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Uppskattning av blomningspotential och tillväxt i en remonterande jordgubbssort

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In this work I have immersed into the morphology and physiology of the everbearing strawberry cv. Favori and the morphological description method called flower mapping. The aim has been to gain deeper knowledge of flower mapping as a tool in everbearing strawberries grown in greenhouse. The work has been a collaboration between SLU, Alnarp and HIR, Skåne with economic support from Partnerskap Alnarp.

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Josefine Lundblad

Abstract

Flower mapping is a morphological mapping method that can be used in strawberry (*Fragaria* x *ananassa*) plant production to get an insight of the status, numbers and the developmental stages of flower buds. It is commonly used by nurseries in order to evaluate plant management techniques to achieve enhanced yield potential over time. In the present study, flower mapping was tested with an everbearing strawberry cultivar Favori in a greenhouse production system. In the trial flower mapping was conducted before planting and after the first harvest on two different batches, planted at two separate dates. This was done to evaluate the applicability of flower mapping on an everbearing cultivar and to gain experience to benefit future production of everbearing strawberries in Sweden.

The study showed that the everbearing strawberry cultivar Favori responds to its cultivation system and surrounding environment. The response was expressed as differences in the development pattern and in the plant architecture. To help the interpretation of flower mapping a frequency model was developed summarizing the bud stages and the bud distribution. The flower mapping performed before planting gave an indication of plant quality e.g. number of initiated buds and crown size, and helped to predict future flowering and yield pattern. The second flower mapping conducted after first harvest peak did not predict future flowering pattern, but gave support for the potential future development by identify initiated buds and secondary crowns. In conclusion, flower mapping is suggested to be used as a method to predict potential future inflorescences and to optimize the production of an everbearing strawberry grown in greenhouse.

Sammanfattning

Flower mapping är en metod som används för att på en grundlig nivå analysera blomsterknoppar och illustrera plantors arkitektur. I jordgubbar (*Fragaria* x *ananassa*) görs det bland annat för att få en uppfattning om framtida plantutveckling och skörd. I detta arbete testades metoden flower mapping i en remonterande jordgubbssort, som var planterad och skördades i växthus. I försöket utfördes flower mapping innan plantering och efter första skörden på två batcher, planterade vid två separata tillfällen. Målet med försöket var att främja framtida produktion av remonterande jordgubbar i Sverige, genom att skapa en djupare förståelse för flower mapping och dess användningsområden.

I studien fastställdes det att den remonterande sorten Favori reagerade på sin omgivande miljö. Detta uttrycktes som variation i plantuppbyggnaden och i tillväxtmönstret hos de båda batcherna. Att utföra flower mapping innan plantering var bäst om man vill förutspå framtida blomsterutveckling. Att utföra andra flower mappingen, efter första skörden, förutspådde inte lika väl utvecklingen av knoppar men kunde användas i andra syften, tillexempel att utvärdera odlingsmetoder. I studien framgick det att flower mapping med fördel kan användas för att uppskatta framtida blomning och optimera skörd i remonterande jordgubbar.

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Introduction

A positive consumption trend of Swedish fruits and vegetables have resulted in a demand to further optimize production and prolong the harvest season (Jordbruksverket 2012). Strawberry (*Fragaria* x *ananassa*) is a high value crop in Sweden. Prolonged season in the northern hemisphere is viable by the use of tunnel or greenhouse settlements combined with everbearing strawberries. These have a recurrent flowering pattern and harvest during the season (Raffle et al. 2010). However, a challenge faced when growing everbearing cultivars (cv.), is the estimation of yield potential and yield pattern; factors necessary to regulate growth conditions and labor requirements.[1] Understanding the flowering behavior is possible by applying flower mapping – a morphologic mapping method, describing initiated buds and their developmental stages. Flower mapping is mainly conducted by private companies, such as Plantalogica Research Center, on the behalf of nursery schools and/or strawberry advisors and growers. The method is widely used for estimating the flower bud initiation of young plants at nurseries. However, flower mapping has not been evaluated as a method to be used during the cropping season in greenhouse produced everbearing strawberries in Sweden. This thesis analyzes the potential use of flower mapping as a method in the everbearing strawberry cv. Favori.

1.1 Aims of the study

The aim of this study was to evaluate the usability of flower mapping, and its potential in estimating bud development, flowering potential and growth pattern in greenhouse grown everbearing strawberries. Moreover, to improve and provide knowledge about the usability of flower mapping for future everbearing strawberry production in Sweden. Research questions to be answered: (I) How does the seasonal truss development look like in an greenhouse production of an everbearing cultivar? (II) How can results from flower mapping be used in order to predict future truss development? (III) Is it possible to estimate the future potential truss development by performing flower mapping before planting and then again after first harvest peak? (IV) Is flower mapping a method to be used in the decision support to optimize cultivation of an everbearing cultivar?

[1]Thilda Håkansson, advisor at HIR Skåne. Interview 20 February 2019.

1.2 Delimitations

Strawberry plant production is a comprehensive subject. The distribution chain from a breeding program to mother plants, nursery schools, producer and consumer, comprises a mass of information. Strawberries can be cultivated in different systems such as in fields or tunnels. Further, strawberry cultivars differ in their flowering behavior and growth pattern. This work is delimitated to analyze flower mapping as a method and its usability on the cv. Favori grown in a greenhouse. The study is set in south of Sweden during the 2019 production season. Some major identified factors and contributors connected to development, and flowering pattern in greenhouse are brought up, whereas plant protection, plant management, irrigation- and climate regulation are just be briefly mentioned. The harvest season in the greenhouse production during this project lasted until October. Nevertheless, data collection was limited to the end of August.

Literature survey

2.1 The strawberry

Strawberry (*Fragaria* x *ananassa*) belongs to the family Rosaceae which comprises several economically important species such as ornamental roses or edible fruits such as pear, apple and plums. *Fragaria* x *ananassa*, or fragrans meaning sweet-smelling (Al-Khayri et al. 2018) was first described by Antoine Nicolas Duchesne in his Histoire Naturelle des Fraisiers (1766). The history of its discovery is described in the book `*The strawberry*´ by Dr. George M. Darrow (1966). According to the story, the hybrid *F.* x *ananassa* was derived by the hybridization of the two wild octoploid species, the Chilean *Fragaria chiloensis* (beach strawberry) and the North American *Fragaria virginiana* (wild strawberry) (Fig. 1). The Duchesne hybrid is now considered as the first ancestor of all current existing *Fragaria* x cultivars (Baruzzi & Faeidi 2016; Al-Khayri et al. 2018).

Genetic phenotyping of *F.* x *ananassa* is complex due to its octoploid genome and breeding of new cultivars with desirable traits is complicated and time-consuming (Tennessen et al. 2014). Thus, in recent years as a result of new technology and expansion of private breeding programs the number of cultivars has gradually increased. In the study by Faedi et al. (2002) identified major aims of many of these breeding programs has been optimizing plant quality, higher yield, resistance against pest and pathogens and an extension of the ripening calendar. Some of these programs also focus on the health aspects and the pre- and post-harvest quality (Baruzzi & Faedi 2016).

In European countries a rather common diploid *F. vesca* subsp. *vesca* also known as wild strawberry or woodland strawberry (in Swedish smultron), is a well-known wild relative of *F.* x *ananassa* (Husaini & Wen Xu 2016). *F. vesca* is frequently used in research programs, due to its less complex genome than its relative *F.* x *ananassa*. In 2011, the sequencing of the whole diploid *F. vesca* genome was completed. It was described as a milestone which would change the future strawberry research (Folta 2013).

Figure 1. The ancestors of Fragaria x *ananassa. Left: F. virginiana (Siegmund 2008) Right: F. chiloensis (Folini 2004)*

2.2 The economic importance of *Fragaria* x *ananassa*

Global strawberry production and yield quantities have had a steady increase since 2010 (FAO 2019). The largest share of strawberry production is found in Asia (49%) followed by USA (25%) and Europe (19%). A general trend seen globally is that the yield outcome per harvested area has increased. More efficient cropping systems and successful breeding of high yielding cultivars are suggested to have contributed to this trend (Karhu & Sønsteby 2006; Jordbruksverket 2015; Baruzzi & Faedi 2016).

In the Swedish market, strawberries are the major produce of fruits and berries, with approximately 89% of the total value of all fruit and berries according to Jordbruksverket statistical analysis (2017). Historically, strawberries are strongly rooted in the Swedish culture as a highly valued and appreciated, freshly consumed berry. Besides beneficial health aspects and important dietary components (Giampieri et al. 2012), the strawberry is a signature fruit of the summer and is more or less obligatory during the traditional midsummer celebration (Jordbruksverket 2015).

The Swedish strawberry production is concentrated to the south of Sweden, and first and foremost conducted in field outdoors or in plastic tunnels with June-bearing cultivars, flowering and harvested only once per season (Andersson et al. 2011). Due to the northern hemisphere climate, the season starts in May and lasts until to June-July. The harvest depends on cultivar and cultivation system (Karhu & Sønsteby 2006). In 2017 the production consisted of 15 500 tons derived by 329 producers (Jordbruksverket 2017). The yield quantity of field production is strongly connected to weather conditions, thus yield outcome can drastically fluctuate from one year to another (Jordbruksverket 2015). Greenhouse production consist of 200 tons derived by 15 producers and greenhouse production is thereby is a minor part of the total strawberry production (SCB & Jordbruksverket 2018). A demand accumulation and positive price trends of Swedish fruit and vegetables (Jordbruksverket 2012, 2015; Lööv et al. 2015) have provided a driving force for an extended harvest season and an increased interest in out-of-season strawberry production.

2.3 Strawberry plant structure

The strawberry is an herbaceous perennial plant, with a short main stem referred to as the crown (Darrow 1966). Propagation occurs sexually by seeds or vegetatively by runners. Strawberries have a distinct determinant growth pattern where apical meristem terminates in an inflorescence at the top of the primary crown (Heide et al. 2013b). Thus, further growth is only possible through axillary buds forming into lateral branches after apical dominance is repealed. The inhibitory effects of apical dominance vary amongst cultivars (Inaba et al. 2004). The development of lateral branching is constant and affects the whole plant architecture, creating a sympodial growth even if it by visual sight indicates a monopodial growth (Fig. 2). On the shortened stem, leaves are structured in a spiral succession and an axillary meristem is located at each node (Fig 3. Left). Meristems differentiate into vegetative (later runners) or generative axillary buds (branched crowns and inflorescence). Induction signals promoting the transition to an either vegetative or generative bud, rely on intrinsic factors (hormones), environmental conditions (Neri et al. 2005; Neri & Savini 2004). Subordinated the primary inflorescence a branched crown or secondary crown can be formed. These branched crowns are desirable from a cultural point of view having the same morphologic properties as the primary and will add to the yield by producing its own leaf and flower trusses (Hytönen & Elomaa 2011) (Fig. 3 right).

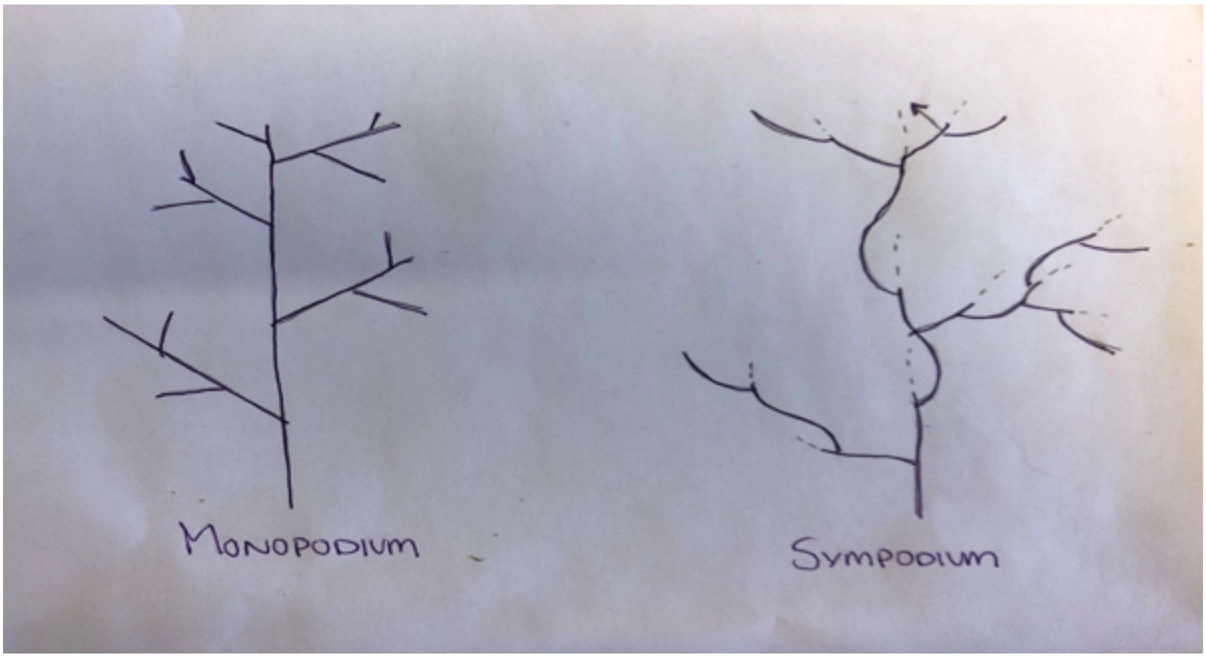

Figure 2. Strawberry plant architecture, a sympodial growth (right) but by visual sight indicates a monopodial growth (left). Illustration & photo: J. Lundblad.

Figure 3. Left: Young strawberry plant crown and development of leaves in a spiral succession. Right: A first- and secondary-crown. Photo: J. Lundblad

The runner consists of two long internodes followed by a terminal rosette (Hytönen & Elomaa 2011). The runner can either terminate in a flower truss or so called inflorescence (Fig. 4) or develop a secondary runner with a new rosette (Fig. 5). Molecular and physiological studies have confirmed that gibberellins (GA) are one of the signals mediating photoperiodic control of axillary bud differentiation to runners and branched crowns. The daughter plant of the runner tip can be used in propagation of new plants.

Figure 4. A runner terminating into an inflorescence. Photo: J. Lundblad

Leaf area index (LAI) differs between cultivars (López et al. 2002) but leaves on the of the upper part of the crown have been found to be major accumulators of photosynthetic compounds, and play an essential role during plant growth and fruit set according to López et al. (2002).

Figure 5. Runner with a secondary runner. Photo: J. Lundblad

The strawberry root system is positively geotropic and grow vigorously during favorable conditions (Neri 2016). Adventitious roots develop from stem tissue of vegetatively propagated plant material, but also from primary roots developed directly from the crown. Primary roots conduct mineral nutrients upwards whereas the photosynthetic products are transferred downwards. These can be stored as starch reservoir in the roots and rhizome. The flowers consist of white round shaped petals and green sepals characteristic of the family *Rosaceae* (Strand 1994). Sepals enclose the flower in the bud stage and become leaflike tissue underneath a fully developed flower. In the center of the flower, stamens are arranged in a circle around a conic-shaped receptacle, which on the surface contains of numerous of pistils. Stamens discharge pollen which germinate and penetrate the pistil and fertilize the ovule at the base of the pistil. During the maturity phase the receptacle swells up and becomes the strawberry fruit.

The strawberry is not the actual true botanical fruit (Beech et al. 1978; Breen & Cheng 1992). It is an enlarged flower stem with numerous of seeds on the surface called `achenes´ are the true botanical fruits. The size of the berry is influenced by the flower position on the truss (Heide et al. 2013b), its size and the number of initiated and fertilized achenes. Each fertilized achene (seed) promotes growth-regulating compounds affecting the receptacle to swell, which later becomes a well-shaped berry (Given et al. 1988). It is concluded that any insufficient pollination, damage or removal of an early stage seeds will result in a malformed berry (Darrow 1966; Strand 1994). Fruit quality is, besides pollination, also influenced by genotype, geoclimate and the carbon partitioning in the plant (López 2002). The trait of self-pollination is common amongst strawberries suggesting that pollinators are not needed in any larger extent (Zebrowska 1998). However, Clough et al. (2014) found that insect pollinators affect the quality and quantity of strawberry fruit formation. Firstly, since it complements the pollination and secondly, due to the beneficial aspects of their ecosystem services.

The final structure of inflorescence was early found to vary amongst cultivars (Darrow 1929) as a result of the relationship between internal physiological factors (Malcolm & Otto 1970), environment and the genetic inheritance (Taylor 2002; Heide et al. 2013b; Giongo et al. 2017). The more flowers a truss has the higher ranking is counted, and the more complex the truss is (Fig. 6). Furthermore, Giongo et al. (2017) have highlighted the importance of the temperature regime in order to achieve more complex trusses in modern recurrent flowering cultivars. In the study 15°C was shown to be more favorable than 25°C. Thus, a high complexity is not always desirable since berries size decrease with an increasing truss complexity (Heide et al. 2013b**)**. The flower arrangement around the terminating flower – the truss – is differently referred in literature. A review conducted by Taylor (2002) suggests the terminating inflorescence pattern as a *compound dichasium* structure, whereas Heide et al. (2013b) refer to a *dichasial cyme* structure. They both refer to the same structure, and the difference between them is the number of flowers and rankings arranged on the truss. According to the mentioned complex relationship between factors influencing the truss structure, it is suggested to be no right or wrong structure. Ridout et al. (1999) refer to a general idealized and characteristic inflorescence development scheme (Fig. 7). This consists of a primary (terminal) flower (1) being the largest and so giving the largest fruit, followed by secondary (2) branching of lateral flowers and then tertiary rank (3), quaternaries (4) and sometimes quinaries (5).

