SUSTAINABLE SCENTS:

The Intersection of Hydroponic Farming and Perfume Production

Grace Bailer

Foreword

We all have a responsibility to do more to help sustainably manage our natural resources. Through our individual actions and choices, we can have massive impacts. While some resources may be more urgently needed, others are more closely tied to our personal or cultural tastes. For the latter, our preferences for fragrances used in a wide range of products presents challenges and a unique opportunity. While often resource intensive in their production (through plant growth, transportation, processing), this need not always be the case.

As Grace Bailer outlines in this policy paper, seeking sustainability does not necessarily mean that we abandon such products. We can, and should, encourage producers to use new technologies and innovative strategies to significantly reduce resource inputs. Such innovations can maintain production, reduce costs, and better manage natural resources.

This policy paper provides one direction, of many, that producers might explore. From these we can continue to enjoy the fragrances we love, while also making the world a more sustainable place.

Mark A. Brennan Ph.D.
Professor and UNESCO Chair on Global Citizenship Education
for Sustainable Peace through Youth and Community Engagement

PART 1

The Suitability of Hydroponic Farming in the Beauty and Fragrance Industry: A Systematic Review Comparing Hydroponic and Traditional Soil Farming

1.0 ABSTRACT

The present work aims to find a more sustainable way to procure flowers for fragrances. Currently, fragrance and beauty companies rely on the integrity of their suppliers' farms, rather than ensuring sustainable procurement themselves. Conservation agriculture and synthetic fragrances are two methods that can increase the environmental sustainability in fragrance development, but do not address massive water consumption and demand for natural products. This paper studies the sustainability and productivity of hydroponic farming in comparison to traditional soil farming. Results of this study are intended to determine if hydroponic farming is a suitable solution. The comprehensive reference articles indicate hydroponic farming is as productive and more sustainable than traditional soil farming. Future research should compare the volatile organic compounds (VOCs), those responsible for scent, in hydroponic and traditional soil grown flowers to ensure this method can be implemented in the fragrance industry.

2.0 INTRODUCTION

A sustainable way to procure flowers within the beauty and fragrance industry is crucial. The Environmental Protection Agency (EPA) explaina the global beauty and fragrance industry emits over one billion tons of CO2 a year on transportation [1]. It also finds that agriculture accounts for 21% of the GHG emissions globally [2]. Agricultural emissions must be cut in industries that are less fundamental than food production, as such the beauty and fragrance industry.

Hydroponics have been used over centuries, and have adjusted to modern day needs. Hydroponic farming dates back to the 8th - 6th century BCE in the hanging gardens of Babylon [5]. Presently, hydroponic farming is primarily used in food production across the globe. Hydroponic farming mitigates agricultural emissions by using nutrient-filled water as the plant's growing medium, rather than extensive land use in soil. These systems use climate control technology including LED lights and a circular water system to mimic a stable climate condition. Companies like Bowery Farms, BrightFarms, Little Leaf Farms and Plenty use hydroponic farming to grow produce such as lettuce, leafy greens, salad mix, and microgreens [6]. However, these modern adaptations aren't widely adapted due to high start-up costs and risks which come with infiltrating large technologies into traditional farming practices.

Hydroponic farming is safer and more sustainable than alternatives. Alternative solutions to sustainable fragrance production include conservation agriculture and synthetic fragrances. Conservation agriculture encourages the use of no-till farming (a system which promotes less soil degradation), natural fertilizers, and crop rotation (rotating different crops each season) to minimize environmental impacts. However, sustainable initiatives in conservation agriculture can lead to smaller crop yields, and more pest invasions because of limited fertilizer and pest control. Synthetic fragrances, chemically composed products mimicking natural scents, can prove

detrimental effects to human health as the scent materials may contain chemicals which disrupt endocrine processes and benzene derivatives [3]. High access to these derivatives can restrict bone marrow from producing enough red blood cells, leading to anemia. The Department of Health and Human Services (DHHH) has also concluded that high levels of benzene can cause leukemia [4].

This review uses 14 articles to analyze the productivity and sustainability of hydroponic farming for application of flower production. Productivity is measured through yield (plant height and weight), and the presence of natural compounds. These natural compounds like flavonals, volatile organic compounds (VOCs), and chlorophyll are responsible for flavor, scent and color respectively. Increased amounts of natural compounds demonstrate the ability of the system to produce premium and robust plants. These preliminary studies suggest hydroponic farming can be used as a sustainable system to procure flowers for fragrances, future research is required to measure scent emissions.

