The Dutch tulip bulb industry in times of change

Will the Netherlands be able to continue supplying the world with bulbs?

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Abstract

The tulip is the quintessential cut flower. Billions of tulips are sold all over the world with the Netherlands as the global centre. Tulips grown in greenhouses all over the world are forced from bulbs grown on Dutch fields. Throughout history tulips has been a lucrative crop. However, the market has been volatile with high risks and potentially great rewards for those involved. In recent times unreliable weather conditions, rising land prices, changing attitudes towards commercial farming and concerns over rising virus- and pest levels, and the control of them has added further risk to an already volatile industry.

Through qualitative analysis of interviews with Dutch professional bulb growers this thesis seeks to identify what the main challenges facing Dutch tulip bulb growing industry, what are done to mitigate them and if the Netherlands will be able to continue supplying the world with bulbs.

It identifies extreme weather conditions causing great losses in production of tulip bulbs. Combined with a rise in dangerous pests and virus and a lack of tools to combat them, the impact of climate change is decreasing the margins of error in an already highly competitive and low-cost focused industry. Adding to these challenges is Dutch legislation prioritizing a reduction of applied chemical plant production products and emissions from the agricultural sector over the growers need to protect their tulips from pathogen and pests. A frustration from the growers about the implementation of legislation causing problems for tulip cultivation is identified in the interviews. The growers give examples of legislation both leading to reduced access to land as well as potentially amplifying the threat of certain important pathogens. The growers' high skill, knowledge, experience, and problem-solving ability, together with the sophistication of the world leading Dutch flower industry are identified in key strengths to mitigate the identified weaknesses and rising threats to tulip bulb growing. Key opportunities are identified as progress in breeding, technology, and plant protection as well a further globalization of tulip bulb production.

This thesis concludes that the identified challenges and the damage they cause to the Dutch tulip cultivations will likely increase in the future, making it likely that the Netherlands will not be able to continue supplying the world with tulip bulbs in the future. A further globalization of tulip bulb cultivation is recommended to increase the long-term resiliency of global bulb production. However, it also recognizes that the Dutch growers and the Dutch tulip bulb industry will remain essential to global tulip cultivation at present stage as well as for the long-term future development the global tulip bulb industry.

Svensk sammanfattning

Tulpanen är den kvintessentiella snittblomman. Miljarder tulpaner säljs över hela världen med Nederländerna som centrum för den globala handeln och produktionen. Tulpaner som odlas i växthus över hela världen drivs fram ur lökar som odlats på holländska fält. Genom historien har tulpaner varit en lukrativ gröda. Marknaden har dock varit volatil med höga risker och potentiellt stora vinster för de inblandade. På senare tid har dock opålitligt väder, stigande markpriser, ändrade

attityder till kommersiellt jordbruk samt en ökning virus- och skadedjursnivåer och kontrollen av dem lagt ytterligare risker för en redan volatil industri.
Genom kvalitativ analys av intervjuer med professionella lökodlare försöker denna kandidatuppsats ta reda på vilka de största utmaningarna nederländska tulpanlöksodlare står inför och om Nederländerna kommer att kunna fortsätta att förse världen med tulpanlök. Den identifierar extrema väderförhållanden, en ökning av skadedjur och virus, strängare regler för jordbruket, minskad lönsamhet för sektorn och strikt reglering som de främsta utmaningarna för odlarna. Odlarnas kunskap, erfarenhet, skicklighet och problemlösningsförmåga tillsammans med den världsledande och sofistikerade relaterade industri samt framsteg inom förädling, teknologi och växtskydd tillsammans med att ökad tulpanlöksproduktion utanför Nederländerna som de styrkor och möjligheter som kan leda till lösningar på utmaningarna. Tyvärr, är det troligt att problem orsakade av väder och skadedjur kommer att förvärras med ökade klimatförändringar. Det troligt att Nederländerna inte kommer att kunna förse världen med tulpanlökar i framtiden. Denna uppsats drar slutsatsen att de identifierade utmaningarna och skadorna de orsakar på nederländska tulpanlöksodlingar sannolikt kommer att öka i framtiden. En ökad globalisering av tulpanlöksodlingen rekommenderas för att öka den globala produktionens långsiktiga motståndskraft. Trots de många utmaningarna så kommer högst troligen de nederländska odlarna och den nederländska tulpanlöksindustrin att förbli essentiella för den globala tulpanlöksindustrin och dess långsiktiga framtida utveckling.

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The Dutch tulip bulb industry in times of changes. Will the Netherlands be able to continue supplying the world with bulbs?

Den nederländska tulpanlöksindustrin i tider av förändring. Kommer Nederländerna att kunna fortsätta att förse världen med tulpanlök?

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1. Introduction

Due to its wide array of colours, shapes, and affordability the tulip is one of the world's most popular flowers (Rodriguez, 2023). The Netherlands is estimated to provide 81 % of global flower bulb export (Rodriguez, 2023) and 90 % of the world's tulips (Muheisen, 2021). In 2020 tulips were grown on 149 000 hectares in the Netherlands and the value of the Dutch tulip bulb export was estimated to over 250 000 million € in 2021 (Statista, 2023). In 2004 tulips bulbs were produced in 14 countries (Buschman, 2004). Most of the production was small and targeted local markets. Buschman (2004) stated that France, Chile, and New Zealand had larger cultivations producing bulbs for export, with the two latter countries having similar costs and yields to the Netherlands. According to Buschman (2004) these companies are usually managed by Dutch growers and the produced bulbs are exported to other countries for early flower production in October-December (Buschman, 2004).

The Netherlands has through its history carved out a central position in the global flower trade (Gebhardt, 2014). In *Holland Flowering* Gebhardt (2014) describes the Dutch flower industry as traditional yet dynamic, consisting of a mix of large-scale multinational companies and family businesses, with a base of small and medium size ventures, and the typical flower farmer being the son of a flower farmer. Equally reliant on collaborative networks consisting of friends, families, and neighbours as on strong competition between the companies involved in the trade, the Netherlands has according to Gebhardt, (2014) managed to build a global network, facilitating flower sales, connecting growers, buyers, and sellers all over the world with the Netherlands at the centre. The country's advanced trade networks and supporting industries have allowed it to remain the centre of the global rose trade despite majority of bulk production moving to east Africa or other regions with greater access to land, cheaper labour, and a more favourable climate (Gebhardt, 2014). The Dutch rose growers have adapted to this development. Many of the east African businesses are run or owned by Dutch people and remaining rose growers in the Netherlands, have to a large extent, specialized in rarer exclusive breeds to remain competitive (Gebhardt, 2014).

The Netherlands strong position is further explained by the country's initial access to rich and loamy soils and a mild climate suitable for flower cultivation (Tavoletti and te Velde, 2008). There are also market leading supporting companies in fields such as logistics, export, auctions, laboratory, and technology specialized to serve the different needs of the flower industry (Tavoletti and te Velde, 2008; Porter, Ramirez-Vallejo and Van Eenennaam, 2012). Porter, Ramirez-Vallejo and Van Eenennaam (2012) describe how the close proximity and the relationships between businesses within the industry has allowed knowledge sharing between professionals in the sector further contributing to building the country a competitive advantage.

However, times are changing. Flower growers are facing tougher regulations from the Dutch government, increasing costs as well as land becoming less available (Tavoletti and te Velde, 2008). Many smaller companies are struggling with profitability leading to a situation with bigger multinational companies and less of the small and medium sized family businesses historically important to the sector (Tavoletti and te Velde, 2008). The authors mention a combination of internal competition and over production as well as competition from developing countries as a reason to the development. A decrease in family workers in the flower sector of 20 % between 2000-2002 was reported (Tavoletti and te Velde, 2008). Furthermore, Dutch public opinion towards agricultural companies' usage of chemical plant protection products (PPP), is becoming more critical (Riemens *et al.*, 2023). The Netherlands have a goal of decreasing the application of chemical PPP: s within horticulture and agriculture by 50 % till 2030 (Riemens *et al.*, 2023). The ability to contain pests and viruses at an acceptable level with less access to plant protection products is becoming a greater challenge for bulb producers (Riemens *et al.*, 2023). In their report Riemens et al. (2023) describe how agriculture in the Netherlands, despite implementing principles of integrated pest management (IPM), are still relying on Chemical PPP: s to manage pests, diseases, and weeds. They describe the reliance on chemical PPP: s and the absence of viable alternatives as one important bottleneck that makes it difficult for the flower bulb sector and Dutch agriculture to change production to align more with the IPM guidelines. Riemens et al. (2023) also mentions that adopting more sustainable practices could lead to higher costs for the growers.
Stricter regulations regarding chemical PPP: s is not the only cloud of worry on the horizon. In 2019 the European Environment Agency reported that climate change was impacting European agriculture negatively (The European Environmental Agency, 2020). The south of Europe is currently most impacted by the rise in temperature, but the effect of extreme weather is causing losses of yield and increases operation costs all around the continent. The report mentions that warmer temperatures might lead to better conditions for agriculture in northern Europe but a worse situation for the continent (The European Environmental Agency, 2020).

After a poor harvest in 2023 caused by a combination of very rainy autumns, 2022 a cold spring in 2023, and a hot summer there was a global shortage of tulip bulbs, 2023 (Wallin, 2024). The rain disrupted the planting season, the cold spring led to slow development, and the hot summer with rain right at harvest time led to losses at harvest (Beytes, 2023; Wallin, 2024). In an interview a Dutch grower estimated losses of 20-30 % of bulb harvest per hectares for the sector on average (Wallin, 2024). The Swedish forcer (Greenhouse grower specializing in producing flowers from bulbs) interviewed is describing how they couldn't get enough bulbs to produce their planned quantity of flowers and how the sizes of delivered bulbs were

smaller than usual (Wallin, 2024). Forcers in USA also noticed smaller sizes on delivered bulbs (Beytes, 2023). It is reported that the combination of the heat wave and rain during harvest in 2023 lead to increased development in the *fusarium* population causing additional losses of bulbs (Beytes, 2023). Bulb prices rose with around 25-30 % for the forcing season of 2023/2024 (Wallin, 2024).
The autumn of 2023 started poorly with twice as much rain as normal (Wallin, 2024). The Dutch grower interviewed is predicting a further increase in bulb price and uncertainty in the market and Swedish forcers had trouble getting quotes on bulbs from their producers (Wallin, 2024) for the upcoming forcing season, 2024/2025.

1.1 Purpose

This study seeks to enhance available knowledge on how bulb growers are facing the challenges of producing high quality bulbs in times of changing conditions. It aims to synthesise the growers' thoughts and opinions on the challenges and to discuss and analyse them.

1.2 Research questions

What are the main challenges facing the Dutch tulip bulb growers and how can they be mitigated?
Will the Dutch growers be able to continue supplying the world with bulbs?