Figure 6. Different complexities of a flower truss. Left: low complexity. Right: high complexity. Photo: J. Lundblad

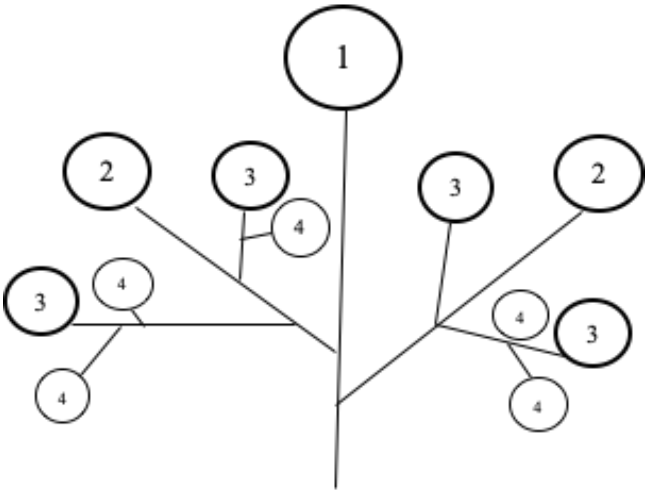

Figure 7. Demonstrating the potential flower arrangement in strawberry Fragaria x *ananassa always starting with a primary flower (1) followed by secondary (2) and so on (modified from Morgan et al. 1999).*

2.4 Flowering cycles

The signal response resulting in a floral induction in *Fragaria* x *ananassa* has been widely studied and concluded to mainly rely on the interaction between day-length and temperature so called thermophotoperiod (Taylor 2002; Folta & Stewart 2010; Massetani & Neri 2016). The signal response to thermophotoperiod differs between strawberry varieties and separate them into categories (Folta & Stewart 2010). This categorization is rather diffuse since the development also is temperature dependent but for now is it generalized as two main divisions. Firstly, the *seasonal,* also called *June-bearing plants* only produces one flower flush during a season. Secondly, the *everbearing* strawberry plants who have several flowering flushes throughout a season. This rough division refers to whether initiation of flower buds occurs. If it is during short-day conditions it is called a seasonal variety if initiation at long-day (or irrespective of daylight) it is an everbearing variety.

The photoperiodic and temperature dependent behavior on plant development is also found in relatives of wild strawberry varieties, as the diploid *F. vesca* (Heide & Sønsteby 2007a; Hytönen & Elomaa 2011). Thermophotoperiod response of the everbearing and seasonal *F. vesca* has been studied and illustrated by Hytönen & Elomaa (2011). The floral initiation of the everbearing *F. vesca* type was most efficient with 16-24 hour photoperiod at temperatures between 15-27°C. Most differentiation of runners appeared to be with the 8 hour photoperiod at 15-18°C. With the seasonal *F. vesca* type an obligatory short-day response was observed, and initiation occurred solely at 8 hour photoperiod at temperature 9-15°C, runner response was highest with 24 hour photoperiod at 15-27°C.

Flower development

Floral induction and further development of the inflorescence can be sectioned into three phases: floral *induction, initiation and differentiation* (Taiz & Zeiger 2010). *Induction* refers to the phase when environmental signals, such as thermophotoperiod, are registered by plant internal control systems and transferred into an actual plant response. This response in strawberries is the transition from vegetative to reproductive phase (Massetani & Neri 2016). The floral *initiation* phase describes physiological and morphologic changes occurring in the meristem of an axillary bud (Taylor 2002). The last phase, *differentiation***,** is the centripetal development of the specific floral organs and flower arrangement until a fully developed flower. The initiation and differentiation phases have been morphologically studied and identified using light microscopy (Dana & Jahn 1970) and scanning electron microscopy (Inaba et al. 2005) and by Taylor et al. (1997) using cryo-scanning electron microscopy. These identification and illustration studies are today used as reference material by breeding programs and propagators. [2]

[2] E.J.J. (Bert) Meurs, Plantalogica BV. Email conversation 24 May 2019.

2.4.1 Short-day strawberries

Annual growth pattern of strawberry plants in northern hemisphere is limited by the seasonal environmental fluctuations (Karhu & Sønsteby 2006). Thus, temperature and day-length are the major contributors strongly influencing plant architecture and establishment (Sønsteby 1997), petiole elongation (Fabien, et al. 1999) and yield (Heide et al. 2013b). Flowering of seasonal strawberries in outdoor conditions in southern Sweden, starts in the spring. The flowers are a result from axillary buds initiated during previous seasons short-day conditions (Fig. 8) and temperature in August/September, in a number of cycles (Sønsteby 1997)

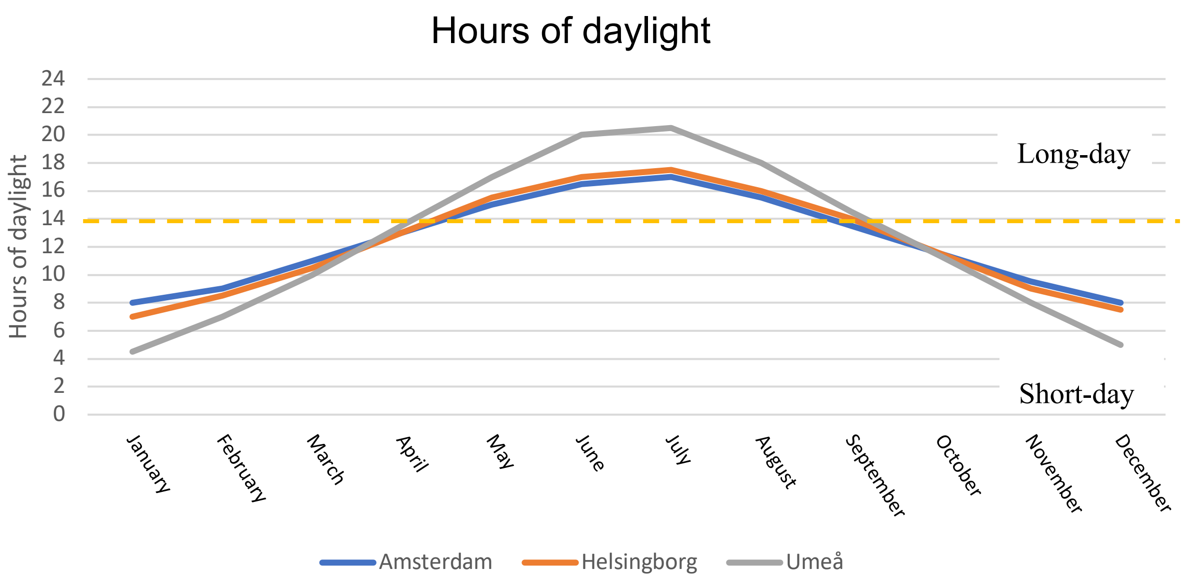

Figure 8. Hours of light in a year cycle. Data presented is light hours, of the 1st day in each month, 2018. When the daylength are under the yellow line (14 hour daylength) it is estimated as short-day, if exceed the line long-day appear. Light hours are presented for, southern (Helsingborg) and northern (Umeå) part of Sweden, as well Amsterdam, the Netherlands (modified from vackertväder n.d.). Initiation behavior during short-day is different between the locations.

Differentiation of these initiated buds occur in October and in November they enter dormancy. Dormancy breaks after a cold period during winter and as temperature rises in the spring, the floral buds develops (Heide et al. 2013b). It has been found that the optimal induction requirements vary amongst short-day varieties. Massetani and Neri (2016) has summarized optimal conditions as, between 11-16 hour daylight and low temperatures (optimal 15-18°C) in a minimum of 11-14 day cycles. During long-day conditions and high temperature, as in southern Sweden (Helsingborg) occurring in April-August, the crown remains vegetative and no flower buds are induced (Fig. 8). Hours of light differ between the southern and northern of Sweden and the Netherlands (Amsterdam).

2.4.2 Long-day & day-neutral strawberries

Everbearing cultivars have a perpetual flowering pattern, where in addition to one flower flush, flower buds are continuously induced and developing (Heide et al. 2013b). This is due to the induction response of long-day (or irrespective to photoperiod) in April-August (Fig. 8). Flowering is generally promoted by intermediate (21°C) to high temperatures (27°C) according to Heide and Sønsteby (2007c). Thus, the photoperiodic responses in combination with temperature was concluded to differ between varieties (Heide and Sønsteby 2007b). In the study (Heide and Sønsteby 2007c) the differentiation into runners was also found to be promoted at 21°C-27°C and long-day.

Yield pattern of everbearing long-day plants and day-neutrals can be easily manipulated, this by systematically changing the daylight regime and/or temperature (Gangatharan et al. 2011; Baruzzi et al. 2012). This is commonly used by nurseries to produce plant material for out-of-season production. Over a growth season there are an general accumulation of yield in everbearing cultivation since the crown size increases with branch crowns and thereby also potential initiation sites. It has been observed that after a harvest peak, in some everbearing cultivations systems, a lag-period emerge. During this lag-period no new trusses can be seen emerging in the base of the plant.[3,4]

A similar lag-time phenomenon called thermodormancy has been observed in greenhouse grown everbearing strawberries in the UK. The sudden decline in flowering and fruiting was observed during hot periods of July and August (Heide & Sønsteby 2007c). Battey and Wagstaffe (2006) studied the phenomenon on the cv. Everst and found that combining high day temperatures with cooler night temperature reduced the impact of the thermodormancy and the sudden drop in yields. Yet, Heide & Sønsteby (2007c) discuss the thermodormacy effect and its connection to high temperatures rather has a connection to the photoperiod response. Night interruption to break the dormancy was suggested as a possibility to eliminate the mid-season dormancy.

Classification of the everbearing genotypes into day-neutral or long-day plants is confusing, since a wide range of responses to temperature and daylight has been found (Massetani & Neri 2016). *Long-days* initiate flower buds during long-day conditions and favorable temperatures which often occurs in the summer (April-August) in northern hemisphere. Everbearing varieties estimated as *day-neutrals* are suggested to have an

[3] Lars Friis, Lindflora. Interview 25 April 2019.
[4] Thilda Håkansson, advisor at HIR Skåne. Interview 21 August 2019.

irrespective response to photoperiod and are rather affected by temperature to initiate flower buds.

The day-neutral response was early observed in octoploid American everbearing varieties (Darrow 1966) and later commercially introduced by Professor Bringhurst and Voth in 1980 (Folta & Stewart 2010; Heide et al. 2013b). However, the day-neutral response have been questioned since there is no convincing evidence or logical background of the day-neutral photoperiodic response according to Heide and Sønsteby (2007c). Heide and Sønsteby (2007c) performed a study to investigate the true day-neutral response in a wide range of everbearing varieties with different inheritance. Their results show that everbearing cultivars are generally long-day plants, since at high temperatures (27°C) plants required long-day photoperiod to flower. At intermediate temperatures, however, they were they promoted by long-day photoperiod, but inflorescence eventually did occur even in its absence. Only at temperatures below 10°C a day-neutral response to floral bud formation was seen. They also conclude that flower initiation and truss development in everbearing cultivars is positively affected by high temperature (27°C) and long days (18-19 hours). The undecided and diffuse classification of day-neutral and long-day plants according to their optimal thermophotoperiod, is confusing. Heide and Sønsteby (2007c) pointed out that there is a need on further understanding which physiological flowering mechanism are underlaying the performances of the initiation responses in specific everbearing cultivars.

2.4.3 Strawberry cv. Favori

F. x *ananassa* cv. Favori used in this thesis, is an everbearing cultivar, originating from the breeding program Flevoberry© as an improvement of cv. Mara the Bois. Favori grows vigorously and has long flower trusses and has large vital canopy and large glossy fruits. It can be cultivated outdoors, in tunnel and greenhouse. Early planting is viable, but a ground temperature of 7-8°C and air temperatures of 10-12°C are recommended (Flevoberry 2018). Per plant 8-10 flowers per truss is expected at first harvest.[5] With temperatures between 10 and 24°C average in a 24-hour cycle, varieties like cv. Favori induce flowers. At temperatures lower than 10°C and above 24°C the plants bud inducive capability is decreased.

The cultivation of everbearing strawberries in Sweden is still rather uncommon. Nonetheless, the interest has risen for tunnel and greenhouse cultivation.[6] Advantages with

[5] Jan Robben, Agronomist FlevoBerry. Email conversation 12 February 2019.
[6] Thilda Håkansson, advisor at HIR Skåne. Interview 21 August 2019.

everbearing flowering types is that they potentially have a larger total yield. Another advantage is that the growers do not have to put efforts in overwintering the plants. Instead pre-cultivated tray plants are planted in the spring and removed in autumn. The variety choice relies on what is available on the market, trends and the kind of cultivation system. However, the taste, a fast establishment and resistance against pathogens are major desired attributes. Other cultivated everbearing varieties in Sweden are cv. Murano, Furore, Evie II, Florentina and Verity.

2.5 Development and flowering pattern

2.5.1 Factors influencing plant development

That seasonal and everbearing cultivars use light and temperature to adjust their annual growth pattern to specific seasonal changes, have been widely studied and several well formulated reviews on the theme have been published (Taylor 2002; Folta & Stewart 2010; Heide et al. 2013b; Massetani & Neri 2016). Bud induction as concluded in previous chapter, mainly rely on the thermophotoperiod responses. However other essential factors also play a role in the further plant development (Gangatharan et al. 2011). Following chapter will pay attention to some of these influencing factors.

Light

Light is one major factor limiting production in greenhouse and field production (Hyo Gil Choi et al. 2016). Light and its composition is essential for photosynthesis, vegetative/generative transition and an important component in the strawberry plant diurnal rhythm. Plant photosynthetic receptors have the ability to perceive changes in light quality (color/wavelength) and quantity (intensity/rate) and respond with morphological and physiological changes.

Andreotti et al. (2017) have shown that it is possible to influence the plant productivity and quality with addition of LED. Kanahama and Nishiyama (2009) have found that light quality of far-red influences the inflorescence rate, and red light influences vegetative leaf production in an everbearing cultivar. In a short-day cultivar it has been possible to delay flower bud initiation by manipulating the light distribution with photoselective nets (Takeda 2012). LED light is still expensive equipment to install in a greenhouse, and cheaper way to manipulate light quality is to use different covering material, net and curtains (Jordbruksverket 2019). Defoliation of the canopy and distance between plants also affect incident and intercepted light (Taiz & Zeiger 2010).

Battey and Wagstaffe (2004) have performed a study on everbearing cv. Everest to investigate impact of shading and temperature on growth and final yield outcome. Shade reduced crown number and fruit yield, but the adaptive response caused an increased leaf area. The interaction between temperature and shading was found most important in the yield response. Treatment of 50% shading and temperatures of 27°C gave least fruit yield per plant, whereas 23°C and no shading gave best results.

Temperature

Temperature fluctuations during a season affect plant photosynthesis and metabolism (Taiz & Zeiger 2010). If temperature exceeds optimal levels, cascades of negative stress symptoms occur and affect the efficiency of metabolic activities and signaling transport. High temperatures cause degradation of important enzymes (Hyo Gil Choi et al. 2016), reduce net CO_2 assimilation, and reduction in total leaf area, shoot and root biomass (Al-Khatib et al. 2006).On the other hand if temperatures are decreasing to lower levels than optimal, metabolic activities decline, and further growth is inhibited. The alternating temperatures during the day and the night affect plant growth (Camp & Wang 1999). Optimal temperature found by Camp & Wang (1999) was 25°C during the day and 12°C during the night, whereas temperatures of 30/22°C (day/night) inhibit plant and fruit growth. Cooler day/ night temperatures of 18/12°C had tendency to promote root growth. Wagstaffe and Battey (2006) performed a study on the everbearing cv. Everest and found as Camp & Wang (1999) that yield increased when a cold night temperature was alternated with higher day temperature, optimal temperature they found was 26°C/13°C.

Tunnel production is an increasing cultivation method according to Jordbruksverket (2015) and entails several benefits, as an elevated temperature in the early season (Raffle 2010). For greenhouses temperatures can be regulated by the use of additional heat or chilling systems as shading (Jordbruksverket 2019). Temperature can easily exceed harmful levels during the summer in tunnels and greenhouses and ventilation is necessary to down regulate the temperature.

Vernalization – to break dormancy

Cold treatment or chilling requirement to repeal dormancy is called vernalization (Taiz & Zeiger 2010). Without cold treatment some strawberry plants show a low growth habit, delayed flowering or even remain dormant in their vegetative stage.

The physiology and genetics of an obligatory vernalization response has been reported in northern Norwegian woodland strawberry (*F. vesca*) (Heide & Sønsteby 2007a). It was concluded to be an adaption developed by the plants preventing them from flowering early in season, which can cause frost damage on crowns and flowers (Elomaa et al. 2017).

Since *F.* x *ananassa* have been extensively refined through centuries vernalization requirements shift amongst cultivars. Lieten (1997) has suggested it necessary with exposure to chill in June-bearing varieties in order to receive normal growth and yield of the autumn-initiated buds. Boonen et al. (2018) showed that the everbearing cv. Verity (a common cultivar in Belgium) performed better with restriction of chilling resulted since it promoted more side crowns, fewer runners and higher total yield.

A high chilling requirement is especially desirable in strawberry (*F.* x *ananassa*) production with overwintering plants (Elomaa et al. 2017) since early spring temperatures can cause frost damage on flowers and crown tissue (Karhu & Sønsteby 2006). The cold damaged flowers result in sterile flowers and malformed berries (Fig. 9) and frost damaged on crown tissue can be an entrance for fungal infection.[7] Low temperature treatment is also an important tool at nurseries where it is used to manipulate plant productivity and to store plants (Massetani & Neri 2016).