3.0 METHODS

3.1 Literature Search Strategy

This review used specific guidelines to find relevant sources. These databases: Agricultural and Environmental Science Database, Google Scholar, and ScienceDirect, were accessed through Hollis Library. The advanced search keywords were "hydroponic AND traditional AND comparative AND flowers." The articles referenced in this review are products of the advanced search or were found in the citations of these articles. The study selection tailored the portfolio of articles to ensure relevancy on the research question and hypothesis.

3.2 Study Selection

The selected articles are peer-reviewed comparative studies. The titles of each article was evaluated for the words: comparison, hydroponic, traditional, soil, soil-less. After ensuring the studies were relevant through the title, the abstract was screened for relevance to the hypothesis. This preliminary search was further specified using inclusion and exclusion criteria.

3.3 Eligibility Criteria

See Table 1 for inclusion and exclusion criteria. This criteria was developed using the SPICE systematic review method: setting, perspective, intervention, comparison, and evaluation [5]. Hydroponic farming is climate controlled, therefore excluding the need to consider geographic location. This review compared common themes relating to produce, herbs and cut-flowers in hydroponic versus traditional farming studies. Other plants with different composition, such as Wood Fiber will be excluded from this review. Insects, microbes, and bacteria are excluded, as the scope relies solely on plant species. There are many different

intervention types throughout the studies including: ploidy level, climate conditions, light exposure, water additives, and water nutrients level.

Table 1: Inclusion and exclusion criteria.

Category	**Inclusions**	**Exclusions**
Setting	Location for these comparative studies can be found around the globe.	Outdoor climate is not necessary because hydroponic farming climates can be controlled.
Perspective	Plants include produce, cut-flowers, herbs.	Other plant species like Wood Fiber. Other species including insects, microbes, bacteria will be excluded in the review as well.
Intervention	The studies should consider interventions like water nutrients level, additives (e.g organic acid), ploidy level, and flower species, climate conditions (e.g temperature, humidity), light exposure, water quality, pH level, time developing	
Comparison	The comparison will focus on the productivity of Hydroponic farming versus traditional soil farming.	Other types of modern farming like aquaponics will be excluded as they include more variables (fish).
Evaluation	The productivity of the system will be evaluated by: Plant height (in any metric), plant weight (in any metric), % of natural compounds, biochemical, antioxidant activities, and sensitivity (in any metric).	Any other metrics that relate to plant strength: e.g. respiration rate, movement, and reproduction rate, infection will be excluded as not deemed relevant for inference with fragrance flowers.

Table 1 illustrates the topics included and excluded during the study to remain focused on the outcomes relating to those of the evaluation.

These inclusions and exclusions provide strict guidelines to funnel relevant results to the research question.

4.0 RESULTS

4.1 Sustainability

11 out of the 14 (78%) of the essays reference hydroponic farming as more sustainable than traditional soil farming. Puturu, et al. elaborates that 48% of the emissions coming from agriculture occur on the farm. These emissions are caused by fertilizer, tractors, and other machinery [8]. Verner et al., and Fussy et al., agree and state that hydroponic farming reduces waste, reduces pollution, consumes less water, relieves soil and land degradation, emits fewer greenhouse gas (GHG) emissions, and preserves biodiversity compared to traditional soil farming [9], [15]. *Figure 1* illustrates that traditional soil farming uses around 7 times as much water as the two hydroponic farming methods [9].

Figure 1: Lettuce Yield, Water Use, and Number of Growing Seasons per Year for Two Hydroponic Systems and the Traditional Soil Method in West Bank and Gaza [7]

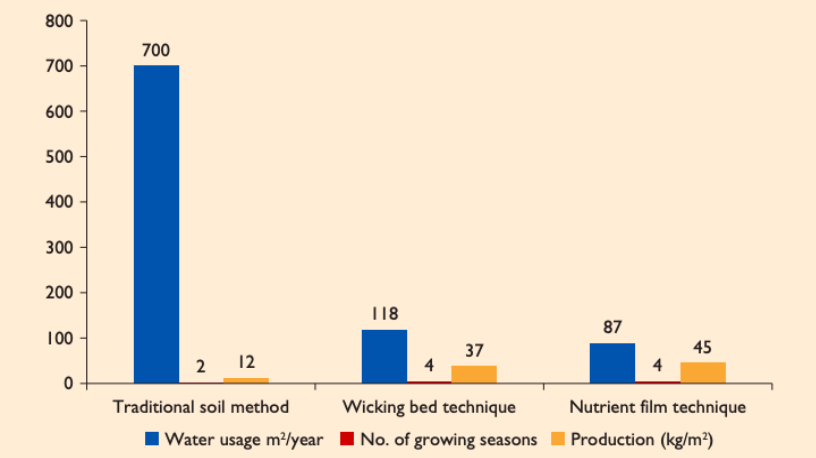

Figure 1: Study by the Applied Research Institute - Jerusalem, as shown in Comparing Lettuce Yields, Water Usage, and Growing Seasons between Traditional Soil Farming and Two Hydroponic Techniques – The Wicking Bed and Nutrient Film Techniques – in West Bank Gaza.by the World Bank.

