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Final report

How to get there? Increasing the sustainable yield and quality of tunnel-cultivated strawberry cultivars

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Part 1.1: Summary/Abstract

Tunnel-cultivated everbearing (EB) strawberry cultivars flower continuously and increase yields by enabling multiple harvest periods over an extended season. However, they are challenged by very strong reproductive tendencies that repress runners, leaf initiation, and fruit growth. To address growers' needs, this project developed strategies for producing vigorous plant material with stable yield potential and fruit production of EB cultivars through optimization and management of two cultivation factors: the growing temperature and the amendment of growing substrates with reused spent mushroom compost (SMC) as a fertilizer. Flower mapping and nectar content were evaluated as indicators of yield potential and quality, and the sustainability of SMC amendment was assessed in greenhouse and tunnel experiments. The EB cultivars with the highest yield potential over the full cultivation period were cv. Florentina and Favori. Flower mapping using a scale based on meristem development showed that cv. Favori reached a generative developmental stage at high temperature (30 °C) under the studied conditions, resulting in a greater number of flowers per plant and a higher yield potential than cv. Florentina, which only reached the generative stage at 20 °C. Favori also performed well when grown on media containing SMC: its yield potential was highest on a substrate of SMC mixed with coco coir. Amending coco coir with SMC enhanced plant growth and yields while also increasing the sugar and total phenol content of the strawberries. In addition, SMC amendment (30%) of both peat and coco coir improved the nectar sugar content and pollination. These results show that amending growing media with SMC can improve strawberry growth and yield, and could thus be a valuable tool in commercial strawberry production if conditions providing predictable harvests while maintaining acceptable product quality could be identified. This would enable more sustainable strawberry production using an organic fertilizer to enhance plant health and quality parameters while also reducing the adverse environmental impacts associated with using coco coir and peat as growing media. The EB cultivar Favori achieved high yields when grown at high temperature with SMC amendment, making it a good candidate for cultivation in tunnels.

Sammanfattning/Abstrakt

Tunnelodlade everbearing (EB) jordgubbssorter blommar kontinuerligt och ökar avkastningen genom att möjliggöra flera skördeperioder under en längre säsong. Men de utmanas av mycket starka reproduktionstendenser som undertrycker löpare, bladinitiering och frukttillväxt. För att möta odlarnas behov utvecklade detta projekt strategier för att producera kraftigt växtmaterial med stabil avkastningspotential och fruktproduktion av EB-sorter genom optimering av två odlingsfaktorer: odlingstemperaturen och blandning i odlingssubstrat med återanvänd svampkompost (SMC)) som gödningsmedel. Blomkartering och nektarinnehåll utvärderades som indikatorer på

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avkastningspotential och kvalitet, och hållbarheten av SMC-tillsattsen utvärderades i växthus- och tunnelförsök. De EB sorter med högst skördepotential under en hel odlingsperiod var cv. Florentina och Favori. Blomkartering med hjälp av en skala baserad på meristemutveckling visade att cv. Favori nådde ett generativt utvecklingsstadium vid hög temperatur (30 °C), vilket resulterade i ett större antal blommor och en högre avkastningspotential än cv. Florentina, som bara nådde det generativa stadiet vid 20 °C. Favoris avkastningspotentialen var också högst i en substratblandning med SMC och kokosfiber som förbättrade planttillväxt och skörd samtidigt som socker och totala fenolhalten i jordgubbarna ökade. Dessutom förbättrade SMC-blandning (30 %) med antigen torv eller kokosfiber innehållet av nektarsocker och pollineringen. Dessa resultat visar att tillsats av SMC i odlingssubstrat kan förbättra planttillväxt och skörd, och kan därför vara ett värdefullt verktyg i kommersiell jordgubbsproduktion med potential att stabilisera och öka skörden. Detta skulle möjliggöra en mer hållbar jordgubbsproduktion med hjälp av ett organiskt gödningsmedel för att förbättra växthälsa och kvalitetsparametrar samtidigt som man minskar den negativa miljöpåverkan som är förknippad med användning av kokoskokos och torv som odlingssubstrat. EB-sorten Favori uppnådde höga skördar när den odlades vid hög temperatur samt vid tillsats av med SMC, vilket gör den till en bra kandidat för odling i tunnlar i syfte att uppnå stabilare skörd.

