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The Art and Science of Flavour: A Journey through Aromas in Horticultural Crops

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Abstract

The abstract delves into the intricate realm of flavour in horticultural crops, blending art and science in a captivating journey through sensory experiences. It explores the multifaceted nature of aromas, tracing their origins from the soil to the table. Through a combination of chemical analysis, sensory evaluation, and cultural context, this exploration unveils the diverse array of flavors found within horticultural crops. From the subtle nuances of floral notes to the robust profiles of fruits and vegetables, each aroma tells a story of genetic heritage, environmental influences, and culinary traditions. By understanding the factors that shape flavor development, horticulturists, chefs, and consumers alike can deepen their appreciation for the bounty of nature's offerings. These abstract invites readers to embark on a sensory adventure, where the artistry of flavor meets the precision of scientific inquiry, illuminating the beauty and complexity of horticultural crops.

Keywords: *chemical, horticulturists, genetic heritage, environmental influences*

Introduction

In horticulture, quality refers to the characteristics of a product, such as its visual appearance, ability to withstand postharvest processing, chemical and nutritional makeup, and taste. Progress in breeding techniques has resulted in the development of fruits that possess favorable attributes for producers, distributors, and sellers [1]. However, these fruits frequently fall short in terms of their nutritional value and flavor. Understanding of the chemical composition and taste characteristics of plants has also grown, along with knowledge of the physiological, metabolic, and biochemical processes involved [2].

Enhancing the flavor of fruits by breeding is a complex task due to several factors that influence the molecules responsible for this attribute, including climate, production methods, and pre- and postharvest treatments [3]. Flavor, which refers to the way taste, orthonasal, and retronasal olfaction sensations interact, is a significant characteristic of fruits and is closely associated with the preferences of individual consumers. Understanding customer preferences and striving to meet these expectations can enhance the likelihood of manufacturers successfully selling their goods and enhance nutritional intake, since more delicious fruits may substitute for less nutritious snack items [4]. Recent advancements in molecular methods have facilitated the discovery of genes involved in the production of chemicals, offering new opportunities for enhancing taste. These approaches include gene cloning, enhancing certain metabolic pathways, and suppressing the expression of genes responsible for undesirable compounds [5].

Floral fragrance and color are essential characteristics of several floricultural crops. Floral volatiles, which are plant-derived compounds, are physiologically and economically important. They have a major function in attracting pollinators, defending against threats, and interacting with the environment [6]. Volatile terpenoids are very prevalent volatile organic compounds (VOCs), with selective benzenoids/phenylpropanoids being the second most numerous. Fruits and vegetables produce a range of volatile chemicals that add to their unique smells and tastes. Flavor consists of two components: the taste experienced on the tongue (sweetness, acidity, or bitterness) and the scent, which is created by various volatile substances [7].

Volatile organic compounds (VOCs) greatly influence human civilization through their wide-ranging uses in the food, cosmetics, and pharmaceutical sectors. These compounds are utilized in a wide range of goods, including rubber, pesticides including pyrethrin, detergents containing carvone and hecogenin, antihistamines and antibiotics containing caryophyllene, and cleaning agents containing methanol [8]. Recent progress in manipulating floral aromas through terpenoid production in model plants has greatly facilitated genetic engineering in plants. Over the past decade, several research has significantly enhanced our comprehension of the functions, constituents, production, and control of flower fragrances and fruit odors [9].