Surendan et al., and Fussy et al., highlight how the circulatory water system is much more environmentally friendly than polluted wastewater in traditional farming [10],[11]. Fussy et al., found that wastewater can limit between 44 and 53% of global warming when paired with direct leachate recycling (DLR) and membrane filtration (MF) processes [11]. The DLR and MF processes are systems used to recycle nutrients in a hydroponic system. The productivity comparison will ultimately determine if this system is suitable for the beauty and fragrance industry.

4.2 Productivity

Preliminary studies reveal hydroponic farming produced more plant weight than traditional farming. Ai, P. et al. found that hydroponic farming cultivated 20.25 ± 5.70 g of dry weight in comparison to the 12.58 ± 1.68 g of traditional farming [12]. Verner D., et al. write about a study where hydroponic farming had over 3 times more yields than traditional farming: 37 kg/m2 to 12 kg/m2 [9].Gumisiriza et al, found that both hydroponic and traditional soil farming produced the same 60 pounds of lettuce [15]. Surendran et al, found that the hydroponic plant produced 380 grams, in comparison to the 235 grams yield from soil grown flowers [10]. The height of plant properties is commonly measured and included in the yield comparison.

The height of hydroponic and traditional flowers were inconsistent and may be significant. Syed et al. compares the growth of spinach to hydroponic (no-soil) to geoponic (soil) systems. After comparing the two farming methods, the researchers found that the qualities of the hydroponic spinach were stronger than those which were soils grown [13]. The hydroponically grown spinach averaged a height of 22cm, stem size of .15cm, and leaf area of 1.95 cm^(2). The average height of the soil grown spinach was 16.59 cm. While the mean stem size was .12cm, and leaf area was 1.50 cm^(2) [13]. Conversely, Surendran. et al found that the hydroponically grown

plants had the smallest root length in comparison to the other methods [10]. It is important to consider natural compounds in each plant, to better understand their molecular strength.

4.3 Natural Compounds

The following preliminary studies suggest hydroponically grown flowers have increased levels of natural compounds, excluding volatile organic compounds (VOCs). The hydroponic chrysanthemums of Ai, P et al.'s research had around 4% higher active compounds than traditionally grown chrysanthemums [12]. The hydroponic flowers have higher levels of flavonoids: chemical compounds that are responsible for the flower's taste and smell. These hydroponic flavonoid levels are around 43.22 ± 2.05 mg/g, compared to the 36.75 ± 3.50 mg/g in traditional farming [12]. Similarly, Zantana et al., shows hydroponically grown *Helichrysum Odoratissimum* had much higher flavonol and antioxidant levels [15]. Flavonol compounds are a subgroup within flavonoids, also responsible for flavor. Zantana et al. uses Frerard Reducing Antioxidant Power (FRAP) to measure the antioxidant activity within field grown and hydroponic grown plants. The hydroponic FRAP measured activity totaled to 3078.55 ± 355.44 (µmol AAE/g) in comparison to the 2198.50 ± 284.01 (µmol AAE/g) in traditional farming [15]. Syed et al. found that their hydroponically grown plants were darker green in color [13]. Lighter color green means there is less chlorophyll (a natural compound) as compared to a dark and vibrant green [13]. Conversely, Zanatana et al. measured the volatile organic compounds (VOCs) of the flowers, resulting in 116 compounds for both hydroponic and field grown [15]. Ujala et al., came to a similar conclusion which shows the VOC were highest in open field grown plants [17].

5.0 DISCUSSION

5.1 Sustainability

Hydroponic farming is more sustainable than traditional farming, and it is established that it can be used to restrict emissions and transportation costs in the beauty and fragrance industry. Most of the emissions in the agricultural industry come from extensive water use, land and soil degradation, pesticides, fertilizers, and CO2 from large scale tractors [9]. *Figure 2* illustrates global areas which use agriculture to produce flowers for fragrances [14].