Figure 9. Left: Cold damage stamens, brown should be yellow/ green in color. Right: Dormant stamens and developed pistils. Photos: J. Lundblad

[7] Lars Friis, Lindflora. Interview 25 April 2019.

Mineral nutrition

Optimal nutrient management promote a vigorous and high quality plant (Gomes-Merino & Trejo-Tellez 2014; Nestby et al. 2018). In order to establish a high yielding crop, it is suggested to regulate and adapt the fertilization recipes during the season to meet the plant need (Gangatharan 2011). Everbearing and June-bearing strawberries have alternating vegetative and generative establishment phases during an annual cycle.[8] Alternation between vegetatively and generatively adapted fertilization receipt is thereby commonly used amongst strawberry growers. Differences in recipes are relying on the composition and ratio of nutrients, either promoting vegetative growth or benefit flower and fruiting.

Another important guiding tool to determine and regulate optimal nutrient management is the knowledge of the chemical composition in the irrigation water (Håkansson & Tönnberg 2018). Continuous measurement of the electrical conductivity (EC) and pH-value of the incoming and drainage water gives an indication of available nutrient concentrations in the water and the nutrient uptakes by the plants. By keeping track of these parameters, a desired equilibrium can be managed to prevent salinity stress or deficiency symptoms.

EC levels have shown to play a major role in the plant aboveground biomass and in the truss complexity in both June-bearing and everbearing varieties (Boonen et al. 2017). Electrical conductivity of the irrigation water affects the aboveground biomass, leaf color, petiole length, number of leaves and total yield. Boonen et al. (2017) have also concluded that different varieties have different sensitivity to EC rates and regulation need to be specific to cultivar and cultivation system.

Cultivation of strawberries in substrate instead of bare soil, gives potential to increased yield and quality of fruits (Dale et al. 2017a; Zucchia et al. 2017), and reduce risk for soil pathogens in prolonged production as in greenhouse and tunnel (Durner 2002). Substrates differ in their physical and chemical properties as, porosity, water holding capacity, electrical conductivity and pH-value (Dale et al. 2017a). Peat is one of the traditional artificial substrates used. Peat is considered having a negative impact on the environment (Naturvårdsverket 2016) and other substrates to use are rising on the market (Massetani et al. 2017).

Nitrogen

Nitrogen is one of the major important nutrients affecting the plant architecture and promotes a high-quality plant (Gomes-Merino & Trejo-Tellez 2014). Nitrogen can also occasionally

[8] Thilda Håkansson, advisor at HIR Skåne. Interview 21 August 2019.

increase fruit number thus, not necessarily fruit weight (Miltiadis & Papadopoulos 2016; Baldi et al. 2000). It is concluded that supply of nitrogen can affect the plant architecture by increases aboveground biomass (Albregts et al. 1996; Miltiadis & Papadopoulos 2016) and root biomass (Heide et al. 2009) in strawberry cultivation. Depending on the timing of the elevated nitrogen it can also change the architecture like stimulate stolon, shoot formation and flower initiation (Neri & Savini 2004; Heide et al. 2009). In 1967 A.J. Abbot suggested that phosphorus and nitrogen promoted the establishment of branch crowns and thereby sites for flower bud initiation. Durner (2015;2016) demonstrated on seed propagated hybrids of long-day strawberry cv. Elan (2015), Tarpan and Gasana (2016) that long day photoperiod, to induce floral initiation, followed by elevated nitrogen, significantly enhanced flowering.

Energy balance

Energy balance in a strawberry plant affect the architecture by the root:shoot interaction in combination with the amount of produced (sources) and consumed (sinks) photosynthetic assimilates (Taiz & Zeiger 2010). The efficiency of photosynthesis relies on factors such as light, nutrient uptake, gas exchange, absorption and temperature. As found by Battey and Wagstaffe 2004, temperature and shading directly affected developmental rate and assimilates partitioning in the everbearing cv. Everest. They also concluded that temperatures above 27°C increased development rate, on the cost of reduced leaf area and ability for plants to produce assimilates to be partitioned towards fruits (Battey & Wagstaffe 2004).

Sink organs (roots, flowers, fruits, buds and developing leaves) compete for the photosynthate assimilates which are exported from the sources (leaves). This partitioning between sinks depend on the sink strength and this strength determines the pattern of growth. For the plant to be able to provide sufficient building blocks as nutrients and water to an increase in biomass, a healthy root system is of importance. Hence, a vigorous aboveground biomass is limited by the specific surface of roots (Neri 2016). Growth must therefore in some cultivation systems be balanced to promote and or sustain a healthy and high yielding cultivar. To balance the equilibrium, plant managements technics as thinning of trusses can be an option. Zucchia et al. (2017), found that selective thinning of early trusses in an everbearing cultivar can be used as a tool to increase yield quality without loss in yield quantity. These early trusses had short and thin stalks with a basal branching, compared to the later emerging main trusses. The result indicated that the first flower flush could be slightly delayed, misshaped berries reduced and the average fruit weight increased. The research on defoliation of leaves and runners in everbearing varieties is limited. Massetani & Neri (2016) suggest that defoliation of leaves stimulates a compensative growth from lateral shoots and thereby the onset of new inflorescence sites. Plant response of removing runners was concluded by (Dale et al. 2017b) to vary between cultivar and cultivation system.

2.6 Plant manipulation

2.6.1 Plant types

Nurseries provide different plant material which enables plant establishment in different cultivation systems (Massetani & Neri 2016). The distinction between plant types rely on plant management and manipulation techniques. The desired attribute is mainly to influence the plant architecture and promote initiation of axillary buds and branch crowns. The wide plant type assortment is derived in two major groups, wherein plants are rooted in soil and sold as bare root, or they are rooted in modular trays (Irving et al. 2010) (Fig. 10). *Bare root* plants are mainly produced in field soils and graded according to size and then sold with a bare root system. Generally, the larger crown, the higher potential yield to expect (Johnson et al. 2006). Bare roots are commonly used in Scandinavian countries where they are planted in outdoors, harvested in early summer and overwintered in the field.[9]

Figure 10. Left. Bare root plants bunched up, before planting Photo: V. Tönnberg. Right. Tray plant before planting. Photo: J. Lundblad

In production systems aiming to prolong the harvest season e.g. tunnel production and greenhouse, tray plants are most commonly used (Lieten 2005). *Tray plants* are often produced from runner tips sampled from a mother plant. They are rooted in modular trays with substrate,

[9] Victoria Tönnberg, advisor at HIR Skåne. Interview 3 September 2019.

which limits contamination of soilborne pathogens. In the dormant season, they are removed from the trays and held in cold storage until sale. Tray plants have a well-developed root system making them resilient to drought and cold storage. The developed root system also enables a fast establishment, compared to the bare roots.

2.6.2 Greenhouse production

Greenhouse production is a way to increase productivity and yield outcome (Heide et al. 2013a; Hyo Gil Choi et al. 2016), since the climate can be controlled and used as a technic to optimize the production (Jordbruksverket 2019). Strawberries in Sweden are mainly produced and picked for direct consumption and damages on berries caused by weather changes or pathogens, makes them unmarketable (Fogelberg & Jansson 2018) and the use of pesticides is a common management to restrict damage.[10] In greenhouse, however, is the use of biological control concluded more efficient than in field, resulting in a decreased need of pesticides. It is also to a certain extent possible to change the environment e.g. humidity and airflow to minimize risk of fungal infections.

Strawberries in greenhouse are often set on table-top, creating a labor-friendly picking position and minimizing mechanical damage (Raffel et al. 2010). Everbearing tray plants planted in February (in a greenhouse) have potential of achieving three harvest peaks[11]. This compared to plastic tunnel with a potential of about two peaks, since it possess a colder climate. Strawberries produced in greenhouse are often known as high-quality berries since the berries are free-hanging, which reduces risk of wounds, infestation and dirt (Jordbruksverket 2018).

2.7 Morphological analysis and flower mapping

A uniform illustrative communication tool has been desired amongst researchers, breeders and nurseries to be able to improve production. This tool would be helpful in connecting plant architecture to growth habitat and genetic inheritance. Neri and Savini (2004) designed and examine the usability of an architectural model where the plant was illustrated as an extended axis, and organs and their position marked as figures with different colors.

The model by Neri and Savini (2004) relies on the performance of dissecting plants. When the plant is dissected into its elementary units, it is possible to identify meristem

[10]Thilda Håkansson, advisor at HIR Skåne. Interview 21 August 2019.
[11]Thilda Håkansson, advisor at HIR Skåne. Interview 21 August 2019.

and future developing axillary buds. Since strawberry plant crown is a short axis, with close nodes and leaves organized as a rosette always terminating in an inflorescence, each leaf starting from the bottom of the plant can be removed and every meristem and axillary bud analyzed (Fig. 11) A schematic drawing of the strawberry plant organs, illustrated in Neri and Savini (2004), later with subsequent modifications in Neri et al. (2005), was concluded to become a useful tool in evaluating plant organs and future development in different cultivation systems. Neri and Savini (2004) and Neri et al. (2005) also suggested the architectural model as a potential tool to increase productivity and efficiency in nursery plant material.

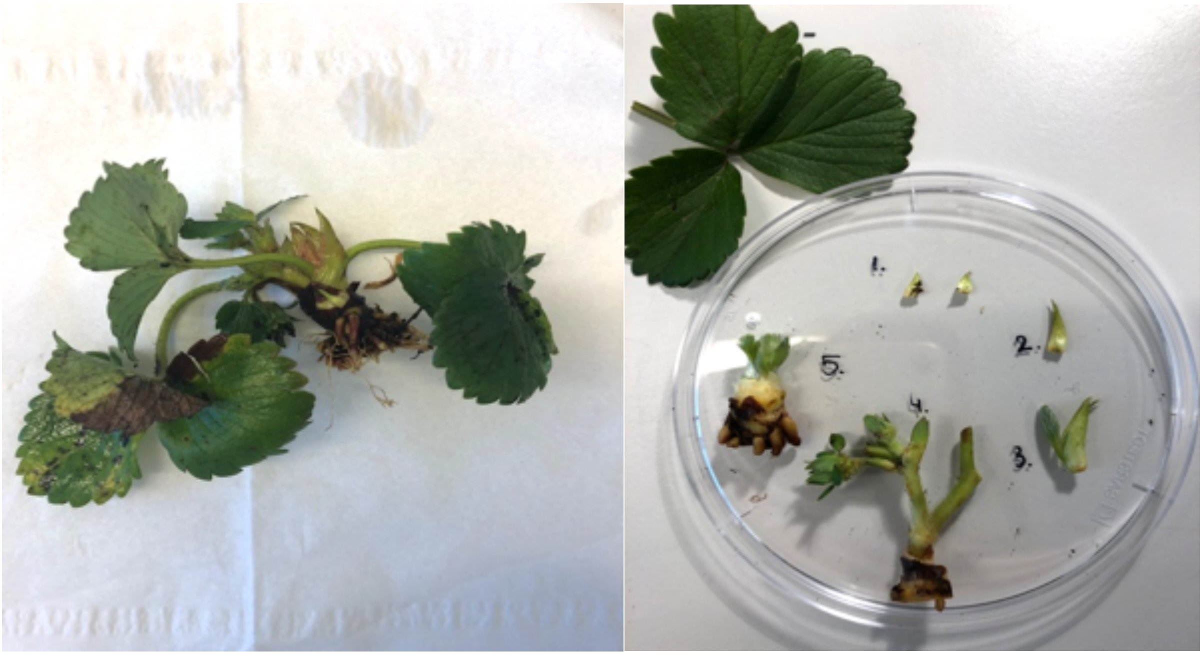

Figure 11. Left: One crown tray plant before dissection. Right: After dissection. Identified axillary buds and a truss. [1] two vegetative buds [2]one generative bud [3] one generative bud with developed leaf [4] A developed truss with flowers [5] The primary flower truss. Photo: J. Lundblad

The schematic drawing of the plant organs and its placement have been modified to a commercially used method called `flower mapping´. Flower mapping (FM) focus on different developmental stages of an axillary bud and the bud position on the stem. Position 1 represents the lowest axillary meristem on the plant, Position 2 the second and so on (Fig. 12) Results from flower mapping give the possibility to forecast yield, yield profiles and plant quality (Gangatharan et al. 2011). The results also provide possibilities to improve plant management technics in order to promote flower bud initiation and plant quality (Baets et al. 2014; Massetani & Neri 2016).

Flower mapping, it can be performed at different phases in the plant lifecycle to evaluate development. In seasonal cultivations, it can preferably be performed ones in the autumn to evaluate initiated buds, then again in the beginning of the cropping season to estimate first flowering. Thus, in an everbearing cultivar initiation occur recurrently, and to evaluate the second harvest flower mapping is suggested once again after first harvest. Then preferably when new leaf primordia visually emerge in plant base which indicates that a new flower truss are emerging.[12]

Position	Development stage
first truss	7
10	5
9	4
8	2
7	2
6	2
5	2
4	2
3	2
2	3
1	R

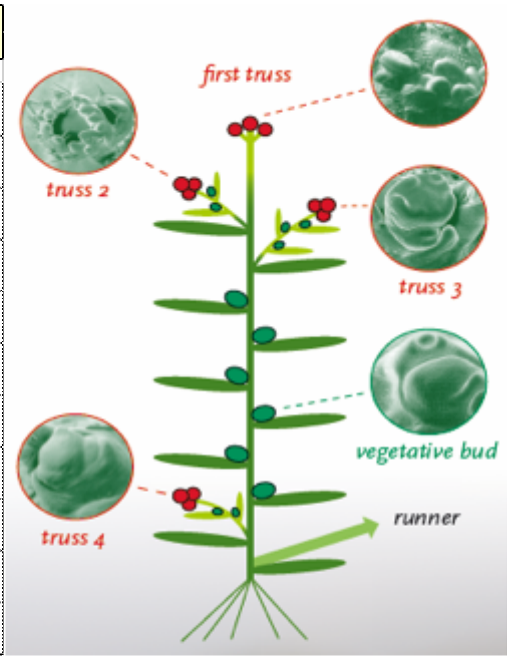

Figure 12. A schematic flower mapping illustration performed by Plantalogica. The table describes bud position and its developmental stage at each node. At the lowest position a runner is identified, second position a bud at developmental stage 3 and the third position a stage 2 bud and so on. The red colored numbers (stage ≤ 3) are generative buds (modified from Plantalogica).

In flower mapping the bud development is described as different stages on a scale. The scale rates according to the centripetal development of the reproductive organs on a microscopic level, in which a flower or truss is formed (Massetani & Neri 2016). However, the number of developmental stages on the scale differs between practitioners and researchers. The most used scales refers to the results by Dana and Jahn (1970) or the findings by Taylor et al. (1997) using cryo-scanning electron microscopy. The lowest number (lowest stage) on the scale refer to the earliest stage of a meristem –the vegetative apex– and the highest number (highest stage) represent anthesis and thereby a fully developed flower.

Number of stages, as described in Massetani and Neri (2016), is 1-9 as follows [0] the vegetative apex [1] primary flower primordium [2] sepal initiation on primary flower [3] petal initiation on primary flower [4] sepals and petals are developed [5] stamen formation on

[12]E.J.J. (Bert) Meurs, Plantalogica BV. Email conversation 24 May 2019.

primary flower [6] primary flower is enclosed by sepals and epidermal hairs are initiated [7] primary flower is completed with green anthers [8] primary flower with yellow anthers [9] Fully developed flower.

Plantalogica, which is the performer of the flower mapping in this thesis, refers to the work by Taylor et al. (1997), with stages 1-11, where there are no distinctions made between stage 1-2. Level 2 is identified as a not yet differentiated bud and thereby can either be a generative or vegetative bud. Stage number 3 is a generative bud, and the earliest stage of a future truss, stage ≤ 3 refer to the future development of a truss. There is also no distinction made between 9-11 and a flower is either a stage 9 or stage 11. Stage 9 refer to the formation of a deeper cavity or rounded cut, on the carpel. At this stage the glandular papillae on the surface of the stigma has not yet appeared, as it is in stage > 11. Stage 11 refers to anthesis, "a fully developed flower". Flower mapping as received from Plantalogica illustrates and presents developmental stages, information about position of buds, bud length and length of the truss (appendix). To notice is that grading performed on later stage buds, only identify the meristem of the primary flower.

2.8 Forecasting yield and growth pattern

With a forecasting/prediction it is easier to time labor force, transport- and storage- facilities, and streamline the production therefore is yield forecasting models desirable amongst producers.[13] Several attempts to create applicable models in order to forecast yield pattern have been conducted (Boivin & Deschênes 2017; Chandler & Mackenzie 2009; Døving 2004).

The research and advisor organization Delphy based in the Netherlands, are providing expertise in the horticultural and agricultural sector. Delphy have performed research in order to develop their own applicable forecasting model by the use of flower mapping.[14] In their forecasting model the developmental stage of an axillary bud, the expected Growing-Degree-Hours (GDH) until harvest, and the past and expected temperature data are combined to get an indication of future development and growth rate. The Growing-degree-hours (GDH) are calculated as the minimum and maximum temperatures of the hour added together and divided by two resulting in an average mean temperature of the hour. Then the base temperature (4,5°C for strawberries) is subtracted from the mean temperature to get growing-degree hours.

[13] Thilda Håkansson, advisor at HIR Skåne. Interview 21 August 2019.
[14] Harrie Pijnenburg, Senior advisor Delphy. Email conversation 9 September 2019.