1.3 Background

Tulips originated as wild plants in central Asia, it is believed they were first domesticated between 1500 and 1600 by the Ottoman empire (Sajid *et al.*, 2013; Leeggangers, 2017). In 1570, the first tulips were exported to the Netherlands from Turkey (Porter, Ramirez-Vallejo and Van Eenennaam, 2012). Shortly thereafter the first bulbs were planted in research purposes by botanist Carolus Celsius at University of Leiden. The popularity of the tulip grew throughout the years and new varieties were added to an already diverse stock. Having a colourful garden became an ideal for the wealthier segments of Dutch society and enthusiasts were collecting bulbs (Gebhardt, 2014). The popularity of the tulip led to speculation in bulbs (Porter, Ramirez-Vallejo and Van Eenennaam, 2012; Gebhardt, 2014). The speculation created an economic bubble where the price of the rare tulip variety *Semper Augustus* would fetch a higher price than top real estate in Amsterdam between the years of 1610-1637.
Over time, the Economic Development enabled other classes of the society to afford tulips which lead to an increased demand. As an effect of the demand, the production also increased and made the tulips more available to a greater part of the society. In 1700's commercial flower and bulb production picked up the the pace and todays flower producing sector started to develop around the city of Haarlem (Porter, Ramirez-Vallejo and Van Eenennaam, 2012). Cultivation of tulips and

other flowers would spread to more areas of the Netherlands but kept its centre around Haarlem and the Westland region (Porter, Ramirez-Vallejo and Van Eenennaam, 2012). Innovations in greenhouse technology would enable flowers to be grown out of season and further expand the scale of flower production (Tavoletti and te Velde, 2008). Responding to an increasing global demand, the industry kept growing to meet the demand through expansion and innovation. It would gradually develop into a sophisticated global network of highly specialized companies and organisations involved in the trade of bulbs and flowers (Tavoletti and te Velde, 2008; Porter, Ramirez-Vallejo and Van Eenennaam, 2012; Gebhardt, 2014) Today tulips are one of the Netherlands most important exported crops with over 4 billion bulbs produced annually (Leeggangers, 2017).

1.4 Tulip botany and morphology

Tulips, in Latin Tulipa are part of the *Lilliaceae* family (Muhammad Sajid *et al.*, 2013; Leeggangers, 2017). *Tulipa gesneriana*, *Tulipa kaufmanniana*, *Tulipa fosteriana* and *Tulipa greigii* are the cultivated subspecies of *Tulipa* (Leeggangers, 2017). Within the four subspecies there are multiple classifications which are based on time of flowering and flower type.

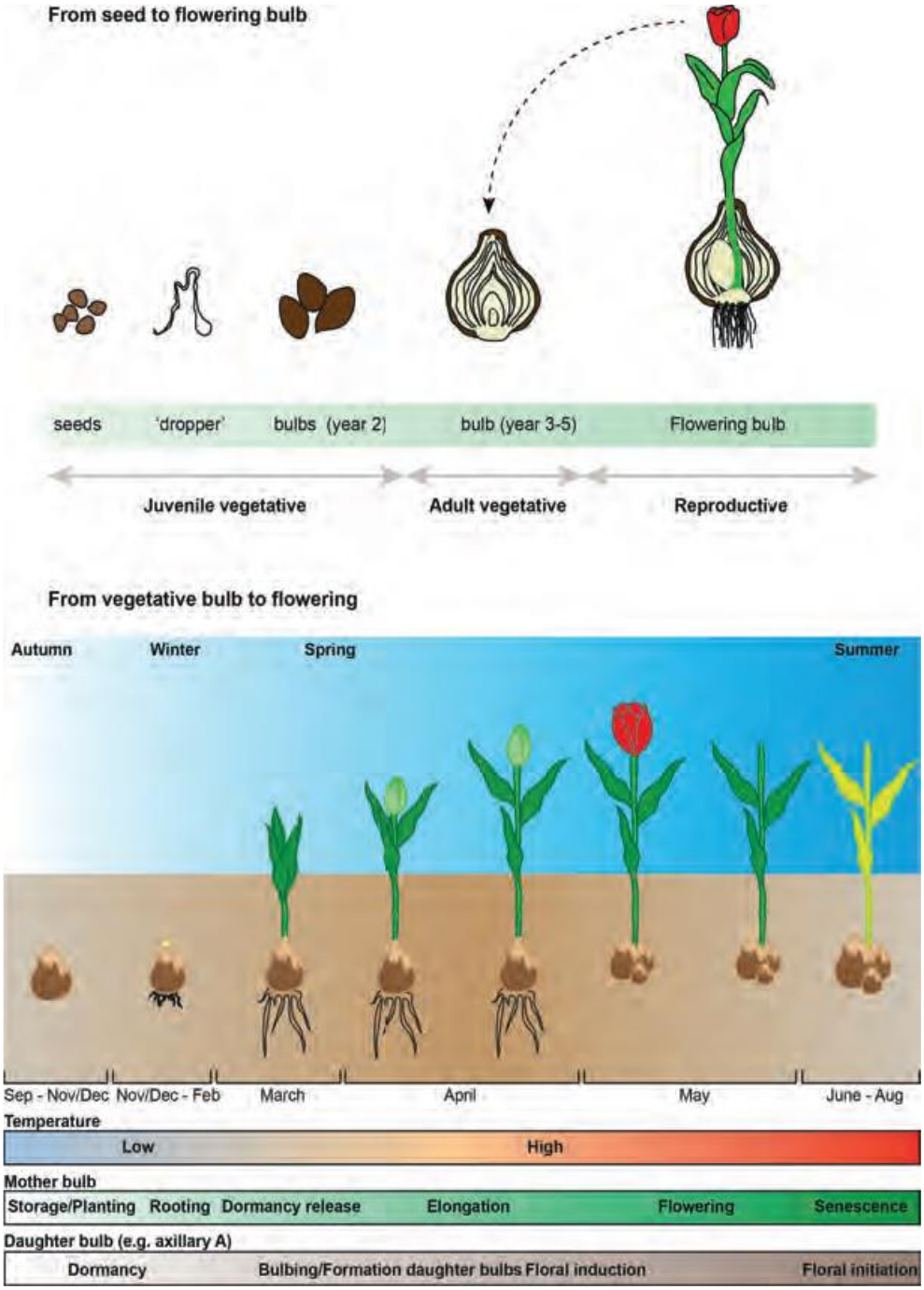


Figure 1. Schematic of tulip life cycle, top of figure from seed to bulb, bottom part from mother bulb to daughter bulbs

Source: Leeggangers (2017), pp 13

Tulips go through two phases, one juvenile and one adult. In the juvenile phase seeds of tulips develop to bulbs (Figure 1, top). During this phase the bulbs are not flowering. After three to five years, depending on subspecies, the bulb has developed enough to enter the adult phase. During the adult phase the bulbs produce annual flowers in springtime and reproduce both sexually through pollination and

asexually by developing daughter bulbs which produces new, identical flowers the next season (Figure 1, bottom). The adult bulb consists of protective outer scales and inner scales containing floral bud meristem, root basal plate containing root meristem and daughter bulbs which also contains meristem to granddaughter bulbs (Muhammad Sajid *et al.*, 2013; Leeggangers, 2017).

In tulip cultivation the adult bulbs are planted between October to December. The tulip starts its development with roots after planting followed by a period of dormancy in winter. The dormancy is necessary for the elongation of the stem and flower bud to develop. The dormancy is broken by warmer temperatures in March which also initiates the development of the daughter bulbs inside the mother bulb. Vegetative development of the plant is continued up until late April and early May where flowering is initiated, see figure 2. After a couple of weeks of flowering the flowers are cut off under the flower bud to focus the plants energy storage to the developing daughter bulbs (Leeggangers, 2017) (Figure 2 and Figure 3). The flowerless tulips reach senescence in summer and daughter bulbs are harvested shortly thereafter.

Figure 2. A flowering tulip field

Source: Smit, personal communication, May 19-21, 2024

Figure 3. Tulip field after flower cutting

Source: G2, May 19, 2024

1.5 Tulip forcing

In general, the tulip has two cultivation systems depending on the end product. For cut flowers the tulip bulbs harvested from the field are placed in storage where they are subjected to a temperature treatment to program designed to initiate flowering at a desired time, see figure 4. e (J.W.J. Munster Export, no date; Vlad *et al.*, 2010; Nayeem and Qayoom, 2015). The temperature treatment varies depending on when bulbs are delivered to forcers and what length the forcer want the stems to develop to (Karlsson, personal communication, May 20, 2024). Bulbs delivered early in the forcing season are cooled the full period at the forcer while bulbs delivered later are usually cooled at the exporting company or growing company so they can be forced soon after delivery.

When the cold treatment is over the bulbs are placed in the greenhouses where they are subjected to optimal conditions for flower development. This type of cultivation

is referred to as forcing since the bulb is forced to flower out of its natural season by imitating nature by using coolers and greenhouses, see Figure 4 for example of temperature program (J.W.J. Munster Export, no date; Vlad *et al.*, 2010; Nayeem and Qayoom, 2015). In the greenhouses the flowers can be forced in soil, in boxes filled with substrate or in boxes filled with water (J.W.J. Munster Export, no date).

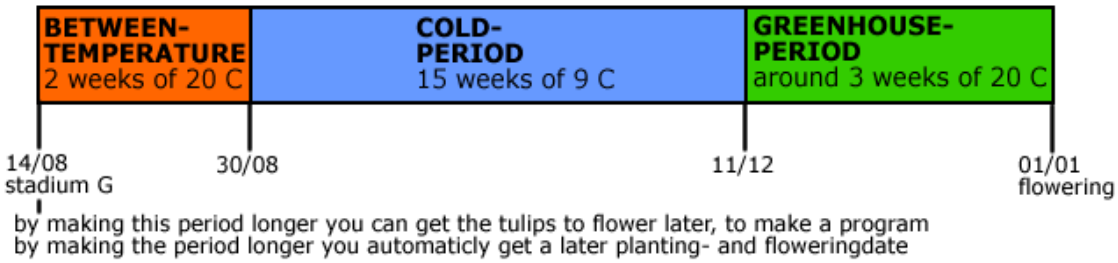


Figure 4. Schematic showing a temperature treatment of tulip Tulip growing

Source: J.W.J. Munster Export (no date)

The tulips grown on fields are mainly grown for bulb production (J.W.J. Munster Export, no date; Leeggangers, 2017). As mentioned in chapter 1.5, tulips need both a period of cold and a period of warmth to sufficiently develop flowers and daughter bulbs (Muhammad Sajid *et al.*, 2013; Leeggangers, 2017). During planting time, a soil temperature under 12 degrees Celsius is necessary to prevent outbreak of Fusarium and Augusta virus (J.W.J. Munster Export, no date). During the dormancy period (October/December-February) air temperatures between -10 and + 5 degrees Celsius are ideal for stem elongation and bud development inside the bulb (J.W.J. Munster Export, no date; Leeggangers, 2017). A slow shift from colder to warmer temperatures is necessary to avoid stress and poor development of the bulbs (late February-march). Tulips need a mild spring for optimal development of stem, leaves, and flower in the field (Leeggangers, 2017). Temperatures between 17-20 degrees are optimal (Nayeem and Qayoom, 2015). After flowering the flowers are cut and flowerless tulips are left on the field until late late spring or late summer depending on planting time to continue photosynthesis until the daughter bulbs are fully developed, also known as stadium G (J.W.J. Munster Export, no date; Sochacki and Chojnowska, 2004). After harvest the bulbs are cleaned from leftovers of mother bulb, soil, and roots and bulbs with symptoms of diseases or pests are removed (J.W.J. Munster Export, no date; van Aartrijk, 1998; De Boer, 2008a). Finally, the bulbs are subjected to two weeks of temperature around 20 degrees Celsius, followed by a longer period in cold temperatures to simulate dormancy until they are ready to flower (J.W.J. Munster Export, no date).

