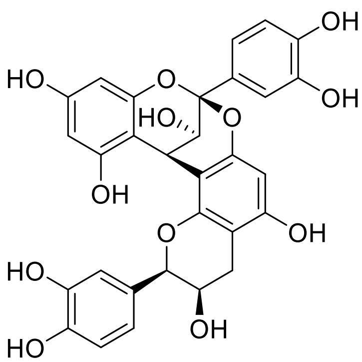

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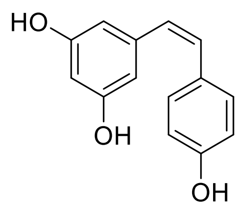

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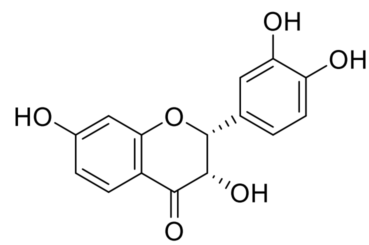

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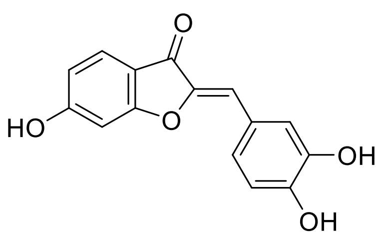

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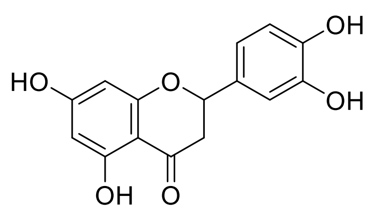

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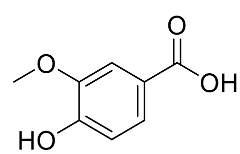

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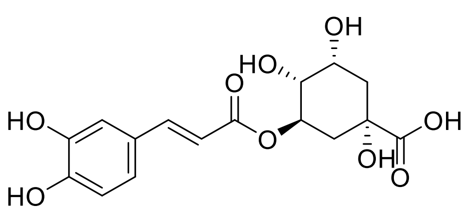

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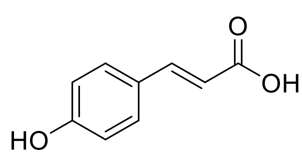

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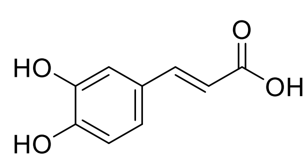

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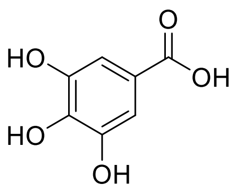

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4. Significance

The significance of C.Sulphureus spans various domains, from ecological to agricultural and pharmacological. This plant species holds notable importance for several reasons, as follows:

4.1 Genetic Enhancement

Application of colchicine to seedlings initiates autotetraploidy in C.Sulphureus, resulting in enlarged dimensions of leaves, stems, flowers, fruits, and seeds, thereby enhancing overall yield [96]. The flower heads of C.Sulphureus exhibit tubular corollas with five petals each, distinguished into outer tubes and inner limbs, featuring sterile ray florets (Batista, M. F., & De Souza, L. A., 2017). Through ten experiments involving 1300 plants, adenine's stimulatory effect on Cosmos growth was confirmed (Bonner, D. M., & Bonner, J., 1940). Within C. Sulphureus, the identification of the CsCh3H gene revealed its homology to CsF3H, with over 84% shared amino acid sequence identity, both belonging to the CYP75 gene family (中山亨, 2022). Crossbreeding attempts showed initiation of fertilization in ovules only when paired with C.Sulphureus, though these enlarged ovules failed to mature into seeds. Nonetheless, due to its diverse floral palette and resilience to environmental stressors and diseases, C.Sulphureus serves as a promising genetic resource to enhance C. atrosanguineus traits (Mii, M. (2012)). By crossbreeding C.Sulphureus with C. atrosanguineus, desirable traits from both species can be combined to create offspring with improved characteristics. These traits may include enhanced disease resistance, increased adaptability to environmental stressors, and a broader range of floral colors and shapes. Additionally, C.Sulphureus may possess genetic variations that contribute to traits such as larger flower size, longer bloom duration, or improved fragrance, which can be introduced into C.atrosanguineus through breeding programs. Through careful selection and breeding efforts, C.Sulphureus can thus serve as a valuable genetic reservoir for improving the overall quality and performance of C.atrosanguineus cultivars.