Every axillary bud stage is assumed having a certain number of GDH until harvest, however these GDH depend on temperature and light. Thereby in Delphy's forecasting model the expected temperature (which is data based on five-year historic temperatures) and the predicted weather for the coming week are included. Most research has been performed on the June-bearing cv. Elsanta. Since plant development and growth rate is affected by temperature, the number of days from one bud stage to another vary greatly. Models are suggested to be individually formed, by sort, production system and geographic position to achieve the best accuracy.[15]

2.9 Environmental impact

Evaluating flower mapping as a method to increase efficiency and profit in greenhouse grown strawberries is one of the aims in this study. Advantages preforming flower mapping need to be promoted for it to become a useful tool, not just only economically, but also in a greater perspective. Therefore, are issues and climate impact regarding the greenhouse production and the use of flower mapping brought up.

It is overall questioned if it is justified with production of strawberries in greenhouse, since it is concluded as a resource intensive cropping system (Bergstrand 2010) if not managed in a thoughtful and integrated way. According to the IPCC 2019 special report, aiming to strengthen global response to the threat of climate change, it was confirmed that there is a need of mitigating the agricultural impact on climate change. In order to evaluate environmental impact of a production system the methodology Product Environmental Footprint (PEF) can be used (European Commission 2012). PEF is a schematic tool founded by the European Union (EU) member states, in order to measure the environmental impacts. This can be achieved by evaluating material, energy, emissions and waist flows associated to a specific product value-chain. Product Environmental Footprint (PEF) can also be used to compare different environmental studies and production systems. In the comprehensive case study performed by Richter et al. (2017) with the aim to analyze PEF on seven strawberry production lines (three conventional open field productions, two organic open field productions, one polythene tunnel production and one greenhouse strawberry production). It was concluded that strawberry production in greenhouse is the system with highest environmental impact, followed by organic open field, and then conventional field alongside with production in polythene tunnel. According to the studied systems, the highest impact came from the use of

[15] Harrie Pijnenburg, Senior advisor Delphy. Email conversation 9 September 2019.

electricity for heating, generated by burning wood chips during the winter, and the one-way carton boxes for strawberry transport to regional distribution centers. In open field the main contributors were diesel and agricultural machinery. An environmental impact analysis performed by the Swedish Board of Agriculture found, as concluded by Richter et al. (2017), to be the energy use (Jordbruksverket 2018). However, since 2002 the total energy used in Swedish greenhouse production has been reduced to half and the use of fossil energy has reduced to 2/3. According to Bergstrand (2010) is it possible to mitigate the environmental impact of greenhouse production in Sweden and it can thereby be viable to prolonging the harvest season and secure a high productivity of strawberries. In 2017 the Government offices of Sweden (2016) implemented a national food strategy to increase the efficiency and production of Swedish crops, this to strengthen the resilience of domestic produce and mitigate climate impact of import transport pathways. The decreasing market shares and self-sufficiency of Swedish rural food production have decreased since Sweden became a member of the European Union in 1995 (LRF 2019a). It was claimed that in the beginning of 1990´s Swedish farmers produced about 75% of consumed food in the country. Today about 30 years later, the human population have increased meanwhile food production has remained or even decreased (LRF 2019b). Resource efficient greenhouse production creating a prolonged harvest season, could strengthen the resilience of domestic produce and reduce climate impact of import and long way transport. Implementing flower mapping, with its optimizing benefits e.g. optimize crop potential, management and minimize waist may be an integrated management for a future sustainable greenhouse production.

Material and methods

3.1 Outline

A literature survey was performed using scientific articles and publications from the databases Primo, Google Scholar and Web of Science in order to gain knowledge of the strawberry plant architecture, factors influencing its development and flower mapping as a tool. The aim of the literature survey was also to gather relevant knowledge in order to put flower mapping in a larger perspective and achieve a deeper understanding of the results of the experimental setup. The book ´Strawberry: Growth, Development and Diseases (ed.) Husaini, A. M., and Neri, D (2016) was also of use. To get a broader perspective of the strawberry value-chain and understand the current progress and obstacles in performing flower mapping, interviews (oral and e-mail) with actors within the strawberry sector have been conducted. Study visits on strawberry farms in Sweden and Denmark have also contribute to an insight into different cultivation systems to support the literature survey with real-life experiences. In addition to the literature survey and interviews, a greenhouse trial and laboratory analysis was performed. In order to process the obtained data from the visual grading and flower mapping, Microsoft excel version 16.30 have been used.

3.2 Plant material and growth conditions

Fragaria x *ananassa* cv. Favori is an everbearing strawberry cultivar originated from the breeding program Flevoberry©. Plant material used in this experiment were sponsored and delivered by the Danish distribution and horticultural sales company Lindflora Aps, with advisor Lars Friis as contact person. Plants were delivered as tray plants (Fig. 10) and kept at low temperatures (0-4°C) until planting. Planting occurred in week 7 and in week 13. All plant material originated from the same batch and been treated in the same way at the nursery.

The study was conducted in February-September 2019, at a professional cultivation company Vikentomater in southwest of Scania, Sweden (56,16°N 12.59°E). Vikentomater has a traditional ridge-and-furrow greenhouse with 1690 m^2 commercial strawberry production. The production is on tabletop with a drip irrigation system and integrated fertilizer. Fertilizer is automatically regulated according to advised EC value. For the vegetative growth recipe 1,62 mS/cm and pH 5,8 and the generative 1,61 mS/cm and pH 5,9. Ground EC of the water is 0,2 mS/cm. Climate regulation; Day: Min 18°C, Max 27°C Night: Min 10°C, Max 17°C. Though, higher temperatures >27°C and night temperatures of 15-20°C in early spring and periods during the summer have been measured in the greenhouse. Regulation with external heating, shading curtains and open/close roof windows. Pollination with bumble bees and plant protection with biological control agents.

3.3 Experimental setup

Favori tray plants Flevoberry© were planted in week 7 (batch 1) and week 13 (batch 2) in substrate containing 80% peat and 20% perlit, BVB Substrates©. Approximately 6 plants per meter in a sick-sack pattern. The 1.28 m width between the tables enabled sufficient space for picking. The plants in this experiment were part of the production and had the same treatment as the other plants in the greenhouse. Production season lasted until late October, but final data collection took place in the end of August.

After planting eight randomly selected plants in week 7 (Batch 1) and eight randomly selected plants in week 13 (Batch 2) were labeled for a seasonal plant developmental analysis. Flower mapping (FM) was performed twice on each batch, first (FM1) before planting and then a second time (FM2) six weeks after the first harvest peak (Fig. 13).

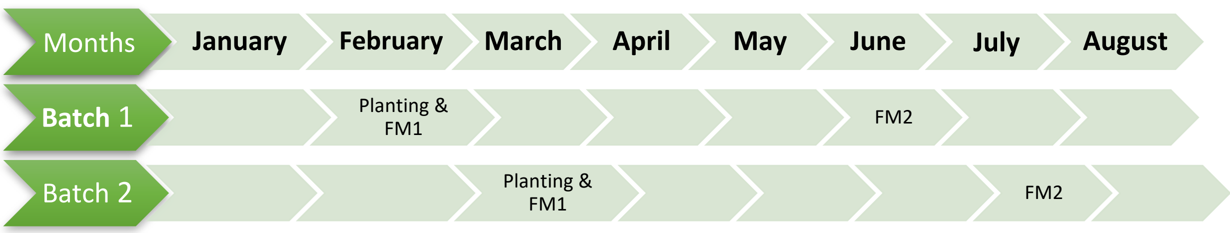

Figure 13. A monthly overview of the experimental setup, planting and performed flower mapping.

3.4 Seasonal evaluation – Visual grading

Visual grading involved monitoring the morphology, counting of trusses per plant and estimating the truss complexity during the cropping season. The counting of trusses was performed by counting the developing trusses of eight plants, then calculating average number of truss per plant. Complexity was estimated by counting total number of flowers on the trusses.

3.5 Morphological analysis – Flower mapping

Flower mapping (FM) was conducted by a professional actor (commissioned) and an untrained actor (selfperformed) before planting (FM1). Flower mapping was then, six weeks after the first harvest peak (FM2) only conducted by a professional actor. Randomly selected plants in replicates of eight from batch 1 and batch 2 was used in the FM1 and FM2 (Fig. 14). The professional performed flower mapping was accomplished by Plantalogica Research Center in the Netherlands. The flower mapping raw-data results were received as an excel file (appendix). Results were summarized in frequency tables, focusing on the number of axillary buds per plant, their developmental stage and the crown complexity (appendix).

Flower mapping by an untrained actor was conducted at Swedish University of Agricultural Sciences (SLU, Alnarp) laboratory, using a stereomicroscope. Flower mapping and organ identification was performed with the aid of reference material such as Plantalogica flower mapping manual, Taylor et al. (1997) and Massetani and Neri (2016), and for illustrations Neri et. al (2010).

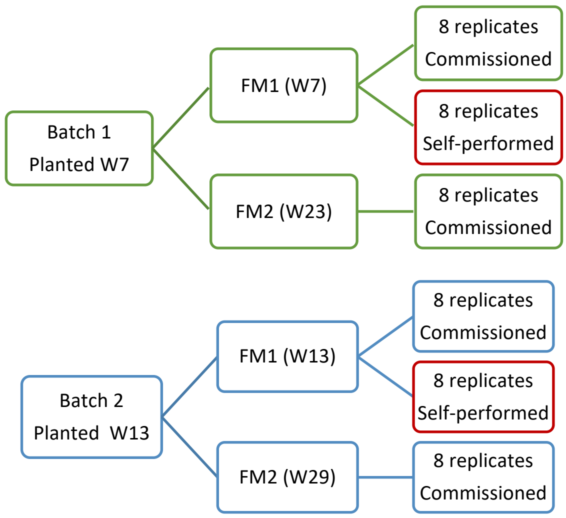

Figure 14. A visual description of the performed flower mappings of the two separately planted batches, batch 1 planted week 7 and batch 2 planted week 13. Each flower mapping was performed in replicates of eight.

Results

The study aims to evaluate the usability of flower mapping, and its potential in estimating bud development, flowering potential and growth pattern in greenhouse grown everbearing strawberries. Moreover, to improve and provide knowledge about the usability of flower mapping for future everbearing strawberry production in Sweden. Research questions to be answered: (I) How does the seasonal truss development look like in an greenhouse production of an everbearing cultivar? (II) How can results from flower mapping be used in order to predict future truss development? (III) Is it possible to estimate the future potential truss development, by performing flower mapping before planting and then again after first harvest peak? (IV) Is flower mapping a method to be used in the decision support to optimize cultivation of an everbearing cultivar?

4.1 Seasonal evaluation – Visual grading

In order to visualize the seasonal truss development and answer research questions (I) (How does the seasonal truss development look like in a greenhouse production of an everbearing cultivar?) a seasonal evaluation and visual grading were performed on batch 1 and batch 2. The plant health of the batches was monitored, since it was assumed that pest and pathogens affected results of the flower mapping. Providing a limitation discussion regarding the research question (IV) If flower mapping is a method to be used in the decision support to optimize cultivation of an everbearing cultivar.

4.1.1 Batch 1

Seasonal development – Visual grading

Planting of partly frozen tray plants occurred in week 7 and greenhouse temperature was kept at temp 7-10°C during the first week then slowly increased (Fig. 16). Four weeks after planting, in week 10, leaves were elongating, the first trusses developing, and some early flowers entering anthesis. Lots of early emerging flowers were cold damaged and removed. It was observed that it was the side positioned axillary buds of the crown that were developing first, also called vampire buds (Massetani & Neri 2016) and not the central. As the vampire buds elongated, they seemed smaller and weaker than the central positioned trusses.

Seven weeks after planting in **week 14**, flower petals started to fall off from the early side positioned trusses and centrally placed trusses had caught up, now being at the same developmental stage as the side positioned. The average maximum value (max value) of the eight replicates was **4.875 truss per plant**. Observations of truss per plant before or after was either less or constant. Trusses at this time had about 5-8 flowers per truss and thereby a complexity of secondary or tertiary rank. Eight weeks after planting in **week 15,** runners were emerging. The same time as runners emerged trusses were elongating, and some trusses had receptacles swelling-up. The first runners elongating was removed. In **week 17**, no more bud or truss development was observed, and the majority of the plants had flowering trusses. The complexity ranking to quaternary. In **week 18**, there was a harvest peak and no truss development were monitored. Runners were developing a second time, in week 19-20. In **week 22**, the second flush of truss development could be seen, indicating that a bud initiation had occurred (plants were sent for FM2 in week 23-24). In **week 27** the first trusses were ready for harvest with a max value of **7.625 truss per plant**. Truss development after week 27 seemed more distributed than before and it was hard to distinguish between old and new trusses. The distributed pattern refers to the behavior of trusses to emerge, being more spread.

Figure 15. A split truss. Photo. Meurs B

After the second harvest had toned out in **week 30**, trusses continued to emerge sporadically. However, most of the plants at this time did not have any trusses developing from the base. In early August at **week 33,** some small berries were still harvested. Some trusses elongating, mainly with tertiary branching. Plants with kept runners had berries ripe for picking. In mid-August **week 34**, trusses were identified in the majority of the plants. Trusses had complexity from tertiary up to quinary ranking and amongst them some split trusses (Fig. 15). High temperatures (>27C°) were measured in the greenhouse at this time. Plants were to enter a third harvest. Flower and berry abortion and reduction of berry size which had not been seen before, was now seen. In mid-August truss development continued and third harvest peak was to expect in mid-September.

Plant health

Tipburn was seen on young developing leaves and trusses in week 13-14. This was assumed to be a result from an insufficient root pressure. Preventative actions were implemented as changes of fertilization and environmental regulations e.g. relative humidity and airflow. In week 14 some young leaves showed symptoms of a thickened stem and a bend neck. However, these were later elongating, and symptoms disappeared. In week 18 crowns had started to wilt and a fungal infection was suspected. Hight temperatures and stress due to poor root activity causing an uneven root:shoot ratio was also suggested as a contributing factor to the crown wilting. Changes was made in the fertilizer composition and environmental regulations to strengthen the plants and hinder further symptoms. The turning point of the wilting occurred 4 weeks after first identified symptoms. During the season aphids, spidermites and plant bugs were monitored. A thrips infestation in August caused significant damage on fruits.

4.1.2 Batch 2

Seasonal development – Visual grading

Cold stored tray plants of cv. Favori, partly frozen was planted at greenhouse temperatures of approximately 15-20°C in week 13 (Fig. 16). Leaf development and root establishment occurred quickly after planting, compared to batch 1. However, the crown size in this batch compared to batch 1 seemed smaller and had fewer secondary crowns. First flowers developing were removed due to cold damage (approximately 1-3 flowers per plant). Three weeks after planting in **week 16**, first truss development was seen. As in batch 1, lower positioned axillary buds were first elongating, then the visually observed central positioned truss elongated. The axillary buds elongating seemed weaker than the first truss. In **week 18** side positioned trusses were entering anthesis and first trusses were still elongating. A lot of runners emerged (week 20-22) as trusses elongated. The early harvest in **week 20** was not a proper peak and since a lot of early flowers had been removed due to cold damage. The average maximum value (max value) of the eight replicates were **2.75 truss per plant**. Observations of truss per plant before or after was either less or constant.

In week 23 a few central or lateral trusses were developing from the base of the plant. The central trusses were of good quality, with complexity of tertiary to quaternary branching. Split trusses (Fig. 15) were also seen in this batch. In **week 25** there were a wide variation of truss stages. Some had green or/and red berries and some still emerging from the crown base. Harvest peak was not as evident as in batch 1 and no distinct vegetative lag-time could be observed. The estimation of when to send plants for flower mapping was not as evident as for batch 1 and a decision was made to use the same interval of approximately 6 weeks as for batch 1. Plants were sent for flower mapping, in week 31. In the beginning of August, **week 34**, some trusses were in anthesis and some trusses emerging from the base. Plants seemed stressed as, leaf lost their glossiness, berry size were reduced, and flowers were aborted. High temperatures (>27C°) were measured in the greenhouse at this time and a drastic increase of a thrips population. No runners could be seen emerging at this time. In mid-august (**week 37**) the quality of the plants seemed better and trusses developing, but the number of trusses varied between plants. A value of **3.25 truss per plant** was measured. Complexity of the emerging trusses were about 5-8 flowers per truss, quaternary ranking. Harvest and truss development were expected to continue until October.

Plant health

Symptoms of tipburn could be seen in week 21 as a result from an insufficient root pressure. Some plants in the batch had their crown or parts of the crown wilting in early season (week18). A fungal infection or high temperatures causing an uneven root:shoot ratio. It started and had its peak about the same time as in batch 1. During the season aphids, spidermites and plant bugs were monitored and a thrips infestation in August caused severe damage on fruits.

4.1.3 Comparison – Batch 1 and Batch 2

In order to describe the truss developmental pattern in the greenhouse a scale influenced by the BBCH-identification key stages of strawberry (Meier 2001) was used in the visual grading. The BBCH is a uniform coding tool to describe phenological growth stages of plant species. The modified scale, stage 0-5 are describing the development pattern of trusses. There were differences and similarities between the batches. Planting occurred about six weeks in between, differences in the establishment and development rate were expected (Fig. 16). Batch 1 had more trusses per plant and distinct lag-periods (lag-time) and no trusses were developing, whereas batch 2 had a more or less constant development of trusses. Batch 2 had fewer truss per plant counted over the season. Presumably a result of less complex crowns (less secondary crowns), poor plant establishment and high temperatures. Batch 2 was notably affected by an infestation of trips in early August. This contributed to reduction of berry size, flowering and fruit abortion at the end of August.