1.6 Pathogens and pests

1.6.1 General

Bulbous flowers are susceptible to several pests, diseases, and viruses (Table 1). Fungi and Oomycetes present in soil are Fussarium ssp, Phytophthora ssp, Phytium ssp, Rhizoctania ssp causes losses of quantity and in quality through different types of bulb- and root rot (De Boer, 2008). Overground fungi are *Botrytis ssp* and *Phoma ssp* causing leaf blight and spotting on leaf and stem. In the case of pests like insects, different species cause losses on the field, in greenhouses and in the storage facilities of bulbous flowers (De Boer, 2008). Bulbous flowers are target of different aphids (sap sucking insects), white flies, thrips, and mites. Aphids causes further problems by being vector of viruses. Some mite species are also vector of virus (De Boer, 2008; Lommen, 2011). Mites also act as vector for *Fusarium oxysporum (Schlecht.) f.sp. tulipae* by feeding on mycelium before feeding on plants (Suazo Jiménez, 2012).

Table 1. List of identified pests and pathogen of bulbous flowers

Insects	**Fungi and Oomycetes**	**Nematodes**	**Virus**	**Bacteria**
Aphids	*Phytophthora spp.*	*Pratylenchus ssp.*	*Tulip breaking virus (TBV)*	*Dickeya spp.*
White flies	*Pythium spp.*	*Meloidogyne spp.*	*Tulip virus X (TVX)*	*Pectobacterium spp.*
Cushion scales	*Fusarium spp.*	*Aphalenchoides spp.*	*Tobacco rattle virus (TRV)*	*Erwinia spp.*
Thrips	*Rhizoctonia spp.*	*Ditylenchus dipsaci.*	*Tobacco necrosis virus (TNV)*	*Xanthomonas spp.*
Mites	*Botrytis spp.*	-	*Cucumber mosaic virus (CMV)*	*Rhodococcus spp.*
Cicades	*Phoma spp.*	-	*Lily symptomless virus (LSV)*	-
Caterpillars	*Peronosporaceae spp.*	-	-	-
May beetle larvae	*Coleosporium spp.*	-	-	-
-	*Puccinia spp.*	-	-	-
-	*Uromyces spp.*	-	-	-

Source: De Boer (2008)

1.6.2 Host specific pests

Fusarium oxysporum (Schlecht.) f.sp. tulipae (in later text referred to as *fusarium*) is problematic in bulb production (Miller, 2002) and causes economic damage to the tulip industry (Suazo Jiménez, 2012). The pathogen infects tulips growing in the field, colonizes the plant resulting in infected daughter bulbs (Miller, 2002; Suazo Jiménez, 2012). *Fusarium* is recognised by the sour smell of decaying bulb tissue and rot starting from the base of the bulb (Figure 5) (Miller, 2002). The infection causes bulbs to rot and produces large amounts of the gas ethylene, a plant hormone that causes several problems for the plant including stunted growth and aborted flowers (Miller, 2002; Suazo Jiménez, 2012). Ethylene affects non infected bulbs in storage as well, leading to further losses (Suazo Jiménez, 2012).

Figure 5. Fusarium infected tulip bulbs

Source: Miller (2002), pp 5

The threat of *Fusarium* is larger during seasons with high soil temperatures from flowering to harvest, early May to mid-July (Miller, 2002). *Fusarium* levels in the field are rising. It is likely that a combination of increased temperatures, different growing and handling practices has led to the rise. New strains and changed regulations regarding fungicides could also be a reason to the rising levels.

On cool and rainy springs and summer the tulips are susceptible to *Botrytis tulipae*, otherwise known as tulip blight or fire, further referred to as *Botrytis* (Plant Disease Diagnostic Clinic, no date) The infection starts after *Botrytis*-spores land on the plant causing spotting on leaves and flower, misshaped leaves, and weak stems (Figure 6 (ii)). During winter it can overwinter on dead plant material through sclerotia (Figure 6 (i)). Once the weather conditions become favorable to the *Botrytis* again it changes back to its active form and starts infecting new tulips.

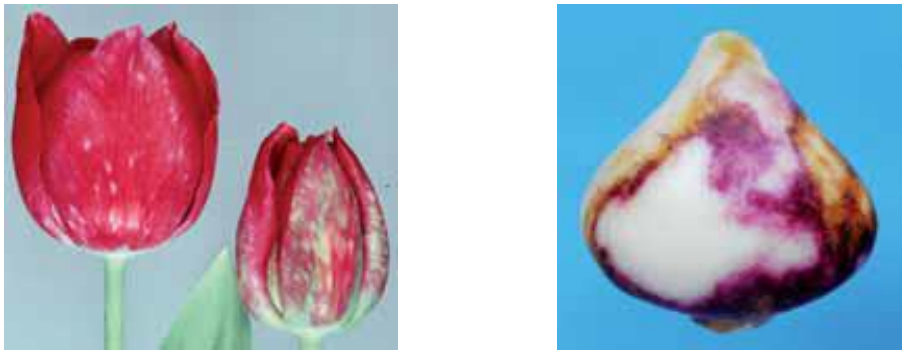
Infected plant material in soil can spread the infection to harvested bulbs, leading to *Botrytis* outbreaks when the bulbs are planted at buyers of them.

(i) *(ii)*

Figure 6. (i) sclerotia on tulip bulb; (ii)Symptoms of Botrytis infection on tulip flower and leaves

Source: Plant Disease Diagnostic Clinic (no date), pp 1-2

Host specific Tulip gall mite, *Eriophyes tulipae* is another threat to the tulip (van der Lans, 2010). The tulip gall mite attacks the bulb in field (Lommen, 2011). The mite disrupts rooting and development of the bulbs which can be observed by sprouts too weak to stand or no sprouts at all. Later, weak stems can be observed and white spots on the flowers (Figure 7 (i)). In storage red discoloration on bulbs can be observed (Figure 7 (ii)). Another big problem associated with tulip gall mites is their role as vector of viruses such as tulip breaking virus, TBV (Lommen, 2011), which causes further damage to the crop and poses increased risk for the grower since several viruses are not only dangerous to the crop but also quarantined in multiple countries the growers export bulbs to (De Boer, 2008). Tulip Gall mite is also suspected as a vector of tulip virus X, TVX (Lommen *et al.*, 2012).



(i) *(ii)*

Figure 7. (i): a tulip flower with symptoms of mite (ii):a tulip bulb with symptoms of mite

Source: Lommen (2011), pp 2

TBV is the oldest known plant virus (Lesnaw and Ghabrial, 2000). The symptom of the virus can be observed in streaks and flames of different colour in previously single-coloured tulips, known in the industry as breaking, fig.8. The most sought-after tulip during the 1700th Netherlands tulip bubble, Semper Augustus, was in fact infected by TBV (Lesnaw and Ghabrial, 2000). The popularity of the TBV-infected tulips would lead many growers and breeders to grow and breed infected stocks. It would later be noticed that the breaking of colour was hard to replicate, and the tulips would decrease in health and quality. Today TBV is still a major problem for tulip growers (Lesnaw and Ghabrial, 2000; Polder *et al.*, 2014). The virus is spread by several different vectors, mainly aphids (Lesnaw and Ghabrial, 2000; De Boer, 2008; Polder et al., 2014) and cost growers a lot of resources since they must remove infected cultivars from the field to prevent further spreading (Polder *et al.*, 2014). In 2014 selection and removal of infected plants was mainly manual but studies on using machine learning and machines to select and remove the infected cultivars have been made (Polder *et al.*, 2014).

Figure 8. Variety madam spoor infected with TBV

Source: Brunt (1996), as found in Lesnaw and Ghabrial (2000), pp 5

Another damaging virus is Tulip virus X, TVX (De Boer, 2008; Lommen et al., 2012). TVX decreases the health of tulips through chlorosis and necrosis on leaves and causes flowers to break in colour (Lommen *et al.*, 2012). The virus spreads through mechanical contact but is also suspected to be spread through mites (Lommen *et al.*, 2012).

1.6.3 Integrated pest management and quality control

All professional growers in Europe must work with integrated pest management, IPM in their plant protection strategy (The European Commission, 2023). The goal

of IPM is to limit chemical PPP usage and to grow commercial crops in such an environmentally and economically sustainable way as possible. The European commission defines IPM as:

"Integrated pest management means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. 'Integrated pest management' emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms (The European Commission, 2023)*."*

When working with IPM growers protects their crops by planning, managing, and monitoring their cultivation to reduce the establishment, and spread of pests and pathogens (The European Commission, 2023). Active pest control measurements should take the specifics of the crop, pest, and immediate surroundings into account to manage the threat in an efficient way safe for human and surrounding habitats. If possible physical and biological control should be applied before chemical control. Figure 9 illustrates the decision-making process of IPM and shows some examples of ways growers can deal with pathogens and pests.