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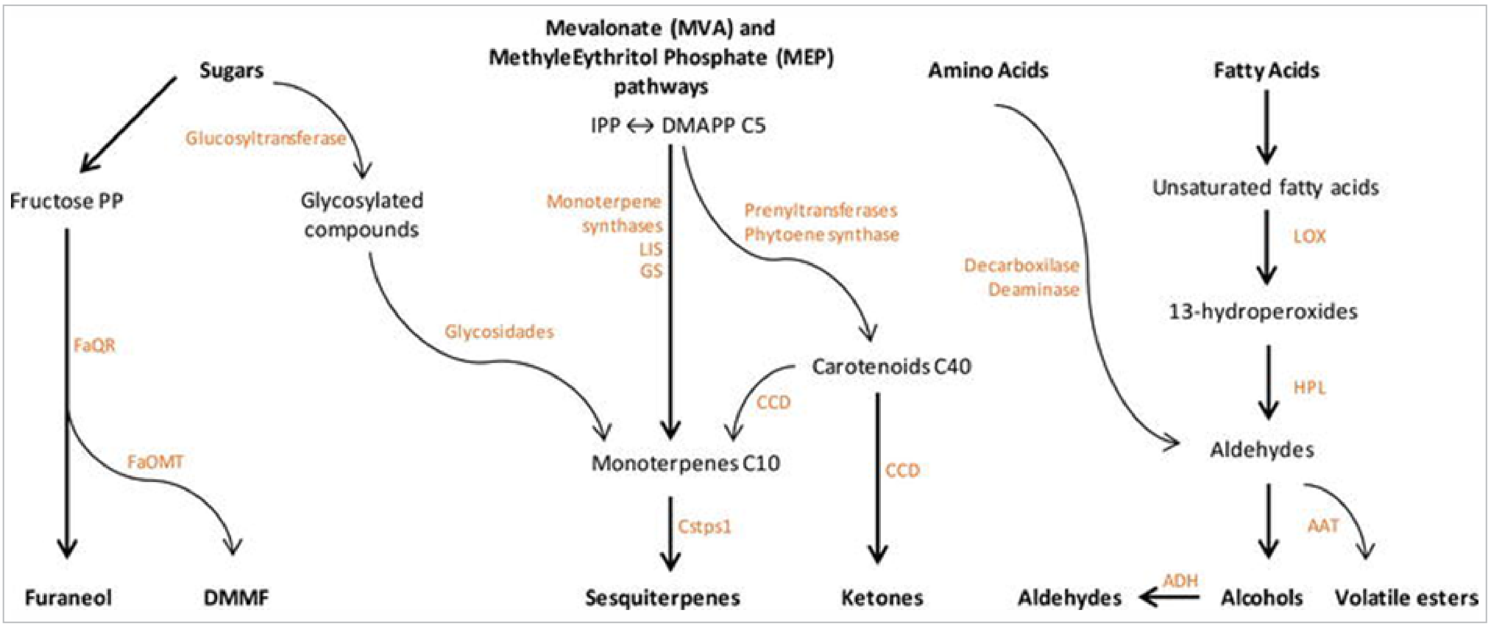

Fig 1

Aromas in horticultural crops

Fruits

The presence of volatile compounds (VOCs) has a significant role in defining the quality of fruit by contributing to the unique scents and tastes found in fruits and vegetables. The chemicals encompass esters, terpenoids, alcohols, lactones, aldehydes, ketones, and apocarotenoids. The quantity, composition, and strength of volatile organic compounds (VOCs) emitted by maturing apple fruit differ based on the specific apple variety, environmental and agricultural factors, the level of ripeness, how the fruit is handled and stored, and the duration of exposure to ultraviolet (UV) radiation [10]. Enzymes and precursors/substrates commonly release aromatic molecules. Monoterpenes and sesquiterpenes are the primary groups responsible for the aroma profile and can also have a substantial impact on the odor profile. The substantial impact of fragrance on the marketability of fruits necessitates further advancement in our understanding of this characteristic [11].

Berry fruits and pomaceous fruits are two notable fruit groups known for their exceptional nutritional profiles. Berry fruits, such as strawberries, blueberries, raspberries, and grapes, are widely recognized in the commercial market for their pleasant taste, which is mostly due to the presence of fructose and volatile chemicals. Apples, citrus, peaches, and mangos are examples of pomaceous fruits that have been extensively studied for their volatile compounds in various varieties [12]. Strawberries, scientifically known as Fragaria x ananassa, are widely recognized as the most popular berry fruit crop globally. They are highly esteemed for their unique flavor and rich nutritional composition. Fresh strawberries have been discovered to possess more than 360 volatile chemicals, which encompass esters, alcohols, ketones, furans, terpenes, aldehydes, and sulfur compounds. Nevertheless, the concentration and content of these substances differ based on the specific cultivar and level of ripeness [13]. Apples, scientifically known as Malus domestica, are highly favored fruits. Their unique scent is the result of an intricate combination of volatile substances, which differ in terms of components, concentrations, and the level at which they can be detected by smell. Blueberries, belonging to the Vaccinium spp., are the second most economically valuable soft fruit species, behind strawberries. The fragrance of blueberries is influenced by the complex interplay of several volatile organic compounds (VOCs) that are emitted by the fruit as it ripens [14]. Studies have shown that the chemical composition of volatile substances differs among different varieties, especially in terms of α/β-ionone, linalool, geraniol, and (Z)-3-hexenol. Blackberries (Rubus laciniata) include a highly abundant array of volatile compounds in their volatile profile, which includes p-cymen-8-ol, α-terpineol, 2-Heptanol, 4-terpineol, 2-heptanone, nonanal, pulegone, isoborneol, 1-octanol, elemicine, 1-hexanol, myrtenol, and carvone [15].

