Hydroponic farming for saffron cultivation in South Africa

Applied Research Project Proposal

submitted by

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EXECUTIVE SUMMARY

In South Africa, saffron has exclusively been cultivated using traditional farming methods. Although farmers face an increasing range of challenges and uncertainties, hydroponic farming offers an opportunity to alleviate many of these challenges, while simultaneously increasing output and reducing input expenses. The primary objective of the planned business venture was to investigate the possibility for hydroponic saffron farming in South Africa. The study focused on the development of a hydroponic system to cultivate saffron, aiming to mitigate the daily difficulties and risks faced by conventional farmers.

The study adopted a qualitative exploratory research approach. The study gathered substantial information through interviews with farmers in both the traditional saffron and non-saffron hydroponic industries. Interviewing farmers provided insights into the perspectives of persons involved in both the traditional saffron industry and the non-saffron hydroponic growing sector. Three hydroponic cultivators and one saffron farmer were interviewed face-face. Another Saffron farmer was interviewed telephonically.

The study examined the necessary requirements for hydroponic saffron cultivation in South Africa, covering technical factors for saffron cultivation, operational prerequisites, financials, market analysis, and challenges. The research findings highlighted the significance of hydroponic systems within an overall context. The main driving force for the transition from traditional farming to hydroponics was climate change among the participants. An essential challenge in hydroponic saffron growing is its relatively lower profitability compared to other crops like herbs, lettuce, and tomatoes. Including the concept of opportunity cost into the breakeven analysis will lead to a reduced repayment period, hence justifying the concept of saffron cultivation with a hydroponic system.

In conclusion, cultivating saffron with hydroponics is a sustainable solution when considering opportunity costs due to the value of the spice, and the increasing uncertainty of climate change affecting output.

KEY WORDS

Saffron, hydroponics, traditional farming, South Africa, climate change.

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CAGR	Compound Annual Growth Rate
ASSA	Association of Saffron Southern Africa

CHAPTER 1. INTRODUCTION

1.1 Background

South Africa is confronted with several challenges. Challenges such as corruption (Baron, 2019), power outages (Benjamin, 2020), and water supply (Adam, 2021; du Plessis, 2023) are only some of the difficulties that South Africans farmers face to name a few. According to Ndlovu (2023), the continued interruption of South Africa's electricity supply, known as load-shedding, poses a risk to the country's ability to ensure its food security. Christo van der Rheede, the Chief Executive Officer of Agri South Africa, states that load-shedding prohibits the food supply chain from cold-storing food goods, packaging, processing slaughter processes, and irrigation (Ndlovu, 2023). Also, it bears a substantial influence on hydroponic systems, which are incapable of functioning without a power source (AgriMag, 2022; The Gardener, 2023). Despite the continuation of load-shedding, ESKOM has implemented an 18.65 % rise in average tariffs (Ngwenya, 2023). The burden of ever-increasing costs that comes with the use of generators under load-shedding schedules is made much heavier by this development. In the end, the consumer will pay more for food, which will have a significant impact on the middle class and lower-class consumer.

In addition to this, load-shedding has an effect on the water supply (Asaram, 2023). Because water cannot be transported or treated without the use of energy (Kotze, 2012), this presents a significant obstacle for residential communities, commercial mining operations, and agricultural operations. The fact that South Africa is one of the world's 30 driest countries (Aina et al., 2023) leads one to believe that the nation should pay closer attention to the preservation of its limited resources, particularly with adverse consequences climatic change have on weather patterns.

All nations are affected by climate change and should collaborate to find ways to slow it down or completely stop it. Unfortunately, stopping climate change is not a short-term solutions and is here to stay in the foreseeable future (Hulme, 2020). According to a study conducted by Roffe et al. (2021) , seasonality patterns are expected to grow in South Africa, and the shorter wet season will be centred around the winter months. Furthermore, Calzadilla et al. (2014) states that climate change will increase temperatures and result in less rainfall. Both authors raising their concerns about the impact of climate change will have on water availability, which will have its consequences on food production. One such example can be seen in India and Spain, where the effects of climate change on saffron agriculture have been significant in decreasing yield (Jones, 2023; Kour et al., 2022). With agricultural food productivity of Africa remaining low for centuries, it requires individuals to consider alternative farming methods (Gerbremeden, 2016). Input costs are increasing, necessitating greater output with less input (Gerbremeden, 2016).

Another underlining issue farmers has encountered and can worsen is soil erosion and degradation. This is the process through which the topsoil layers are stripped of their minerals and vitamins (Gashgari et al., 2018). Human activities such as allowing overgrazing, deforestation, and land removal for crop production are especially detrimental to the soil's uppermost layer (Mulvihill, 2021).

It is time to investigate more sustainable farming options because the agricultural business is now dealing with issues such as load shedding, interruptions in water supply, climate change, soil erosion and degradation, and rising input costs. As a result of the inevitability of encountering obstacles, it is essential for people to devise methods that can lessen the impact of these challenges. The use of hydroponic farming is such a method. Hydroponics system grows crops without soil mainly through vertical farming. Crops absorb nutrients through a water circulation system (Kumar et al., 2023). The initial investment in hydroponic farming may be substantial; nevertheless, in the long run, it provides farmers with a greater degree of control over the environmental shifts and obstacles that are experienced in South Africa.

Planting saffron, which is the world most expensive spice, in hydronic environment can aid many benefits (Kour et al., 2022). It can mitigate many of the aforementioned challenges, since the farmer can control the climate, produce higher yields with less input.

1.2 Research problem

Various agricultural researchers acknowledge the importance of developing sustainable agricultural production systems (Eyhorn et al., 2019; Pacini et al., 2003; Rigby & Cáceres, 2001). The literature has shown hydroponic farming to be one of the most sustainable farming methods (Kannan et al., 2022; Suhl et al., 2016). While the advantages (Kannan et al., 2022; Kour et al., 2022) and disadvantages of hydroponic systems (Brahlek, 2023; Lee & Lee, 2015) have been well documented, especially when comparing it to conventional farming, there is no published literature available exploring the cultivation of saffron with hydroponic systems in South Africa. A comparable study has documented a theoretical application of a hydroponic system specifically created for cultivating saffron, which depends on sustainable energy sources (Kour et al., 2022). The gap found in this research is the need to conduct market research to assess the economic viability of implementation. The conventional method of growing saffron served as a point of comparison for the hydroponic farming technique that was investigated in this study. The proposed study applied business theories and research to develop a business venture model to cultivate saffron in South Africa using hydroponic system. Only a few selected farmers in South Africa effectively cultivate saffron using conventional methods, but lack the use of a hydroponic approach.

1.3 Background of cultivating saffron in hydroponic farm

Saffron is grown in many different countries, although Iran is the producer of 90% of the world's saffron (Cardone et al., 2019; Kothari et al., 2021), and India is the country that imports the most saffron (Kothari et al., 2021). The vast majority of saffron comes from farms that practice more conventional techniques of agriculture. This is due to the fact that the spice market is the most important market for saffron (Grand view research, 2020) and the spice market does not have to conform to the stringent requirements that are required by the medicinal market.

Only a select few farmers in South Africa have been successful in cultivating saffron (van Eeden, 2021). All of whom cultivated their saffron crops using the more conventional techniques. It was not possible to locate any studies pertaining to the cultivation of saffron in South Africa utilizing the hydroponic approach. As a result, this presents a possibility for the cultivation of saffron through the use of hydroponics. Given that this is the most expensive spice in the world (Piccantino, 2023) an increase in output can be of tremendous financial advantage to the farmer. Growing plants in a hydroponic setting gives a person the opportunity to sell their produce not just to the markets for the dyeing of textiles and spices, but also to the market for medicinal uses (Piccantino, 2023).

Farmers in South Africa are not only forced to contend with numerous difficulties, such as the intermittent supply of water and electricity as well as rising input costs, but also with risks. The natural environment is the primary source of risk for the agricultural sector (Riaman et al., 2022). The farmer will have more control over the majority of these dangers if they use hydroponic farming. This strategy allows for the control of risks such as shifts in the weather conditions, humidity fluctuations, diseases in the soil, and inadequate water quality. The threat of farming can be mitigated significantly by the management of the inherent difficulties posed by the natural environment.

Not only does hydroponic farming present opportunities for farmers, but this technique also has the potential to be used in virtually any setting. This opportunity is available to a large number of people as a result of the scalability of hydroponic farming, which ranges from a small-scale operation (Xydis et al., 2017), rooftop hydroponic farming (Ezziddine & Liltved, 2021) to a large-scale farming operation (Saint Louis Science Center, 2021). Saffron is expected to enjoy a Compound Annual Growth Rate (CAGR) of 8.5% from 2020 to 2028, as stated by (Grand view research, 2020). However, (PR Newswire, 2023) stated a CAGR of 8.1% in the United States, both affirming profitable growth rates for a high end commodity. Of this growth, roughly a third of it will be provided by medical applications (Grand view research, 2020). As a result, hydroponic saffron cultivation presents South African farmers and investors with a potentially lucrative business opportunity.

1.4 Scope of the proposed business venture

The feasibility of growing saffron in hydroponic systems was investigated in this study. This included an investigation of different saffron cultivation enterprises both locally and abroad. Through research, optical climatic conditions were assessed to determine the ideal environment to set up a hydroponic operation. Additional changes to alter climate condition for cultivation would lead to unnecessary additional costs.

The proposed business venture raised awareness about the advantages of hydroponic farming in the long run. The study also found the most effective hydroponic method to cultivate saffron. The implementation of a hydroponic system was the focus of the study, with the goal of reducing the challenges and risks that farmers encounter daily. In addition to this, the business venture shed light on the operational, commercial, and infrastructure difficulties that may be a potential threat to the cultivation of saffron.

1.5 Objective of the proposed business venture

The objective of the proposed business venture was to explore potential for hydroponic saffron cultivation in South Africa. This was achieved through the process of engaging with experts in the field of hydroponic crop cultivation, as well as with conventional farmers who specialize in saffron cultivation.

In South Africa, saffron has only been grown through conventional cultivation. While farmers are exposed to a growing array of challenges and risks, hydroponic farming provides a chance to mitigate a number of these issues, while also increasing productivity and decreasing input costs.

The researcher investigated the important needs for hydroponic saffron cultivation in South Africa, including all vital aspects. These include:

- Technical aspects to grow saffron
- Operational requirements
- Financials
- Market research
- Challenges

The aim of the proposed business venture was to explore the feasibility of hydroponic saffron cultivation in South Africa.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The history of Crocus Sativus, commonly known as saffron, dates back more than 3 500 years (Dai et al., 2021). The saffron plant belongs to the Iridaceae family, which comprises of Crocus, Gladiolus, Iris, and Ixia (Di Primo et al., 2002). The spice originated in the Middle East, but today is cultivated in many countries, including Iran, India, France, Italy, Greece and Spain (Britannica, 2023; Cardone et al., 2019). Iran is the largest producer of saffron in the world and contributes 90% of the world's saffron supply (Cardone et al., 2019; Kothari et al., 2021).

Saffron is the most expensive spice in the world and, depending on the quality of the product, its price may range from 3 000 to 14 000 Euros per kilogram (R55 000 to R275 000) (Piccantino, 2023). In South Africa, saffron sells for around R200 000 per kilogram (Ken, 2021). In addition to being used as seasoning in cooking, saffron has a variety of other applications, such as in textiles and fabric dyeing, for medicinal purposes, and in the fragrance industry (Piccantino, 2023). The greatest contributor to the price of saffron is the labour-intensive harvesting process. Saffron stems are triploid and must be plucked separately (See Figure 1). According to CNN Money (2008), the weight of a saffron flower stem can range from 200 to 300 stems per gram; hence, one kilogram of 100 000 flowers can be sold for R200 000.

In South Africa, saffron has only been successfully cultivated by a small number of farmers (van Eeden, 2021). These farmers have focused much of their agricultural efforts into the culinary side of saffron due to its less-stringent quality requirements, the expanding culinary market and because it is the most lucrative application of saffron. There was no evidence that anyone had attempted to cultivate saffron in South Africa using hydroponic systems that could be found. The purpose of this literature study is therefore to focus on the contrast between hydroponic farming and traditional agricultural methods. It will concentrate on how hydroponic operations can be beneficial to agriculture in the long term and give larger yields with reduced input costs, all while obtaining a lower carbon footprint than conventional farming methods. The literature review further aims to provide a comprehensive understanding of the saffron flower and the potential market opportunities for the business venture.