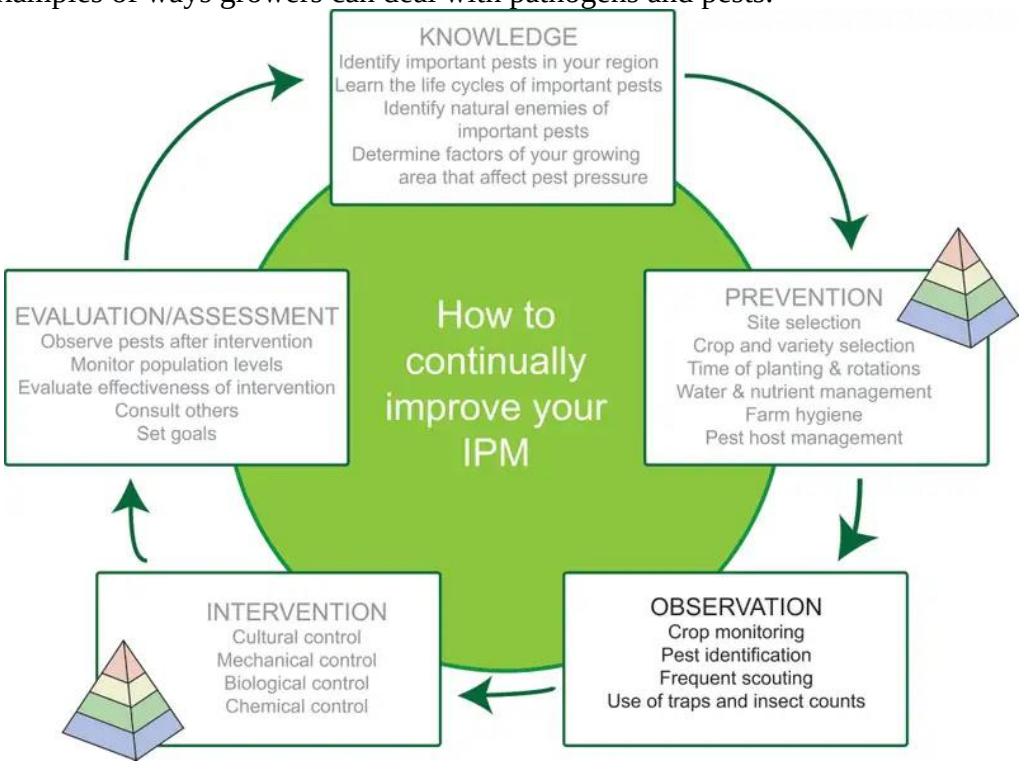


Figure 9. schematic showing the working practices of IPM are implemented in practice

Source: ECHO (no date)

To avoid economic losses from pests and pathogens there are different PPP: s and methods available for the grower (van Aartrijk, 1998; De Boer, 2008). For flower bulbs growers it is important to keep good hygiene, healthy plant material, practice crop rotation, growing in healthy soil as well as selecting resistant varieties when possible (van Aartrijk, 1998; De Boer, 2008). It is very important to remove infected or dead plant material from the storages to avoid infection of healthy plants (van Aartrijk, 1998). There are different biological and chemical PPP: s available for the growers to apply to actively supress the pests (De Boer, 2008). However, the biological PPP: s takes time to get registered and the market is limited which in 2008 made them less prominent in the market according to De Boer (2008). Using natural enemies was also hard to do in a successful way in field cultivations due to the presence of more variables than greenhouses where they were used with success (De Boer, 2008). Both van Aartrijk (1998) and De Boer (2008) meant that chemical PPP: s were still the most efficient and most used form of plant protection. That is still the case according Riemens et al. (2023).

The health and quality of bulbous flowers are inspected by independent governmental control agency Bloemenbollenkeuringsdist, BKD (BKD, 2024). If a batch of tulips have too high disease levels or quarantined viruses the grower is not allowed to sell it. The BKD inspects tulips both when flowering in the field and later when the bulbs are harvested. Samples of tulips are lab tested for quarantined viruses like TBV.

1.7 Climate change and weather-related issues for tulips

Climate change is expected to affect field flower cultivation negatively by disrupting normal growing patterns, making cultivation planning harder, increasing problems with heat stress (especially for temperate plants) and cause more draughts, putting high emphasis on irrigation systems (De, 2018). Furthermore, warmer temperatures might lead to an increase in pests and diseases (Leeggangers, 2017; De, 2018).

For tulips grown on heavy clay soils heavy rainfalls are big problems (Boekel, 1970). The soils become water saturated quicker than sandy soils. This makes planting harder since the soil can be unworkable or the fields might become damaged by the machines used in the cultivations. The highly saturated soils can lead to damages on the bulbs due to lack of oxygen. Examples of this were shown in 2022 and 2023 when the heavy rainfalls caused flooding which led to bulbs not being able to root and develop causing significant losses (Wallin, 2024).

High temperatures can damage the disrupt the development of the floral bud inside the bulb leading to flowers of poor quality or lack of flowers (Leeggangers, 2017). If temperatures reach extremes it can lead to flowers wilting and dying in the field which was also seen in the summer of 2023 (Wallin, 2024). Furthermore,

unexpected rain during hot summertime can lead to *fusarium* outbreaks (Miller, 2002; Beytes, 2023).

2. Method

2.1 Qualitative method and purposive sampling

The primary data of the study was collected by interviewing growers and observing their fields and facilities. According to Bryman (2016) this is a qualitative research method since it relies on the words of the interviewed and the words describing observations to generate qualitative data (Bryman, 2016). Six growers of tulip bulbs were selected strategically using Bryman (2016):s method of purposive sampling. The goal of purposive sampling is to select participants based on different criteria that makes them relevant to the research and helps the researcher answer their research questions, in this case the selected participants Dutch tulip growers. Participants were chosen based on their business model and the scale of their operations (Table 2). The aim of the selection was to get a wide scope of perspectives to be able to get a broad picture of the tulip bulb industry and to find answers to the research questions.

Table 2. Showing the participants in the study and information that made them viable for the study

Participant	**Grower 1 (G1)**	**Grower 2 (G2)**	**Grower 3 (G3)**	**Grower 4 (G4)**	**Grower 5 (G5)**
Business type	Grower and exporter	Grower and exporter	Grower and forcer	Grower and forcer	Grower and exporter
Scale	Medium	Small	Medium/Large	Small	Large
Tulip (Ha)	65	2,5	160	6	250
Other cultivars	Yes	No	No	No	Yes
Cut flowers in greenhouses	No	No	20 000 000	1 200 000	No

2.2 Semi structured interviews

According to Bryman (2016) the point of conducting semi structured interview is to get a deeper understanding of the world the participants in the study are active in and to allow a greater deal of flexibility to the interviewer to gain answers to their research questions.

The interviews were conducted in semi-structured form with the aim of engaging the growers in conversation. The questions were written in an open way to give the grower space to reflect and elaborate on the topics (Appendix 1). The questions were constructed to collect data on four preformulated topics designed to provide. Follow up questions were asked for clarification and for further elaboration. The timeframe for the interviews were 45-60 minutes.

2.3 Transcription

The interviews were recorded and later transcribed using the digital service oTranscribe.com (Bentley, 2024). During the transcription the audio files were transcribed onto a document with timestamps for every question. The purpose of transcribing the interviews is to make the data more accessible and faster to analyse. The interviews were transcribed word for word and included describing gestures made by respondents and items or places referred to in the conversations. During transcription the audio was replayed multiple times to make sure transcripts were correct.

2.4 Thematical Analysis

Thematic analysis is used to identify, interpret, and analyse the data from interviews or observational data in a flexible way (Clarke and Braun, 2017). Relevant data from the interviews, codes, are identified, reoccurring codes are organized into themes, the themes are then organized and analysed with regards to the research question and chosen theoretical framework.

When analysing the transcript's interesting data was color-coded after the chosen theoretical framework. At the end of every transcript a summary of the coded data was written. After coding each individual transcript, the summaries were put in a joint document and the codes where thematically interpreted to identify relevant themes to answer the research questions.

2.5 SWOT-analysis

The SWOT analysis was chosen as theoretical framework for analysing the data. It was chosen due to its wide applicability and due to it previously being used to analyse cases in agriculture and horticulture (Benzaghta *et al.*, 2021). SWOT stands for strengths, weaknesses, opportunities, and threats. The model seeks to analyse a case by putting the subject's strengths in relation to its weaknesses and its opportunities in relation to its threats (Benzaghta *et al.*, 2021). In this case the subject were Dutch bulb farmers, and the strengths, weaknesses, opportunities, and threats are those identified in the interviews. The SWOT-analysis in this paper is based on Kotler, Armstrong and Parment (2017):s version. However, the case analysing one company is replaced by the Dutch tulip bulb growing industry, it's internal strengths and weaknesses and its external opportunities.

2.6 Literature study

To acquire background information on the subject and to investigate the current body of literature searches was made in the Google Scholar database. Key words used were *Tulips, agriculture, economics, tulip breaking virus, TBV, tulip virus X, TVX, Pest management.* The keywords were combined in different ways.

In-between interviews a secondary, complementary literature search was conducted using google to find Dutch scientific papers, news articles and industry information

using dutch search words: Galmijt, beheersung, tulip, tulp. After finishing another complementary search was made using Google to find news articles and general information about the effect of climate change and its effect on agriculture.

2.7 Ethical considerations

The participation in the study is anonymous. Details that could identify the participants such as gender, age, other cultivars grown, or location of their businesses are not included in the report. The respondents were informed of how SLU will process their data according to GDPR and how the data of their interviews would be used in the study. They were asked to consent before the interview and could at any point during the interview cancel it. The recordings of their interviews will be deleted upon publication of the work. Furthermore, the paper is written in English instead of Swedish so that the participants in the study can read the paper if they are interested.

2.8 Method of contact, practicalities, and summary

The growers were contacted through WhatsApp (Acton and Koum, 2009) with brief information about the project and its purpose and a request to participate with two forwarded documents. One containing further information about the project and information on how the data from the interviews were going to be processed. The second document was the questionnaire containing the interview questions. Five out of six growers responded and five were willing to participate in the study. The preferred way of interview was in person at the growers 'companies during week 16 in April. The interviews took place from the 16th to 24th April. Four interviews were conducted in person at the respective company sites. One interview was conducted on phone due to time constraints. The physical interviews were combined with the grower's showing their respective operations. After the interviews had been conducted, they were transcribed and analysed using thematical analysis and a SWOT-analysis.

3. Results

3.1 Result analysis

First an interpretation of the tulip bulb industry based on the codes and themes generated from the thematical analysis of the data provided by the participants and observational data acquired during the visit. The results are presented in three key themes:

The industry

The weather conditions

Plant protection and regulation

The results are concluded by summarizing key strengths, weaknesses, opportunities and threats to the grower's ability to produce a good tulip bulb harvest and putting them in a SWOT-table. The results are analysed in the discussion where strengths and weaknesses, as well as threat and opportunities are of the three key themes are related to each other.

3.2 The industry

The growers participated in the interviews with interest and showed great knowledge for all things regarding tulips. They are all experienced tulip growers. Many of them started working in the field at a young age. There is a sense of professional pride and commitment to their industry conveyed when discussing tulip bulbs. From their bulbs tulips are forced in greenhouses in countries such as Sweden, USA, Poland, the Netherlands, and other countries across the globe. Despite forcers producing cut flowers from bulbs all over the world no other country has manage to develop a tulip growing industry able to compete with the Dutch one.

"One of the strengths is that bulb industry is typical Dutch industry. The bulb industry because of the weather or whatever reason it's just a typical Dutch thing. For example, lilies or potatoes they are grown worldwide. When in Holland the weather is very bad the potatoes in Germany or the lilies in China, they're very good so on the whole global trading. Holland is such a small country, but this strength is also a weakness. When there is a lack of bulb it's just a Dutch thing so the price will get higher. Like last flower season the prices on flowers were good because they are no tulip bulbs from abroad grown in Germany or France (G4)."

Four out of five are generational flower farmers. Four of five studied agriculture at the same university, one studied business and political science at a different university. Two of the interviewed has started their own ventures, the other three have continued their parents or relative's businesses. Two participants have worked

for different businesses outside their current ventures. It's clear when talking to the growers that the family connection is important. All the respondents refer to family when talking about their businesses. It's most clearly exemplified when G1 is asked about their company´s history.

"This company is a family company, from my father and my uncles. They took it over from my grandfather long time ago, in XXXX I started the export company besides our growing company so after that we grow a little and my father and uncles stopped with company and now, I'm going on with it with my companions, two of us and all my sisters are working in it now (G1)."