Grapes, an extensively cultivated fruit crop, possess a distinctive look and flavor that have garnered them significant commercial significance. Based on their physiochemical qualities and usage, grapes are categorized as either wine grapes or table grapes. The flavor of ripe fresh grapes plays a crucial role in determining consumer acceptance. It is often perceived as a mix of taste in the mouth and scent in the nose. The fruit volatiles of Vitis vinifera consist of a wide variety of chemicals, such as monoterpenes, C13 norisoprenoids, alcohols, esters, and carbonyls. The distinct fragrance of each grape variety is the outcome of an intricate interplay among several volatile chemicals [16]. Mandarins are a notable representation of citrus, which is a crucial component of people's diets globally. The main aromatic chemicals found in citrus fruits are terpenoids, including β-pinene, S-linalool, valencene, and limonene. Terpenoids such as d-limonene, valencene, linalool, terpinen-4-ol, and α-terpineol are important components of fragrance compounds found in 'Dortyol yerli' orange juice. These chemicals greatly contribute to the unique flavor of the juice. The juice of four citrus species includes more than one hundred volatile chemicals, including some molecules that are exclusive to certain citrus kinds [17]. The volatile components of Peach (Prunus persica) have been thoroughly examined, and over 100 chemicals that contribute to the scent quality of peaches have been found. The peach volatiles that are found in the highest quantities include C6 compounds, linalool, esters, C13 norisoprenoids, benzaldehyde, and lactones. The flavour of peach fruit is greatly affected by esters, namely hexyl acetate and (Z)-3-hexenyl acetate. The strength and content of the scent of peach fruit vary based on the specific cultivar, the stage of fruit development, the processing methods used, and the circumstances in which the fruit is stored [18].

Mango (Mangifera indica) possesses a highly enticing taste, characterized by the presence of over 270 distinct volatile chemicals responsible for its scent, found in different mango cultivars. Terpenes are the predominant group of chemicals found in New World mangos, comprising 16-90% of the total. Most of these chemicals are hexanal derivatives and terpenes, which are important volatile molecules that contribute to the scent of pomegranate fruits [19].

The volatile composition of fresh fruit is constantly changing due to the intricate nature of volatile profiles. The volatile content of fruit is influenced by several factors such as fruit genetics, maturity, and climatic fluctuations throughout fruit growth, postharvest practices, and storage conditions [20]. Advancements in metabolic engineering have been achieved by the identification and analysis of crucial enzymes that play a role in the production of taste and fragrance components in specific fruits. Utilizing QTL and linkage studies, marker-assisted selection can facilitate the transfer of desirable taste and aroma traits from aromatic lines to non-scented or less aromatic lines, while also incorporating promising agronomic characteristics [21].

Vegetables

Fruits and vegetables contain volatile compounds that possess various therapeutic characteristics, enhancing their overall quality and exerting substantial effects on human health. The worldwide fascination with plant-based meals, namely fruits and vegetables, has grown because of their capacity to eliminate free radicals, combat microbes, reduce inflammation, and inhibit cell growth. Secondary metabolites, including polyphenols, carotenoids, and terpenoids, contribute to their functional qualities by providing increased protection against chronic illnesses such as cardiovascular disease, cancer, neurological disorders, and diabetes [22]. Carrots, tomatoes, onions, and spinach are often utilized aromatic vegetables in the everyday culinary practices of several cultural cuisines worldwide. Terpene compounds are the main components of the volatile profile of different carrot types. In particular, orange carrots include 31 volatile metabolites, which make up 58.1% of the total volatile compounds. A total of 65 volatile biomarkers were detected in tamarillo, comprising 20 terpenes, 17 esters, 7 alcohols, 5 benzyl compounds, 4 aldehydes, 4 furans, and 7 miscellaneous substances [23].