Figure 1: Saffron flower and stems (EdenBrothers, 2023)

2.2 Saffron

Saffron is a purple flower with three scarlet stems that contain the natural chemical that gives the plant its versatility (See Figure 1). Saffron apocarotenoids (crocin, picrocrocin, and safranal) are the leading qualitative indicators (Fallahi et al., 2021). Crocins, picrocrocin, and safranal are the secondary metabolites responsible for the stems' colour, flavour, and scent, respectively (Li et al., 2018). These three primary components are subject to change based on the prevailing climatic circumstances, as well as the cultivation practices of the farmers (Kothari et al., 2021). Different industries value the combination of the three key components differently. In short, Crocins is desirable for the textile market and culinary market due to its dark colour for dyeing or natural food colouring. Crocins is also high in anti-oxidants, making it appealing for the medicinal industry (Kothari et al., 2021). Picrocrocin, responsible for the bitter taste, and safranal, popular for its flavouring and aroma, are the most attractive for the culinary market. However, the economic value of saffron is determined by the combination of crocins, picrocrocin, and safranal (Predieri et al., 2021). The quality of saffron is most widely determined by ISO/TS 3632-2:2003 standards (del Campo et al., 2010b).

In addition, crocin, a water-soluble pigment, gives saffron its characteristic golden yellow colour. Crocin is a carotenoid chemical component that is present in crocus and gardenia flowers. In essence, Crocin affects colour, but larger concentrations of Crocin have other medical applications. For instance, due to its anti-oxidant and anti-inflammatory properties, Crocin has anti-cancer benefits and is beneficial for cardiovascular and neurological illnesses. (Rameshrad et al., 2018). However, the cultivation of saffron for medical use is subject to more stringent requirements than for culinary use (Fallahi et al., 2021).

Of note, certain elements of saffron can be harvested at different stages of the plant's biological development, the latter consisting of five major stages. These are: sprouting, flowering, leaf development, development of daughter corms and dormancy (Lopez-Corcoles et al., 2015). For example, picrocrocin concentration will reach its maximin concentration at the end of its flowering stage (Chrysanthou et al., 2016). Interestingly, safranal is not present in fresh saffron flowers; it only forms after the dehydration process (Kothari et al., 2021). However, picrocrocin and safranal are related in that the harvested concentration of picrocrocin determines how much safranal is produced during the dehydration process (del Campo et al., 2010b).

The above section aimed to provide a brief introduction to the saffron plant and its variety of applications and uses. Saffron farming and the technicalities associated with the two known methods will be discussed next: beginning first with the traditional farming method, followed by the second, which is hydroculture cultivation.

2.3 Traditional farming method

2.3.1 *Planting conditions*

As a plant, saffron is extremely adaptable and can thrive in a wide variety of environments and under several climatic conditions. These conditions include the state of the soil, the weather, and water availability among other factors (Fallahi et al., 2021). Because of the plant's adaptability, it may be grown in a wide variety of environments in South Africa. There is evidence that saffron grows optimally in climates which are similar to those found in the Mediterranean (Dai et al., 2021; Lage & Cantrell, 2009). Nevertheless, both (Karoo Fresh, 2023) and (van Eeden, 2021) state that climates similar to those found in the Karoo in South Africa also prove to be favourable conditions for the saffron plant to grow in. Lage and Cantrell (2009) state that saffron can grow in areas with an average rainfall of between 100 to 300mm. Whereas (Karoo Fresh, 2023) statement supports this, they suggest a slightly smaller range, namely that a rainfall of between 200 and 350mm is ideal. Please see the areas circled in red in Figure 2 below, as these are areas with sandy soil, which meet the average rainfall conditions.

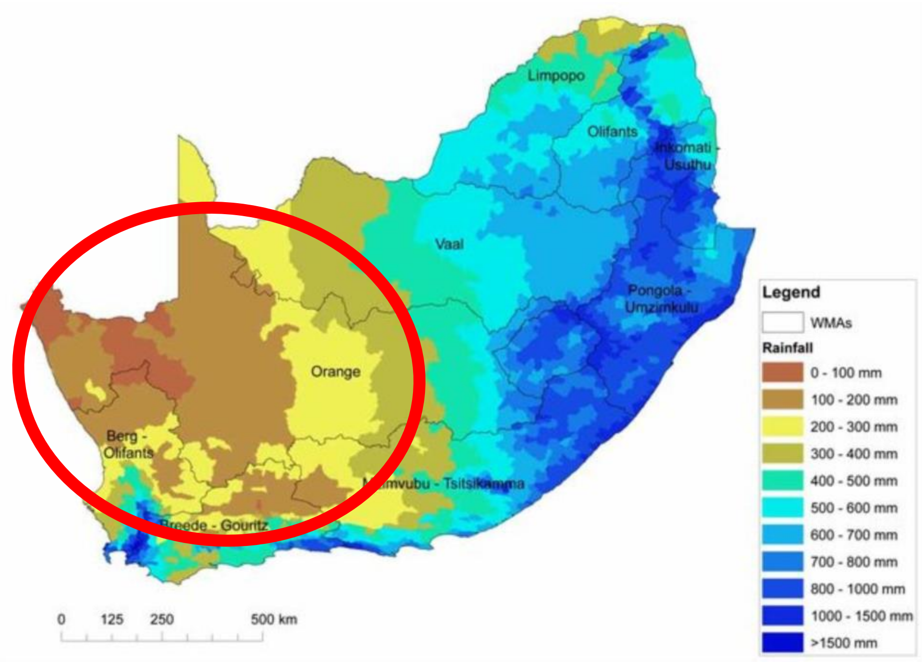


Figure 2: Map of South Africa's annual rainfall (Cole et al., 2018)

Sandier soils are ideal for growing saffron, according to Sativus (2023), Gresta (2010) and MasterClass (2021), therefore, conditions present in the Karoo and the Kalahari desert are ideal for planting saffron in South Africa. Iran, with similar conditions as the aforementioned, is the largest producer of saffron, but according to Karoo Fresh (2023) & Barnes (2022), New Zeeland has also successfully cultivated saffron despite their predominantly cold and wet weather conditions. Therefore, although some conditions may be more favourable for cultivating saffron than others, the spice may be grown in a wide variety of environments. Bennie Engelbrecht, the founder and CEO of South Africa's largest saffron producer, Safricon, planted the very first saffron bulbs in 2013 (Saffricon, 2023a). The saffron plants that Engelbrecht planted in Pretoria on small scale were so successful that the farmer is currently producing on a large scale in Calvinia, near Tankwa in the Karoo.

The capacity of saffron to absorb moisture is an important aspect to consider. Saffron cultivation requires soil that drains effectively; otherwise, excess moisture might have lower yields or possibly cause the spread of fungal diseases, which would result in no harvest at all (Cardone et al., 2019). The nutrients that are present in the soil are also paramount to consider. Saffron needs a mixture of nitrogen, phosphorus, and potassium in a ratio of 5:10:5 (PictureThis, 2023). If saffron is planted in soil that was previously used for the cultivation of the Iridaceae family's plants, the saffron's growth will be stunted as both processes remove the same nutrients from the soil.

Studies have showed that the saffron plant can withstand temperatures ranging from -18 degrees Celsius to an average maximum temperature of 36 degrees Celsius, making this a plant that is incredibly resilient (Karoo Fresh, 2023; Lage & Cantrell, 2009). Although saffron can endure harsh climatic conditions, saffron is susceptible to being damaged by weeds and wild animals or rodents. The growth of weeds throughout the year might cause the bulb to become overgrown and prevent it from blossoming (Sativus, 2023). It is essential to remove weeds, preferably by hand, in order to prevent bulbs from being suffocated (Kothari et al., 2021). For wild animals, the green leaf of the flower is very appealing during the winter when the plant grows. The animals will graze the leaves but end up spoiling the harvest. Rodents will eat the bulbs underground. When the plants start turning brown it is already dying, by which time is too late to revive the plant. There are many ways to protect the harvest from animals and rodents. These include among others (Sativus, 2023):

- Fencing plantations.
- Using stench, like garlic cloves.
- Planting the flower in a plastic container.
- Using vibration to shield against rodents.
- Using ultrasonic sound to fend animals.

2.3.2 *Planting saffron*

The environment in which saffron can flourish has been discussed. The actual act of planting saffron will be the primary emphasis of this section. It is recommended that saffron be planted in the southern hemisphere during the months of March to May (van Eeden, 2021), during which time temperatures should range from 20 to 27 degrees Celsius on average, and the soil should not be too wet (Kothari et al., 2021; Sativus, 2023). Please refer to Figure 3 for an explanation of how saffron grows in the southern hemisphere. The climate of your surroundings will have an effect on the date you plant saffron. If the climate is warmer, you can plant the bulbs later in the winter, once the temperatures have dropped.

Either bulbs saved from a previous harvest or bulbs purchased from a farm or distributor can be used. After one year, bulbs begin to reproduce, at which point they are referred to as the daughter bulbs (Kothari et al., 2021; Sativus, 2023). See Figure 3 for annual growth rate of saffron in the southern hemisphere. These bulbs are small, therefore there is no guarantee that they will provide a harvest after one year. It is recommended that larger bulbs (10g or more) be purchased from a farm or distributor to ensure a successful harvest (Mollafilabi et al., 2014; Sativus, 2023). Between February and April, bulbs undergo dormancy and do not require watering. However, under optimal weather conditions, each bulb is capable of producing up to three daughter bulbs (Smith, 2022). Since the seedlings can be replanted or sold, this is an additional source of revenue to consider.

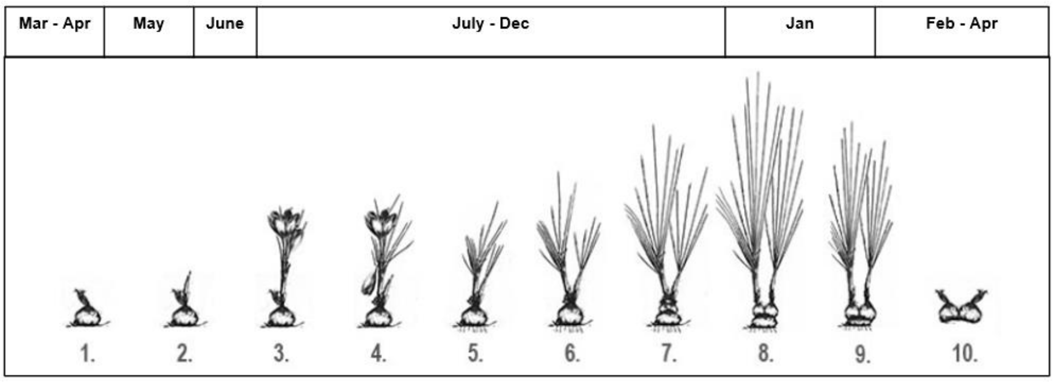


Figure 3: The annual growth cycle of saffron in the southern hemisphere (*Adapted from (Sativus, 2023)*)

Saffron can be grown using one of the following techniques: the first is the traditional practice of planting saffron seeds directly in the ground as described above. The second method makes use of hydroponics and other forms of modern agriculture. Because the farmer can make use of the land and natural environment that is already available, the conventional method has a lower initial investment cost than the hydroponic method. The purchase of the bulbs is the only significant initial cost that would be incurred. See Figure 4 how to plant saffron using the traditional method:

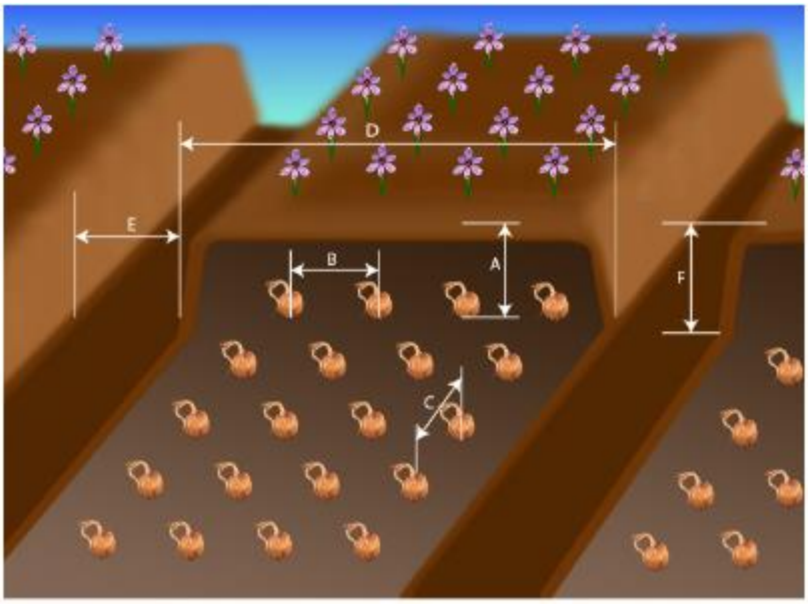


Figure 4: Seedbed system to plant saffron (Sativus, 2023)

A) Planting depth, 10 – 15 cm.
B) Row spacing, 15 cm.
C) Distance between the bulbs on the row, 5 - 10 cm.
D) Width of the seedbed, 75 cm.
E) Width of the walkway, 25 cm.
F) Height of the seedbed, 15 – 35 cm.