Figure 2: Location of raw materials for fragrances [14]

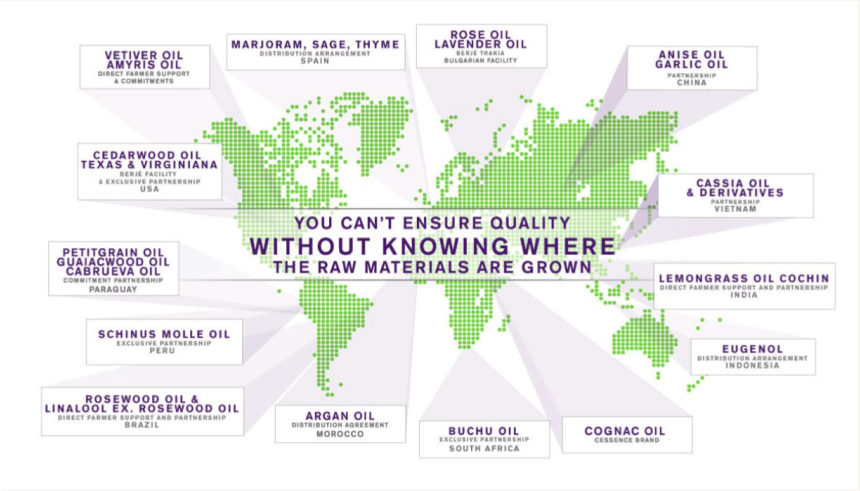

Figure 2: Berjé map of where fragrance raw materials are located around the world [14]

Hydroponic farming is a climate controlled environment, so there is less of a need for fertilizers, pesticides, and its use totally eliminates the land and soil degradation that we see in traditional farming.

5.2 Productivity Metrics

Hydroponic farming produced consistently heavier yields than traditional farming, but heights varied noticeably. Verner et al. shows that hydroponic farming increases yield by 3 times [9]. Ai, P et al's statistics show that hydroponic farming increased yield by almost double [13]. Surendran et al, illustrates a little over 1.5 times increase of hydroponic farming compared to traditional farming [10]. The variability in reported increases may introduce concern as there is

no common percentage increase. The increased yield weight ultimately supports the hypothesis and provides evidence that hydroponic farming obtains larger yields than traditional soil farming. The general increase in yield suggests that hydroponic farming is a suitable option to grow fragrance flowers. Natural compounds will determine if the plants have suitable composition to be made into fragrances.

5.3 Natural Compounds

The results show a general increase in natural compounds, therefore providing evidence that hydroponic farming can produce high quality flowers. The darker green spinach from Syed et al., represents higher levels of natural compounds [13]. The increased flavonol, flavonoid, chlorophyll and antioxidant traits as observed previously provide sturdy evidence that natural compounds succeed in hydroponic conditions. Conversely, Ujala, et al. and Zantana et al., find that volatile organic compounds (VOCs) are higher in field grown farms [15], [17]. This could be a result of increased pollination from bees and animals in outdoor farming. Increased natural compounds prove that these flowers are just as strong, and they can be translated into the fragrance industry. Higher amounts of VOCs present a limitation for the adaptation of hydroponics in fragrance development.

6.0 Limitations

The inconsistencies in weight increase, height, and VOC's require future research to determine if hydroponic farming is the best alternative. Zantana et al, and Ujala et al,'s findings that the VOC percentages are higher in field grown plants might have to do with increased pollination from bees and other insects. Pollination in a hydroponic farm will have to be manually implemented with physical labor spreading pollen around each flower. Although tedious, the hydroponic's climate controlled environment protects from invasive species like insects, and disease which field grown crops are susceptible to. The varying difference in percentage increase, mentioned in 5.2, serves as evidence that hydroponic farming can increase yields, but not by any specific amount. The difference in yield increase could stem from differing nutrient levels, climatic conditions, and growth period. A future study should analyze the average increase of hydroponic farming to traditional farming. Regardless, each study showed an increase of yield, which is relevant to the viability of hydroponic farming to replace traditional farming methods in the fragrance industry.

7.0 CONCLUSION

Hydroponic farming is a suitable option for growing flowers used for fragrances. Implementing this technology into the beauty and fragrance industry will cut transportation and agricultural emissions, while eliminating related costs. Higher amounts of natural compounds and yields serve as a strong foundation permitting hydroponic farming to substitute traditional farming of fragrance flowers. Further research on VOC should be determined before implementing this technology.