Family businesses like this are quite typical for the Dutch flower industry according to the literature (Tavoletti and te Velde, 2008; Porter, Ramirez-Vallejo and Van Eenennaam, 2012; Gebhardt, 2014). Participants refer to other growers and, sometimes each other, indicating a tight knit community, showing example of the social networks that Gebhardt (2014) attributes the success of the Dutch flower industry to. An example of how growers work together is how G2 plants their tulips. Together with other smaller growers a planting schedule for 60 hectares is made together with a machinery company hired to do the planting for the group of smaller growers. Furthermore, all the growers work together with nearby farmers for crop rotation.
The Dutch dominance is not only a source of pride. The lack of international competition provides safety during bad years since it makes it possible for tulip growers to sell bulbs at higher prices during bad years to cover their costs. Although the growers agree that the last couple of years have been bad, they are used to the ups and downs of the tulip market.

"I think the industry will run like this because when the weather is good people start to produce too much then the market will go down so I think the tulip market is still that good because there is always something that will happen to affect the tulip market. It's always a good situation, I think(G1)."

The Netherlands is a small country with well-developed infrastructure for regional transport and shipping abroad (Porter, Ramirez-Vallejo and Van Eenennaam, 2012). Growers, exporters, local forcers, machine and tech companies and other supporting industries all operate in a close proximity to each other making the flower sector an efficient network for growing and selling flowers (Tavoletti and te Velde, 2008). The concentration of the industry to certain areas was confirmed while driving to the interviews. A great amount of flower fields, predominantly tulips, as well as several large and small professional greenhouses were observed.

However, the small size of the country and the concentration of the industry is also a weakness for the growers as it makes them more susceptible to be equally impacted by the weather. Opposite to the autumn rain and early summer heat spike leading to shortages of bulbs caused by 2023: s harvest (Beytes, 2023; Wallin, 2024) good weather conditions can lead to surpluses causing different problems.

"Yeah, we bought the greenhouses in XXXX. It was really a fucking season in the summertime because we have 3,5 million bulbs left in august, we can't sell nothing for nothing, we couldn't sell! (G3)"

Everyone had a lot of bulbs?

"*Everyone and, the market was not, you know, and the greenhouse was the half, what it is now, and it was empty, and the owner wants to sell it because he needed money, so we bought it and we started forcing over there (G3)."*

The story does not only illustrate the big risks growers face but also the importance of investing when necessary as well as being at the right place at the right time. To stay competitive growers must produce a large enough quantity of bulbs and they must be of sufficient quality in terms of flower producing ability, size, pest-level and be virus-free. They also need plant stock for next season. To meet these goals the growers practice precision agriculture, relying on specialized equipment, facilities, and machines as far as possible. Figure 10 showing the net planting machine, a technical innovation necessary to plant and harvest bulbs in an efficient way on clay soils.

Figure 10. showing net planting machine. The bulbs are planted between two nets. When they are harvested later the nets are rolled up into a machine that separate the bulbs from the net. This machine is used by all growers growing tulips on clay soils.

Source: G2, May 19, 2024

Furthermore, the growers monitor their fields routinely for looking signs of pest attacks. Weather forecasts are important for the growers as it gives them important information on if they need to water their crops and predict pest attacks. Some of the use sensors to monitor the current level of water in the soil for more precise irrigation. The cultural methods applied by the growers is aligning with the examples given on how to implement IPM to prevent pathogen spread (The European Comission, 2023) as well as recommendations for pest control made by van Aartrijk (1998) and De Boer (2008).

The short tulip season makes it common for companies to grow other crops when the tulips are done, as well as combing their field tulips with forcing bulbs in greenhouses. Tulips have three labour peaks: planting in autumn, virus selection in spring, and harvest during the summer. Extending the season with other cultures allows growers to offer more steady work opportunities to staff. The growers' main clients are forcers. Even though they are divided into two separate markets, cut flowers and new bulbs are produced from the same bulb. A recent development are bigger companies, traditionally specialized in one market, venturing into the other.

"No, it's competition but in the flower production it's more. Bulbs are mainly half products, a lot of companies nowadays have both, they are growing bulbs and forcing tulips. They have hard competition with the sellers with these forcers (G2). […]It depends on the market, kijken (look), when we have a of bulbs the forcers can use it themselves and the growers are depending on them and exporters to buy them but we cannot do anything ourselves but now at this time the prize is so high (bulbs) that actually grower who are also forcers when they calculate the prize they should not even force, they should sell all the bulbs, if you look at it economically but they don't do it of course since they have these buildings. So, when it's too much it works better to be a forcer as well but when it's too little, it works well for the bulb grower (G2)."

Despite the demand for tulips a lot of companies are struggling to stay profitable. From what the growers say it seems that the current situation is tough for all companies but especially the smaller ones. All the growers mention that good tulip fields are getting harder and harder to find and the price of renting or buying is becoming more expensive. According to one grower the yearly cost of renting a field is close to 5000 € per hectare. All the growers can find staff but finding and keeping them are getting harder. Due to a bad planting for many growers many of them don't dare to give prices and the bulbs that are sold are sold at very high prices.

Growers use to be able to sell bigger shares of their bulbs before harvest but after bad weather during the planting season of 23/24 it's too uncertain for many growers to give a price.

"I am worried for all the companies that we're losing. To stay as this industry, I think we need a large group of bulb producing companies but also mechanical companies, transport companies. All different kinds of companies specialized in helping us. We are becoming less and less number of companies I feel like we're starting to lose this base. The foundation is getting more uncertain (G5). […] I see the companies that remain becoming more proffesional. In every aspect of their business. I see the quality of flowers inproving with newer varieties with better vase life. More professional companies having a better cold chain. So, there is a lot of positive things happening as well. More varieties, more shapes, in differrent colors. In principle I would say we're a beautiful industry with a beautiful product. It's getting a bit tough (G5)."

The growers report a situation in the industry where bigger companies that can cover the increasing costs and do the necessary investments are growing bigger while many smaller companies are struggling to make results. Many of the growers mean that the cost of producing bulbs is rising faster than the price of the cut flower which is a big problem since forcers are the main client for the growers. The price of tulip bulbs has been high the previous season due to the bad harvest. The past forcing season (23/24) had a high enough price of flowers for the forcers, so the forcers could afford paying sufficiently for the bulbs.
There are also growers specializing in exclusive tulips, which have created a separate market. The exclusive tulips are rarer varieties which are usually harder to grow. The rarity and limited supply of them makes it possible for growers and forcers to sell the bulbs and flowers at higher prices. However, when growing other varieties, growers to large extent must compete on price. Many of the growers are worried that big sellers like supermarkets and garden centers are competing too much on price, creating a pressure on all lines of the production chain to focus on cost cutting.

"*I think it's equal, it's equal. But I think the very big companies they produce a lot for retail. The cost price is getting higher and higher because of everything. The tulip growing outside is becoming more and more difficult. The cost of everything getting higher and higher and higher but making contracts is not. We don't do it with our company, we are auction sellers. But making contracts is a difficult I think because the supermarkets are tempering with the price (G4)."*

3.3 The weather conditions

Historically the mild Dutch climate has been good for growing flowers (Gebhardt, 2014). High temperatures in October delayed planting times for some growers since the soil temperature was not under 12 degrees Celsius (2023). However, a bit higher average temperatures than usual is not the biggest problem. Its recent years extreme weather conditions are causing a great amount of stress for the tulip growers. When a heat wave hits, it puts high pressure on irrigation systems. Supplying water is of utmost importance for the survival of the crops. Droughts leads to wilted, burned and in worst case dead flowers before the bulbs have developed enough resulting in lower harvests and economic losses.

"Last growing season? Yeah, last weeks of May first weeks of June was very hot so the tulips collapsed (G4)." [….] The weight of harvest was about 20-15 % less than average. It was not normal the harvest (G4). [….] *"On average and we have never, our season was very very bad. It has never been as bad as this year. We didn't have a worse season than 2022-2023 (G4)."*

The current season of 2023-2024 did not start better than the previous one G4 described. Heavy rainfall in autumn disrupted planting schedules all over the Netherlands by tractors not being able to work the fields and losses due to flooded fields drowning the freshly planted bulbs. Signs of water damage can be observed in Figure 11 on the uneven edges of the beds and the naked spot in the bed with two different cultivars to the center right of the field.

Figure 11. A field with water damage

Source: G3, May 19, 2024

One of the interviewed growers says that last season they calculated losses due to water damaged fields at 100 000 € /hectare. After planting this season (23-24), they have lost 15-20 hectares worth of tulip bulbs due to water damaged fields. The heavy rain also reduces the root development of the bulbs that survives, hampering their development resulting in smaller sizes of next year's plant bulbs.
After planting season, the flowering started two weeks earlier than normal in April. During field visits and interviews between the 15th and 21st a varied degree of healthy-looking fields and water damaged fields could be observed. Most days of the week had frequent, short rain showers and strong winds. Hail was also observed. In the interviews the growers give examples on different planting depths and how planting two weeks before the rain let the bulbs develop root before heavy rains come making them more resistant to water damage. However, the weather forecast is not absolute, and the most important preventive measure the growers can take is to plant on good fields.

"It starts with where you plant your tulips. So, this year, normally we're in heavy clay soils, this year we went to the east of Holland on top of a hill, a clay soil hill. There we have a sandy soil and a higher position so the water will run off more easily. That's one of the options next to the drainage. Right now, it's normal in Holland that they're in the soil so like every 15 meters. You can also but the at every 7 meters or 3,5 meters. In principle the farmers we rented field from already put it down. If it's in the field already a few years, it's much better in getting rid of the

water than when you placed it just before it's planted. On the drainage system you can also put pump system to make it more effective (G5).”

The April weather disrupted virus selection since tulips cannot be graded when wet. The heavy rains, strong winds and hail caused some tulips to fall disrupting the flower cutting since it’s done by machine relying on crops of even height. The growers also reported losing tulips in the field due to hail damage. The hail injured leaves and flowers in worst cases causing stems to snap, see figure 12 and 13.

Figure 12. Hail damage on tulips in field

Source: G2, May 19, 2024

Figure 13. Close up of hail damage on leaves
Source: G2, May 19, 2024

Some of the interviewed growers are pessimistic for this bulb seasons harvest (2023-2024). Despite the weather already causing losses to growers all over the Netherlands good weather during spring and summer could mitigate the bad start. The growers are now hoping for a mild spring with moderate amounts of rain and summer that's not too hot without rain showers during harvest time.

3.4 Plant protection and regulation issues

Protecting the tulips from attack by managing the threat level of pests successfully is an important aspect of being a good grower and producing bulbs of good quality and quantity. The growers are all aware of this and puts a big emphasis on it. While visiting the facilities the equipment and machines were clean and well organized. The facilities are also clean, and the growers seem to be aware of the importance of practicing good hygiene to contain pests during handling of the crops. Their emphasis on hygiene and grading and discarded infected bulbs and flowers are aligning with recommended practices of IPM (The European Comission, 2023).