2.4 Hydroculture cultivation methods

Methods of hydroculture cultivation include hydroponic, aquaponic, and aeroponic systems. Each has unique advantages. In the next section, all three methods will be covered, with the primary goal being to determine which method produces the highest quality saffron.

2.4.1 *Hydroponic*

Hydroponic agriculture has gained popularity in the food industry as an environmentally friendly alternative to traditional farming (Sambo et al., 2019). Hydroponic agriculture is a technique by which plants are grown utilizing water-based nutrients as opposed to standard soil-based approaches. According to (WWF, 2023), fifty percent of the world's topsoil has been lost to erosion and degradation. Soil erosion is the process of soil decomposition caused by water and wind (Poesen, 2018). The causes of soil deterioration are improper agricultural management, deforestation, and overgrazing (Jie et al., 2002). Soil erosion and degradation strip soil from its minerals and vitamins, therefore, fewer crops can be grown (Gashgari et al., 2018). Thus, environmentalists view hydroponic agriculture as a sustainable (and favourable) alternative. Hydroponics has several advantages, such as soil-less cultivation, efficient land utilisation, clean planting environment, conservation of fertilisers and resources, reduced water use, and maintenance (Pomoni et al., 2023). The disadvantages of hydroponics are substantial initial capital expenditure, technical expertise requirements and increased energy consumption. In addition, hydroponic systems can be stacked vertically, hence there is a markedly increased yield per square meter of land. In theory, this appears to be very advantageous for farmers, but there are disadvantages.

The disadvantages to hydroponic systems as defined by (Brahlek, 2023; Lee & Lee, 2015; Pomoni et al., 2023) include:

A) A higher initial investment compared to conventional farming techniques.

B) As the system is connected in series, diseases propagate significantly more rapidly, such as fungi.
C) This system also necessitates a higher level of management expertise that monitors and provides constant maintenance.
D) And in the context of South Africa, power outages hamper this system.
E) Increased energy consumption

Even though hydroponic systems do consume more energy compared to conventional farming methods, it is feasible to construct a self-sustaining system by utilising renewable energy (Jaimes et al., 2019). To expand on the above, as mentioned, hydroponic cultivation requires a greater initial investment in the form of additional infrastructure, such as an enclosed environment, a water irrigation system, shelving, air pump, and container storage (Gashgari et al., 2018). By contrast, in traditional farming, saffron cultivation simply requires irrigation and manure fertilizer. However, hydroponic farming has numerous advantages. As mentioned, a major advantage of hydroponic farming is that it is not affected by soil erosion. Other advantages include (Kannan et al., 2022):

A) Better control over the quality of crops.
B) Higher yield per square meter of land
C) Uses 70-80% water.
D) Less prone to pesticides or soil borne diseases.
E) Full control over climate conditions

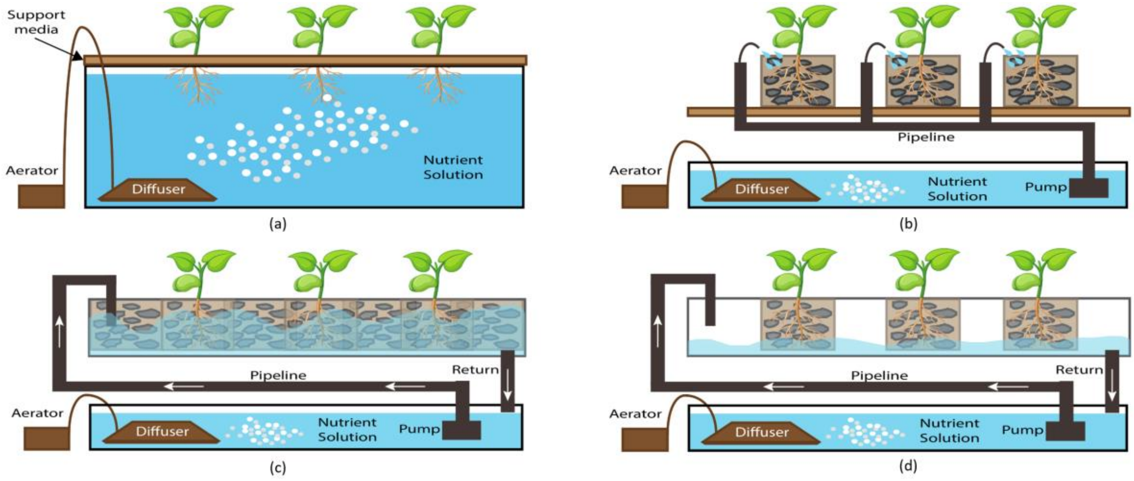


Figure 5: Different types of hydroponic systems. (a) Deep Water Culture. (b) Drip System. (c) Ebb and flow. (d) Nutrient Film Technique (NFT). Adapted from (Velazquez-Gonzalez et al., 2022)

Furthermore, with hydroponic farming environmental conditions can be mediated to optimise saffron yield. Since farmers can manage the plant's growing environment, including temperature, humidity, airflow, and CO2 levels, hydroponics guarantees more consistent results in flavour and harvest (Godge, 2022). This contributes to enhanced profitability and satisfaction with customers (Godge, 2022). Maintaining a constant temperature is one of the most critical environmental factors for ensuring the quality of saffron, which can be accomplished through hydroponic cultivation (Kumar et al., 2009). The downside of mediating the environment is the cost. The more changes are made to the environmental condition, the more expensive it will become to use this method of saffron farming. Nonetheless, once optimised, hydroponic systems can achieve yields of 20-25% higher than traditional soil farming with productivity 2-5 times higher (Gashgari et al., 2018). Indeed, a recent study demonstrated that saffron can generate yields up to 16 times more than soil based farming techniques (Nardi et al., 2022)..

Hydroponic farming consists of four main systems (See Figure 5). Each of these are discussed in turn below.

A) Deep water culture
B) Ebb & Flow
C) Drip Hydroponic
D) Nutrient Film technique

A: Deep water culture

Deep water culture is one of the most productive hydroponic techniques and includes the continuous recirculation of nutrient and oxygen-rich solutions to plant roots. This requires a substantial amount of water to ensure nutritional stability. This method needs a continually operating air stone and air pump to avoid oxygen deficiency and root suffocation. This method is ideal for the cultivation of non-flowering herbs and tiny plants such as tomatoes, peppers, and lettuces. This technique may be used in situations when yield maximization is desired, since it doubles the plant's growth rate (Gunasekaran et al., 2019).

B: Ebb and Flow

In the ebb and flow system, a pump is used to transport nutrients to the roots of the plants, which are suspended in the canal below. This conduit is then lined with a substrate or support material that is suited to the plants that are being grown in it. The channel contains nutrient-rich water, which is absorbed by the plant's roots as it travels down the channel. This is a continual process. The channel’s extensive root system makes it difficult to remove plants, making it suited only for small plants (Kour et al., 2022).

C: Drip Hydroponic

Emitters slowly sprinkle nutrient-rich fluid from main reservoir. Onions, melons, strawberries, cucumbers, and peas grow well in this setup. However, its intricacy makes it unsuitable for smaller projects (Gentry & Sveriges, 2019; Kour et al., 2022).

D: Nutrient film technique (NFT)

The nutrient film technique (NFT) system functions similarly to an Ebb and Flow system. The only difference is that the channel has a slope of 1 to 40° so that the nutrient-rich water can be gently transported via the roots of the plants (Kour et al., 2022). This method works best with plants that have a lower watering requirement. (Kour et al., 2022) comprehensive study indicates that the NFT is the best approach for hydroponically cultivating saffron. This approach is ideal because saffron requires minimal water, the structure of saffron roots, and the inexpensive cost of constructing this system.

2.4.2 *Aquaponics*

Aquaponics uses the same technology and infrastructure as hydroponics (See Figure 6). The only difference is that aquaponics gets it nutrition from fish waste (Suhl et al., 2016). Non-exchange-based farming is regarded as the most effective agricultural technique. The flowers absorb nutrients from fish excrement, thereby purifying the water. Tilapia is the most used fish. This fish is popular because of its resilience to many diseases, rapid growth, and adaptability to varying water quality (Javanmardi et al., 2022).

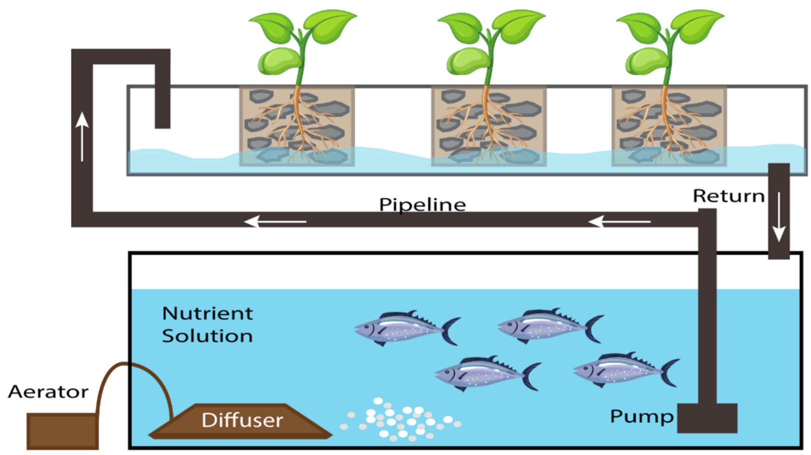


Figure 6: Aquaponics system (Velazquez-Gonzalez et al., 2022)

2.4.3 *Aeroponics*

The term "aeroponics" refers to an artificial technique of plant growing that does not involve the use of soil. Instead, the roots of the plant are suspended in the air, and the plant's nutrients are delivered to it by spraying them through nozzles either constantly or at regular intervals (Lakhiar et al., 2018)

2.4.4 *Summary*

In summary, saffron is an ideal plant to cultivate using any hydroculture technique. Due to its stature, the plant is manageable, requires little water, and reproduces spontaneously (Kour et al., 2022). Better controlled environments provide better quality of saffron, and are able to achieve higher concentrations of bioactive molecules such as crocin, picrocrocin, and safranal (Godge, 2022; Kour et al., 2022). Based on the various systems available for hydroponic cultivation and the optimal conditions required for the best possible saffron yield, the nutrient film technique (NFT) appears to be the best suited method. It seems to have a lower initial cost compared to the other methods and provide the optimal measured conditions for saffron cultivation. The next section will address the process of harvesting and preparation of saffron. Because harvesting and preparation are similar in hydroponics and traditional farming, they will be discussed in the same section.

2.5 Harvesting

2.5.1 *Harvesting saffron*

Harvesting saffron is a time-consuming and labour-intensive procedure requiring manual labour. The labour component of the process contributes towards the production cost of saffron (Asimopoulos et al., 2013). The picker picks all the flowers once the plant has produced new saffron stigmas. The flower is picked early in the morning when the corolla is still closed to retain the stigma's quality and colour (Kothari et al., 2021). The picker separates the leaves from the flower by holding the stem between the thumb and index finger. The stem of the flower is then broken, and the flower is placed in a basket for further processing (Denarda et al., 2021). The conventional farming approach requires the worker to constantly physically bend his/her back over to harvest the flowers, which is a significant difference between soil-based and hydroponic farming. Indeed, when harvesting saffron from a hydroponic system, it is termed hydroponic gardening which is done upright and provides an ergonomic benefit to the picker.