Onions have unique and specific chemical compositions. Red onions are characterized by the presence of aldehydes (26.7%), organosulfur compounds (19.6%), and carboxylic acids (15.3%). On the other hand, yellow onions mostly include organosulfur compounds (73.8%). Beta vulgaris, commonly known as beet, has a total of 61 volatile chemicals. The largest proportion of these compounds (61.0%) are terpenoids, followed by furanic compounds (20.6%), carboxylic acids (5.6%), and benzene derivatives (5.2%) [24].

Tomatoes include 71% of the overall volatile profile, while the remaining portion consists of alcohols, esters, terpenoid chemicals, carboxylic acids, organosulfur compounds, and ketones (1.6%). The volatile profile of Spinacia oleracea consists of 57 metabolites, which comprise 14 esters, 13 terpenes, 8 alcohols, and 7 aldehydes. Studying the volatile composition of fruits and vegetables is valuable for improving their taste and identifying the most important metabolites, which may be used for targeted nutraceutical treatments [25].

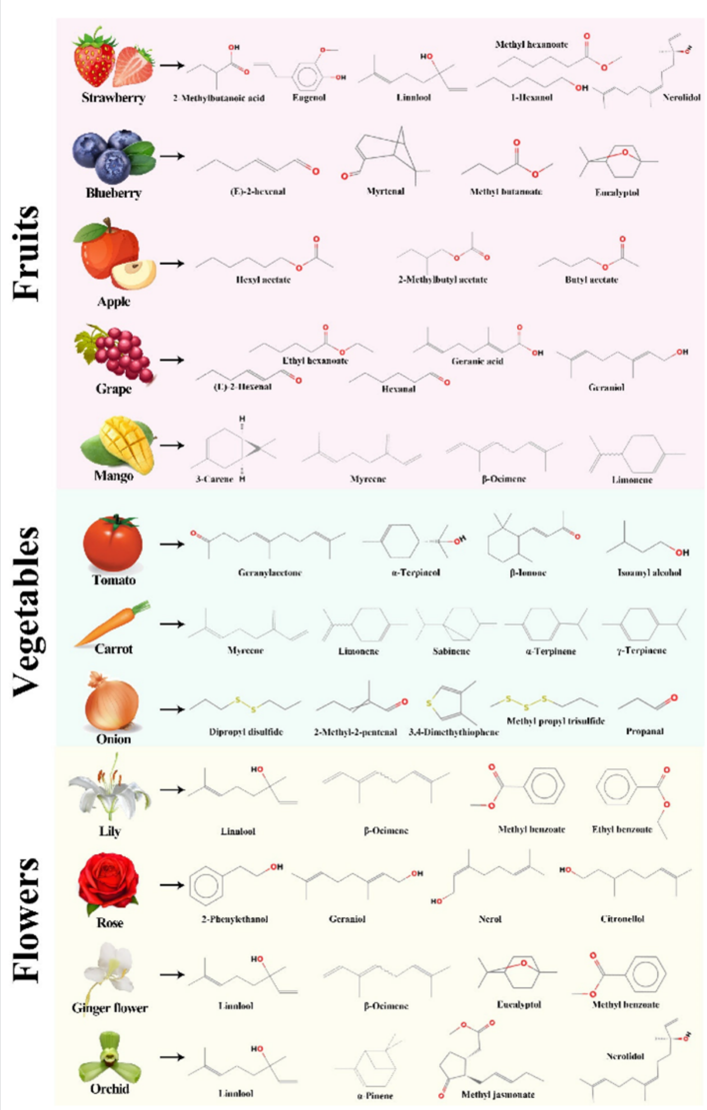

Fig 2

Flowers

Flower scents consist of an intricate combination of substances that have several functions in different sectors, such as aromatherapy, perfume, cosmetics, flavouring, and medications. They enhance pollinator, herbivore, and pathogen interactions in their original environments. Floral visitors utilize floral aroma to anticipate the amount of reward present in flowers, assist in the specific characteristics of host flowers, or serve as chemically analogous signals to those necessary for pollinating insects in different ecological situations [26]. Floral smells consist of a diverse range of molecules, which may be categorized as terpenoids, phenylpropanoids/benzenoids, and fatty acid derivatives. Terpenoids are a very varied group of volatile chemicals, consisting of more than 40,000 structures that are produced from C5 isoprene units. Ginger blossoms, jasmine, and Narcissus are fragrant plants with unique scent characteristics, and their volatile compounds have garnered significant attention in commercial uses in recent times [27]. Orchids are the most diverse family of blooming plants, consisting of 20,000–30,000 species, of which 75% possess a pleasant fragrance. Cymbidium and Phalaenopsis orchids contain a significant amount of monoterpenes, including cineole, (-) selinene, linalool, and geraniol.