A.

<u>Truss development</u>

Stage 0= No trusses are emerging

Stage 1= Leaf emerging in the base of the plant

Stage 2 = First set of trusses <u>with cold damaged flowers</u> *(this stage, only in the first flush)*

Stage 3= Flower trusses emerging

Stage 4= Flower trusses elongating

Stage 5= No new trusses emerging, end elongation flower trusses.

B.

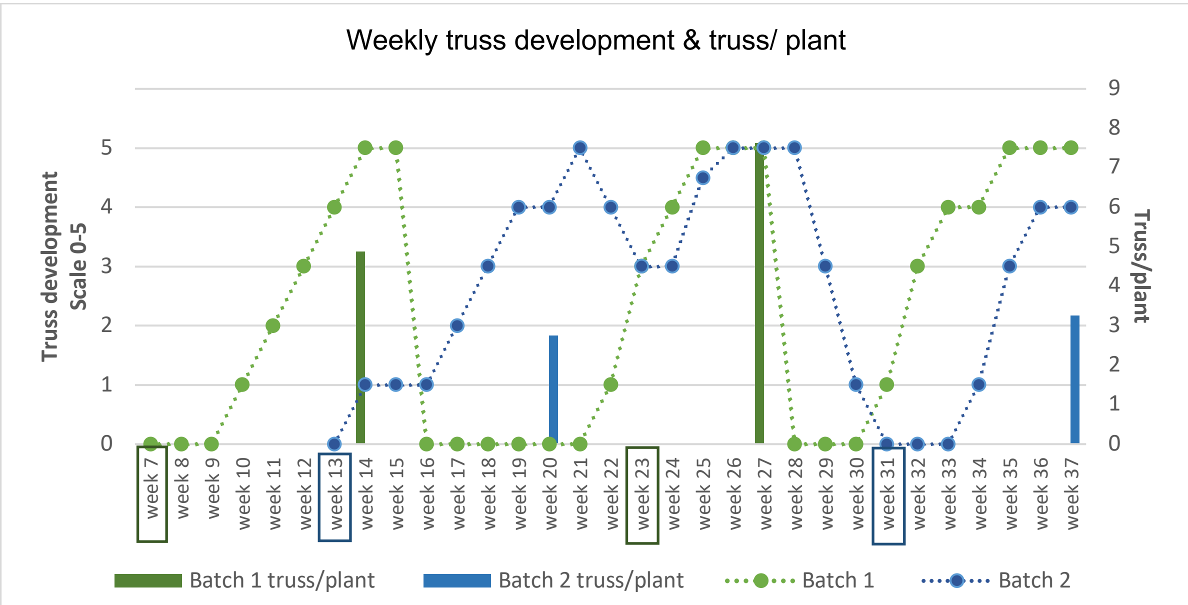

*Figure 16. **A**. Plant development grading using scaling 0-5 modified from Meier (2001). **B**. A comparison of batch 1 and 2, truss development. Dotted line is the estimated truss development in batch 1 and 2, according to the scale 0-5. <u>This line does not present yield or harvest pattern</u>. Values are mean values of eight plants in each batch. Flower mapping was performed in week 7 and 23 (batch 1) and week 13 and 31 (batch 2). Bars present the max value of truss per plant measured in greenhouse after performed flower mapping. Final assessment occurred in week 37. Difference is seen in the development pattern and trusses per plant between the batches.*

Major similarities (Table 1) in both batches was that it was the side positioned axillary buds that were first developing, followed by the central positioned truss. These trusses had cold damaged flowers. During the cropping season complexity of trusses was quite similar in the batches and both had a large canopy. Later in the season plants within a batch differed a lot in crown complexity. Damages due to pest and pathogen was as well similar, besides the infestation of thrips. Major differences were the rate of plant establishment. Resulting in Batch 1 having its first flowering 7 weeks after planting whereas batch 2 flowered after just 5 weeks. Batch 1 had two runner formation peaks, and batch 1 only one runner peak. Batch 1 had more trusses in average and a distinct harvest peak pattern. Batch 2 had fewer truss in average and the peak of harvest was not as distinct as in Batch 1.

Table 1. The major similarities and differences between Batch 1 and Batch 2.

Similarities	
Batch 1	Batch 2
Cold damaged flowers	
Side positioned axillary buds emerging first (vampire buds)	
Complexity of trusses	
Within a batch – large variation between crowns	
Pest and pathogens	
Differences	
Batch 1	Batch 2
Development until first inflorescence, slow	Development until first inflorescence, fast
1st peak anthesis, 7 weeks after planting	1st peak anthesis, 5 weeks after planting
Runner formation, twice	Runner formation, once
Two lag-times	One lag-time
More trusses in average	Less trusses in average

4.2 Flower mapping

To evaluate flower mapping as a method, which was one of the major aims of the study pro- and cons of the professional and self-performed mapping are highlighted. A frequency table was formed to answer research question (II) How can results from flower mapping be used in order to predict future truss development?

4.2.1 Results flower mapping

Flower mapping performed by an untrained actor was moderately successful. Identifying stages of bud development and floral organs was most difficult. Length of axillary buds and the structural placement was on the other hand successfully managed. Results from self-performed flower mapping gave insight of morphologic characteristics and structures in a young strawberry plant. Results from the self-performed mapping were not used further in the experiment.

Flower mapping (FM1 and FM2) conducted by the professional actor Plantalogica, plants were presented referring to its specific morphologic structure (appendix). This raw-data representing each plant morphologic structure was summarized in a frequency table. The frequency table was managed with the aid get an overview of bud developmental stages and their distribution in average per plant (table 2-5). Then a future `potential truss´ development based on specific individual terms was calculated. Description of the grading available in, section *2.7* Morphological analysis and flower mapping and Fig. 12.

Section `Crowns´ in table 2-5, shows the number of crowns and secondary crowns on each plant, e.g. 1+1 means one main crown + one secondary ranking crown. This secondary crown is set in an axillary position of the main crown. A crown with a secondary crown is thereby a more complex crown. A third ranking crown set in an axillary meristem of a secondary ranking crown was also found in some plants; these are included in the counting of a secondary crown. `First truss´ is the terminal inflorescence of a crown or branch crown, with several subordinated axillary meristem. `Stage 2´ is a vegetative or generative bud not yet differentiated. `Stage ≥ 3´ is a developing differentiated generative flower truss. `Cut back´ means that a truss or runner was cut off before entering cold storage at the nursery. `Runner´ is an actual differentiated vegetative runner. Section `total potential truss´ refers to the estimated potential of bud development in the future and `total bud´ is all the bud stages summarized.

Batch 1

First flower mapping (FM1)

In the first flower mapping (FM1) section `potential truss´ refers to the estimated potential of bud development in the future. In the calculation, stage 2 was excluded since these buds were not yet differentiated and could either develop into vegetative runners or a generative truss. Stage 8-11 was also excluded since they most probably were cold damage and not adding to the yield.

One or two crowns were monitored on the young tray plants and the complexity of the crowns differed. Five out of eight plants had a secondary ranking crown (Table 2). Many of the flowers of the later stages ≥ 8, were to be removed due to cold damage. There was an average of two stage 2 buds per plant, these buds would either become vegetative or generative. Potential trusses to develop in the future were estimated **to 4.625 per plant** (stage 2 and stage 8-11 excluded). The distribution of buds within the interval was mainly stage 6 and 5, which are those presumably becoming the first trusses with a full flowering potential.

*Table 2. Result from the first flower mapping and summarized bud distribution of batch 1. Standard deviation(**σ**) for ´potential truss´ in brackets.*

Batch 1: Flower mapping 1,February											
Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	2+1	1	2+1	2	2+1	2+1	2	2+1		
	First truss	3	2	4	3	4	4	3	4	27	3.375
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3	2			1					3	0.375
	Stage 4						1		1	2	0.25
	Stage 5	1	2	4		1		2	2	12	1.5
	Stage 6	2	3	1	1	4			4	15	1.875
	Stage 7			1	1	1	1		1	5	0.625
	Total pot. truss	5	5	6	3	6	2	2	8	37	4.625 (σ= 2.134)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	2	1	3	3	2	2	2	1	16	2
	Stage 8	2	1	1	1		1	2	1	9	1.125
	Stage 9	1		1	1	2	2		2	9	1.125
	Stage 10									0	0
	Stage 11		1			1		1		3	0.375
	Cut back			1	1				1	3	0
	Runner	8	7	8	5	9	5	5	11	58	7.25
All bud stages summarized	Total bud	10	8	11	8	11	7	7	12	74	9.25

Second flower mapping (FM2)

The second flower mapping (FM2) section `potential truss´, stage 2 is excluded since they were not yet differentiated. Stage 10-11 were excluded since these buds already had developed into trusses/flowers and are therefore a part of the current plant architecture and not the upcoming future.

Flower mapping performed six weeks after the harvest peak shows that there was an increase in the crown size and the complexity of the crowns (Table 3) compared to (FM1). Notable is the number of potential trusses varied greatly between plants. This could be confirmed by the value of the standard deviation (**σ**). There were 1-5 crowns per plant and 1-5 secondary crowns per plant. The second ranking crowns are desirable since they add to the yield by producing their own flower clusters and axillary meristem set at each leaf node. The bud distribution was mainly at the stages 6-9, indicating that trusses would soon emerge and elongate. Young buds in stages 3-5, indicated a prolonged truss development. The estimated future flowering potential was **13 trusses per plant** (stage 2 and 10-11 excluded). Beside the truss development a large number of differentiated runners were identified. These were mainly emerging at the lower positions of a crown. A large harvest peak was to be expected alongside with elongation of many runners.

*Table 3. Result from second flower mapping and summarized bud distribution of batch 1. Standard deviation(**σ**) for ´potential truss´ in brackets.*

Batch 1: Flower mapping 2, June											
Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	3+2	5+5	3+3	4+2	4+3	4+1	2+2	1+2		
	First truss	5	10	6	6	7	5	4	3	46	5.75
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3	1	1			2	1			5	0.625
	Stage 4	2	2	2			1			7	0.875
	Stage 5		2	1	1	3	1		1	9	1.125
	Stage 6	2	7	3	3	5	3	4	2	29	3.625
	Stage 7		2		2	2		2	7	15	1.875
	Stage 8	3	2		3	2	4	1		15	1.875
	Stage 9	3	7	2	3	3	3	1	2	24	3
	Total pot. truss	11	23	8	12	17	13	8	12	104	13 (σ= 4.95)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	1	5	4	2	3	2	2	3	22	2.75
	Stage 10									0	0
	Stage 11	1		3	1	1				6	0.75
	Cut back									0	0
	Runner	7	21	12	10	9	13	5	8	85	10.625
All bud stages summarized	Total bud	13	28	15	15	21	15	10	15	132	16.5

Batch 2

First flower mapping (FM1)

About 1-3 crowns per plant were identified and a complexity of second ranking crowns in four of eight plants (Table 4). Since flowers of stage ≥ 8 would most likely be removed due to cold damage and the stage 2 buds were not yet differentiated, the estimated potential truss value was **3.125 per plant** (stage 2 and stage 8-11 excluded). There was an average of 2.875 stage 2 buds per plant, and the most buds in stage 5, stage 6 and lastly stage 8. This distribution of buds indicated there would be a development of several trusses at the same time. Followed by a runner elongation or a truss development from stage 2 graded buds.

*Table 4. Result from first flower mapping and summarized bud distribution of batch 2. Standard deviation(**σ**) for ´potential truss´ in brackets.*

Batch 2: Flower mapping 1, March											
Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	1	1+1	1+1	2	2	3	1+1	1+1		
	First truss	1	2	2	2	2	3	2	2	16	2
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3					1			1	2	0.25
	Stage 4							1	1	2	0.25
	Stage 5	1		1	2	2			1	7	0.875
	Stage 6	1	2		3	1	1	2	1	11	1.375
	Stage 7					1	1		1	3	0.375
	Total pot. truss	2	2	1	5	5	2	3	5	25	3.125 (σ= 1.642)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	2	0	3	1	8	5	3	1	23	2.875
	Stage 8	1	3	1	1	1	2	1	1	11	1.375
	Stage 9			1	1		1			3	0.375
	Stage 10									0	0
	Stage 11		1					1	1	3	0.375
	Cut back									0	0
	Runner									0	0
All bud stages summarized	Total bud	5	6	6	8	14	10	8	8	65	8.125

Second flower mapping (FM2)

Flower mapping performed six weeks after the harvest peak shows that there was an increase in the crown size and complexity (Table 5.) However, the number of crowns and buds varied greatly between the plants. This influenced the number of potential truss which also varied between plants, compared to the FM1 results. This variation was confirmed by the value on the standard deviation (**σ**).

Table 5. Result from second flower mapping and summarized bud distribution of batch 1. Performed on established plants six weeks after first harvest peak. Standard deviation for ´potential truss´ in brackets.

Batch 2: Flower mapping 2, July											
Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	4+1	2+4	3+4	1	1	5+1	2+6	2+3		
	First truss	5	6	7	1	1	6	8	5	39	4.875
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3		1							1	0.125
	Stage 4							4	1	5	0.625
	Stage 5		2			1		1	2	6	0.75
	Stage 6	3	1	2		1	6	6	1	20	2.5
	Stage 7		1			1	1		1	4	0.5
	Stage 8	1	2	4			1	1	1	10	1.25
	Stage 9	1	1	4				1	1	8	1
	Total pot. truss	5	8	10	0	3	8	13	7	54	6.75 (σ= 4.02)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	1	5	0	4	0	2	2	0	14	1.75
	Stage 10									0	0
	Stage 11	8	2	9			5	4	3	31	3.875
	Cut back									0	0
	Runner		2	1						3	0.375
All bud stages summarized	Total bud	14	15	19	4	3	15	19	10	99	12,375

The estimated flowering potential was **6.75 trusses per plant** (stage 2 and 10-11 excluded). The analyzed plant material had most trusses stage 11 (anthesis) followed by buds in stage 6, stage 2 and stage 8. Flower mapping results sex weeks after estimated harvest peak did show that buds had continuously been initiated. Future potential flowering and growth pattern seemed to be distributed over a longer time. Not so many runners were identified as in batch 1.

4.3 Flower mapping in relation to truss development.

To answer the aims (III) Is it possible to estimate the future potential truss development, by performing flower mapping before planting and then again after first harvest peak? and (IV) Is flower mapping a method to be used in the decision support to optimize cultivation of an everbearing cultivar? Estimated truss development values and reality values are set against each other.

Batch 1

First flower mapping result showed secondary ranking crowns which is positive since it adds to the plant quality with leaf and axillary meristems. Potential flower trusses estimated to develop first was **4.625 truss per plant** (Table 2). The actual development after 7 weeks (in week 14) was **4.875 truss per plant** shown in the two-axis chart Fig. 16, bar W14. According to the results illustrated in Fig. 17 the estimated value was close to the real value. Indicating that FM1 was successful in predicting future truss development. In week 15 lots of runners emerged indicating that some of the stage 2 buds had differentiated into runners. In week 17 a new flush of trusses was emerging in the base of the plants. These were presumably initiated after the plants had been planted. In week 19-20 a new runner flush emerged indicating that all the buds from previous year had elongated and new initiation had occurred.

Second flower mapping in week 23 confirmed an increase in crown size and complexity, buds had initiated and differentiated both as runners and trusses (Table 3). Potential flower trusses estimated to develop were **13 truss per plant**. Actual average number of trusses was counted to **7.625 truss per plant (**Fig. 16). The results in Fig. 17 indicates that values are far placed from the predicted value, and the FM2 was not successful in predicting future inflorescence.

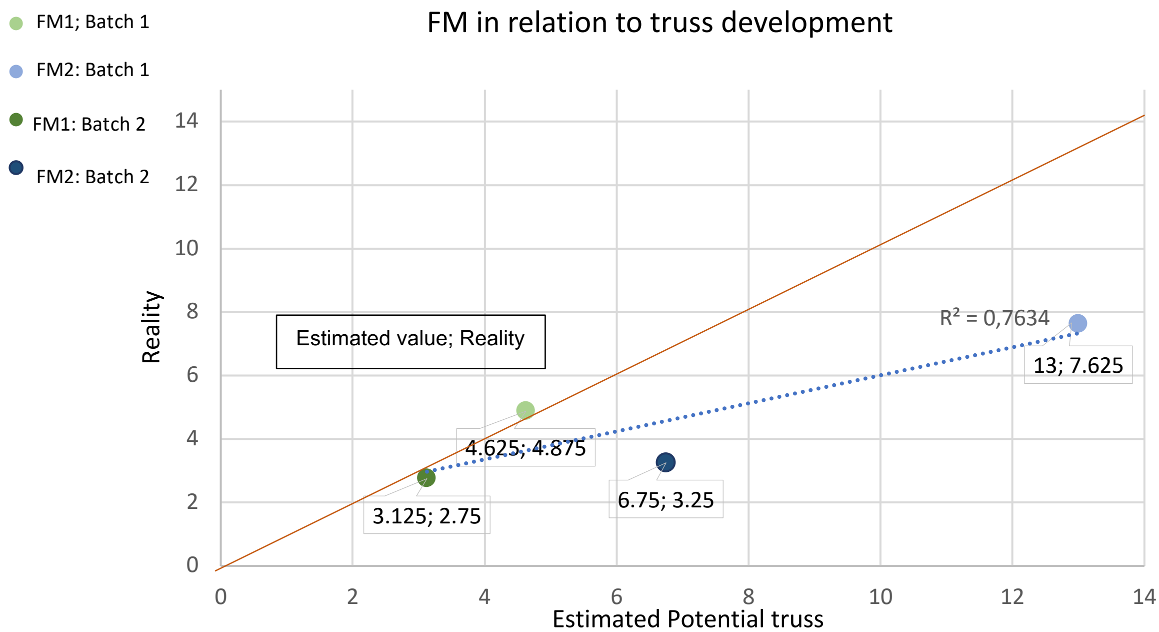

Figure 17. The scatterplot illustrates the estimated values from FM1 and FM2 and compare to the values of the actual truss development. The closer a value is to the red line, the more the estimated value matches the actual truss development in the greenhouse. FM1 gave the best result in predicting future truss development. R^2 value of 0.7634.