Additionally, feasibility studies on automated harvesting have been carried out; however, very few concepts have been successfully developed to the point where they can be used on a wide scale (Asimopoulos et al., 2013). More commonly used and widely accessible means of harvesting include semi-automatic harvesting equipment (Amirkhani, 2021; Denarda et al., 2021). There are demonstration videos available of machines used to harvest and process saffron (Baratzadeh, 2019; Rishe, 2022), however it is unknown how successful these machines are or what effect they have over the long term on the saffron bulb. Because of its fragility, the flower necessitates the use of precise technology. Of interest, iSaffron (2023) is one of the only organizations in the world that harvests saffron using artificial intelligence with only a minimum amount of assistance from employees. However, this is incredibly expensive and is only feasible for farming on a large scale, more specifically for cultivation in a greenhouse or by hydroponic methods.

2.5.2 *Dehydrating*

Once harvested, the picked flower is then taken to separate the stigmas from the flower. The stigmas are then left scattered to dry naturally in the shade (Kothari et al., 2021). Depending on the weather, the traditional drying process can take between two and three days. Of note, the dehydration is the most crucial post-harvest step (Cid-Pérez et al., 2021). This step has a significant impact on the final product's flavour, taste, and colour (del Campo et al., 2010a). India uses the traditional drying method, which has long drying times at low temperatures, but this reduces the crocin levels (Kumar et al., 2009). As a result, several studies have been undertaken to investigate the best way to dry saffron. del Campo et al. (2010a) discovered that drying at higher temperatures results in a greater uniform colour space (UCS) measurement for the stigma. USC is a metric used to assess the colour quality of saffron (Mac Evoy, 2005). This is a crucial feature of saffron because it is the first characteristic a potential client notices, which will influence the price or brand perception.

Furthermore, other researchers have investigated other non-conventional methods to drying saffron. These methods include freeze drying, electrical ovens, hot air, vacuum ovens, and infrared and microwave radiation (Cid-Pérez et al., 2021; Kothari et al., 2021). Chen et al. (2020) tested these techniques and found that freeze drying and oven drying provided the best results for crocin, picrocrocin and safranal. This is mainly because these techniques extract moisture with higher temperatures in a shorter time than the other methods. Both methods have high energy requirements, making these methods more expensive than conventional drying.

After reaching a maximum moisture content of 12%, the drying process is complete and the product is ready for use, according to ISO 3632 (2011) standards (Cid-Pérez et al., 2021). The stigmas will lose 80% of their weight after the dehydration process (Moratalla-López et al., 2021). As a result, 78 kg of flowers produce 1 kg of dried saffron stigmas (Kothari et al., 2021).

2.5.3 *Storage*

The most important consideration for storing saffron is to avoid saffron absorbing moisture. Moisture can initiate sprouting and discolouring, which will spoil the value of saffron spice (Kumar et al., 2009). Other environmental reactions to avoid are light exposure and temperature (Cid-Pérez et al., 2021). Saffron can be safely stored at an ambient temperature of 10 degrees Celsius (Kothari et al., 2021). The storage should be air tight and not be exposed to light. Not following these guideline will reduce the crocins (bleaching) and picrocrocin (flavour) concentrations (Cid-Pérez et al., 2021). Provided saffron is stored properly, it can achieve a shelf life of three to four years (del Campo et al., 2010a).

2.6 Hydroponic vs conventional saffron farming

The table below provides short summary of the unique differences between hydroponic and conventional farming.

Table 1: Comparison between hydroponic and conventional farming

Criteria	Conventional farming	Hydroponics	Reference
Investment cost	Low investment cost	High investment cost	(Brahlek, 2023; Kannan et al., 2022; Lee & Lee, 2015)
Operational cost			
Water	Uses 30 mm per week	Uses 70-80% less water	(Kannan et al., 2022; MasterClass, 2021; Sativus, 2023)
Input costs	Requires higher input cost	Require less input cost	(Kour et al., 2022)

Labour	Highly labour intensive, but can be reduced with semi-automated machines	Due to its controlled environment, it has access to more technology to reduce labour intensity.	(Amirkhani, 2021; Asimopoulos et al., 2013; Denarda et al., 2021)
Yield	Lower yield per square meter of land.	Higher yield per square meter of land.	(Gashgari et al., 2018; Kannan et al., 2022; Nardi et al., 2022)
Sustainability	Less sustainable due to climate change, soil erosion, urbanisation.	Sustainable, since it is considered a non-exchange based farming.	(Kannan et al., 2022; Suhl et al., 2016)
Produce quality	Less crop quality assurance.	Higher quality predictability as a result of greater control over the environment and input.	(Godge, 2022; Kannan et al., 2022)
Diseases	Diseases are more likely, but they can be sectioned and managed before the harvest is lost.	Pesticides and soil-borne diseases are less likely, but if present, they can spread rapidly.	(Brahlek, 2023; Lee & Lee, 2015)

2.7 Market Analysis: Saffron

In the next section the saffron market with a specific emphasis on the South African market will be covered. A brief overview of saffron adulteration will be discussed.

2.7.1 *Saffron markets*

Saffron can be marketed in three forms: powder, stigmas, and liquid, with stigmas being the most popular (Grand view research, 2020). As previously mentioned, saffron is utilised in the culinary, medicinal, cosmetic, and textile industries (Ambardar et al., 2021; Khilare et al., 2019). Due to its flavouring and colouring properties, saffron is utilized in the culinary industry. This industry is the largest consumer of saffron. Since it also has nutritional advantages, it contributes to the market's expansion.

Saffron is rich in antioxidants and is used to treat minor health issues (Mashmoul et al., 2013). Furthermore, saffron possesses anti-depressant, anti-anxiety, and anti-tumour properties (Nair et al., 1991; Shafiee et al., 2018). The cosmetic industry uses saffron for its anti-inflammatory and antioxidant properties, but most importantly, saffron is a source of bioactive compounds which act as a base for many cosmetic formulas (Addi & Berrichi, 2019; Vought, 2016). Saffron is most used for its colour properties in the textile industry, specifically for its unique golden yellow colour that can be extracted (Addi & Berrichi, 2019; Quintero Balbas et al., 2022).

2.7.2 *Saffron market in South Africa*

The world's most costly spice, saffron, is a profitable crop to cultivate. According to Corné Liebenberg, it offers excellent opportunities for emerging small-scale farmers (Leaveld Agrochem, 2023). Saffron can be sold for R200 000 per kilogram, conservatively. This price is set for the culinary industry, but saffron of a superior quality which is sold to other industries, such as the medical or cosmetic industries, may be sold at a higher price. Using a hydroponic system to cultivate saffron almost guarantees quality and yield, placing the farmer in a better position to sell to the high-end market and to remain competitive in the long term.

A CAGR of 8.5% is anticipated between 2020 and 2028, of which a third is projected to be sold to the medical industry (Grand view research, 2020). This further demonstrates that hydroponic cultivation is a worthy investment. Saffricon, the first commercial saffron producer, offers starter packs that enable farmers to begin production on a modest scale and acquire the knowledge required to compete in the commercial market (Saffricon, 2023b). Saffricon also offers a “buy back” option for bulbs purchased from them, thereby guaranteeing a future market and price for the farmer (Leaveld Agrochem, 2023; Saffricon, 2023b).

The Association of Saffron Southern Africa (ASSA) was founded in 2022 (Smith, 2022) and was established to ensure that Southern Africa receives a reasonable price for its high-quality goods. To prevent internal price wars, the organization also seeks to prevent emerging producers from selling far below market value. In addition, ASSA established the Saffron Incubation Program (SIPS) to aid government-funded initiatives aimed at assisting emerging farmers (Smith, 2022).

2.7.3 *Adulteration*

Due to its high selling price, saffron is susceptible to market fraud. According to Cambridge dictionary, adulteration is "the act of making food or drugs worse in quality by adding something to them" (Dictionary, 2023). Most commonly, saffron is adulterated with flowers that resemble saffron physical appearance, such as safflower, lotus stamens, or dyed maize stigmas (Heidarbeigi et al., 2015; Li et al., 2020). The similarities are depicted in Figure 7.

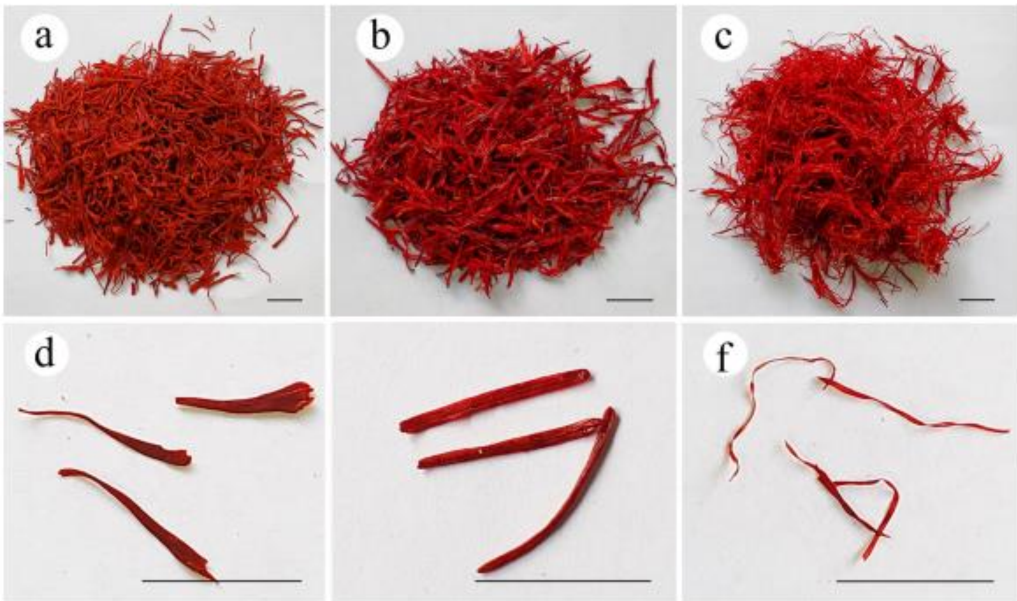


Figure 7: Samples of saffron (a, d), lotus stamens (b, e), and corn stigmas (c, f) after drying (Li et al., 2020).

There are a few methods to distinguish actual saffron from imitation. Near-Infrared spectroscopy combined with chemometrics, the electric nose process, and nuclear magnetic resonance are examples of techniques (Heidarbeigi et al., 2015; Li et al., 2020; Petrakis et al., 2017). However, most people cannot access or afford this technology. The most prevalent and useful test is the lukewarm water test. This test requires heating water between 70 and 80 degrees Celsius and adding saffron stigmas. The water should change instantaneously to the golden yellow hue of saffron; if it turns red, it is not pure saffron (Fssaiindia, 2021; TimesofIndia, 2022). See Figure 8 for comparison of pure saffron versus adulterated saffron.

Figure 8: Hot water testing for adulterated saffron results (Fssaiindia, 2021).

The present study is contextualized within the theoretical framework of innovation diffusion. The application of this theory to the current research is discussed next.

2.8 The adoption of hydroponic systems to cultivate saffron

This section will briefly discuss the significance of innovation diffusion by incorporating concepts from the principle of disseminating innovations in farming community to adopt hydroponic systems. According to the theory of innovation diffusion, individuals generally fall into one of five ‘adopter’ categories when it comes to adopting new technologies (Kaminski, 2011). Briefly, the theory of innovation diffusion states that ‘adopter’ groups resemble the commonly used ‘bell curve’ with categories ranging from the extreme left (individuals who adopt technology quickly) to the extreme right (individuals who adopt technology slowly)

(Kaminski, 2011; Orr, 2003). Below, in the context of the theory of innovation diffusion, I briefly discuss possible reasons why hydroponic farming has not yet been widely adopted among conventional farmers.

Despite the advantages of using a hydroponic system reviewed in this chapter, this technology is still in the early phases of becoming commercial practices, whereas conventional farming is still prevalent. One reason, as Daberkow and McBride (2003) discovered, is that education was associated with awareness but did not always result in adoption; this could be explained by the fact that farmers have the ability to evaluate and reject such a development if they determine it is not financially advantageous. A second hinderance to adoption of this technology within this industry can be age. Michels et al. (2020) concluded that increasing age is a key characteristic to not adopting advances in technology in the farming industry. One reason for this is that older generations are resistant to a steep learning curve (Briggs, 2020). Padel (2001) conducted a study on the adoption of organic farming and determined that for farmers to adopt this innovative method of farming, it must be low-risk and easy for them to understand. New agricultural technologies are quite the opposite and are frequently associated with risks and uncertainties regarding proper application, scalability, and compatibility with the prevailing environment. In addition, new agriculture technologies are subjected to producers' perceptions and expectations (Mottaleb, 2018). Therefore, the next generation of producers play a crucial role in the implementation of innovations.