Roses are highly valued ornamental plants that have significant economic importance. This is mostly because they are extensively grown for the purpose of producing cut flowers, essential oil, and fragrances [28]. Lilium species and variants are highly esteemed for their exceptional qualities as cut flowers and potted plants globally. There are more than a hundred commercially accessible cultivars, distinguished by their bloom form and colour.

Hedychium is a cultivated plant that is valued for its pleasant scent and is used for both decorative and medicinal purposes [29]. Lavender plants are renowned for their remarkable fragrant and healing properties, with terpenoids being the main components of essential oils in both Lavandula officinale and L. angustifolia. The cosmetics industry widely utilizes the volatile chemicals and essential oils derived from Narcissus flowers. The primary volatile organic compounds (VOCs) present in Chinese daffodil blossoms are acetic acid phenethyl ester, ocimene, α-linalool, 1,8 cineole, and benzenoids. The fragrance of jasmine blossoms is renowned for its intricate and unique scent compositions, primarily characterized by the presence of the monoterpene linalool and the sesquiterpene (3E, 6E)-α-farnesene [30].

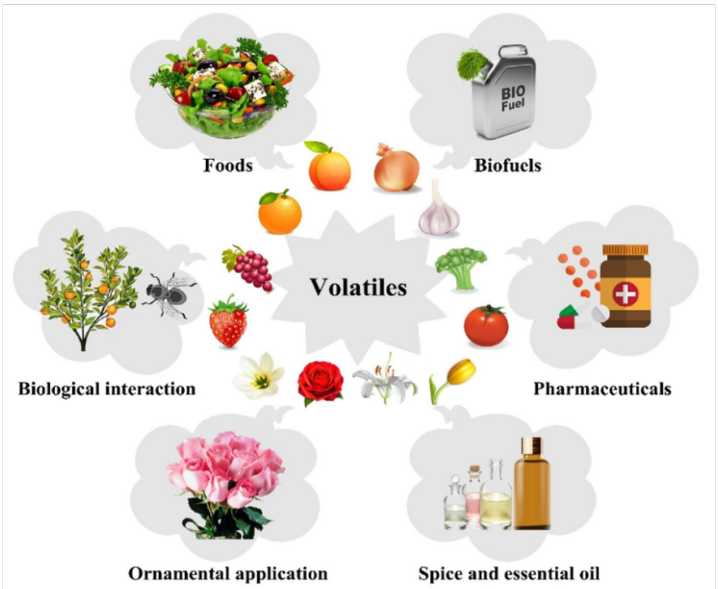

Fig 3

Applications in different sectors

Plants possess the capacity to produce, amass, and emit volatile chemicals that can function as aromatic and flavourful molecules. Flavor and scent are favorable characteristics that impact the quality of crops. To assure consumer impression, it is necessary to have a favourable combination of volatile chemicals [31]. Terpenoids are the main constituents of the majority of plant essential oils, offering a diverse array of delightful aromas, including floral, fruity, woody, or balsamic undertones. Terpenoids, which are highly esteemed in the fragrance and taste sectors, play a crucial role in producing various scents such as "fruity," "floral," "earthy," and "woody" [32].

The economic success of flavourings, medicines, agricultural pesticides, and chemical industries is dependent on the use of volatile molecules. Terpenoids make up over 90% of the volatile compounds found in citrus peel oil. In lime, the most abundant volatile compounds are limonene (73.5%), geranial (8.4%), neral (4.9%), myrcene (2.1%), and β-bisabolene (1.6%) [33]. The mango fruit was subjected to quantitative analysis, revealing that the most abundant volatile chemicals present were monoterpenes, specifically δ-3-carene, limonene, terpinolene, and β-phellandrene. Terpenoids make up over 96% of the volatile compounds found in oranges, which are responsible for the fruit's taste [34]. The raspberry fruit was discovered to have a significant amount of C13 norisoprenoids, which are volatile compounds generated from carotenoids. These compounds accounted for the majority of the volatile content in the fruit, ranging from 64% to 94%, across nine distinct raspberry genotypes. β-ionone was the primary aromatic molecule found in 'Meeker' raspberry, contributing to its distinct aroma characterized by notes of raspberry, perfume, and floral scents [35].