Counted trusses were assumed to be the buds of stage 6-9 from the performed flower mapping, since the measurement took place two-tree weeks after flower mapping was conducted. However, trusses continued to develop after the peak measurement, adding to the total emergence of trusses. These later coming trusses were presumably the stage 2-3 buds in the flower mapping results. Data collection after the first observed peak (of 7.625 truss per plant) became difficult, since trusses emerged sporadically and to distinguish old from new trusses was difficult.

Batch 2

Flower mapping in week 13 showed plants with secondary ranking crowns which add to the plant, with leaf and axillary meristems. Potential flower trusses first to develop was **3.125 truss per plant** (Table 4) the actual development at the first peak in week 18 (5 weeks after planting) was **2.75 truss per plant** (Fig. 16, bar W20). According to the results (Fig. 17) the estimated value was close to the real value. Indicating that FM1 was successful in predicting future truss development. Runners were also developing at this time, indicating that the stage 2 buds had differentiated into runners. The truss development continued sporadically and added to the yield. When some trusses were harvested others were emerging in the base and a small peak in week 28 was observed. This peak was a result of buds initiated after planting and the first flowering flush. After this peak, truss development drastically decreased, into a lag-period.

Flower mapping section \`crowns´ conducted in week 31 showed increase in the crown size and crown complexity for some plants (Table 5). But there were great differences between plants, and some had not even formed secondary crowns. According to the \`potential truss´ development, it was estimated to develop **6.75 truss per plant**. In week 34, 3 weeks after flower mapping, trusses started to emerge sporadically and in week 37 about 6 weeks after flower mapping the max value of **3.25 truss per plant** was monitored. The truss development continued after the final assessment in week 37. The results of the estimated value (Fig. 17) was quite far placed from the real value, and the FM2 was not successful in predicting future inflorescence.

Discussion

The objective of the thesis was to evaluate and predict the truss development and flowering potential in an everbearing strawberry cultivation in greenhouse. This was done by visual grading selected plant material and flower mapping, before and after the first harvest peak.

5.1 Seasonal evaluation – Visual grading

5.1.1 Seasonal truss development

Results from the present study showed that greenhouse production is a system resilient to weather changes, and berries can be picked during a long season compared to filed production. This conclusion is in agreement with Karhu and Sønsteby (2006), who suggest greenhouse production as a system to prolong the harvest season in northern climates. This provide partly an answer to the first aim of the study, on how the seasonal truss development look like in a greenhouse environment. The planting at two separate dates in this trial was conducted in order to have overlapping harvests. The assumed growth pattern was that batch 1 would have a harvest peak and then enter a lag-period. By this time, batch 2 would have entered its harvest peak, since it was planted later, and vice versa. Having overlapping harvest is considered to be more profitable.[16] An even supply of berries to the market can meet the demand of the consumers and result in higher profits. The differences in plant development between batches (Table 1) also challenge decisions as timing for fertilization and plant management inputs.[17]

According to the results of the study, the yield pattern was overlapping in the first harvest but not in the second (Fig. 16). The quest for having overlapping harvest and distinct lag- time was thereby not fully successful. Truss development in Fig. 16 can be divided into two periods, the nursery differentiated buds-period (the first development) and the recurrent-period (the second development) which originate from buds initiated in the greenhouse. This also answer the first aim of the study and confirms /illustrates the differences in the seasonal truss development.

[16]Mats Olofsson, Vikentomater. Interview 21 August 2019.
[17]Mats Olofsson, Vikentomater. Interview 21 August 2019.

Lag-time seen in between the flower flushes is a common feature and by advisors referred to as a `recovery phase´. This is a pause in the bud development before the next generation trusses or runners visually emerge. The scientific literature and research of the `recovery phase´ in greenhouse grown everbearing strawberries is limited. The available theories are deviating but an overall concluded factor according to the literature survey is the inherent response of thermophotoperiod influencing the initiation of flower buds. According to Heide and Sønsteby (2007c) cultivars as Favori are promoted to flower at long-day and higher temperatures. This conclusion can explain the distinct lag-time in week 16-21 and 28-30, seen in the truss developmental pattern of batch 1 (Fig. 16). Plants in batch 1 were planted at short-day conditions and no bud initiation occurred until the transition to long-day in March/April. The first buds emerging were the nursery differentiated buds followed by a lag-time. This lag-time could be a result of the absence of long-day photoperiod at planting about week 7-13.

In batch 2 the first lag-time was estimated to occur after the first truss development peak in week 21, but it did not. The first distinct lag-time was seen later in the season, between week 31-33 (Fig. 16). This behavior is in line with the findings of Heide and Sønsteby (2007c) who suggest that cultivars as Favori have a long-day response. An immediate bud initiation of batch 2 occurred at planting during long-day conditions in week 13. This resulted in a prolonged truss development and the early lag-period as seen in batch 1 did not occur.

To achieve overlapping harvests a longer interval between the planting dates would presumably not be an option. It would rather limit the total yield outcome in the end of the season. Using the more expensive coldstored tray plants would then be for no reason. Shorter gap between the planting dates and by that planting in the same photoperiod would presumably not either be a successful option, because the bud development/elongation is connected to day-length and temperature, in the literature survey referred to as GDH. This means that at a lower temperature bud development until anthesis takes longer time compared to at a higher temperature. Planting with a shorter interval would therefore presumably not result in an overlapping harvest.

To achieve a desired overlapping harvest, planting of the batches could occur at the same photoperiod, but with different temperature regimes one at a lower temperature and one with elevated temperature. Applying a low temperature (<10C°) inhibit the growth rate and yield (Flevoberry 2018; Gangatharan et al. 2019). Low temperature at planting followed by a slowly increase was applied in batch 1 but not batch 2 in the trial. Thus, the greenhouse temperature was adjusted to batch 1 and when planting occurred for batch 2 temperature was above >10C°, and a fast development of leaves and trusses as a result was observed. Separate climate regulations for batch 1 and batch 2 could presumably manipulate the plant to overlapping harvests. Another suggestion to achieve overlapping harvest of the second flush is the use of thinning or removal of trusses (Zucchia et al. 2017). However, the research on this area is still limited and further investigation is needed.

5.1.2 Duration of the lag-time

The duration of the lag-time is affected by light, being important in the strawberry plant diurnal rhythm (Hyo Gil Choi et al. 2016). Excessively hot temperatures are another factor found by Battey and Wagstaffe (2006) that could lead to the stress reaction "thermodormancy", which prevents the initiation of new flower buds. This reaction could explain the long lag-period seen between week16-21 for batch 1, compared to the shorter second lag-time between week 28-30 (Fig. 16). The duration of the lag-time could also be a result from an imbalance in the nutrient supply. Especially the timing of nutrient, found by Heide et al. (2009) important for flower initiation. In order to shorten the vegetative lag-time, as suggested by Wagstaffe and Battey (2006) difference between day temperature and night temperature could be applied. Night interruption is another alternative discussed by Heide and Sønsteby (2007c). Some actors (Massetani & Neri 2016) suggest stress induced factors to manipulate plant architecture initiation and differentiation of buds. However, induced stress is difficult to control and there is a risk of severely damaging the plants instead of promoting them.

5.1.3 Seasonal development of runners

The truss elongating from a runner rosette can be a complement to the harvest in a greenhouse production. In the greenhouse trial, runners were kept in some of the rows with the aim of adding to the yield. Previous research has demonstrated that intermediate to high temperatures and long-day generally promote runner formation in some cultivars (Heide & Sønsteby 2007c). These findings could explain the results of the different runner elongation pattern found in this study. Runner formation of batch 1 according to the visual grading started as truss elongation in week 15 (intermediate temperatures and long-day conditions) and a second runner flush was observed in week 19 (intermediate-high temperatures and long-day), whereas batch 2 only had one runner flush around week 20-22 (at intermediate-high temperatures and long-day conditions). Batch 1 was planted in February and first runners emerge when temperature increased and the shift in photoperiod occurred in week 15 (April). These buds were presumably nursery-differentiated buds developing as runners. The second runner flush, in week 19, would then have been a result from bud initiation in the greenhouse after planting during favorable conditions.

Batch 2 had only one runner flush. According to the theory (Heide & Sønsteby 2007c), nursery-initiated buds were directly promoted to develop as planting occurred at the shift to long-day conditions. A second initiation of runners did, however, not emerge even if the desired preferences of long-day and intermediate temperatures were applied. The limitation of the runner capacity in strawberry plants rely on the interference between the runner and the flower bud differentiation (Neri et al. 2008; Heide & Sønsteby 2007c). Since flower buds in everbearing cultivars as the runners are promoted by long-day and intermediate to high temperatures (20-27C°). This finding environmental cues affect the runner formation. However, removing runners is labor-intensive, the limited runner formation in batch 2 was therefore an advantage to keep the labor costs down.

5.1.4 Crown and truss complexity

The first inflorescence appearing in the cultivation showed weak and short stalks with basal branching which were features also seen in the study by Zucchia et al. (2017). These early flower-differentiated buds were concluded by Massetani and Neri (2016) to be competing with the main truss for assimilates. Many of the early trusses had cold damaged flowers presumably as a result from cold storage and some were removed. This was concluded an advantage since they were not adding to the yield.[18]

The study did not include a statistical analyze of truss complexity. But visually it seemed like the truss complexity at the end of the season was higher than in the beginning of season in both batches. The influence of higher temperatures (15-25°C) and long day was found to enhance the truss complexity by Giongo et al. (2017). These temperatures were measured in the greenhouse. The findings by Giongo et al. (2017) could be the explanation to the higher complexity seen in this trial. Nevertheless, a high truss complexity is not always desirable as, the higher ranking a truss has, the smaller berries are harvested. Small berries are more

[18] Lars Friis, Lindflora. Interview 25 April 2019.

expensive to pick since they are classified as second-class berries. In order to achieve high yield and sustain the quality of the berries, it would be economically more favorable to promote the formation of initiation sites and secondary crowns than high complexity trusses since the larger and more complex a crown is, the higher potential yield to expect (Johnson et al. 2006). Major identified factors to influence crown complexity and secondary crown formation according to the literature are thermophotoperiod (Heide and Sønsteby 2007c), temperature of the day and night (Camp & Wang 1999), light quality and quantity (Battey and Wagstaffe 2004), and mineral nutrition (Gomes-Merino & Trejo-Tellez 2014), especially nitrogen (Miltiadis & Papadopoulos 2016).

5.1.5 Plant health

It was beyond the scope of this study to investigate pest and pathogens in relation to the plant productivity. However, pest and pathogens did significantly influence the plant architectures and development pattern, and therefore need to be further discussed. Reduced berry size and flower abortion were some identified stress responses. Plant stress limits the bud initiation, truss development and the potential yield (Gahrangan et al. 2011.). Crown wilting was seen in the beginning of the summer when batch 1 was in the start of its first harvest and batch 2 was in the first truss elongation phase. The crown wilting could be a result of a fungus, either latent in the plant material or caused by an infection after planting. Wounds appearing in frost damaged tissues could be an entrance for the hyphae (Karhu & Sønsteby 2006). Another explanation to the crown wilting could be plant stress, due to poor root activity causing an uneven ratio between roots and shoots. This explanation is supported by the study of Neri (2016) where the same type of wilting symptoms was seen in high density planting under high irradiation, high temperatures and low transpiration. Climate adjustments were made to increase the relative humidity and airflow turbulence in the greenhouse, and the occurrence of wilting crown was decreased. These climate factors were found by Neri (2016) necessary for a good root activity and establishment. Other factors that could hinder the crown wilting, are the same as previously discussed to reduce the growth rate, by keeping temperature low at planting. If temperature is kept low followed by slow increase, it limits the aboveground growth rate and favor the root establishment (Neri 2016). Optimal temperature for root growth is at 18°C during day and 12°C during night according to Camp and Wang (1999). Pruning or thinning of the early trusses, as suggested by Zucchia et al. (2017) and Neri (2016) could also be an option to limit aboveground sinks and promote the root establishment to prevent crown wilting. However, this pruning management can lower the first marketable yield (Zucchia et al. 2017) and need to be considered in relation to the profits.

5.1.6 Limitations

There were limitations in the visual grading to evaluate the development of truss, runners, root and berries. In the beginning of the season when plants were less complex and canopy thin, the visual grading was easily conducted. Later in the season did the higher complexity and the large canopy constrained the visual grading. To collect the data describing the plant development was also concluded complicated and time consuming. In further studies a framework formed to benefit the evaluation of the different developmental stages of a plant would favor the measurements. In such a framework the use of the BBCH-scale from the beginning of the experiment to identify phenological stages of flower development, would be a recommendation. Labelling trusses and runners and performing measurements every second day would also be a method to be used in the data collection. In the study eight replicates were used, which was presumably not sufficient because there were large differences found between plants within a batch. In further studies a larger sample size would give a more representative and holistic view of the cultivation. The overall climate data (temperature, relative humidity, airflow), or cumulative harvest data could unfortunately not be included in this study. With help of a complete climate data it would have been possible to evaluate the whole development pattern and find connections between the yield and the climate. In future studies asses to this data would be an advantage of further understand the plant architecture and development connected to the greenhouse environment.

5.2 Flower mapping

Flower mapping by a professional actor gave most reliable results, and high detail data was received as an excel file (appendix). Flower mapping performed by an untrained actor (self-performed) was only moderately successful, since it was time consuming and gave uncertain result in the grading of early axillary bud stages. The uncertain result was mainly due to the implementation of the reference material used to identify the bud stages. The reference material did not reflect properly was seen in the microscope. To find the axillary bud core without damaging the meristem, was also a concluded challenge, since the analyzed bud meristems were wrapped and sealed in layers of plant tissue and trichomes. Training to gain more experience in combination with the access to a high-resolution microscope would ease the process and give more reliable results. However, this less exhaustively performed flower mapping had its advantages and gave insights in the morphologic characteristics, as length of axillary buds and its structural placement on a plant. Another advantage is that the self-performed flower mapping is less expensive to conduct than the professional and can be performed quite fast without any advanced facilities. An applied situation in the greenhouse of a self-conducted flower mapping would be to evaluate, depending on the number of identified buds on a plant, if it is profitable to keep plants in a cultivation. Flower mapping could also be used in harvest forecasting. The performance of the forecasting would be likewise the setup of this trial but, instead of focusing on the overall development pattern, the focus would be to monitor the harvest pattern. It takes a certain time for a flower truss to develop until it is harvest. This time is connected to light and temperature and the stage of an axillary bud, which can be calculated as GDH. Identify the harvest pattern with GDH, is used by the advisor company Delphy. Thus, GDH needs to be individually defined by cultivar, production system and geographic position.[19] Further research on GDH specific for the cultivar Favori would be helpful to perform a reliable future forecasting framework.

5.2.1 The frequency tables

The frequency tables were an efficient tool to overview and analyze the raw-data (table 2-5) and predict future truss development and the second objective of the study successfully fulfilled. Frequency tables summarized the initiated buds per plant, their distribution and crown complexity of the eight replicates in each batch. The knowledge of the bud distribution could be used as a guideline to predict and estimate future truss development. It could also be a quality insurance to assure that buds have been initiated. Bud stages excluded in the frequency table to calculate `potential trusses´ were chosen to fit the objectives of this thesis. These values are exchangeable and could be replaced in order to fit other desired objectives or studies.

5.3 Flower mapping in relation to truss development

Previous research on professionally performed flower mapping (Neri 2011; Gahrangan et al. 2011) have concluded flower mapping to be successful in evaluating plant architecture, production potential and monitoring efficiency of cultivation technics. The results of this thesis

[19]Harrie Pijnenburg, Senior advisor Delphy. Email conversation 9 September 2019.

demonstrate flower mapping to be useful in predicting future truss development pattern in the first truss development. A second flower mapping with aim to estimate future truss development was, on the other hand, only moderately successful. To answer the third research question, it is thereby concluded that yes, it was possible to estimate the future truss development in before harvest peak, but just partly after first harvest peak.

The failure of the attempt was because the observed values did not cohere to the reality values (Fig. 17). However, the second flower mapping was concluded being useful to attest that bud initiation had occurred. It could thereby be a tool to support plant management and stress response. Flower mapping is superior as a quality insurance technical to confirm initiation of axillary buds and their faith compared to other quality techniques e.g. measure size of the crown. The results from this study provide knowledge of flower mapping as a method, which could benefit future everbearing strawberry in greenhouse, tunnel and field. However, it is most profitable implementing flower mapping in a greenhouse since it is a more expensive production with several harvest peaks. The climate in greenhouse is also more stable and easier to regulate/ forecast. Result from flower mapping is therefore of more use, since plant health and development can be manipulated by the surrounding climate.

The deviating results in estimating future truss development of the second flower mapping rely on the sporadic and distributed behavior of bud initiation and truss development after the first harvest. To evaluate flower mapping as a tool the plan was to, first perform a flower mapping and then count the trusses emerging in the cultivation. The results of the maximum counted value of trusses would then be correlated to the potential truss value in the frequency table. For this setup to actually work out it was assumed that trusses would emerge, elongate and become harvested at approximately the same time. It was also assumed that after a harvest there would be a lag-time when bud initiation would occur, and plants were going to be sent for a second flower mapping. Results received, would be used to estimate the future truss development and so on. Anyhow, this pattern was not what was observed in the greenhouse.