A third hinderance to adopting new technologies is that the majority of farmers are set in their ways, valuing tradition and methodologies that have been handed down for generations. However, family farms, which are the predominant mode of production, are more amenable to change than other farms (Darnhofer et al., 2016). Family farms, therefore, play an essential role in the adoption of innovations. There is a present and future market that can be exploited via a proposition for a new business venture, and the literature supports this concept. This is due to the application of academic and technological theories to the proposed business venture, which indicates the existence of a current market.

2.9 Conclusion

The literature review sought to provide an overview of the hydroponic cultivation of saffron in South Africa. In summary, saffron contains the naturally occurring chemicals crocin, picrocrocin, and safranal, which serve as the most reliable quality indicators. The concentration and combination of crocins, picrocrocin, and safranal determine the commercial value of saffron. A few farmers have successfully cultivated saffron through conventional farming. In South Africa, no cultivator or individual has attempted hydroponic saffron cultivation. Hydroponic farming is the solution to the majority of South Africa's political and infrastructural problems, as well as its growing concern for sustainable agriculture and environmental changes.

Hydroponic cultivation requires a greater initial investment, but has numerous benefits, including no impact on soil erosion, higher yield per square meter of land, 70-80% water utilisation, resistance to pesticides and soil-borne diseases, and complete control over environmental conditions. It also ensures more consistent flavour profiles and harvested results and can achieve 20 to 25% higher yields than traditional soil cultivation. Various hydroponic systems, including the Deep Water Culture System, Drip System, Ebb and Flow, Nutrient Film Technique (NFT), Aquaponics and Aeroponics, are utilized. NFT is the most effective method for hydroponically cultivating saffron because it requires little water, has a solid structure, and is inexpensive.

Given that saffron is currently the most costly spice globally and is anticipated to experience market expansion in the forthcoming years, it represents a potentially profitable prospect for investors, small-scale farmers, and enthusiasts alike. Small-scale producers and hobbyists typically incur minimal initial start-up costs. Once a process becomes a commercial enterprise, the price increases significantly and can be sold for R200 000 per kilogram. Assuming that the product exhibits superior quality and is marketed to diverse industries, it is reasonable that the price point could be elevated. The cultivation of saffron is a highly profitable venture, offering promising prospects for novice cultivators.

In the next chapter, the researcher provides an overview of the methodology to be used in the proposed study. It includes an overview of the overall research design and outlines the proposed manner of data collection methods, analysis and ethical considerations.

CHAPTER 3. METHODOLOGY

This chapter discusses the methodology that was used by the researcher to obtain the necessary data for the successful cultivation of saffron using hydroponic processes.

3.1 Research approach

The research approach was qualitative in nature, as it was more suitable for an interpretative approach (Cypress, 2015). This approach was chosen because it enables the researcher to observe and analyse the phenomenon of interest in a natural manner (Patton, 2002). It helped the researcher to identify and prioritise different and unanticipated responses, which assisted the researcher in obtaining more comprehensive data (Sofaer, 1999).

3.2 Research design

The proposed study adopted a qualitative exploratory research design. The study collected comprehensive data from farmers in the conventional saffron and non-saffron hydroponic sectors using interviews. See Appendix A for questionnaire. Conducting interviews assisted in understanding the viewpoints held by farmers operating within the conventional saffron industry and those engaged in the non-saffron hydroponic farming sector. Qualitative research offers a notable advantage in that it allows the researcher to formulate a hypothesis and subsequently assess it through empirical observations. Moreover, interviews facilitated researcher-participant interaction, thereby enabling a more comprehensive understanding of the subject matter, given the unknown nature of their motivations (Jain, 2021). Unfortunately, conducting interviews in person presents certain difficulties. Transcribing audio recordings can be a time-consuming process, and conducting face-to-face meetings may incur significant travel expenses. Furthermore, conducting exploratory research is unlikely to provide a solution to the problem at hand, but it can establish a foundation upon which a business can be established for the purpose of cultivate saffron using hydroponics.

3.3 Data collection

The researcher contacted the 5 participants through email to schedule interview. Four interview was conducted face-to-face and one interview telephonically. Industry expert from both saffron cultivation and hydroponic cultivation was interviewed. Data was collected through semi-structured interviews and using open ended questions. As compared to unstructured approaches, semi-structured techniques allow for more structure in the interview process by keeping a similar format across interviews (Corbin & Morse, 2003).

Furthermore, by using a semi-structured format it provides the study with comparable data from interview to interview, but without confining the interviewee’s responses to a binary format. The interviews were conversational in style allowing the researcher to collaborate with the participant to further probe and investigate pertinent topics, thereby enriching the study's data. The interviews were conducted in either English or Afrikaans, depending on the participant’s preference. All interviews were audio-recorded with the participant’s permission.

3.4 Population and sampling

3.4.1 *Population*

The research population involved industry experts on hydroponic farming and farmers who successfully cultivated saffron. The industry professionals discussed how to get started with hydroponic saffron farming and some of the challenges they encountered. Assisting the researcher in developing a model for hydroponic saffron farming. This population cover both aspects of saffron farming, first from the saffron farmer entering hydroponics, and secondly the hydroponic farmer entering saffron cultivation.

3.4.2 *Sampling and sampling method*

The research utilised purposeful sampling technique. This technique is non-random and allowed the researcher to select participants based on the contribution that their knowledge made, to the understanding of the phenomenon being investigated (Smit, 2020). The sample included two saffron farmers and three hydroponic farming organisations. A sample size of five was deemed adequate due to the participants possessed direct knowledge of hydroponics or saffron farming, which enhances the information power that can be obtained through interviews, as noted by Malterud et al. (2016). The organisations are located in the regions of the Western Cape and Gauteng Province. These businesses are accessible and have promoted themselves online.

The demographic characteristics of the population under study are deemed inconsequential to the research, as they are not expected to exert any impact on the research findings. The objective is to conduct as many face-to-face interviews as possible. Four of the five interviews were conducted in person, only one participant was conducted telephonically due to availability.

3.5 Data analysis

The collection of data was conducted by means of semi-structured interviews, wherein open-ended questions were used. An interview was conducted with industry experts in the fields of saffron cultivation and hydroponic cultivation. All interviews were conducted through scheduled appointments. The researcher identified a strong correlation between the participants answers suggesting that the data is credible. Furthermore, the individuals involved in this study possess direct personal experience pertaining to the topic under investigation, thereby enabling them to offer significant and substantial insights and knowledge. In this context, it is assumed that all the findings in the current study are accurate and reliable.

CHAPTER 4. FINDINGS AND DISCUSSIONS

4.1 Findings and discussion

The findings of the research emphasised the necessity of hydroponic systems in a broader context. The primary correlation observed between the research findings and existing literature is the advantageous impact of hydroponic systems in the context of climate change. The findings emphasised the potential of hydroponic systems as a solution to mitigate the effects of climate change. (Calzadilla et al., 2014; Hulme, 2020; Jones, 2023; Kannan et al., 2022; Kour et al., 2022; Suhl et al., 2016).

Participant A and E cultivate saffron, whereas Participants B, C, and D use hydroponic methods. The following discussion will include the findings, addressing all essential topics that were intended to be answered. The results will be analysed in light of the following subjects, which are defined within the scope of this research:

- Technical aspects to grow saffron
- Operational requirements
- Financials
- Market research
- Challenges

4.1.1 *Technical aspects to grow saffron*

The interviews revealed that South Africa possesses expertise in both hydroponics and traditional saffron cultivation methods, but has not integrated the two approaches. This information was not discovered through research. Each discipline is applied in isolation. Participant A provided the following statement about his knowledge of hydroponics (translated to English):

"So, the bulb just has to, if you, I'm trying to work towards your hydroponic system, <u>I have no experience of it</u>, all I have is what I've read myself."

The participant has a low-level understanding of hydroponics, but would have to conduct a few trails to implement it successfully. Collaboration between parties from both disciplines is crucial for the cultivation of saffron using hydroponics. Each discipline possesses profound expertise in their respective fields. On the contrary, hydroponics farmers possess limited information regarding saffron. Participant B provided the following statement about saffron:

"Saffron and I know that it's expensive, but that's all, I don't know it. I just know that it's an expensive spice because I like watching cooking."

It was evident from observing Participants C and D (hydroponic farmers) that they, too, possessed a restricted understanding of saffron. All participants were conscious of the excessive price of this spice, as it is well established in research (Kour et al., 2022; Piccantino, 2023). The interview sample representing hydroponic farmers was small, so these results do not represent the perspectives of all hydroponic producers; however, it is noteworthy that all three hydroponic farmers had limited knowledge of saffron cultivation. This further demonstrates that literature did not provide any studies on the hydroponic growth of saffron in South Africa.

One of the risks associated with hydroponic systems is the requirement for specialised technical expertise. A lack of understanding of the system's technical aspects can result in the complete destruction of the crop in a single day.

Participant C confirmed the following statement (translated to English):

"…management is another risk in terms of your system that has been affected, you don't notice it (crops) are dying."

The study revealed that the traditional farmer lacks the necessary technical expertise to effectively manage hydroponic systems, which was not discovered in research. In order to mitigate the risk, expertise can be channelled using

Association of Saffron Southern Africa (ASSA), given that this company will initially engage in saffron sales through ASSA. Additionally, ASSA would benefit from assisting. Alternatively, according to literature, foreign nations has made successful attempts in cultivating saffron utilising hydroponics and may contribute their expertise to South Africa.

One participant has already started to collaborate with international businesses in order to cultivate saffron with hydroponics. The participants primary reason for this is the mitigate the risks of climate change and obtain a consistent yield. As highlighted in literature, hydroponic systems are known to withstand climate change and provide sustainable and consistent produce.

4.1.2 *Operational requirements*

The interviews have confirmed the literature that a hydroponic system possesses low power demands to enable the utilisation of renewable energy sources for hydroponic operations (Pomoni et al., 2023). A small-scale system usually needs approximately 3 kilowatts (kW) of power to function, hence eliminating the need for a substantial financial commitment to sustain production. However, growing saffron would need additional lighting during flowering, which is 8-9 months. The bulbs then go into the dormant stage of the life cycle for another 3-4 months. Participant C has the following to say about the hydroponic system power usage (translated to English):

“Yes, That's the entire systems power requirements. That's about 3 kw/h. And you can make it run on solar power. Then if you add a heating system, then it pushes power up a bit. Then you can now check which heating system you have installed. If we use some of our geothermal that you just add a pump to drive the water or if you now add a heat pump, then you can talk about adding another 1 kw or 3 kw."

Additionally, Participant C confirmed that they have operational systems in the middle of Africa that are powered by batteries and solar energy to operate the hydroponic system. One of the challenges with saffron is that it requires a lot of light.

Participant A had the following to say (translated to English):

"Saffron is a full sun flower, it seeks full sun, if you plant it in the shade then it does not do as well as it does in full sun. So, if you are going to use lights on things to imitate the sun, then you just have to make sure that your light comes out everywhere."

The interviewer proposed the implementation of a system that functions in a triangle orientation. This technology operates in a manner similar to a water wheel positioned within a flowing river. The flow of water propels the wheel. The saffron will undergo a rotational movement in the shape of a triangle, with the apex of the triangle positioned at the top of the hydroponic system. The water will be introduced at the apex of the triangle structure. The absence of water on the left side causes the system to rotate clockwise, therefore propelling it through the force of gravity. This will ensure uniform sunshine exposure for the flowers throughout the day, hence reducing the lighting needs in the hydroponic system.

4.1.3 *Financials*

One of the primary obstacles associated with the hydroponic cultivation of saffron pertains to its comparatively lower profitability when compared to other crops such as herbs, lettuce, and tomatoes. This is mostly due to the fact that the latter crops can be harvested numerous times within a single year, hence generating higher earnings. According to the literature, the bulbs must go through all five stages in order to sprout, a process that takes one year. The implementation of hydroponic systems will result in a substantial reduction in the breakeven period associated with their high investment costs. The annual harvest of saffron is limited to a single harvest, hence resulting in a notable increase in the breakeven threshold. However, the aforementioned statement is grounded in the typical yields that are achieved in saffron cultivation. The consensus among the participants was that climate change will negatively affect saffron production.