In the processing lines for bulbs, they are graded and if pests are seen on plant material it's immediately discarded. The growers need high harvesting capacity to lift the bulbs from the soil as quick as possible during the short harvest window (two to three weeks) to avoid losses. The fast and organized processing is essential for the growers to be able process and store their bulbs in time. The mechanization of production is mentioned by the growers as necessary to compete. However, despite its advantages in efficiency and oversight of production it leads to a great deal of contact areas for the bulbs which creates more opportunities for pests to spread.

"It's harder I think, but it's also I think in old days everything went by hand and now everything is done by machines. So that makes them more sensitive for diseases. Can you do more about, I remember my grandfather for example, in those days they planted less tulips per square meter, so they were much earlier big. But you started to make more and more, as much as possible. There we could maybe go back a little to produce less bulbs but bigger, better quality. But that's depending on the price. When you get the same almost for a small bulb as big bulb automatically you plant closer. The tendency in Holland is that everything is based on cost. You cannot make a higher selling price for flowers, so they try to take down the cost (G2)"

The growers are experiencing a higher level of pests. There is a difference in opinion on how much the weather is affecting the rise of pests. Some focus more

on the decrease of efficient control methods, some on the rise in temperatures. However, all agree that the situation is troublesome.

"What's normal? There is always something. It's getting some kind of extreme. It's changing but it was always changing in the past. What you see it's getting a little bit warmer, so temperatures are rising, that's for the virus it's a little bit difficult. You get more mites. It's more difficult to grow in Holland. We were looking to produce a little bit higher, in Denmark or maybe in Sweden. That's a little too difficult at this moment but maybe there is some opportunities in the future (G1)."

The most mentioned pathogens are TBV, TVX, tulip gal mite and *fusarium*. The growers report that it's getting harder and harder to keep the pest level down. There are robots used for sorting out *fusarium*-bulbs when the bulbs are graded before storage. Some of the growers interviewed are using them. There are robots being used and developed for virus-selection. However, the robots are too expensive for the smaller growers to invest in. One of the growers are using selection robots as well as the more common manual selection which all growers do. When flowering start in April, virus-selection is done. Cultivars susceptible to viruses are inspected. At that time viruses can be identified on color variegation on the flower, which is most common. Less commonly, some cultivars show symptom on the leaves. Flowers with symptoms are cut under the flower bud and herbicides are applied to through the stem to kill the infected plant before removal. Selection takes time and trained labor. During the visit to the Netherlands teams of workers doing selection on the fields were a common observation.

"*Yeah, we have 4 robots. We started the project; we were the first one. We started with 6 or 5 other companies, we started that project 6 years ago, to pick it up, we were the first one and we develop with the guys from the university and company from the neighbour. We put money in it, and they make it and its last year was not well but this year it goes quite well. It's for the future, it's super. He's autonom, he drives his own routes (G3)."*

Since growers are not allowed to export bulbs infected with TBV growers of all sizes must put in a lot of resources on selection, whether it is done manually or by robots. To contain virus levels, it is of utmost importance to control the vectors. All growers' express worries over an increasing tulip gall mite population. Although control methods such as low oxygen storage are available, the most effective method seems to be applying one chemical PPP in the field since it is mentioned by all the participants. Although the results are not perfect, by applying it growers can contain the mite population at an acceptable degree. However, the substance is scheduled to be banned from practice by 2025.

"There is one pesticide we can use for them, and this is the last season, no 2025 is the last season we can use it and then it's forbidden. It's the only pesticide that works against Galmijt (tulip gall mite in dutch). Now they're trying to figure things out with vacuum metals, I think. Ozon some companies do if it works Im not sure. […] Yeah, but movento (trade name of the chemical) can give damage. In one variety we had that. It's damage in forcing. It goes in the plant, with forcing the wax on the leaves is sticky. With one variety there is a problem. We had to help them because the flower couldn't break through the leaves (G4)."

The growers mention several methods developed and tested by scientists and industry, but the results are not clear and applying different practices might require sizable investments and changes to current practices. Most of the growers are confident that they can deal with different pests if they have access to efficient PPP: s. There is however a uniform opinion that the products and methods accessible are not enough and a worry that more of them will be banned from usage. One grower mention being part of a grower organization trying to change plant protection methods to be more sustainable but acknowledges that it is a challenge and mentioned a college growing without chemical PPP: s having a very hard time dealing with pests. There are disease resistant varieties on the market and growers are hoping that more varieties will be added to relieve the pest problem.

No, we do the drying and grade them a little and then the peeling, then the grading, and then you wait a couple of weeks and then you check them. Sometimes and now a lot of times a lot of parties they will get Fusarium which you do not see in the beginning, you see later so then you take it out. This Fusarium is really becoming stronger and stronger it's a big threat. It makes new strain/stem, it starts later for example. Then you think now I checked everything it's good and four weeks later you, like this year it happened a lot. You planted at a customer and then 10 % Fusarium. I already did a reclamation for 10 % in October for example. That is something you can get rid of with breeding. When you do a good selection in the breeding, that's also the breeding is a thig, it really takes a lot of time to make a new variety, but they have companies who are checking this and they can now make it faster, they can cut off little pieces of a bulb and make it, that's big. It takes a lot shorter time. They can much easily make a bigger amount of those varieties (G2).

The growers report using biological methods when viable. There are also different temperature treatments of stored bulbs to deal with pests applied by growers. However, the most effective way of dealing with most pests seem to be through chemical PPP: s. All the growers report adapting their usage after legislation by decreasing doses and limiting the amount of usage. The growers all

express frustration with environmental and chemical legislation making land more expensive and making plant protection harder.

"I am, yeah for sure. Tulip gall mite is looking to be a bigger issue already now. What we would hope for is that we would have more techniques and more different ways to prevent this but what is happening is that the main chemical we're using to prevent this will be banned after 2025. This is causing a lot of uncertainty. Because this date is starting many companies are doing a lot of tests to find a good substitution for this. But then you are getting a lot of different techniques and it's unsure what the right technique will be. But for some of the techniques for example I should build new storage facilities. Well, if I want to do that, in 2026, I think I should start already now when the government and all the regulation concerning building new buildings and having the right equipment for that, but the test has not been finalized yet so it's uncertain which way it will go. Then you also never know. Right now, they say it's for sure Movento will be banned in 2025 but it could also be that they say we will extend it to 26/27. Or not, nobody knows. We had this problem one year ago that the government said we should keep a certain number of meters from the waterways and this they told me as a rule. It was a law or rule already in august. Then there was a lot of farmers saying it's stupid and it doesn't count and everything, but we followed that rule. Then afterwards, after we planted all the bulbs, they said oh no, you don't have to follow it for this year it starts next year but we had already planted the tulips so there was no way that we could change it anymore (G4)."

3.5 SWOT-analysis

Concluding the results are a SWOT-analysis on the Dutch tulip bulb industry's ability to face its challenges and to continue supplying the world with bulbs.

Table 3. SWOT-analysis

Strengths	**Weaknesses**
Experienced and resilient	The cost of doing business
Competitive and collaborative	Competing on price
Specialised and diverse	Pest control options
Innovative and solution oriented	Open field cultivation
Opportunities	**Threats**
Technological innovations	Changing climate
Breeding possibilities	Increase of pests
New PPP: s	Stricter regulation

Growing in different locations	Decrease of efficient pest control
	Increasing costs

3.5.1 Strengths

The key strengths identified lie in the growers' experience and resilience towards threats. The growers know that harvests can be ruined by bad weather and tries to mitigate the consequences by choosing optimal locations for their cultivation and practice optimal routines for planting, harvesting, and processing. There is an awareness of which pests to monitor, and the plant protection strategies are applied in a scientific manner based on how efficient threats are managed. There seems to be a Dutch way, where growers compete by continuously improving in terms of growing methods and investing in technology as well as collaborating with each other, when necessary, through crop rotation, joint planting and harvesting by smaller growers and knowledge sharing. The bulb growers are highly specialized, creating diversity by growing different varieties and specializing in different markets. The growers are innovative and solution-oriented, continuously evaluating their operations and implementing new technologies and methods in an evidence-based manner.

3.5.2 Weaknesses

Key weaknesses identified are the high costs of doing business, which is making it harder for companies to stay profitable and creating barriers for newcomers seeking to enter the industry. Key components like land, specialized machinery, bulb processing lines, storage- and cooling facilities, all necessary to produce tulip bulbs in a competitive way, demands high capital investments and upkeep costs. Furthermore, the low consumer cost of cut flowers have made it harder for growers to cover the cost of operations and make profits. The efficient and highly mechanized production are likely contributing to some pathogen like TVX and *Fusarium* spreading after harvest. The growers are despite, generally aligning their plant protection strategies with IPM-practices, reliant on chemical PPP: s to combat pests due to absence of equally efficient tools. With the outspoken goal of the Dutch government to decrease the usage of chemical PPP: s by 50 % till 2030 (Riemens *et al.*, 2023) the growers´ dependency on the products is a weakness. Unlike the crops grown in greenhouses, the tulip bulbs are grown on fields, limiting the growers' protective options for weather and pests.

3.5.3 Opportunities

The growers investing into finding new solutions to improve their growing practices or deal with pests are likely going to lead to new technical innovations that improves their production and makes current plant protection more effective. The net planting machine is an older example of an impactful innovation, and the TBV-selecting robots are of an invention being developed. Furthermore, breeders

are aware of the damage caused by the pests and are working on varieties resistant to key pathogens. Lastly, there are some successful tulip cultivations in other countries and tests are being conducted to find new suitable locations. There could be opportunities outside of the Netherlands to explore.

3.5.4 Threats

Extreme weather conditions have caused sizable damage to the tulip industry and growers are having a hard time planning for and mitigating the consequences. A further increase in the unpredictable weather swings is a major threat to the growing safety of tulip bulbs. Furthermore, the increase in average temperatures, although currently not a major problem, risks becoming one in the future by making the Dutch climate more unsuitable for tulips and more suitable for pests like tulip gall mite and *Fusarium.* Dealing with pests are a constant challenge and future tightening of regulations on chemical PPP: s before successful implementation of viable options risks causing greater losses to pests. Furthermore, the regulations on land- and pesticide usage are increasing the costs of growing operations and unclear communication when implementing them is causing operational problems for the growers leading to an increased frustration. All these issues combined with the already high costs of operation, producing a product sold at a low-price, risk decreasing the profitability of the industry even further.

4. Discussion

4.1 The industry

The growers are all interconnected in social networks of friends, families, and neighbours. With collaborative efforts for important aspects of their business such as crop rotation, joint ventures for developing sustainable growing methods as well as the smaller growers hiring a machinery company together and setting up mutual planting schedules, they show example of the strengths of the social fabrics of the flower sector mentioned by Gebhardt (2014) as well as the proximity of the actors mentioned by Porter, Ramirez-Vallejo and Van Eenennaam (2012) Furthermore, the growers are children of flower farmers (4) or farmers (1) making them quite typical Dutch flower farmers according to Gebhardt (2014). The growers have likely acquired a great amount of knowledge about growing tulips from parents, relatives and family friends in the sector while growing up that they later through education and practice have developed and applied into their businesses.