In the literature, flower mapping is suggested to be performed after harvest in order to predict future flowering pattern, presumably because it refers to that initiation occur during and short after harvest. However, the visual grading and observation of the trial showed that new trusses emerged even during harvest in batch 2. This made it hard to distinguish between previous or current initiated buds and made it difficult to estimate the optimum time for performing the second flower mapping. The results achieved conducting a second flower mapping only gave a short forecasting. In order to attain an actual correlation between the second flower mapping and future development, flower mapping after the first harvest is suggested to be performed several times.

The deviating results of second flower mapping were also a result of the continued truss development after the final measurement, specially the batch 2 data collection. Prolonged data collection would might give a more holistic view of the seasonal growth pattern. Another factor that influenced the results of the second flower mapping was, the unpredictable events in the greenhouse. When plants were exposed to stress factors such as pests and high temperature fluctuations, the bud initiation and differentiation hindered. These stress factors can not be predicted but need to be considered in order to estimate future growth and development pattern. As previously discussed, there was a wide variation of crown complexity and this presumably also influenced the overall flower mapping results. In future studies the use of more replicates would therefore be an advantage.

To answer to the objective of the usability and applicability of flower mappings. When taking in to account the reliability and the costs of sending plants for a second flower mapping, it is not suggested as a tool to predict future development pattern of the second inflorescences. The second professionally performed flower mapping did, though, confirm that bud initiation had taken place after the first harvest and could be used in some decision support to optimize production. Meanwhile a self-conducted flower mapping could give important information to growers identify lag-periods or if it is profitable to end a harvest.

5.4 Future perspective

Flower mapping could be used in the decision support to optimize production and increase economical profits. It could also result in a larger self-sufficiency and strengthen Swedish produced, mitigating a global climate impact. But, in order to implement a less exhaustive flower mapping into the daily routine, growers need to realize the profits there is to earn by understanding their crop and the influences of environmental and cultural practices. Dissection of plants can give insight in evaluate plant quality e.g. branched crowns, initiations sites and initiated buds. Next step is to connect this quality attributes to the plant management to understand management actions and promote a high yielding cultivar. Send plants for a professional mapping is more expensive but could take the optimization to the next level. The future perspective everbearing cultivars in Sweden will probably be increasead. The demand for domestically produced strawberries and favorable market prices (Jordbruksverket 2015) are probably some contributors. Future perspective of the strawberry production in greenhouse would be the focus on cultivar-specific research and plant management in order to target and optimize a specific production system. Next step for flower mapping in the horticultural industry would be to integrate the method in the automatization of microclimate regulation. Thus, combining flower mapping results with GDH on a microclimate level would even further give possibilities to evaluate management and forecast yield on a batch level instead of as today, on a greenhouse level. In order to perform a flower mapping, plants need to be dissected into their elementary units. In the future, flower mapping conducted without dissecting the plants would even further enhance its usefulness and applicability. High resolution cameras are used to identify photosynthetic surfaces in the current automatized plug plant technology. If this type of technique could be used to scan and identify plant architecture, flower mapping on a large scale would then be an option to implement it in the daily routine.

Conclusion

Plant response to the environment vary between cultivars and amongst plants in a cultivation system. The architecture and flower bud formation in *F.* x *ananassa* cultivar Favori relies on several cultural and environmental cues. Light and temperature (thermophotoperiod) have the largest effect on bud initiation and influence the seasonal truss development pattern in a greenhouse. To dissect a strawberry plant into its elementary units, so called flower mapping, provide an insight of the plant morphology. Flower mapping results can be summarized in a frequency model to predict potential future truss development, and to get an overview of the bud distribution. Flower mapping performed by a professional actor gives a prediction of future plant development in the first harvest. Results from a less exhaustive, self-preformed flower mapping could give information of short-term plant development.

In conclusion, in order to streamline production, professional flower mapping performed before planting could be used as decision support to optimize cultivation practices and predict the future truss development. Flower mapping conducted after the first harvest peak and during the cropping season could be used to evaluate current plant quality, cultivation practices and stress response in an everbearing strawberry cultivar.

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Appendix

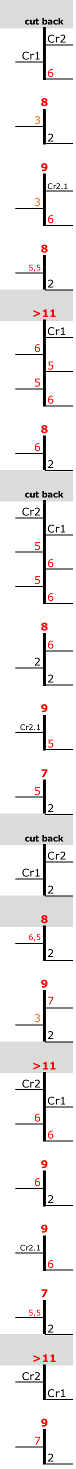
First flower mapping – an example

STRAWBERRY 'FLOWER MAPPING'

(1 = lowest position)

Date	Grower	Sample code	Plantnr.	Crownnr.	Position	Runner	Bud length (cm) ≥ 1	Bud length (cm) 0.2 - 1	Bud length (cm) < 0.2	Development stage	Truss length (cm)
14 February 2019	**SLU**	**week 7 Favori minitray**	**1**		**first truss**					**cut back**	**cut back**
14 February 2019	SLU	week 7 Favori minitray	1		3		*			Cr2	
14 February 2019	SLU	week 7 Favori minitray	1		2		*			Cr1	
14 February 2019	SLU	week 7 Favori minitray	1		1			*		6	0,18
14 February 2019	**SLU**	**week 7 Favori minitray**	**1**	**1**	**first truss**					**8**	**0,80**
14 February 2019	SLU	week 7 Favori minitray	1	1	2			*		3	0,05
14 February 2019	SLU	week 7 Favori minitray	1	1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**1**	**2**	**first truss**					**9**	**3,50**
14 February 2019	SLU	week 7 Favori minitray	1	2	3		*			Cr2.1	
14 February 2019	SLU	week 7 Favori minitray	1	2	2			*		3	0,06
14 February 2019	SLU	week 7 Favori minitray	1	2	1			*		6	0,18
14 February 2019	**SLU**	**week 7 Favori minitray**	**1**	**2,1**	**first truss**					**8**	**0,90**
14 February 2019	SLU	week 7 Favori minitray	1	2,1	2			*		5,5	0,16
14 February 2019	SLU	week 7 Favori minitray	1	2,1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**2**		**first truss**					**>11**	**7,50**
14 February 2019	SLU	week 7 Favori minitray	2		5		*			Cr1	
14 February 2019	SLU	week 7 Favori minitray	2		4		*			6	0,50
14 February 2019	SLU	week 7 Favori minitray	2		3			*		5	0,12
14 February 2019	SLU	week 7 Favori minitray	2		2			*		5	0,12
14 February 2019	SLU	week 7 Favori minitray	2		1			*		6	0,22
14 February 2019	**SLU**	**week 7 Favori minitray**	**2**	**1**	**first truss**					**8**	**1,50**
14 February 2019	SLU	week 7 Favori minitray	2	1	2			*		6	0,40
14 February 2019	SLU	week 7 Favori minitray	2	1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**3**		**first truss**					**cut back**	**cut back**
14 February 2019	SLU	week 7 Favori minitray	3		6		*			Cr2	
14 February 2019	SLU	week 7 Favori minitray	3		5		*			Cr1	
14 February 2019	SLU	week 7 Favori minitray	3		4		*			5	0,14
14 February 2019	SLU	week 7 Favori minitray	3		3			*		6	0,40
14 February 2019	SLU	week 7 Favori minitray	3		2			*		5	0,12
14 February 2019	SLU	week 7 Favori minitray	3		1			*		6	0,20
14 February 2019	**SLU**	**week 7 Favori minitray**	**3**	**1**	**first truss**					**8**	**1,00**
14 February 2019	SLU	week 7 Favori minitray	3	1	3			*		6	0,18
14 February 2019	SLU	week 7 Favori minitray	3	1	2			*		2	
14 February 2019	SLU	week 7 Favori minitray	3	1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**3**	**2**	**first truss**					**9**	**2,20**
14 February 2019	SLU	week 7 Favori minitray	3	2	2		*			Cr2.1	
14 February 2019	SLU	week 7 Favori minitray	3	2	1			*		5	0,10
14 February 2019	**SLU**	**week 7 Favori minitray**	**3**	**2,1**	**first truss**					**7**	**0,70**
14 February 2019	SLU	week 7 Favori minitray	3	2,1	2			*		5	0,09
14 February 2019	SLU	week 7 Favori minitray	3	2,1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**4**		**first truss**					**cut back**	**cut back**
14 February 2019	SLU	week 7 Favori minitray	4		3		*			Cr2	
14 February 2019	SLU	week 7 Favori minitray	4		2		*			Cr1	
14 February 2019	SLU	week 7 Favori minitray	4		1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**4**	**1**	**first truss**					**8**	**1,30**
14 February 2019	SLU	week 7 Favori minitray	4	1	2			*		6,5	0,50
14 February 2019	SLU	week 7 Favori minitray	4	1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**4**	**2**	**first truss**					**9**	**4,00**
14 February 2019	SLU	week 7 Favori minitray	4	2	3		*			7	0,70
14 February 2019	SLU	week 7 Favori minitray	4	2	2			*		3	0,04
14 February 2019	SLU	week 7 Favori minitray	4	2	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**5**		**first truss**					**>11**	**6,50**
14 February 2019	SLU	week 7 Favori minitray	5		4		*			Cr2	
14 February 2019	SLU	week 7 Favori minitray	5		3		*			Cr1	
14 February 2019	SLU	week 7 Favori minitray	5		2			*		6	0,25
14 February 2019	SLU	week 7 Favori minitray	5		1			*		6	0,18
14 February 2019	**SLU**	**week 7 Favori minitray**	**5**	**1**	**first truss**					**9**	**1,70**
14 February 2019	SLU	week 7 Favori minitray	5	1	2		*			6	0,50
14 February 2019	SLU	week 7 Favori minitray	5	1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**5**	**2**	**first truss**					**9**	**3,40**
14 February 2019	SLU	week 7 Favori minitray	5	2	2		*			Cr2.1	
14 February 2019	SLU	week 7 Favori minitray	5	2	1		*			6	0,25
14 February 2019	**SLU**	**week 7 Favori minitray**	**5**	**2,1**	**first truss**					**7**	**0,80**
14 February 2019	SLU	week 7 Favori minitray	5	2,1	2			*		5,5	0,16
14 February 2019	SLU	week 7 Favori minitray	5	2,1	1			*		2	
14 February 2019	**SLU**	**week 7 Favori minitray**	**6**		**first truss**					**>11**	**10,00**
14 February 2019	SLU	week 7 Favori minitray	6		2		*			Cr2	
14 February 2019	SLU	week 7 Favori minitray	6		1		*			Cr1	
14 February 2019	**SLU**	**week 7 Favori minitray**	**6**	**1**	**first truss**					**9**	**1,90**
14 February 2019	SLU	week 7 Favori minitray	6	1	2		*			7	0,65
14 February 2019	SLU	week 7 Favori minitray	6	1	1			*		2	

Drawing



14 February 2019	**SLU**	**week 7 Favori minitray**	**6**	**2**	**first truss**					**9**	**2,60**	**9**
14 February 2019	SLU	week 7 Favori minitray	6	2	1		*			Cr2.1		Cr2.1
14 February 2019	**SLU**	**week 7 Favori minitray**	**6**	**2,1**	**first truss**					**8**	**0,90**	**8**
14 February 2019	SLU	week 7 Favori minitray	6	2,1	2			*		4	0,08	4
14 February 2019	SLU	week 7 Favori minitray	6	2,1	1				*	2		2
14 February 2019	**SLU**	**week 7 Favori minitray**	**7**		**first truss**					**>11**	**8,20**	**>11**
14 February 2019	SLU	week 7 Favori minitray	7		2		*			Cr2		Cr2
14 February 2019	SLU	week 7 Favori minitray	7		1		*			Cr1		Cr1
14 February 2019	**SLU**	**week 7 Favori minitray**	**7**	**1**	**first truss**					**8**	**1,20**	**8**
14 February 2019	SLU	week 7 Favori minitray	7	1	2			*		5	0,14	5
14 February 2019	SLU	week 7 Favori minitray	7	1	1				*	2		2
14 February 2019	**SLU**	**week 7 Favori minitray**	**7**	**2**	**first truss**					**8**	**1,40**	**8**
14 February 2019	SLU	week 7 Favori minitray	7	2	2			*		5	0,14	5
14 February 2019	SLU	week 7 Favori minitray	7	2	1			*		2		2
14 February 2019	**SLU**	**week 7 Favori minitray**	**8**		**first truss**					**cut back**	**cut back**	**cut back**
14 February 2019	SLU	week 7 Favori minitray	8		6		*			Cr2		Cr2
14 February 2019	SLU	week 7 Favori minitray	8		5		*			Cr1		Cr1
14 February 2019	SLU	week 7 Favori minitray	8		4		*			6	0,18	6
14 February 2019	SLU	week 7 Favori minitray	8		3		*			5	0,14	5
14 February 2019	SLU	week 7 Favori minitray	8		2		*			6	0,20	6
14 February 2019	SLU	week 7 Favori minitray	8		1			*		2		2
14 February 2019	**SLU**	**week 7 Favori minitray**	**8**	**1**	**first truss**					**9**	**2,80**	**9**
14 February 2019	SLU	week 7 Favori minitray	8	1	2		*			7	0,55	7
14 February 2019	SLU	week 7 Favori minitray	8	1	1			*		6	0,18	6
14 February 2019	**SLU**	**week 7 Favori minitray**	**8**	**2**	**first truss**					**9**	**2,60**	**9**
14 February 2019	SLU	week 7 Favori minitray	8	2	2		*			Cr2.1		Cr2.1
14 February 2019	SLU	week 7 Favori minitray	8	2	1		*			6	0,50	6
14 February 2019	**SLU**	**week 7 Favori minitray**	**8**	**2,1**	**first truss**					**8**	**1,00**	**8**
14 February 2019	SLU	week 7 Favori minitray	8	2,1	2			*		5	0,14	5
14 February 2019	SLU	week 7 Favori minitray	8	2,1	1			*		4	0,08	4

Second flower mapping - an example

STRAWBERRY 'FLOWER MAPPING'

Date	Grower	Sample code	Plantnr.	Crownnr.	Position (1 = lowest position)	Runner	Bud length (cm) ≥ 1	Bud length (cm) 0.2 - 1	Bud length (cm) < 0.2	Development stage	Truss length (cm)	Number of leaves	Drawing
03 June 2019	**SLU**	**week 23 Favori minitray**	**1**	**1**	**first truss**					**>11**	**28,00**		**>11**
03 June 2019	SLU	week 23 Favori minitray	1	1	6		*			9	5,20	0	9
03 June 2019	SLU	week 23 Favori minitray	1	1	5		*			Cr1.1			Cr1.1
03 June 2019	SLU	week 23 Favori minitray	1	1	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	1	1	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	1	1	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	1	1	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**1**	**1,1**	**first truss**					**8**	**3,30**		**8**
03 June 2019	SLU	week 23 Favori minitray	1	1,1	2			*		4	0,08	0	4
03 June 2019	SLU	week 23 Favori minitray	1	1,1	1			*		6	0,40	2	6
03 June 2019	**SLU**	**week 23 Favori minitray**	**1**	**2**	**first truss**					**9**	**4,30**		**9**
03 June 2019	SLU	week 23 Favori minitray	1	2	3					8	2,60	0	8
03 June 2019	SLU	week 23 Favori minitray	1	2	2		*			3	0,04	4	3
03 June 2019	SLU	week 23 Favori minitray	1	2	1		*			2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**1**	**3**	**first truss**					**9**	**5,80**		**9**
03 June 2019	SLU	week 23 Favori minitray	1	3	5		*			9	5,30	0	9
03 June 2019	SLU	week 23 Favori minitray	1	3	4		*			Cr3.1			Cr3.1
03 June 2019	SLU	week 23 Favori minitray	1	3	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	1	3	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	1	3	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**1**	**3,1**	**first truss**					**8**	**1,50**		**8**
03 June 2019	SLU	week 23 Favori minitray	1	3,1	2			*		4	0,07	3	4
03 June 2019	SLU	week 23 Favori minitray	1	3,1	1			*		6	0,18	3	6
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**1**	**first truss**					**9**	**5,40**		**9**
03 June 2019	SLU	week 23 Favori minitray	2	1	6		*			8	2,00	0	8
03 June 2019	SLU	week 23 Favori minitray	2	1	5		*			Cr1.1			Cr1.1
03 June 2019	SLU	week 23 Favori minitray	2	1	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	1	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	1	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	1	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**1,1**	**first truss**					**6**	**0,70**		**6**
03 June 2019	SLU	week 23 Favori minitray	2	1,1	2			*		6	0,25	0	6
03 June 2019	SLU	week 23 Favori minitray	2	1,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**2**	**first truss**					**9**	**10,50**		**9**
03 June 2019	SLU	week 23 Favori minitray	2	2	6		*			9	4,10	0	9
03 June 2019	SLU	week 23 Favori minitray	2	2	5		*			Cr2.1			Cr2.1
03 June 2019	SLU	week 23 Favori minitray	2	2	4		*			5	0,10	4	5
03 June 2019	SLU	week 23 Favori minitray	2	2	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	2	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	2	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**2,1**	**first truss**					**7**	**1,20**		**7**
03 June 2019	SLU	week 23 Favori minitray	2	2,1	2			*		6	0,25	2	6
03 June 2019	SLU	week 23 Favori minitray	2	2,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**3**	**first truss**					**9**	**14,00**		**9**
03 June 2019	SLU	week 23 Favori minitray	2	3	9		*			9	4,40	0	9
03 June 2019	SLU	week 23 Favori minitray	2	3	8		*			Cr3.1			Cr3.1
03 June 2019	SLU	week 23 Favori minitray	2	3	7		*			6	0,40	3	6
03 June 2019	SLU	week 23 Favori minitray	2	3	6	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	3	5	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	3	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	3	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	3	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	3	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**3,1**	**first truss**					**7**	**1,40**		**7**
03 June 2019	SLU	week 23 Favori minitray	2	3,1	2			*		6	0,30	1	6
03 June 2019	SLU	week 23 Favori minitray	2	3,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**4**	**first truss**					**9**	**10,00**		**9**
03 June 2019	SLU	week 23 Favori minitray	2	4	6		*			8	3,70	0	8
03 June 2019	SLU	week 23 Favori minitray	2	4	5		*			Cr4.1			Cr4.1
03 June 2019	SLU	week 23 Favori minitray	2	4	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	4	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	4	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	4	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**4,1**	**first truss**					**6**	**0,60**		**6**
03 June 2019	SLU	week 23 Favori minitray	2	4,1	2			*		3	0,05	3	3
03 June 2019	SLU	week 23 Favori minitray	2	4,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**5**	**first truss**					**9**	**7,90**		**9**
03 June 2019	SLU	week 23 Favori minitray	2	5	6		*			Cr5.1			Cr5.1
03 June 2019	SLU	week 23 Favori minitray	2	5	5		*			6	0,22	3	6
03 June 2019	SLU	week 23 Favori minitray	2	5	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	5	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	5	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	2	5	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**5,1**	**first truss**					**6**	**0,75**		**6**
03 June 2019	SLU	week 23 Favori minitray	2	5,1	2			*		5	0,09	2	5
03 June 2019	SLU	week 23 Favori minitray	2	5,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**1**	**first truss**					**>11**	**21,50**		**>11**
03 June 2019	SLU	week 23 Favori minitray	3	1	7		*			9	6,10	0	9