Incorporating opportunity cost into the breakeven analysis will also result in a shorter repayment period. This finding, although not documented in existing literature, has the potential to substantially improve the financials if considered.

Participant C currently grow tomatoes and greenly leaves and confirmed the following statement (translated to English):

"*So, I asked if you tried planting saffron. So, you're looking to see if the costs add up, but it's more effective to stick with tomatoes and lettuce."*

Participant E expressed concern regarding the suitability of the hydroponic environment for saffron cultivation. Additionally, the participant mentioned that the initial investment required for hydroponic systems is substantial, and the participant preferred to plant the saffron in the readily available soil. Nevertheless, opportunity cost must be taken into account when attempting to justify hydroponics systems. As mentioned previously, saffron is an expensive spice; consequently, a cultivator would prefer to guarantee a consistent harvest.

The findings revealed that the not many can enter the hydroponic market on large scale due to it high initial setup cost (AgriMag, 2022; Brahlek, 2023; The Gardener, 2023). When comparing the investment cost of a hydroponic system to the relatively low cost of inheriting land through generations, a farmer may find it challenging to justify investing in the hydroponic system instead of investing in their current business.

4.1.4 *Market research*

Both participant A and E are selling saffron in the spice market. In addition, they sell the bulbs locally, whereas participant A also sells bulbs to the international market. Participant A confirmed their intention to sell oil taken from the leaves and extract crocin from bulbs for medical purposes. This occurrence will be delayed until a later time since they still need to enhance their production capabilities and allocate resources towards acquiring specialised equipment.

A local opportunity has arisen to market chamomile tea infused with saffron extracts, thereby enhancing saffron awareness and acquainting South African consumers with the flavour of saffron.

Furthermore, saffron has many possibilities for expansion in the market. The predominant market, as previously mentioned, revolves around the sale of bulbs and saffron as a spice. Saffron can also be marketed as an infusion-ready product. Like tea, saffron can be brewed in gin, used in incense, or combined with chocolate. In addition, saffron possesses numerous medicinal benefits that may be derived from the flower. This has led to an expanding market, as studies continue to uncover the various advantages offered by the flower.

The culinary industry has been and continues to be the primary market for saffron (Ambardar et al., 2021; Grand view research, 2020; Khilare et al., 2019). South Africa, a confirmed saffron provider, intends to expand its presence in further areas, including medicinal and essential oils (Kothari et al., 2021; Piccantino, 2023). The findings also emphasised the potential to use saffron into beverages and food delicacies as a means to enhance the profitability of saffron. As recommended, there are alternative methods to incorporate saffron into different substances in order to enhance the prestigious reputation associated with saffron. Infusing saffron with tea opportunity is unique to the South African market and has not been documented in literature.

4.1.5 *Challenges*

The key challenge contributing towards shifting traditional farming to hydroponics was climate change amongst the participants. According to literature, Iran, which is recognised as the leading producer of saffron, has encountered substantial rainfall. This factor has had a substantial negative impact on the production of saffron. Moreover, it is worth noting that both India and Spain, who are major saffron growers, have encountered reduced crop yields in the past two years as a consequence of climate change.

Another key finding were consistent answers received from participants about the bigger risks for hydroponics. The collaborative answers were two or three of the following; electricity availability, expertise to manage saffron and hydroponic system, damping on saffron bulbs, which can cause fungus or deplete the yield. All three will be discussed next.

a) Electricity availability

Electricity availability in a major concern for hydroponic cultivators, since the system is reliant on power to be operational. The traditional farmer is not too worried about electricity, since the natural environment does most of the work.

Participant C stated the following (translated to English):

" At the moment the biggest risk is Eskom because we are still on Eskom."

Participant A stated the following (translated to English):

“There is not any influence, water is only given for about 2 hours a day. So you plan water application accordingly.”

During the walk-through with participant B, it was observed that over 50% of the crop was in poor condition due to Stage 6 power outages that occurred over the weekend. This suggests that hydroponic farmers should have alternative energy measures in place, wither generators or renewable energy.

Furthermore, hydroponic systems require a sufficient power supply for it to function successfully. Loadshedding was identified as a prominent risk factor for hydroponics (AgriMag, 2022; The Gardener, 2023). Research has verified that hydroponic systems are a more sustainable choice and can operate using renewable energy sources (Pomoni et al., 2023). Consequently, implementing an alternative power source would effectively mitigate one of the primary risks associated with hydroponic systems.

b) Expertise to manage saffron and hydroponic system.

See participant C response below (translated to English):

"…management is another risk in terms of your system that has been affected, you don't notice it (crops) are dying."

While knowledge does pose a certain risk, it is rather minor compared to the risks associated with conventional farming. Participant C acknowledged that management carries risks, but also made the following statement:

"I have done a risk analysis for business plans, and I literally have to scratch things out" for hydroponic systems.

Furthermore, participant B has stated that hydroponic systems are fairly low risk and easy to manage.

Participant B statement:

"Hydroponic farming is easier than conventional farming. You don't need to know anything."

The responses suggest that hydroponic systems are easy to manage, but any oversight in their management can have significant harmful consequences, therefore deeming it high-risk. According to literature, technical skill is one of the most critical criteria to consider. This statement was made by an individual who is already experienced and skilled in the field of hydroponics. As a result, it may not hold much significance for them, but it will be valuable for someone transitioning from traditional farming to hydroponics.

c) Damping on saffron bulbs, which can cause fungus or deplete the yield.

An excessive amount of water promotes the growth of fungi, leading to the destruction of the saffron bulb, daughter bulbs, and neighbouring bulbs. This support research conducted by (Kumar et al., 2009). This has a deleterious effect on saffron production. Participant A stated that it was the most threatening enemy. See response below (translated to English):

“I tell you what is this bulb biggest enemy is fungi.”

When using a hydroponics integrated system, there is an elevated danger of fungal growth. This can lead to a rapid spread of the fungi, perhaps resulting in the destruction of all saffron bulbs. Refer to the response of participant B below:

“The biggest risk is if, because of the system is interconnected right, we are circulating the water. If you've got a problem in that water, all of your crops going to go in hydroponics, you're either going to harvest zero or going to harvest 90% or very rain.”

Therefore, it is imperative that the cultivator install a real-time water quality assessment kit that can promptly alert you to the presence of fungi such as Rhizoctonia crocorum, Phoma crocophila,Macrophomina phaseolina, Fusarium moniliforme var intermedium, Fusarium oxysporum, F. solani in the water.

To overcome the electricity supply inconsistency would be to implement an alternative power supply. Either a generations unit or as stated in literature, the system can function sustainably from renewable energy (Pomoni et al., 2023). To address the second challenge, it is advisable to establish a collaborative alliance with saffron and hydroponic farmers from both industries. The third challenge can be mitigated by implementing a real-time water quality assessment kit. This will provide the farmer with a notification, allowing the farmer to respond promptly before the produce becomes spoilt.

4.2 Summary

The research highlights the importance of hydroponic systems for saffron cultivation in South Africa. Two out of five participants cultivate saffron, while others use hydroponic methods to cultivate other crops. However, South Africa lacks expertise in both hydroponics and traditional saffron cultivation methods. Collaboration between hydroponic and traditional farmers is crucial for successful cultivation. Risks associated with hydroponic systems include the need for specialized technical expertise and management. To mitigate these risks, the Association of Saffron Southern Africa (ASSA) can be a valuable resource. Additionally, foreign nations can contribute their expertise to South Africa. Hydroponic systems have low power demands, allowing for renewable energy sources. However, saffron requires a lot of light, which can be addressed by implementing a triangle-oriented system.

The hydroponic cultivation of saffron faces challenges due to its lower profitability compared to other crops like herbs, lettuce, and tomatoes. The initial investment required for hydroponic systems is substantial, and the annual harvest is limited to a single harvest. Climate change negatively affects saffron production, and incorporating opportunity cost into the breakeven analysis can improve financials. Saffron has numerous opportunities for expansion in the market, including selling bulbs and saffron as a spice, infusion-ready products, and medicinal benefits. However, infusing saffron with tea is unique to the South African market and has not been documented in literature. Challenges for hydroponic cultivation include electricity availability, expertise to manage saffron and hydroponic systems, and the risk of fungi growth on saffron bulbs.

Based on the findings, it can be inferred that the literature review was effectively completed, and the results aligned with the existing literature. Therefore, it is feasible to grow saffron using hydroponics. However, this option is more appealing to existing saffron farmers rather than hydroponic growers who are currently cultivating other crops.

CHAPTER 5. BUSINESS VENTURE PROPOSAL

5.1 Introduction

The cultivation of saffron using traditional methods presents many challenges, particularly in relation to climate disruptions, such as excessive or insufficient sunlight and water availability. The events in Iran and India are proof of this. Saffron, being harvested just once annually, its essential that maximum saffron is harvested. There is an opportunity to cultivate saffron using hydroponic techniques. The scale of this opportunity is expected to increase with the escalating unpredictability of climate change.

The primary objective of the business venture is to utilise hydroponic techniques in the cultivation of saffron as a means of mitigating the potential threats associated with climate change. This method of farming will potentially guarantee harvest volumes and quality of saffron stems, bulbs and oil extract.

5.1.1 *Vision, mission and objectives*

Vision

To become a leading provider of high-quality saffron produced through innovative hydroponic systems, contributing to sustainable agriculture and enhancing the well-being of our community and customers.

Mission

To cultivating saffron using state-of-the-art hydroponic techniques that maximize resource efficiency and product quality. We aim to deliver premium saffron to our customers while promoting environmentally friendly practices and supporting local communities.

Objectives

d) *Quality Excellence:* Produce saffron of the highest quality, meeting international standards, ensuring customer satisfaction.
e) *Innovative Hydroponic Practices*: Continuously research and implement hydroponic methods to improve saffron yields and resource efficiency.
f) *Sustainability:* Minimise our environmental footprint by reducing water consumption, waste, and energy usage while maintaining product quality.
g) *Market Expansion:* Increase market share and global reach by expanding sales channels, both domestically and internationally.
h) *Research and Development:* Invest in ongoing research and development to enhance saffron cultivation techniques and product offerings.
i) *Customer Satisfaction:* Maintain a strong focus on customer service, addressing customer needs, and ensuring a positive customer experience.
j) *Cost Efficiency:* Optimise production costs and resource allocation to achieve sustainable profitability.
k) *Social Responsibility:* Give back to society through charitable initiatives and partnerships that benefit the underprivileged and vulnerable communities.

The above-mentioned vision, mission, and objectives statements demonstrate a dedication to the sustainable cultivation of saffron using hydroponic systems, with a particular focus on quality, innovation, and community engagement.

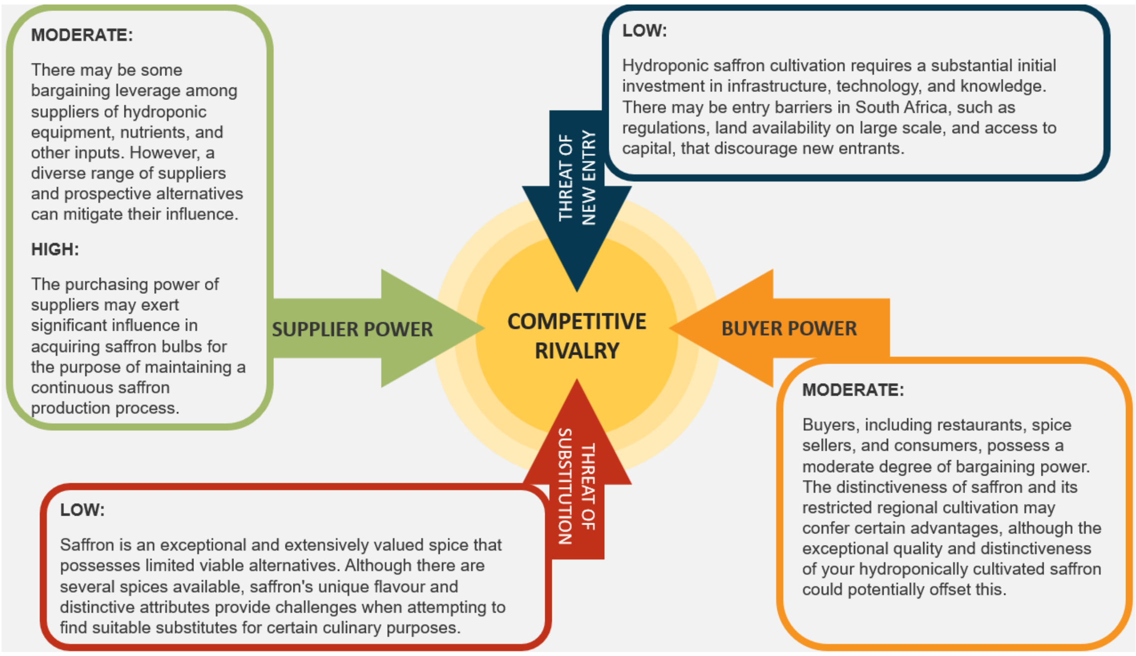
5.2 Industry analysis

5.2.1 *Macro environmental analysis*

Political	
Regulations and Permits	Compliance with agricultural laws and any potential changes in government policies that might affect agriculture. Brexit, AGOA and SADC-EU.