4.2 Impacts on Cotesia vestalis's (Parasitoid Wasp) Lifespan and Parasitic activity

The investigation into the lifespan and parasitic behavior of Cotesia vestalis wasps in relation to honey and yellow cosmos (C.Sulphureus) pollen unveiled significant revelations (Chau et al., 2019). When exposed to a 50% honey solution, both male and female wasps exhibited a remarkable extension in longevity. This finding alone suggests the pivotal role of honey as a dietary component in influencing the lifespan of these parasitoid wasps. However, the study delved deeper, revealing even more intriguing results.

Upon consuming a combined diet of honey and pollen, specifically sourced from yellow cosmos, the lifespan of C.vestalis wasps experienced a notable augmentation. This observation highlights the synergistic effect of honey and yellow cosmos pollen on the physiological processes governing the lifespan of these insects. The intricate interplay between dietary components and physiological mechanisms merits further exploration to elucidate the underlying mechanisms driving this phenomenon.

Moreover, the study uncovered another compelling facet of the relationship between diet and parasitic activity. The utilization of a diet comprising honey and pollen, particularly sourced from yellow cosmos, significantly enhanced the parasitic capacity of C. vestaliswasps against diamondback moth larvae. This heightened parasitic efficacy resulted in a greater abundance of parasitic wasps compared to the control group, indicating a pronounced impact on their reproductive success and population dynamics.

These findings shed light on the multifaceted role of dietary resources in shaping the behavior and ecological interactions of parasitoid wasps. The symbiotic relationship between these insects and their dietary sources, including honey and yellow cosmos pollen, underscores the intricate ecological dynamics at play within natural ecosystems. Further research into the underlying mechanisms governing these interactions holds the potential to enhance our understanding of insect behavior and inform strategies for biological pest control and ecosystem management.

4.3 Pharmacological Relevance

C.Sulphureus, renowned for its captivating beauty and medicinal efficacy, boasts a rich heritage in traditional healing practices. For centuries, it has been esteemed for its ability to address a spectrum of health concerns, including splenomegaly, intermittent fever, malaria, and jaundice. In recent scientific explorations, the medicinal potential of C.Sulphureus has been unveiled, revealing a plethora of beneficial properties. Its antimicrobial prowess positions it as a promising contender in the fight against microbial infections. Moreover, studies have highlighted its hepatoprotective qualities, showcasing its ability to safeguard liver cells from harm and dysfunction. Additionally, its antioxidative capacity suggests it can neutralize harmful free radicals, thus mitigating oxidative stress and associated health risks. Furthermore, C.Sulphureus has exhibited pesticidal activity, indicating its potential utility in agricultural pest management strategies. Its anti-inflammatory attributes stand out as particularly noteworthy, offering relief from inflammatory ailments. These diverse therapeutic benefits stem from the presence of bioactive compounds within the plant, including alkaloids, terpenoids, and polyphenols (Liu et al., (2023)). In the context of managing jaundice, Cosmos sulphureus's multifaceted properties prove invaluable. By alleviating inflammation, combating microbial infections, and reducing oxidative stress, it offers a comprehensive approach to addressing jaundice and its accompanying symptoms. Thus, C.Sulphureusemerges as a valuable botanical resource with significant potential in both traditional and contemporary medicinal practices.

4.3.1 Hepatoprotective potential

In a study conducted by Mohammad et al., the hepatoprotective potential of C. Sulphureuswas investigated(Saleem et al, 2019).The researchers employed aqua-methanolic extracts of the plant and administered them to rats over a nine-day period. Silymarin, administered at a dose of 100 mg/kg, served as the standard control. On the ninth day, hepatotoxicity was induced by administering paracetamol at a dose of 1 gm/kg, three hours post-treatment. Blood samples were collected for the evaluation of liver biochemical markers, while liver tissues were extracted for histopathological assessment 24 hours after paracetamol treatment.High-performance liquid chromatography (HPLC) analysis revealed the presence of several compounds in the plant extract, including quercetin(5), gallic acid(27), caffeic acid(26), and chlorogenic acid(24). Notably, these compounds are recognized for their antioxidant and hepatoprotective properties.