They show great resilience towards the volatile nature of tulip farming, likely from their years of accumulated experiences as well as advice from parents, relatives and friends on what to do to avoid crisis.

There is little variation in what the growers say on how to grow tulips. There seems to be a tried and proven way growers follow. Tulips are grown on beds, utilizing as high technology as possible to plant, select, harvest, process and store the bulbs as efficiently and pest free as possible. It is likely due to the high competition of the sector mentioned by both the growers as well as (Tavoletti and te Velde, 2008) and Porter, Ramirez-Vallejo and Van Eenennaam (2012). Furthermore, it could be attributed to the shared knowledge of the interwoven flower cluster (Tavoletti and te Velde, 2008). Another reason could be their similar educational backgrounds, four out of five studied the same program at the same university, as well as the previously mentioned similar family backgrounds. The reasoning of the growers is usually based in a combination of science and practical experiences. The climatical conditions they mention as optimal for tulips are supported by the reviewed literature (Muhammad Sajid *et al.*, 2013; Leeggangers, 2017) as well as their reasoning around how to mitigate problems with clay soils being over saturated with water (Boekel, 1970).

The growers are not only agreeing on most matters in how to grow tulips but also that the equipment needed demands investments. From what it seems in the interviews a key to success in the industry is the ability to invest in your business. The specialized equipment used to cultivate the tulips and the facilities used to store the bulbs all demand investments. The growers have all, to some extent, depending on their financial capabilities, invested in the required technology. The smaller growers a lower access to the newest technology. The increased reliance on specialised machinery and technological solutions is making the growers more

efficient and production cheaper. It is both recognized by the growers and (Tavoletti and te Velde, 2008) as driver in increasing the competition of the industry. The high competition of the industry is further increased by a price pressure starting in flower sales at consumer levels. A reason for the low price of cut flowers is likely that tulips are competing with other flowers for consumer money. One of the key parts of the tulips´ widespread popularity is their affordability (Rodriguez, 2023).
Despite many growers meaning that the consumer prize for tulips is too low it seems hard to justify raising prices to the customers. The growers are stuck trying to compete on price. There is opportunity to grow exclusive tulips, it is however not clear if the market is large enough for companies with high investment costs to venture into. If the consumer price of tulips becomes too high, there is risk of competing in the same price range as roses or other more expensive flowers.

It seems that the competition is getting too hard for many of the smaller family companies identified by (Gebhardt, 2014) as a core part of the flower industry's backbone. If family businesses disappear there is a risk of next generation's growers not only being fewer in numbers but also less prepared for a life in the industry. The focus on cost-cutting in all lines of the production chain mentioned by the participants is not only making it harder for businesses to stay profitable but is also risking compromising their financial security in case of unexpected events. The increasing costs of doing business together with stricter regulation and the decreasing access to land are identified by the growers as key factors making it harder to grow bulbs in the Netherlands. This aligns with Tavoletti and te Velde (2008):s thoughts on the same issues making the surrounding flower sector less viable. It is not sure a grower would be able to make a big investment to salvage a bad year like grower 3 did if they are struggling to stay profitable before the event. Tulips are already grown successfully in New Zeeland as well as Chile (Buschman, 2004) perhaps relocating more of core bulb production to those and other suitable countries taking advantage of the existing global trade networks (Gebhardt, 2014) could be future development for the bulb industry to avoid the high costs of doing business in the Netherlands.

4.2 The weather conditions

Tulips drowned by rains after planting in autumn, snapped by hail during flowering in mid-April and collapsing from summer heat waves in early June are all losses caused by unfavourable weather conditions identified in the results of this report. After the bad harvest last season (2022- 2023) due to extreme weather conditions (Wallin, 2024) the result of this study is indicating another poor harvest. A key factor to the low supply and smaller sizes of bulbs during last forcing season (2023-2024) was the heavy rains during bulb planting in 2022-2023 (Wallin, 2024). The planting season of 2023-2024 also suffered damage caused by heavy rains (Wallin,

2024). From the results of this study is clear that many growers suffered heavy losses due to the rain. It seems likely that upcoming forcing season will struggle with small bulbs and a low supply of bulbs in the market, likely leading to further increases in price. This aligns with the prognosis made by the Dutch grower in the viola interview (Wallin, 2024). The heavy rainfall during this planting season (2023-2024) disrupting planting schedules and damaging tulips in the fields is a clear example of climate change severely impacting the growing safety of tulips. It is aligning with reported irregular weather events causing damage to agriculture in Europe (The European environmental agency, 2020).

Even though the growers are used to the volatile Dutch weather it seems that present years have been harder than usual. Furthermore, the decreased margins of many growers discussed in chapter 4.1 are likely making them more susceptible to financial troubles caused by economic losses from the unfavourable weather conditions. Taking losses of 100 000 £/ha for water damage is a huge blow to any business but for smaller growers with less hectares in cultivation it is an even harder hit.

Unusual weather or amplified weather patterns like this growing year´s (2023/2024) heavy rains, april hail and last summer's Dutch heat wave is likely to increase in frequency and severity further jeopardizing the security of harvests for agricultural products like tulip bulbs (De, 2018; The European environmental agency, 2020).

Furthermore, the growers identify warmer temperatures as one factor that could possibly have increased the levels of important pests like *Fusarium* and tulip gall mite. Climate change is likely leading to changes in pest populations and their behaviour (De, 2018; The European environmental agency, 2020; Riemens *et al.*, 2023). A scenario where a grower starts their season by losing 10 % of planted hectares due to water damage in planting season, followed by additional losses from hail damage in spring, suffering further losses due to heat spikes in late spring to early summer and ending their season in summer with rainfalls combined with hot temperatures causing additional losses from *fusarium* outbreaks is not an unlikely worst-case scenario.

The growers are acutely aware of the vulnerability of their cultivation to the forces of the weather. They are taking preventive measurements like trying to choose fields with good structure and good drainage. They are aware of the clay soils sensitivity to oversaturation of water (Boekel, 1970). There is a great variety in resilience towards the heavy rain between a good field and bad field. The growers report that a good field can mitigate some of the water damage. However, they are harder to come by due to a combination of agricultural politics causing farmers to rent less land to tulip growers as well as the high population density and small land area of the Netherlands.

4.3 Pest control and regulations

The growers all show clear examples of implementing key aspects of IPM-guidelines in their pre-emptive measurements such as practicing good hygiene, trying to choose optimal sites of cultivation, continuously monitoring their crops for signs of pests, and reevaluating their practices critically (The European Comission, 2023). They seem to be aware of different methods and PPP: s suggested by van Aartrijk (1998) and De Boer (2008). Robot technology for selection like the one mentioned in the literature (Polder *et al.*, 2014) are being put into practice by some growers. The technology doesn't seem up to the mark yet but is likely to develop further due to the joint interest of growers and scientists seeking to combat virus as well as technological support industry wanting to develop new products to support growers. The highly mechanized and efficient production is key for growers to be successful in the bulb sector. Despite its many advantages it poses problems since it spreads diseases like TVX quicker among the bulbs (Lommen *et al.*, 2012). The growers are mitigating this by routinely cleaning their equipment and machines as suggested in the IPM-guidelines by the The European Comission (2023). Given the high pace of operation during planting and harvest it is impossible to fully supress the threat by cleaning their machinery and some pathogen will most likely spread in the cultivation.

Key weakness identified by the growers and Riemens et al. (2023) is the lack of viable tools to combat the pests. The Dutch governments increasingly restrictive policies on chemical PPP: s is identified as a reason to the rise in pest populations by the growers. The lack of fungicides could be one of the reasons behind the rise of *Fusarium* according to Miller (2002). A further example of the weakness of current plant protection is the growers worries over the upcoming ban in 2025 of a chemical used to control tulip gall mite. According to the growers applying Movento is the most efficient way of controlling mites. The tulip gall mite is a confirmed vector of TBV(Lommen, 2011), *Fusarium* (Suazo Jiménez, 2012) and suspected vector of TVX (Lommen *et al.*, 2012). An increase of a pathogen capable of causing huge damage by itself is a problem, if the pathogen is potentially spreading three other prominent pathogen it's a quadruple threat to the safety of tulips.

There seems to be a clash of priorities between European and Dutch legislators wanting to reduce emissions and chemical PPP-usage and growers seeking to protect their crop from pests. Furthermore, from the results it seems that despite trying to work out alternative options the most efficient way of dealing with most pests are still chemical PPP: s, confirming reports on the bulb growing sectors´ reliance on them (Riemens *et al.*, 2023). Another reason to the growers' reliance on chemical PPP: s could be that the products are part of the best practice discussed in

chapter 4.1. The growers have developed routines that allows them to stay competitive in their sector. Changing from working plant protection procedures could not only lead to an increase of pest attacks but also competitive losses due to an increase in production cost while working out new routines. Furthermore, growers mention that alternative treatments could require investing into new facilities, which could be a cost too high for growers to risk if they are not convinced of a positive outcome. Warmer temperatures could lead to a further escalation of the threat level of pathogen preferring warmer climate (De, 2018; The European environmental agency, 2020; Riemens *et al.*, 2023). TBV is already a big problem for growers to deal with. Warmer climate causing population developments of vectors could lead to grave consequences if viable PPP are not available to the growers.

5. Conclusion

The Dutch growers are highly skilled and professional continuously looking to improve their practices and to find solutions to the challenges facing them. This has allowed them to adapt technology into their cultivations and to a high degree practice precision agriculture. Resulting in an efficient production line from bulb to flower. The collaborative as well as competitive nature of the growers together with their embrace of technology and strive for effectiveness has created a competitive industry supplying bulbs to the world.

However, extreme weather patterns during the bulb growing season of 2022-2023 caused losses of tulip bulbs in the Netherlands resulting in a decreased global supply of tulip bulbs during last forcing season 2023-2024. The small size of the country and the concentration of bulb cultivations to certain areas make the industry vulnerable to losses caused by bad weather conditions. The growers report losses all over the Netherlands at the start of the of the bulb growing season of 2023-2024, which indicates another poor harvest. In the results growers account for tulips being desiccated from heat waves before harvest, snapped by hails during flowering, and drowned by heavy rainfalls after planting, despite great effort being put into the drainage and irrigation capabilities of the cultivated fields.

A rise in pest and virus levels are causing damage to the tulips and growers are feeling more and more frustrated with the Dutch government's laws on plant protection limiting their available tools to combat the rise of important pests like *fusarium,* Tulip gall mite and dangerous virus like tulip breaking virus and tulip virus X. The growers report a rise in tulip gall mite and are worried that the population is going to increase further after the most effective chemical control method is due to be banned in 2025. The costs of weather-related losses combined with the increasing pest threat together with the high cost of land and technology are putting a high pressure on the growers who are already in a fierce, low-cost driven, competition with each other resulting in poor margins of many growers. The growers report of colleagues losing their businesses unable to keep up with the increasing costs of doing business.