03 June 2019	**SLU**	**week 23 Favori minitray**	**2**	**5,1**	**first truss**					**6**	**0,75**		**6**	
03 June 2019	SLU	week 23 Favori minitray	2	5,1	2			*		5	0,09	2	5	
03 June 2019	SLU	week 23 Favori minitray	2	5,1	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**1**	**first truss**					**>11**	**21,50**		**>11**	
03 June 2019	SLU	week 23 Favori minitray	3	1	7		*			9	6,10	0		9
03 June 2019	SLU	week 23 Favori minitray	3	1	6		*			Cr1.1			Cr1.1	
03 June 2019	SLU	week 23 Favori minitray	3	1	5	*				R				R
03 June 2019	SLU	week 23 Favori minitray	3	1	4	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	3	1	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	3	1	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	3	1	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**1,1**	**first truss**					**6**	**0,50**		**6**	
03 June 2019	SLU	week 23 Favori minitray	3	1,1	3			*		4	0,08	2		4
03 June 2019	SLU	week 23 Favori minitray	3	1,1	2			*		2			2	
03 June 2019	SLU	week 23 Favori minitray	3	1,1	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**2**	**first truss**					**>11**	**20,00**		**>11**	
03 June 2019	SLU	week 23 Favori minitray	3	2	4		*			Cr2.1			Cr2.1	
03 June 2019	SLU	week 23 Favori minitray	3	2	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	3	2	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	3	2	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**2,1**	**first truss**					**6**	**0,55**		**6**	
03 June 2019	SLU	week 23 Favori minitray	3	2,1	2			*		4	0,08	2	4	
03 June 2019	SLU	week 23 Favori minitray	3	2,1	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**3**	**first truss**					**>11**	**19,50**		**>11**	
03 June 2019	SLU	week 23 Favori minitray	3	3	6		*			9	6,50	0	9	
03 June 2019	SLU	week 23 Favori minitray	3	3	5		*			Cr3.1				Cr3.1
03 June 2019	SLU	week 23 Favori minitray	3	3	4	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	3	3	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	3	3	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	3	3	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**3**	**3,1**	**first truss**					**6,5**	**0,90**		**6.5**	
03 June 2019	SLU	week 23 Favori minitray	3	3,1	2			*		5	0,09	2	5	
03 June 2019	SLU	week 23 Favori minitray	3	3,1	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**4**	**1**	**first truss**					**8**	**3,50**		**8**	
03 June 2019	SLU	week 23 Favori minitray	4	1	7		*			8	3,20	0		8
03 June 2019	SLU	week 23 Favori minitray	4	1	6		*			7	1,20	2	7	
03 June 2019	SLU	week 23 Favori minitray	4	1	5	*				R				R
03 June 2019	SLU	week 23 Favori minitray	4	1	4	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	4	1	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	4	1	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	4	1	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**4**	**2**	**first truss**					**11**	**9,50**		**11**	
03 June 2019	SLU	week 23 Favori minitray	4	2	2		*			2			2	
03 June 2019	SLU	week 23 Favori minitray	4	2	1		*			2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**4**	**3**	**first truss**					**9**	**9,50**		**9**	
03 June 2019	SLU	week 23 Favori minitray	4	3	6		*			9	4,60	0	9	
03 June 2019	SLU	week 23 Favori minitray	4	3	5		*			Cr3.2				Cr3.2
03 June 2019	SLU	week 23 Favori minitray	4	3	4		*			Cr3.1			Cr3.1	
03 June 2019	SLU	week 23 Favori minitray	4	3	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	4	3	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	4	3	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**4**	**3,1**	**first truss**					**6**	**0,50**		**6**	
03 June 2019	SLU	week 23 Favori minitray	4	3,1	2			*		5	0,12	2	5	
03 June 2019	SLU	week 23 Favori minitray	4	3,1	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**4**	**3,2**	**first truss**					**7**	**1,20**		**7**	
03 June 2019	SLU	week 23 Favori minitray	4	3,2	2			*		6	0,20	2	6	
03 June 2019	SLU	week 23 Favori minitray	4	3,2	1			*		6	0,18	2		6
03 June 2019	**SLU**	**week 23 Favori minitray**	**4**	**4**	**first truss**					**9**	**5,00**		**9**	
03 June 2019	SLU	week 23 Favori minitray	4	4	3		*			8	3,50	0		8
03 June 2019	SLU	week 23 Favori minitray	4	4	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	4	4	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**1**	**first truss**					**9**	**6,50**		**9**	
03 June 2019	SLU	week 23 Favori minitray	5	1	8		*			7	1,50	0	7	
03 June 2019	SLU	week 23 Favori minitray	5	1	7		*			Cr1.1				Cr1.1
03 June 2019	SLU	week 23 Favori minitray	5	1	6		*			6	0,22	2	6	
03 June 2019	SLU	week 23 Favori minitray	5	1	5	*				R				R
03 June 2019	SLU	week 23 Favori minitray	5	1	4	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	5	1	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	5	1	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	5	1	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**1,1**	**first truss**					**6**	**0,75**		**6**	
03 June 2019	SLU	week 23 Favori minitray	5	1,1	2			*		5,5	0,16	2	5,5	
03 June 2019	SLU	week 23 Favori minitray	5	1,1	1			*		3	0,04	2		3
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**2**	**first truss**					**8**	**2,00**		**8**	
03 June 2019	SLU	week 23 Favori minitray	5	2	3			*		7	1,00	0		7
03 June 2019	SLU	week 23 Favori minitray	5	2	2			*		6	0,18	2	6	
03 June 2019	SLU	week 23 Favori minitray	5	2	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**3**	**first truss**					**9**	**4,50**		**9**	
03 June 2019	SLU	week 23 Favori minitray	5	3	6		*			Cr3.1			Cr3.1	
03 June 2019	SLU	week 23 Favori minitray	5	3	5		*			5,5	0,16	3		5,5
03 June 2019	SLU	week 23 Favori minitray	5	3	4	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	5	3	3	*				R				R
03 June 2019	SLU	week 23 Favori minitray	5	3	2	*				R			R	
03 June 2019	SLU	week 23 Favori minitray	5	3	1	*				R				R
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**3,1**	**first truss**					**6**	**0,65**		**6**	
03 June 2019	SLU	week 23 Favori minitray	5	3,1	2			*		5	0,12	1	5	
03 June 2019	SLU	week 23 Favori minitray	5	3,1	1			*		2				2
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**4**	**first truss**					**>11**	**13,00**		**>11**	
03 June 2019	SLU	week 23 Favori minitray	5	4	3		*			Cr4.1				Cr4.1
03 June 2019	SLU	week 23 Favori minitray	5	4	2			*		2			2	
03 June 2019	SLU	week 23 Favori minitray	5	4	1			*		3	0,06	2		3
03 June 2019	**SLU**	**week 23 Favori minitray**	**5**	**4,1**	**first truss**					**8**	**1,80**		**8**	
03 June 2019	SLU	week 23 Favori minitray	5	4,1	2			*		6	0,25	2	6	
03 June 2019	SLU	week 23 Favori minitray	5	4,1	1			*		5	0,14	2		5
03 June 2019	**SLU**	**week 23 Favori minitray**	**6**	**1**	**first truss**					**9**	**6,50**		**9**	
03 June 2019	SLU	week 23 Favori minitray	6	1	9		*			8	2,20	0		8

03 June 2019	**SLU**	**week 23 Favori minitray**	**6**	**1**	**first truss**					**9**	**6,50**		**9**
03 June 2019	SLU	week 23 Favori minitray	6	1	9		*			8	2,20	0	8
03 June 2019	SLU	week 23 Favori minitray	6	1	8		*			5	0,12	3	5
03 June 2019	SLU	week 23 Favori minitray	6	1	7	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	1	6	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	1	5	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	1	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	1	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	1	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	1	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**6**	**2**	**first truss**					**9**	**10,50**		**9**
03 June 2019	SLU	week 23 Favori minitray	6	2	7		*			8	2,60	0	8
03 June 2019	SLU	week 23 Favori minitray	6	2	6		*			Cr2.1			Cr2.1
03 June 2019	SLU	week 23 Favori minitray	6	2	5		*			4	0,07	4	4
03 June 2019	SLU	week 23 Favori minitray	6	2	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	2	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	2	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	6	2	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**6**	**2,1**	**first truss**					**6,5**	**0,90**		**6.5**
03 June 2019	SLU	week 23 Favori minitray	6	2,1	2			*		6	0,22	2	6
03 June 2019	SLU	week 23 Favori minitray	6	2,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**6**	**3**	**first truss**					**9**	**5,00**		**9**
03 June 2019	SLU	week 23 Favori minitray	6	3	3		*			8	2,80	0	8
03 June 2019	SLU	week 23 Favori minitray	6	3	2		*			3	0,06	4	3
03 June 2019	SLU	week 23 Favori minitray	6	3	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**6**	**4**	**first truss**					**8**	**2,30**		**8**
03 June 2019	SLU	week 23 Favori minitray	6	4	3			*		6	0,60	2	6
03 June 2019	SLU	week 23 Favori minitray	6	4	2			*		2			2
03 June 2019	SLU	week 23 Favori minitray	6	4	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**7**	**1**	**first truss**					**8**	**2,90**		**8**
03 June 2019	SLU	week 23 Favori minitray	7	1	7		*			7	1,40	0	7
03 June 2019	SLU	week 23 Favori minitray	7	1	6		*			Cr1.1			Cr1.1
03 June 2019	SLU	week 23 Favori minitray	7	1	5		*			6	0,20	2	6
03 June 2019	SLU	week 23 Favori minitray	7	1	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	7	1	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	7	1	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	7	1	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**7**	**1,1**	**first truss**					**6**	**0,75**		**6**
03 June 2019	SLU	week 23 Favori minitray	7	1,1	2			*		6	0,30	0	6
03 June 2019	SLU	week 23 Favori minitray	7	1,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**7**	**2**	**first truss**					**9**	**4,90**		**9**
03 June 2019	SLU	week 23 Favori minitray	7	2	2		*			Cr2.1			Cr2.1
03 June 2019	SLU	week 23 Favori minitray	7	2	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**7**	**2,1**	**first truss**					**7**	**0,90**		**7**
03 June 2019	SLU	week 23 Favori minitray	7	2,1	2			*		6	0,30	0	6
03 June 2019	SLU	week 23 Favori minitray	7	2,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**8**	**1**	**first truss**					**9**	**5,80**		**9**
03 June 2019	SLU	week 23 Favori minitray	8	1	11		*			9	4,30	0	9
03 June 2019	SLU	week 23 Favori minitray	8	1	10		*			Cr1.2			Cr1.2
03 June 2019	SLU	week 23 Favori minitray	8	1	9		*			Cr1.1			Cr1.1
03 June 2019	SLU	week 23 Favori minitray	8	1	8	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	7	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	6	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	5	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	4	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	3	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	2	*				R			R
03 June 2019	SLU	week 23 Favori minitray	8	1	1	*				R			R
03 June 2019	**SLU**	**week 23 Favori minitray**	**8**	**1,1**	**first truss**					**6**	**0,50**		**6**
03 June 2019	SLU	week 23 Favori minitray	8	1,1	2			*		6	0,20	0	6
03 June 2019	SLU	week 23 Favori minitray	8	1,1	1			*		2			2
03 June 2019	**SLU**	**week 23 Favori minitray**	**8**	**1,2**	**first truss**					**7**	**1,10**		**7**
03 June 2019	SLU	week 23 Favori minitray	8	1,2	3			*		5	0,12	2	5
03 June 2019	SLU	week 23 Favori minitray	8	1,2	2			*		2			2
03 June 2019	SLU	week 23 Favori minitray	8	1,2	1			*		2			2

The bud distribution frequency tables

Batch 1: Flower mapping 1,February

Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	2+1	1	2+1	2	2+1	2+1	2	2+1		
	First truss	3	2	4	3	4	4	3	4	27	3.375
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3	2			1					3	0.375
	Stage 4						1		1	2	0.25
	Stage 5	1	2	4		1		2	2	12	1.5
	Stage 6	2	3	1	1	4			4	15	1.875
	Stage 7			1	1	1	1		1	5	0.625
	Total pot. truss	5	5	6	3	6	2	2	8	37	4.625 (σ= 2.134)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	2	1	3	3	2	2	2	1	16	2
	Stage 8	2	1	1	1		1	2	1	9	1.125
	Stage 9	1		1	1	2	2		2	9	1.125
	Stage 10									0	0
	Stage 11		1			1		1		3	0.375
	Cut back			1	1				1	3	0
	Runner	8	7	8	5	9	5	5	11	58	7.25
All bud stages summarized	Total bud	10	8	11	8	11	7	7	12	74	9.25

Batch 1: Flower mapping 2, June

Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	3+2	5+5	3+3	4+2	4+3	4+1	2+2	1+2		
	First truss	5	10	6	6	7	5	4	3	46	5.75
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3	1	1			2	1			5	0.625
	Stage 4	2	2	2			1			7	0.875
	Stage 5		2	1	1	3	1		1	9	1.125
	Stage 6	2	7	3	3	5	3	4	2	29	3.625
	Stage 7		2		2	2		2	7	15	1.875
	Stage 8	3	2		3	2	4	1		15	1.875
	Stage 9	3	7	2	3	3	3	1	2	24	3
	Total pot. truss	11	23	8	12	17	13	8	12	104	13 (σ= 4.95)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	1	5	4	2	3	2	2	3	22	2.75
	Stage 10									0	0
	Stage 11	1		3	1	1				6	0.75
	Cut back									0	0
	Runner	7	21	12	10	9	13	5	8	85	10.625
All bud stages summarized	Total bud	13	28	15	15	21	15	10	15	132	16.5

Batch 2: Flower mapping 1, March

Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	1	1+1	1+1	2	2	3	1+1	1+1		
	First truss	1	2	2	2	2	3	2	2	16	2
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3					1			1	2	0.25
	Stage 4							1	1	2	0.25
	Stage 5	1		1	2	2			1	7	0.875
	Stage 6	1	2		3	1	1	2	1	11	1.375
	Stage 7					1	1		1	3	0.375
	Total pot. truss	2	2	1	5	5	2	3	5	25	3.125 (σ= 1.642)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	2	0	3	1	8	5	3	1	23	2.875
	Stage 8	1	3	1	1	1	2	1	1	11	1.375
	Stage 9			1	1		1			3	0.375
	Stage 10									0	0
	Stage 11		1					1	1	3	0.375
	Cut back									0	0
	Runner									0	0
All bud stages summarized	Total bud	5	6	6	8	14	10	8	8	65	8.125

Batch 2: Flower mapping 2, July

Description	Stages	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Total	Per plant
	Crowns	4+1	2+4	3+4	1	1	5+1	2+6	2+3		
	First truss	5	6	7	1	1	6	8	5	39	4.875
				Potential trusses							
Buds which are included in the potential future truss development	Stage 3		1							1	0.125
	Stage 4							4	1	5	0.625
	Stage 5		2			1		1	2	6	0.75
	Stage 6	3	1	2		1	6	6	1	20	2.5
	Stage 7		1			1	1		1	4	0.5
	Stage 8	1	2	4			1	1	1	10	1.25
	Stage 9	1	1	4				1	1	8	1
	Total pot. truss	5	8	10	0	3	8	13	7	54	6.75 (σ= 4.02)
				Other buds							
Buds which are exluded in the potential truss development	Stage 2	1	5	0	4	0	2	2	0	14	1.75
	Stage 10									0	0
	Stage 11	8	2	9			5	4	3	31	3.875
	Cut back									0	0
	Runner		2	1						3	0.375
All bud stages summarized	Total bud	14	15	19	4	3	15	19	10	99	12,375