The study results demonstrated a significant reduction in the levels of alanine aminotransaminase (ALT) and total bilirubin upon administration of the C.Sulphureusextract in a dose-dependent manner ($p<0.05$). Additionally, the extract exhibited a protective effect on hepatocytes, mitigating the hepatotoxicity induced by paracetamol. This study provides valuable insights into the hepatoprotective activity of C.Sulphureus, highlighting its potential as a natural remedy for liver-related disorders. The identification of specific bioactive compounds through HPLC analysis further elucidates the mechanism underlying its pharmacological effects.

4.3.2 Antidiabetic activity

Wangkir et al. embarked on a study aimed at exploring the inhibitory effects of plant extracts on two pivotal enzymes involved in carbohydrate metabolism: -

amylase and glucosidase. This investigation was motivated by the prospect of medicinal herbs mitigating diabetes mellitus, a prevalent non-communicable disease, with fewer adverse effects compared to synthetic medications.

The study outcomes unveiled C.Sulphureus as exhibiting noteworthy inhibitory activity against both -amylase and -glucosidase, showcasing a dose-dependent relationship. This suggests the presence of compounds within C.Sulphureuscapable of impeding carbohydrate digestion by targeting these enzymes. These promising findings highlight the potential of plant extracts as alternative therapeutic agents for diabetes mellitus management, offering a safer and potentially more sustainable approach compared to synthetic medications (Wangkiri, 2021).

4.3.3 Nematocidal activity

Elodie et al. conducted an investigation into the nematocidal activity of crude extracts derived from a C.Sulphureus, focusing on their efficacy against male worms (Megnigueu et al., 2020). The screening encompassed 15 different extracts, each tested at a concentration of 300 µg/mL. Results indicated that 6 out of the 15 extracts induced complete immobilization of the worms within 72 hours at 37°C, demonstrating their potent nematocidal effects. In contrast, the negative control, consisting of RPMI+DMSO at 0.015%, showed all worms to be active, highlighting the effectiveness of the tested extracts. Further analysis revealed variations in the inhibition of motility among the extracts, with 6 exhibiting faster inhibition and 9 showing relatively slower activity, primarily stemming from stem extracts. Notably, extracts obtained using methyl alcohol (MeOH) and a mixture of MeOH and dichloromethane (CH_2CL_2) demonstrated superior nematocidal effects compared to other solvents.To refine the investigation, the 6 most active extracts were selected for additional studies. They underwent screening at six different concentrations ranging from 300 to 50 µg/mL on both male and female O. ochengi worms to determine their LC_{50} values. The nematocidal activity of these extracts was confirmed by comparing the treated worms with untreated control worms and those treated with ivermectin, a known nematocide. A colorimetric assay using MTT was employed to assess worm viability, with a purple coloration indicating live worms and yellow indicating dead ones. Results showed distinct trends in worm motility following exposure to the extracts for 72 hours at 37°C.

Leaves exhibited significant nematocidal effects, with certain solvents leading to complete immobilization of the worms, particularly extracts obtained using H_2O and $MeOH/CH_2CL_2$, which showed 100.00% motility inhibition. In contrast, stems displayed comparatively lower activity, with a considerable proportion of worms remaining active despite exposure to the extracts. Roots demonstrated effective nematocidal activity, particularly with the EtOH (70%), MeOH, and $MeOH/CH_2Cl_2$ extracts, resulting in complete immobilization of worms. Overall, extracts obtained using MeOH and MeOH/CH_2Cl_2 consistently displayed higher nematocidal activity across all plant parts. These findings underscore the significance of both plant part and solvent selection in extracting bioactive compounds with potent nematocidal properties. Further studies aimed at identifying and characterizing specific compounds responsible for the observed nematocidal activity hold promise for the development of novel nematocides for agricultural or medical applications.