The recent extreme weather patterns are very likely caused by climate change. The rise in pest levels is likely due to a combination of climate change and a limited amount of effective control methods available to the growers as well as the mechanization of the production creating more contact areas for some pests to spread. New control methods such as autonomous robots limiting virus or *Fusarium* spread are being developed and applied. Breeders are breeding more for pest resistant varieties, and growers continuously applying all their skill and knowledge to limit the damages caused by weather and pests are identified as the potential solutions to the problems. It is possible that the growers together with scientists will find more effective solutions to the pest problem than currently available. However, it seems that the threats of climate change, rising pests and a government

prioritizing other matters over the grower's ability to protect the tulips from pests, is too strong for the possible opportunities of technological innovation, new resistant varieties, and new plant protection products to solve. Combined with the high cost of land as well as the increasing costs of doing business identified in this study and other (Tavoletti and te Velde, 2008), it is likely that the Netherlands will not be able to continue supplying the world with bulbs in the future.

It is, however, very likely that the Dutch growers will. Successful tulip cultivations ran by Dutch growers, are already present in New Zeeland and Chile, complementing the existing cultivations in the Netherlands (Buschman, 2004). The industry is already global and the demand for tulips around the world will likely continue. The Dutch managed to relocate bulk production of roses to more suitable countries while keeping the more demanding cultivations of exclusive varieties as well as the global trade centre in the Netherlands (Gebhardt, 2014). The result of this paper indicates that a similar development of the tulip bulb producing industry is necessary for a more resilient and stable production of tulip bulbs. It worked for roses, why wouldn't it work for tulips?

It is important to note that these changes are suggestions on future development and not present development. It is most likely that the larger part of the world´s tulip bulb production will remain in the Netherlands in the coming decades due the many competitive advantages and the sheer dominance of the Dutch industry. However, given severity of the challenges, and the multifaceted nature of the problems they cause to the Dutch tulip bulb industry, a further globalization of the production of tulip bulbs is deemed necessary to avoid a future with increased market volatility and an unreliable global tulip bulb supply.

6. References

van Aartrijk, J. (1998) ‘Integrated pest management: the case of flower bulb production in the Netherlands’, in *Active methodology: proceedings of a seminar series 1997-1998*. DLO, pp. 65–73.

Acton, B. and Koum, J. (2009) ‘Whatsapp ’. Facebook.

Bentley, E. (2024) ‘oTranscribe’. The Muckrock Foundation.

Benzaghta, M.A., Elwalda, A., Mousa, M.M., Erkan, I. and Rahman, M. (2021) ‘SWOT analysis applications: An integrative literature review’, *Journal of Global Business Insights*, 6(1), pp. 54–72.

Beytes, C. (2023) *Tulip Shortage; Alaska Peonies; Blue Mums, Grower Talks´ Acress Online, News and Commentary from GrowerTalks Magazine*.

BKD (2024) *BKD Your link to quality, BKD*. Home - BKD - Uw schakel in kwaliteit

Boekel, P. (1970) ‘Soil structure problems in tulip culture’, in *I International Symposium on Flowerbulbs 23*, pp. 338–343.

De Boer, M. (2008a) ‘Producing bulbs and perennials; sustainable control of diseases, pests and weeds’, in *X International Symposium on Flower Bulbs and Herbaceous Perennials 886*, pp. 59–67.

De Boer, M. (2008b) *Producing Bulbs and Perennials; Sustainable Control of Diseases, Pests and Weeds*. Available at: www.iobc-wprs.org.

Brunt, A.A. (1996) *Plant viruses online: descriptions and lists from the VIDE database*. University of Idaho.

Bryman, A. (2016) *Social Research Methods*. 4th edn. Oxford University press.

Buschman, J.C.M. (2004) ‘Globalisation-flower-flower bulbs-bulb flowers’, in *IX International Symposium on Flower Bulbs 673*, pp. 27–33.

Clarke, V. and Braun, V. (2017) ‘Thematic analysis’, *Journal of Positive Psychology*. Routledge, pp. 297–298. Available at: https://doi.org/10.1080/17439760.2016.1262613.

De, L.C. (2018) ‘Impact of climate change on floriculture and landscape gardening’, *International Journal of Agriculture Sciences*, 10(11), pp. 6253–6256.

ECHO (no date) *IPM Cycle, ECHO Community*.

Gebhardt, A. (2014) *Holland flowering: how the Dutch flower industry conquered the world*. Amsterdam University Press.

J.W.J. Munster Export (no date) *Munster Flower Bulbs-Export, Exporting flower bulbs from Holland to every country in the world, J.W.J. Munster Export*.

Kotler, P., Armstrong, G. and Parment, A. (2017) *Marknadsföring- Teori, Strategi och Praktik*. 2nd edn. Pearson education Ltd.

van der Lans, A.M. (2010) *Galmijtbestrijding in tulp: In deze openbare versie worden de niet-toegelaten middelen onder code vermeld: Resultaten onderzoek 2008-2010*. Praktijkonderzoek Plant & Omgeving.

Leeggangers, H.A.C.F. (2017) *The hot, the cold and the tulip The regulation of flowering time and dormancy release*. PhD Dissertation . Wagening University. Available at: https://library.wur.nl/WebQuery/wurpubs/513281 (Accessed: 20 May 2024).

Lesnaw, J.A. and Ghabrial, S.A. (2000) 'Tulip breaking: past, present, and future', *Plant Disease*, 84(10), pp. 1052–1060.

Lommen, S.T.E. (2011) *Beheersing tulpengalmijt in teelt, handel en broeierij*. Available at: www.tuinbouw.nl (Accessed: 28 May 2024).

Lommen, S.T.E., Conijn, C.G.M., Lemmers, M.E.C., Pham, K.T.K. and de Kock, M.J.D. (2012) 'Mites as vector of Tulip Virus X in stored tulip bulbs', *IOBC/WPRS Bulletin*, 81(2012), pp. 57–67.

Miller, W.B. (2002) 'Fusarium in tulips: Ethylene, gum, and aborted flowers', *Greenhouse Product News*, 12(13), pp. 36–39.

Muhammad Sajid, M.S., Abdur Rab, A.R., Noor-ul-Amin, N.-A., Abid Khan, A.K., Abdul Mateen, A.M., Naveed Ahmad, N.A., Fazal-i-Wahid, F.-W. and Amanatullah, A. (2013) 'Effect of diammonium phosphate (dap) on flowers and bulb production of tulip's cultivars.'

Muheisen, M. (2021) 'Dutch tulip farmers are hoping for a post-pandemic boom', *National Geographic*, 13 May.

Nayeem, M. and Qayoom, A. (2015) 'Inside greenhouses for cultivation of tulip flowers', *Int. J. Adv. Prod. Mech*, 1, pp. 34–44.

Plant Disease Diagnostic Clinic (no date) *Botrytis Blight of Tulip: Botrytis tulipae*. Available at: http://plantclinic.cornell.edu/factsheets/ (Accessed: 28 May 2024).

Polder, G., van der Heijden, G.W.A.M., van Doorn, J. and Baltissen, T.A. (2014) 'Automatic detection of tulip breaking virus (TBV) in tulip fields using machine vision', *Biosystems Engineering*, 117, pp. 35–42.

Porter, M.E., Ramirez-Vallejo, J. and Van Eenennaam, F. (2012) *The Dutch flower cluster*. SSRN.

Riemens, M., Beerling, E., Bonants, P., Bremmer, J., Kempenaar, C., Lotz, B., Nederpel, C., Ruigrok, P., van der Salm, C. and Tielen, J. (2023) *Staat van Plantgezondheid 2023: In de Nederlandse Land-en tuinbouw*. Wageningen Plant Research.

Rodriguez, C. (2023) 'Tulip Mania and The Multimillion-Dollar Industry Behind The World's New Most Popular Flower', *Forbes*, 16 April.

Sajid, M., Rab, A., ul Amin, N., Khan, A., Mateen, A. and Ahmad, N. (2013) *Effect of Diammonium Phosphate (DAP) on flowers and bulb production of Tulip's cultivars*, *Pure Appl. Bio*.

Sochacki, D. and Chojnowska, E. (2004) 'Quality evaluation of forced tulip flowers depending on bulb production environment and forcing medium', in *IX International Symposium on Flower Bulbs 673*, pp. 675–678.

Statista (2023) *Netherlands: value import and export tulip bulbs 2021* .

Suazo Jiménez, G.J. (2012) *Pathological Studies of Fusarium Oxysporum (Schlecht.) F. Sp. Tulipae Apt. In Tulip (Tulipa Gesneriana L.) Bulbs After Harvest.* PhD Dissertation. Cornell University. Available at: https://ecommons.cornell.edu/items/6471ca97-2a66-4ed0-802c-9ebeef15aa7f (Accessed: 28 May 2024).

Tavoletti, E. and te Velde, R. (2008) 'Cutting Porter's last diamond: Competitive and comparative (dis) advantages in the Dutch flower cluster', *Transition Studies Review*, 15, pp. 303–319.

The European Comission (2023) *Integrated Pest Management (IPM)*.

The European environmental agency (2020) *Climate change threatens future of farming in Europe, The European enviromental agency website*.

Vlad, I., Vlad, M., Motiu, T., Bartha, S., Timis, G.V., Dorog, S., Chebeleu, M., Bodog, M., Budau, R. and Pantea, S. (2010) 'Tulip bulbs preparation by heat treatment for forced culture in green house', *Acta Agraria Debreceniensis*, (I), pp. 70–72.

Wallin, E. (2024) 'Extremväder orsakar global lökbrist', *Viola*, February, pp. 18–19.

7. Appendix

Appendix 1. Interview questions

1. What's your business- and educational background?

2. What's your current venture and its history?
   Cultures, hectars, varieties, import export, business model?
   The season, growing methods?

3. Can you describe the tulip bulb industry?
   How does it look from your perspective, what´s your place in it?
   Competition cooperation?

4. How does a tulip grower produce bulbs of high quality and what are the biggest challenges currently?
   Pests, weather, politics, labour, prices? draughts

5. How do you handle extreme weather as a tulip bulb grower?
   What measurements can you take to prevent negative consequences?

6. How was the 2023 season for you?
   How was the harvest? How was bulb quality? Anything different from previous years?

7. How's the talk among colleges?
   Positive/negative? Worries/hope? Ideas?

8. What consequences will the 2023 season have for bulb forcers reliable access to bulbs of sufficient quality in terms of acceptable pest levels and bulb size?
   Prices? Quality? Problems?

9. What strengths do you see in the bulb industry?
   Aspects that makes the growers resilient towards bad weather?

10. What weaknesses do you see?
    Aspects that makes them more susceptible to it?

11. What opportunities do you see?
    Future developments, technology, prediction tools, growing methods, changes?

12. What threats?

Viruses, fungi, poor soils due to weather conditions?

13. What are your thoughts about the future for your business and the industry as a whole?

14. Is there anything I have forgotten or something you would like to add?

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"Yeah, it's like this, you work with the seasons. You plant in the autumn, depending on the weather, exactly when, and you start with the selecting when they flower in spring, and you harvest in the summer. That's the life of a bulb grower (G2)."