Land Use Policies	Land use policies and zoning regulations may influence the location and expansion of the hydroponic saffron farm. Another factor to consider is South African Land reform program.
Economic	
Market Demand	Low current market demand for saffron in South Africa, but has potential for further growth. International market is expected to grow.
Exchange rate	Fluctuations in exchange rate volatility have an immediate impact on both input expenses and output revenue.
Socio-cultural	
Consumer Preferences	The cultural preferences and attitudes of South African consumers towards saffron are relatively low. Develop a market for products containing saffron and raise awareness of its health benefits.
Labor Force	Limited skilled labour is accessible for saffron cultivation, whereas skilled labour with a high level of proficiency is available for hydroponics.
Technological Factors	
Hydroponic Technology	Stay updated on the latest advancements in hydroponic technology for saffron cultivation. Focus on companies such as I-Saffron.
Automation and Data Analysis	Explore opportunities to integrate automation and data analysis tools to optimize the hydroponic saffron cultivation process.
Environmental Factors	
Climate	South Africa's climate is suitable for saffron cultivation in a hydroponic environment. Low risk due to hydroponic environment.
Sustainability	No soil degradation with hydroponics, low water usage and can be powered by solar and batteries alone.
Water	South Africa is on of the 30 driest countries in the word and strict water regulation can be implemented.
Legal	
Food Safety and Quality Standards	Require compliance with food safety and quality standards in South Africa and internationally. i.e. ISO 3632 (2011).
Regulation	High-value commodities such as saffron, may present bureaucratic obstacles. For example, BRICS.

5.2.2 *Porters' Five forces*



5.2.3 *SWOT analysis*

STRENGHT

- **Climate Suitability:** The Mediterranean climate and arid summers of South Africa are conducive to saffron cultivation, particularly in certain regions.
- **Hydroponic Advantages:** Hydroponic cultivation allows for precise control over water, nutrient, and environmental conditions, leading to potentially higher saffron yields and better quality.
- **Year-Round Cultivation:** Hydroponics permits year-round saffron cultivation, thereby reducing reliance on seasonal weather fluctuations.
- **Water Efficiency:** In some regions of South Africa, there is a water shortage, and hydroponics offers more water-efficient methods than traditional soil-based cultivation.
- **Premium Market Demand:** Saffron is a high-valued spice that is in high demand in the gourmet and culinary industries, which could result in higher profit margins.

WEAKNESS

- **High Initial Investment:** Setting up a hydroponic saffron cultivation system necessitates a substantial initial investment in infrastructure, technology, and expertise.
- **Skill and Knowledge Gap:** Hydroponic cultivation necessitates the acquisition or training of specialised skills and knowledge by local cultivators.
- **Energy Dependence:** Hydroponic systems require energy for temperature control, illumination, and other functions, which may result in higher operational expenses.
- **Market Competition:** The production of saffron is dominated by a few of countries, and gaining a foothold on the international market could be difficult due to the presence of established competitors.

OPPORTUNITIES

- **Export Potential**: Successful hydroponic saffron cultivation could provide export opportunities to global markets, particularly during off-seasons for traditional saffron-producing nations.
- **Research and Development:** Developing novel hydroponic techniques for saffron cultivation could contribute to the advancement of agricultural technology.
- **Local Gourmet Market:** Local Gourmet Market: A local market for upscale saffron-based products could be created, targeting upscale restaurants and specialty shops.
- **Diversification:** Hydroponics permits diversification into other high-value commodities, such as vanilla and dragon fruit, if saffron cultivation encounters difficulties.

THREATS

- **Market Volatility:** Due to factors including climate conditions, geopolitical events, and market demand, saffron prices can be volatile.
- **Disease and Pest Management:** Hydroponic systems can be susceptible to disease and pest outbreaks if not properly managed.
- **Technological Risks:** Hydroponic systems are reliant on technology, and any technical failures could disrupt production.
- **Changing Regulations:** Changing regulations concerning hydroponic cultivation or the import/export of saffron may influence business operations.
- **Cultural Acceptance:** Saffron has cultural and traditional significance in numerous regions; therefore, introducing a non-traditional cultivation method may be met with resistance or scepticism.

5.3 Market analysis

5.3.1 *Market and strategy analysis*

Target market

Saffron will be sold through the Association of Saffron Southern Africa (ASSA), targeting international customers. This business has already cultivated a loyal clientele and has successfully positioned itself as a reputable provider of premium saffron. It will save time to establish a company brand in the market and sell the produce. Additionally, the oil extracts derived from the flower, crocin extracted from the bulbs and additional premium bulbs will also be distributed via the ASSA.

Market size and trends

The yearly production is estimated to be around 418 tons per year (Cardone et al., 2020). According to a report by Grand View Research in 2020, it is projected that saffron will experience a Compound Annual Growth Rate (CAGR) of 8.5% from the year 2020 to 2028. According to a report by PR Newswire in 2023, there was a Compound Annual Growth Rate (CAGR) of 8.1% seen in the United States. This finding indicates a sustained and positive growth trend for a premium commodity. According to a study conducted by Grand View Research in 2020, around one-third of the overall growth can be attributed to advancements in medical applications.

Marketing strategy

a) Short term strategy:
   The objective is to establish a strong presence in the market and expand globally, while simultaneously enhancing production capabilities to emerge as a prominent producer of saffron in South Africa.
b) Long term strategy:
   Increase footprint and production volume to vertically diversify saffron production. One potential approach to enhance the versatility of saffron is

to convert it into a liquid form or grind it into a powder, so expanding the range of available possibilities for its use. The medical sector is experiencing significant growth, and the cultivation of saffron through hydroponic methods has the potential to address issues related to soil-borne diseases while also enabling direct sales to the medicinal sector.

Market segmentation

Market segmentation	
Demographic	The intended audience would consist of professional and home chefs on board. The age range will be 25 to 60, given the widespread use of saffron. The primary emphasis will be on women, as the majority of household cooks in Middle Eastern countries are female.
Technographic	Instagram and TikTok are the most extensive digital platforms utilised for brand establishment and product promotion. Priority will be given to utilising social media influencers for the purpose of promoting this product, particularly when it enters the South African market. This marketing strategy has not been implemented for saffron products in South Africa.
Psychographic	LSM 6-10
Behavioural	Users often incorporate saffron into their meals; therefore, it is essential to guarantee a consistent quality in terms of physical appearance, taste, and aroma. The objective is to cultivate brand loyalty through providing consistent quality of saffron as an item that is grown in a sustainable manner.
Geographic	In consideration of saffron's widespread appeal, it will be introduced to the global market initially. South African culture is comparatively less inclined to incorporate saffron than that of other nations. Consequently, selling to an established market will be less challenging than managing a new venture and establishing a brand in the local market.

5.3.2 *Marketing mix*

Product

c) *Quality Saffron:* Ensure that the saffron produced through hydroponic systems is of the highest quality, with a distinct aroma, colour, and flavour.
d) *Varieties:* Offer the stigmas associated with fragrance, colour, and flavour. Provide an aromatic substance derived from the extraction of the flower. Isolate crocin from the maternal bulb subsequent to harvesting.
e) *Certification:* Obtain necessary certifications for organic or sustainable saffron, if applicable, to appeal to environmentally conscious consumers.

Price

a) *Competitive Pricing*: The majority of saffron is mostly distributed throughout the global market. A strategic customer can be defined as an individual or entity that does not engage in mass purchasing, but rather focuses on offering saffron to a niche market consisting of small players who are willing to pay a premium price. The objective is to become a member of the Association of Saffron Southern Africa (ASSA) in order to guarantee the promotion of saffron as a premium product that is devoid of any form of contamination.

Place

a) *Distribution Channels*: Saffron will be sold to international markets via ASSA, where higher prices are offered opposed to local markets.
b) *Local Markets*: Most South Africans are not familiar with saffron and its properties. Engaging in local farmers' markets and establishing partnerships with local restaurants to establish a presence within the community can effectively generate awareness and educate the South African population about the quality of saffron. Furthermore, this approach has the potential to enhance the selling price of saffron in the local market.

c) *Regional Partnerships*: Partner with agricultural co-ops and local suppliers to expand saffron's reach within South Africa.

Promotion

a) *Digital Marketing*: To create an informative website and leverage social media platforms to educate consumers about hydroponically grown saffron’s benefits and quality.
b) *Content Marketing*: Share content like blogs, videos, and recipes to engage with potential customers and raise awareness about saffron.
c) *Partnerships*: Collaborate with chefs, food bloggers, and wellness influencers to promote saffron's use in cooking and wellness routines.
d) *Sampling*: Offer saffron samples at food and trade events to allow potential customers to experience the product.

People

a) *Skilled Workforce*: Employ and train personnel ensuring a skilled and knowledgeable team.
b) *Customer Service*: Provide excellent customer service to address inquiries and maintain a positive brand image.
c) *Community Engagement:* Engage with the local community through job creation, partnerships, and involvement in local events to build trust and goodwill.
d) *Supplier Relationships:* Foster strong relationships with suppliers of hydroponic equipment, bulbs, and other resources to ensure a stable supply chain.

5.4 Financials

	Startup	2024	2025	2026	2027	2028	Totals	Notes
Income								
Loan	R 5 200 000				R 4 000 000		R 9 200 000	1
Income		R 720 000	R 756 000	R 793 800	R 3 333 960	R 3 500 658	R 5 603 760	
Income: Safforn bulbs			R 180 000	R 189 000	R 198 450	R 416 745	R 567 450	2
Income: Oil extract		R -	R -	R -	R -	R -	R -	
Income: Procicin		R -	R -	R -	R -	R -	R -	
Total income	R 5 200 000	R 720 000	R 936 000	R 982 800	R 7 532 410	R 3 917 403	R 15 371 210	
Payments								
Land, buildings		R 2 000 000					R 2 000 000	3
Hydroponic setup cost		R 2 000 000			R 4 000 000		R 6 000 000	
Security		R 80 000	R 1 200	R 1 200	R 1 200	R 1 201	R 83 600	
Loan repayment		R 520 000	R 520 000	R 520 000	R 920 000	R 920 000	R 2 480 000	
Purchase bulbs		R 360 000	R 180 000		R 360 000	R 180 000	R 900 000	4
Business registration		R 1 350					R 1 350	
Business website design and maintenance		R 2 600	R 600	R 650	R 700	R 700	R 4 550	
Office supplies		R 25 000	R 350	R 350	R 350	R 350	R 26 050	
Repairs and maintenance		R 20 000	R 22 000	R 24 200	R 106 480	R 117 128	R 172 680	5
Phone and Internet		R 1 200	R 1 200	R 1 200	R 1 200	R 1 201	R 4 800	
Vechile		R 450 000					R 450 000	
Insurance		R 12 000	R 12 600	R 13 230	R 13 892	R 14 586	R 51 722	
Travelling expenses		R 10 000	R 10 000	R 10 000	R 10 000	R 10 001	R 40 000	
Utilities		R 105 000	R 105 000	R 105 000	R 105 000	R 105 000	R 420 000	
Backup power		R 50 000	R 12 000	R 12 000	R 12 000	R 12 000	R 86 000	6
Nutrients		R 18 000	R 19 080	R 20 225	R 85 753	R 90 898	R 143 058	
Soil analysis		R 675	R 709	R 744	R 781	R 820	R 2 909	
Wages and salaries		R 120 000	R 126 000	R 132 300	R 793 800	R 841 428	R 1 172 100	7
Total payments	R -	R 5 775 825	R 1 010 739	R 841 099	R 6 411 156	R 2 295 314	R 14 038 819	
Cash flow surplus/deficit (-)	R 5 200 000	-R 5 055 825	-R 74 739	R 141 701	R 1 121 254	R 1 622 089	R 1 332 391	
Opening cash balance		R 5 200 000	R 144 175	R 69 436	R 211 137	R 1 332 391	R 2 954 480	
Closing cash balance	R 5 200 000	R 144 175	R 69 436	R 211 137	R 1 332 391	R 2 954 480	R 4 286 872	

Notes:

1. To enhance capacity, an additional loan is necessary. Most of the overhead costs will remain constant while output increases. The key rationale for not raising capacity in the first year is to reduce risk. The two main risks are that this is a new endeavour with insufficient knowledge of saffron hydroponics. After three years, the risk of investing in more equipment is substantially smaller, and the owner can negotiate a better prime rate or approach investors.
2. Only 50% of the bulbs will be sold, as the corporation requires a supply of bulbs to support its expansion.
3. Vacant land is available for R1 million. The other R1 million will be spend on offices (80-100 square meters)
4. 10% of the hydroponic system cost will be allocated to maintenance.
5. The initial three years are perceived as a period of brand development and development of expertise and knowledge.
6. The backup power will be provided by a generator specifically designed for starting operations. The cost of implementing a fully functional solar and battery solution is exorbitant, but the objective is to eventually transition to an off-grid system.
7. The system will be first operated with a semi-skilled employee. An individual with an elementary understanding of agricultural practices and mechanical machinery. Skilled workers will be incorporated after the project gains momentum and the business attains the financial capacity to support it. It is important to emphasise that the goal is to transform semi-skilled employees into skilled manager.