4.3.4 Antioxidant and Anti-hemolytic potential

Extensive research into the antioxidant activity of various parts of Cosmos species has unveiled their promising therapeutic benefits **(Shown in Table 4).** In C.Sulphureus, for instance, ethyl acetate extracts derived from florets exhibited noteworthy DPPH radical scavenging activity, demonstrating an inhibition rate of 87.0%. Additionally, these extracts displayed potent ferric reducing antioxidant power (FRAP) and oxygen radical absorbance capacity (ORAC), indicative of their efficacy in neutralizing free radicals and thwarting oxidative damage. Similarly, methanol extracts from C.Sulphureusshowcased significant antioxidant activity, with an impressive 89.87% inhibition of DPPH radicals. Moreover, investigations into C.caudatus revealed intriguing results, particularly concerning the antioxidant potential of its leaves. Extracts obtained using various solvents exhibited varying degrees of DPPH radical scavenging activity, with methanol and ethanol extracts displaying higher inhibitions compared to water and juice extracts. Additionally, FRAP assays demonstrated the leaves' capacity to reduce ferric ions, with elevated values detected in methanol and ethanol extracts. Similarly, studies focusing on C.bipinnatus underscored the antioxidant prowess of its florets, with different color variants exhibiting diverse levels of DPPH radical scavenging activity. These collective findings underscore the rich and varied antioxidant properties inherent in Cosmos species (Table 4). Such attributes position them as promising natural reservoirs of antioxidants for potential applications in both medicinal and functional food arenas.

Table 4:Antioxidant activities shown by various plant parts of Cosmos species.

Species	Analyzed plant parts	Antioxidant Activity (Applied Assay)	Inhibition/IC_{50} Values	Applied Solvent	References
C.Sulphureus	Florets	DPPH Radical Scavenging Activity	87.0% inhibition	Ethyl Acetate	Kaisoon, O., Konczak, I., &Siriamornpun, S. 2012

C.Sulphureus	Florets	Ferric Reducing Antioxidant Power (FRAP)	99.9–538.6 µmol Fe2+/g DW	Ethyl Acetate	Megnigueu et al, 2020
C.Sulphureus	Florets	Oxygen Radical Absorbance Capacity (ORAC)	214.8 µmol TE/g DW	Ethyl Acetate	Megnigueu et al, 2020
C.Sulphureus	Florets	Cellular Antioxidant Activity (CAA)	966.1 µM QE/g DW	Ethyl Acetate	Megnigueu et al, 2020
C.Sulphureus	Florets	Oxygen Radical Absorbance Capacity (ORAC)	320.36 µmol TE/g DW	Ethyl Acetate	Megnigueu et al, 2020
C.Sulphureus	Florets	DPPH Radical Scavenging Activity	89.87% inhibition	Methanol	Kaisoon, O., Konczak, I., &Siriamornpun, S., 2012
C.Sulphureus	Leaves	Nitric Oxide Scavenging Activity (NOSA)	18.1–80.2% inhibition	Ethyl Acetate	JADAV, K. M., & GOWDA, K. N. 2017
C.Bipinnatus	Florets (white)	DPPH Radical Scavenging Activity (IC50)	1.65 mg/ml	Methanol	Phuse, S. S., & Khan, Z. H. 2018
C.Bipinnatus	Florets (pink)	DPPH Radical Scavenging Activity (IC50)	1.45 mg/ml	Methanol	Phuse, S. S., & Khan, Z. H. 2018
C.Bipinnatus	Florets (violet)	DPPH Radical Scavenging Activity (IC50)	0.61 mg/ml	Methanol	Phuse, S. S., & Khan, Z. H. 2018
C.Bipinnatus	Florets	DPPH Radical	0.84 mg/ml	Methanol	Phuse, S. S.,

	(orange)	Scavenging Activity (IC50)			&Khan, Z. H. 2018
C.Caudatus	Herb	DPPH Radical Scavenging Activity (IC50)	0.047 mg/ml	Methanol	Jang et al., 2008
C.Caudatus	Herb	DPPH Radical Scavenging Activity (IC50)	0.054 mg/ml	Ethanol	Jang et al., 2008
C.Caudatus	Leaves	DPPH Radical Scavenging Activity	87.52% inhibition	100% Methanol	Mediani et al, 2013
C.Caudatus	Leaves	DPPH Radical Scavenging Activity	63.70% inhibition	100% Ethanol	Mediani et al, 2013
C.Caudatus	Leaves	DPPH Radical Scavenging Activity	52.64% inhibition	95% Ethanol	Mediani et al, 2013
C.Caudatus	Leaves	DPPH Radical Scavenging Activity	70.85% inhibition	50% Ethanol	Mediani et al, 2013
C.Caudatus	Leaves	DPPH Radical Scavenging Activity	30.76% inhibition	Distilled Water	Mediani et al, 2013
C.Caudatus	Leaves	DPPH Radical Scavenging Activity	28.98% inhibition	Juice	Mediani et al, 2013
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	1197 μmol Fe^{2+}/g DW	100% Methanol	Mediani et al, 2013
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	1113.50 μmol Fe^{2+}/g DW	100% Ethanol	Mediani et al, 2013
C.Caudatus	Leaves	Ferric Reducing	840.73 μmolFe^{2+}/g	95% Ethanol	Mediani et al, 2013