PART 2

Moving Forward: Recommendations and Trailblazers

8.0 RECOMMENDATIONS

8.1 United States Department of Agriculture

The Federal Advisory Committee for Urban Agriculture and Innovative Production should advocate for the expansion of grant programs to include horticultural crops in industries other than food and beverage. The Federal Advisory Committee for Urban Agriculture and Innovation was implemented in the 2018 Farm Bill to increase support through policies and outreach, for urban, indoor, and other emerging agricultural farmers [18]. This committee can and should influence the secretary of the USDA to pass or alter policies. The Urban Agriculture and Innovative Production Grants are a series of competitive grants that seek to expand, "efforts of farmers, gardeners, citizens, government officials, schools, and other stakeholders in urban areas and suburbs," including business start-up costs. Hydroponic farming for fragrances would fall under this category as it is innovative, business oriented and propagating agricultural products. According to the USDA webpage, hydroponic farming only applies to 6/15 of the example planning and implementation activities for the Urban Agriculture and Innovative Production Grant [19]. Understandably, the food system is the main concern for the USDA. But, horticulture production is a subgroup of agriculture, and should be considered for grants to increase sustainability initiatives and to limit emissions. In turn, the Federal Advisory Committee for Urban Agriculture and Innovative Production should argue for increased support for horticultural products spanning over multiple industries.

The Federal Advisory Committee for Urban Agriculture and Innovative Production should create a new grant that targets horticulture in different industries. This grant should

support businesses who want to use agricultural technology in industries like medicine, cosmetics, beauty, and fashion. Beauty, medicine, and fashion companies can apply for a grant which will support initial start-up costs to implement sustainable hydroponic practices to locally produce products, limit emissions, conserve water, and increase traceability. There is so much room for creativity as large-scale hydroponic cotton farming can be used to substitute most agricultural practices, including cotton and medicinal plants. Implementing this grant program will encourage different industries to use hydroponic farming locally, and doing so would cut transportation and production emissions drastically.

8.2 Trailblazers: Ulé

The cosmetic company Ulé has successfully implemented hydroponic farming into their cosmetic production. Ulé grows plants for their cosmetic line, using vertical hydroponic farming. Vertical farming uses hydroponics to supply plants with nutrients in a vertical structure. Three crops they grow include Coleus, Tulsi, and Centella. Coleus is extremely rich in antioxidants and can contribute to +51% cell growth and +35% cell protection. Tulsi has natural compounds which are used to destress in cosmetic products, and Centella is used to stimulate collagen.

Since the hydroponic farm is climate controlled and locally processed, the fresh plant creates richer agents in cosmetics. Lindsay, the CEO, explains that the circular water system inside the vertical hydroponic farm recycles 95% of their water [22]. In an article published by Grozine, the R&D director explains this hydroponic farm, “can produce any plant all year round with no seasonal constraints,” limiting environmental factors increasing with the current climate emergency [23]. The company plans on introducing Lily of the Valley into their hydroponic farm. This is ground breaking because its natural lifecycle, exposed in nature, is too short to

extract essential oils. The controlled climate conditions, and localized processes introduce the possibility of using lily of the valley in perfumes and cosmetics.

8.3 Beauty and Fragrance Companies

Beauty and fragrance companies should consider implementing an in-house hydroponic system to replace select fragrance flowers that otherwise would be shipped from across the world. The hydroponic farm will limit scope 3 emissions of a company, producing high-quality fragrances from natural materials. Scope 3 emissions are defined as emissions from other aspects not controlled by the organization, including downstream and upstream activities in the value chain [20]. Since the hydroponic farm localizes the extraction of flowers in one spot, the costs and emissions needed to transport flowers and essential oils across the ocean are expedited. At Chanel, transportation emissions account for 20% of their carbon footprint [21]. Their sustainability reports are searching for more ways to eliminate them as their goal is to minimize emissions by 90%. 98% of their carbon emissions come from scope 3 emissions [21] . High scope 3 emissions are often the highest percentage of emissions across the beauty industry. The hydroponic farm will minimize the need for as many transportation carbon emissions as possible.

9.0 CONCLUSION

Moving forward, the USDA should encourage grant access by supporting horticultural farmers in industries other than food and beverage, specifically in the beauty, fashion, and cosmetic industries. This access will increase sustainable practices in the billion dollar industry. Plants are agricultural products and should be considered equally important in this fight for climate resilience. Ulé's incredible initiative to use hydroponic farming in cosmetic creation should be used as inspiration and motivation to adapt this local, sustainable and natural production process in fragrance production. With increasing climate emergencies, it is essential to instill sustainability initiatives that focus on lower emissions, benefiting the communities, and increasing profit. Cosmetic, and fragrance companies should consider implementing an in-house hydroponic system, as it significantly lowers scope 3 emissions from transportation emissions, and agricultural runoff. The hydroponic garden will increase economic security as plants are grown all year long, and safe from climate events such as drought, hurricanes, or flood. The money saved from overseas transportation can be used to employ more people in the community, strengthening the local economy. Ultimately, this solution touches on all three pillars of sustainability, making it a valuable option to increase sustainability in the beauty, fragrance and cosmetic industries.

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