5.5 Risk analysis

Operational risk	**Impact**	**Probability**	**Financial risk**	**Impact**	**Probability**	**Market risk**	**Impact**	**Probability**
Failure to grow saffron due to lack of knowledge			Increase in energy costs			Market price volatility		
Bulbs do not yield flowers			Failure to secure financing			Market demand fluctuations		
Technical failures - Energy - Maintenance			Currency exchange rates			Counterfeit and fraud		
Diseases and pests kill bulbs			Labor costs			Cultural and culinary trends		
Labor dependence - Knowledge and rate			Financial market risks, such as increase in interest rates'			Increase in competition		

Low	
Medium	
High	

5.6 Plan implementation strategy

5.6.1 *Geographical location analysis*

The start of the business venture will involve the identification and selection of an appropriate site for the cultivation of saffron. Two crucial factors for determining the suitable location are the presence of adequate electricity and water resources, as well as a geographical setting that closely reflects the optimal environmental conditions for saffron cultivation. The cost of hydroponic production is expected to decrease due to the use of a more efficient hydroponic system that requires reduced energy consumption and equipment utilisation for the establishment of optimal growing conditions. The geographical regions being examined are Philadelphia, Malmsbury, and Wellington. The present triangle possesses the necessary power and water resources, creating an environment that closely resembles the optimal conditions for cultivating saffron. Additionally, the cost of land in this region is affordable when compared to other places. Farmland range from R40 per sq. meter to R55 per sq. meter, as opposed to Ceres which is double this (Property24, 2023a). Vacant land with a business zone classification can be bought for R1 million with an area of 8 520 square meters (Property24, 2023b).

5.6.2 *Operational equipment*

A hydroponic system will be installed once the location has been located and acquired. The identified hydroponic system is aeroponics and will cost R2 million for a 10x30x4m (LxBxH) setup. This system will require 350 square metres of land and has the potential to increase.

A 1.1kW pump is required for water circulation in the hydroponic system, which also includes a manual nutrient dosing mechanism. Both pieces of equipment are included under the initial setup cost of R 2 million. The investment will additionally comprise a saffron-planting structure. It is therefore a turnkey solution.

Traditional farming can produce 40 bulbs per square metre, whereas hydroponics can produce ten times as many. As a result, the hydroponic solution has the capacity to cultivate 120,000 bulbs in the same area, whereas conventional farming is limited to 12,000 bulbs.

5.6.3 *Management team*

This system is manageable by one person. During harvesting, the business may make use of seasonal workers to assist with harvesting. The first three years are regarded as the period of growth and skill development. After three years, the objective is to develop the business and increase the team.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Presented in this chapter is a brief overview of the findings that were obtained from the study. Moreover, the chapter will offer suggestions on how to initiate the cultivation of saffron through hydroponic methods, as well as present the reader with ideas for further research.

6.2 Conclusion

A comparative study has documented a theoretical implementation of a hydroponic system designed specifically for saffron growing, which relies on renewable sources of energy. The gap identified between literature and this research pertains to the necessity of doing market research to determine the economic feasibility for implementation. Therefore, the study's aim was to explore potential for hydroponic saffron cultivation in South Africa. This was achieved by conducting a business venture that involved interviewing experts from both the saffron and hydroponics industries, and subsequently applying the findings to develop a business proposal.

The study stressed the importance of hydroponic systems, with the key driver being climate change. In practical terms, saffron can be cultivated using a hydroponic system. The main challenges revolve around the duration required to recover the investment for cultivating saffron in a hydroponic system. The initial capital outlay for saffron bulbs, which can only be harvested annually, is substantial. Farming practitioners may prefer cultivating herbs, tomatoes, and leafy greens due to their ability to be harvested numerous times throughout the year. This characteristic substantially shortens the time required to recoup the investment in the hydroponic system, thereby enhancing its overall profitability.

Nevertheless, the saffron grower holds a contrasting perspective. The saffron harvest is of utmost importance, as the stems possess significant value. The fluctuation in saffron stem production from year to year, caused by climate change, greatly enhances the viability of a hydroponic system. The scale of this opportunity is anticipated to grow in tandem with the intensifying uncertainty caused by climate change.

In conclusion, using hydroponics for saffron cultivation proves to be a viable and environmentally friendly approach, taking into account the potential loss in terms of the spice's value and the growing unpredictability of climate change impacting production.

6.3 Possible unintended consequences of cultivating saffron with hydroponics

Cultivating saffron in a hydroponic system can result in various unforeseen repercussions, despite its obvious advantages. An important concern is the substantial upfront expenses and intricacy involved in the initial setup. Hydroponic systems necessitate a substantial investment in equipment, including grow lights, nutrient delivery systems, and climate control mechanisms. These systems require a considerable amount of technical expertise and ongoing supervision to ensure that the growing conditions are kept at their best. Any failure or disruption in the system can have a significant impact on the output and quality of saffron, potentially leading to financial losses for unprepared producers.

Another unforeseen ramification is the possible ecological repercussions. Although hydroponics is sometimes promoted as a sustainable kind of agriculture, it still necessitates a significant amount of electricity, especially for crops such as saffron that require certain temperature and light conditions. The energy consumption required to maintain these conditions can contribute to a bigger carbon footprint. In addition, improper management of used fertiliser solutions during disposal can result in water pollution, hence posing an environmental danger. Therefore, although hydroponics can provide substantial crop yields and optimise space utilisation, it also entails potential environmental and economic hazards that necessitate thorough evaluation.

6.4 Recommendations

The findings revealed that the individuals were highly skilled in their respective disciplines, but had limited understanding of integrating the two processes. It is recommended that the two fields collaborate in order to acquire the necessary expertise for efficient hydroponic cultivation. The business venture proposal suggests that it would be advisable to start with a small-scale initial expenditure. This approach would provide sufficient time to acquire knowledge and establish a market presence before scaling up production to a larger scale. The proposal recommended that the firm depend on ASSA for expertise in saffron cultivation and on a hydroponic supplier for hydroponic operations in order to start the business.

6.5 Suggestions for future research

Saffron is a remarkable flower and possesses significant value, but can only be cultivated once a year. There is an opportunity to genetically modify the bulbs to produce saffron twice a year if not more. Alternatively, one can operate two hydroponic systems, one which is able to cultivate southern hemisphere bulbs and another to cultivate northern hemisphere bulbs. This would allow the business to cultivate twice per year with lower initial investment cost opposed to a large hydroponic system.

Further research can be conducted by incorporating saffron into a diverse range of food or beverages. Saffron is considered an aristocratic and opulent flavouring agent that would add significant value to existing products. These products include, tea, gin Lindt chocolate to name a few.

Furthermore, an additional commercial proposition emerged throughout the course of this study. Given the significant capital required for installing a hydroponic system, it is advisable to provide individuals the opportunity to lease space within the system for crop cultivation. Technical assistance will be offered to persons engaged in the cultivation of crops, whether for commercial purposes or for personal consumption. Individuals need not be concerned about making an investment, as they have the option to lease a block that carries little financial risk to them or requires technical expertise to manage a hydroponic system.

Moreover, it was observed that there is no differentiation made between conventional crops and those cultivated in hydroponic systems. The primary distinctions between the two lies in the nutritional composition of the crop. Hydroponic crops can provide significantly enhanced nutritional value for human consumption. Further investigation is recommended to determine why South Africa has not widely embraced the cultivation of crops with enhanced nutritional content.

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CHAPTER 8. APPENDIX

8.1 Appendix A

No.	Questions to farmers cultivating saffron	Reason why question is part of interview
1	What crops are you cultivating besides saffron?	To establish size and variety. Researcher will do online research to show interest.
2	How has saffron the yield been the last few years?	To identify information that led to good or poor yields. Can be used to compare with hydroponic.
3	What event has the greatest impact on output and why?	To see if hydroponic can address this issue.
4	What other issues can result in poor output?	To see if hydroponic can address this issue.
5	What is the greatest impact on saffron quality?	To see if hydroponic can address this issue.
6	How has loadshedding affected your business?	To find a solution that can work with hydroponic system, since it is smaller and easier to control.
7	Do you have sustainable or alternative energy supply? What kind and why?	To establish if saffron can be cultivated with sustainable energy.
8	Has water supply been a challenge for your business? Please elaborate.	To find a solution that can work with hydroponic system, since it is smaller and easier to control.
9	Has water quality been a challenge for your business? Please elaborate.	To find a solution that can work with hydroponic system, since it is smaller and easier to control.
10	In which industries do you sell saffron and what percentage is each industry?	To identify an untouched industry for South Africa.
11	Have you tested any autonomous harvesting equipment?	To identify if labour cost can be lower.
12	In which other industries do you want to sell saffron and why?	To determine a preferred industry and motivation for choosing that industry.
13	In which industry are you able to obtain the highest price per kg?	Since saffron can be optimised in hydroponic, max value should be expected.
14	What is preventing you from starting hydroponic farming, opposed to conventional farming?	To determine if they have any interest and why or why not.
15	Do you have any use for the flower after it has been harvested? Does it bear any economic value?	Currently regarded as waste, but I want to see if someone has found an alternative use.

No.	Questions to farmers with hydroponic systems:	Reason why question is part of interview
1	What crops are you growing with hydroponics?	To establish size and knowledge. Researcher will do online research to show interest.
2	Which hydroponic system are you using?	To see if their hydroponic system will be beneficial to for saffron.
3	Why have you chosen hydroponics above conventional farming?	This will provide supporting evidence to my study and can be compared with literature.
4	Can you compete on price with conventional farmers produce? Or do you have a different marketing strategy?	Determine how competitive hydroponics can be.
5	How has loadshedding affected your business?	To determine the impact of power outages on hydroponics, which requires consistent power.
6	Do you have sustainable or alternative energy supply? What kind and why?	To establish if hydroponic crops can be cultivated with sustainable energy.
7	Have you attempted or are you growing saffron in a hydroponic system?	
8	**If no:**	
a	What is preventing you from attempting to plant saffron?	To identify challenges which could not be found in literature.
b	Do you see this as a profitable opportunity for your business?	To see if they have considered it.
c	Will you attempt to cultivate saffron?	To test their willingness to explore in different crop and understand why or why not.
d	What do you see as your biggest challenge to cultivate saffron?	Determine if they are able to incorporate saffron in their current business.
9	**If yes:**	Unlikely, because it is nowhere documented.
a	Was it difficult to master?	
b	What challenges most the hardest to overcome?	
c	How has the yield been the last few years?	
d	What is the greatest impact on output?	
e	What is the greatest impact on saffron quality?	