		Antioxidant Power (FRAP)	DW		
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	1820.70 μmol $Fe2+$/g DW	50% Ethanol	Mediani et al, 2013
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	392.94 μmol $Fe2+$/g DW	Distilled Water	Mediani et al, 2013
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	229.85 μmol $Fe2+$/g DW	Juice	Mediani et al, 2013
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	502.21 μM TE/ml	Distilled Water	Cheng et al, 2016
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	332.00 μM TE/ml	Distilled Water	Cheng et al, 2016
C.Caudatus	Leaves	Ferric Reducing Antioxidant Power (FRAP)	239.18 μM TE/ml	Distilled Water	Cheng et al, 2016

Shital and Zia conducted a study evaluating the antioxidant and anti-hemolytic properties of extracts obtained from C.Sulphureusflowers (Phuse, S. S., & Khan, Z. H. 2018). They assessed the percentage of DPPH radical scavenging activity and the % inhibition of hemolysis at various concentrations of dried extract, comparing the results with a standard antioxidant (STD).In terms of antioxidant activity, both C.Sulphureusflower acetone (CSF A) and C.Sulphureusflower ethyl acetate (CSF EA) extracts exhibited DPPH radical scavenging activity, albeit to differing extents compared to the standard. These findings highlight the importance of extraction methods and solvent choice in maximizing the bioactivity of plant extracts for potential therapeutic applications. Overall, the study underscores the antioxidant and anti-hemolytic potential of C.Sulphureusflower extracts, particularly CSF A, which demonstrated significant activity comparable to or even surpassing the standard antioxidant used. These results suggest the therapeutic value of C.Sulphureusflower extracts in combating oxidative stress-related disorders and protecting against erythrocyte damage, emphasizing the importance of exploring natural sources for antioxidant and anti-hemolytic agents in health research.

Further, Andrushchenko et al. explored the antioxidant capacity of C.Sulphureus plants cultivated in a temperate climate (Andrushchenko, O., Vergun, O., &Rakhmetov, D. 2022).Two genotypes, C.Sulphureus (CS-361294) and C.Sulphureus 'Cosmic Orang' (CSCO368812), were selected based on variations in the color and quantity of ray florets in the inflorescence. Regarding antioxidant activity, the researchers assessed the percent inhibition of DPPH radical reaction by water and methanol extracts from various parts of the C.Sulphureus plants. These inhibition values signify the extracts' capability to scavenge DPPH radicals, reflecting their antioxidant potential. Across both genotypes, leaves consistently demonstrated the highest antioxidant activity, with percent inhibition values ranging from approximately 79% to 89% for methanol extracts and from approximately 79% to 84% for water extracts. Inflorescences also exhibited notable antioxidant activity, particularly in methanol extracts, with percent inhibition values ranging from approximately 59% to 71% for CS-361294 and from approximately 60% to 72% for CSCO368812. Stems showcased moderate antioxidant activity, especially in methanol extracts, while roots displayed comparatively lower antioxidant activity compared to other plant parts. These findings suggested the antioxidant potential of C.Sulphureus plants, particularly leaves and inflorescences, as valuable sources of antioxidants in temperate climates.

4.3.5 Antibacterial and Antifungal potential

Malaka and her collaborators synthesized silver nanoparticles using leaf extracts from C.Sulphureus. They then investigated how these nanoparticles, when combined with compounds from C.Sulphureus, affected antibacterial and antifungal activity. These findings underscore the potent antimicrobial activity of CsAgNPs against a spectrum of clinical isolates, suggesting their potential as effective antimicrobial agents.Moreover, a clear dose-dependent relationship emerged between CsAgNPs concentration and antimicrobial effectiveness, with higher concentrations correlating with expanded inhibition zones. This linear augmentation in antimicrobial activity implies a direct association between CsAgNPs concentration and their efficacy against bacterial and fungal pathogens. Notably, when compared to traditional antibiotics, CsAgNPsshowcased superior antimicrobial activity, further accentuating their potential as alternative therapeutic modalities. Additionally, the study identified several virulent bacterial and fungal pathogens, including Aeromonas hydrophila, Staphylococcus aureus, and Candida albicans, which were effectively targeted by CsAgNPs. This broad-spectrum activity against clinically relevant pathogens highlights the versatility and efficacy of CsAgNPs as antimicrobial agents.Furthermore, the speculated mechanism underlying the antimicrobial action of CsAgNPs involves disruption of bacterial and fungal cell membranes' permeability and respiration control mechanisms. By adhering to the surface of the cell wall membrane, CsAgNPs may have interfered with vital cellular processes, leading to suppressed growth and eventual cell demise. This proposed mechanism of action highlights the potential of CsAgNPs as potent antimicrobial agents by selectively targeting fundamental processes essential for microbial survival. Overall, the study underscores the promising antimicrobial attributes of CsAgNPs, offering a potential avenue for combatting antibiotic-resistant pathogens and propelling advancements in the field of nanomedicine [112].