Aromatic plants, herbs, and shrubs including rose, jasmine, Hedychium, Boswellia, and Santalum produce essential oils that have gained significant value in the worldwide market because of their delightful fragrances. Fragrant plant species' essential oils have been professionally utilized for their unique tastes in the perfume, beverage, and food sectors. One such example is valencene, a sesquiterpene obtained from citrus fruits. Limonene, linalool, and 1,8-cineole, which are monoterpenes, are commonly employed to impart the fragrance of lime/lemon drinks. The fragrance and flavor of hops in beer are influenced by sesquiterpenes, specifically β-caryophyllene, and α-humulene, which add to the overall beer quality [36]. In the future, we may expect to get a more comprehensive understanding of how flavors are formed, particularly due to the emergence of advanced genomic and metabolomics technologies. Enhancing the flavor of fresh horticulture goods can lead to increased consumption and greater customer satisfaction [37].

Studies indicate that both natural monoterpenes and their synthesized derivatives provide a wide range of health advantages, such as antiarrhythmic, anti-aggregating, antibacterial, anti-inflammatory, antioxidant, anticancer, anti-spasmodic, antinociceptive, antifungal, antihistaminic, and local anesthetic qualities. Terpenoid compounds engage with crucial molecular targets in the physiology of humans and animals, functioning as immunostimulants, regulating blood coagulation hemostasis, enhancing antioxidant activity, and controlling gene transcription associated with chronic illnesses [38]. Taxol, a diterpene, has demonstrated efficacy against cancer and malaria, so providing substantial assistance to the pharmaceutical industry, which heavily depends on natural goods and is worth in the billions of dollars. Cineole, a kind of monoterpenoid oxide present in the essential oils of plants, is utilized for the treatment of respiratory conditions that are worsened by infection. Eugenol exhibited anticancer activities and rapid bactericidal actions against Salmonella enterica. Terpineol had evident bactericidal effects on S. aureus strains, but citronellol, carveol, and geraniol all exhibited evident bactericidal effects on Escherichia coli [39].

Essential oils derived from trees, shrubs, and plants include terpene-based volatile organic compounds (VOCs) that possess antioxidant, sedative-hypnotic, and anti-inflammatory activities. Terpenes are vital constituents found in several human nutritional and healthcare goods, including carotenoids and tocopherols. These substances serve as sources of vitamins A, E, and K, as well as coenzyme Q10 [40].

Since ancient times, the cosmetics industry has utilized plants and their volatile organic compounds (VOCs) for their fragrance. Essential oils, which are a complex blend of volatile molecules, especially terpenoids, are employed to improve the physical well-being and look of the human body. Aromatic essential oils are also crucial fragrance enhancers in cosmetic goods [41]. Nevertheless, there exist fragrant species whose natural chemicals have not been fully understood, potentially offering a reservoir of novel terpenes that might benefit humans. There is still a significant amount of study that has to be conducted on these aromatic compounds [42].

Conclusion

In conclusion, the exploration of aromas in horticultural crops reveals a captivating intersection of art and science, offering insights into the rich tapestry of flavours that grace our plates. Through this journey, we've uncovered the intricate relationships between genetics, environment, and cultural practices that shape the sensory profiles of crops. The significance of flavour extends beyond mere gustatory pleasure, influencing culinary traditions, consumer preferences, and even economic markets. As we continue to delve into the art and science of flavour, it becomes evident that horticultural crops hold a treasure trove of diversity waiting to be savoured and appreciated. By nurturing this diversity and understanding the complexities of flavour development, we can not only enrich our culinary experiences but also cultivate sustainable agricultural practices that preserve the essence of our natural heritage. Let us embark on this journey with a newfound appreciation for the aromas that grace our tables, celebrating the beauty and diversity of horticultural crops.

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