5. Conclusion

In conclusion, the review provides a comprehensive overview of the diverse significance of Cosmos sulphureus, elucidating its pivotal role in ecological systems, agricultural practices, and medicinal traditions. The genetic enhancement potential of C.Sulphureus holds promise for crop improvement efforts, while its influence on parasitoid wasp behavior highlights its ecological importance in pest management strategies. Furthermore, the pharmacological relevance of C. Sulphureus, demonstrated through its hepatoprotective, antidiabetic, nematocidal, antioxidant, and antimicrobial properties, highlights its potential as a source of novel therapeutic agents. Future research endeavors aimed at elucidating the molecular mechanisms underlying these pharmacological activities and exploring the therapeutic potential of C.Sulphureus compounds are warranted. Overall, C.Sulphureus emerges as a versatile botanical resource with significant implications for ecological conservation, agricultural sustainability, and human health.

Abbreviation	**Full form**
%	Percentage
CS-361294	C. Sulphureus
CSCO368812	C.Sulphureus 'Cosmic Orang'
C. atrosanguineus	Cosmos atrosanguineus
C. Sulphureus	Cosmos sulphureus
C.Vestalis	Cotesia vestalis
C.Caudatus	Cosmos caudatus
C. Bipinnatus	Cosmos bipinnatus
CSF A	C.Sulphureus flower acetone
CsAgNPs	C. Sulphureus Silver nanoparticles
CSF EA	C.Sulphureus flower ethyl acetate

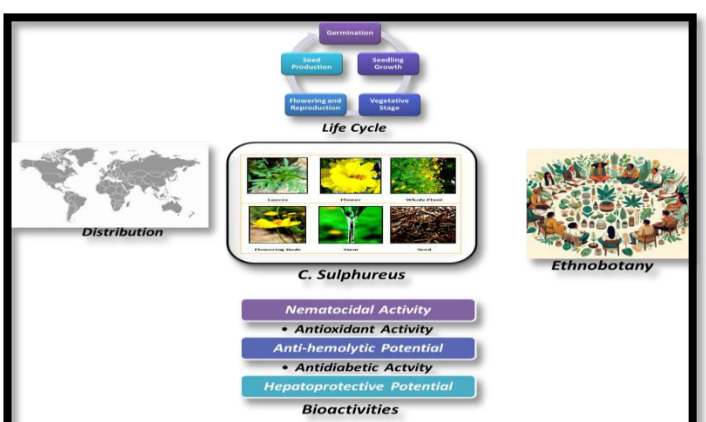
STD	Standard
DPPH	2,2-Diphenyl-1-picrylhydrazyl
FRAP	Ferric ion reducing antioxidant power
ORAC	Oxygen radical absorbance capacity
MeOH	Methanol
EtOH	Ethanol
CH_2Cl_2	Dichloromethane
H_2O	Water
MTT	(3-[4,5-dimethylthiazol-2-yl]-2,5 diphenyl tetrazolium bromide)
DMSO	Dimethyl sulfoxide
ALT	Alanine aminotransaminase
HPLC	High-performance liquid chromatography
CH3H	Chalcone 3-hydroxylase

Table 5 : Abbrevation and full forms used

Highlights

- C.Sulphureus has significant ecological and agricultural importance.
- The plant has diverse medicinal properties, including being hepatoprotective, antidiabetic, and antimicrobial properties.
- It plays a crucial role in pollination and adapts to various habitats.
- Further research on C.Sulphureus could benefit conservation and health.

Graphical Abstract



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