Part 1.2: Main report (max. 10 pages)

Introduction

In Sweden, EB strawberry cultivars are used for production in tunnels. However, their yields can fall substantially short of their potential because they depend on the cultivation conditions, the plants' growth, flowering ability and pollination. A common problem with EB cultivars is their very strong reproductive tendency, which limits runner formation and represses leaf initiation and growth, thereby reducing yields and the plants' ability to support fruit growth. This presents significant challenges in their propagation, production and use (1;2). It would therefore be desirable to increase the tendency of EB cultivars to produce flowers and provide stable yields over a growing season. However, the effects of environmental factors on flower induction and development in EB cultivars are poorly understood. More knowledge about their adaptation to Nordic climates is thus needed to avoid problems like those encountered in the summer of 2018, when low strawberry yields were obtained due to extreme weather conditions and high temperatures (Growers, personal comm.) despite the ability of EB cultivars to flower at high temperatures. Therefore, to facilitate sustainable strawberry production, this project investigated the effects of temperature and fertilization with spent mushroom compost (SMC) on the yield potential of tunnel-grown EB cultivars. SMC is a waste stream from the mushroom industry with high nutrient and microbial content (3) that could be a highly beneficial fertilizer. Yields also depend heavily on pollination; both the density of pollinators and the number of pollinator visits are important. We therefore investigated the utility of floral nectar content as a predictor of pollinator attraction and visitation. The project was based on the following research questions:

1. Can flower mapping and nectar content data enable sustainable EB cultivar production in tunnels?
2. Can flower mapping and nectar content data be used to estimate yield potential?
3. What are the effects of different EB cultivars, temperature regimes, and fertilization on flower mapping results and the nectar content of EB strawberry flowers?
4. Can yield potential be stabilized by amending growing media with mushroom compost?
5. Can flower mapping and nectar content be used as indicators of effective pollination, yield potential, and fruit quality in EB strawberry cultivation?

Materials and methods

The project was divided into four work packages (WP), which are described below:

WP1: Yield potential in relation to EB cultivars

In this WP EB cultivars were screened for growth and yield potential. The investigations were carried out in three steps:

Step 1: Four EB cultivars commonly used in commercial production - Florentine, Furore, Favori, and Altess – were screened in a tunnel experiment to identify those with the highest yield potential. Plants

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were fertilized with a nutrient mixture containing Kristalon superba red and Calcinite as described by Samad et al. (4) and grown in trays with four plants per tray and four trays (replicates) per cultivar. Four growth parameters were measured: number of flowers, number and weight of berries, and number of runners per plant. In addition, the yield and biomass (fresh and dry weights of leaves and roots) of each cultivar were determined at the end of the experiment. Additional trays of plants were grown for flower mapping. During the cultivation period, eight plants per cultivar were collected at six-week intervals to assess their flower development, which was characterized in terms of the number of buds as well as their position and development.

Step 2: The effect of temperature on plant growth, flower development, and yield was evaluated using the Florentina and Favori EB cultivars, which had the highest flowering and yield potential in Step 1. A scoring scale or key for assessing the flowering potential and meristem development of strawberry cultivars (Figure 1) was developed by a Master's student (5) working with the postdoc, Samia Samad.

Scoring

Table 2: Phenotypic identification of each meristematic stage was regarded as reproductive (stage 4 to stage 9).

Meristem stages	Identification
S4	Cup-shaped with flat carpel with stamens shorter than the carpel
S5	Stamen taller than a slightly dommed carpel
S6	Colorless/ white stamen taller than a fully defined domed shaped carpel
S7	Pistil starting to differentiate into individual stigma and visible small colorless petals
S8	Fully formed flower with differentiated pistil taller than yellow stamen and white petals
S9	Open flower

Figure 1*. Scoring scale based on phenotypic identification of meristematic stages during flower development*

Experiments were conducted in greenhouses at 20, 25, and 30 °C under short- and long-day conditions over a 15-week period. The plants were grown in trays as described above in step 1 and their numbers of flowers and runners, growth, and meristem development were recorded.

Step 3: This step was performed in collaboration with Anita Sønsteby and her doctoral students studying flower mapping and the effect of temperature on flowering and gene expression. The cold-stored overwintered (Frigo) plants of cvs. Florentina and Favori with flowers initiated during the preceding year in the propagation stage were expected to be in an advanced flowering stage when planted. More knowledge is thus needed on molecular basis regarding flower initiation of plants cultivated from the seed stage. The aim in this step was to: (a) demonstrate the applicability of flower mapping for mapping flowering in a relatively homogeneous set of plants; (b) compare the results obtained with Frigo plants to those for seed-grown plants and investigate the viability of using seeds rather than Frigo plants in cultivation; and (c) identify genes responsible for flower induction. The strawberry cultivar Delisemo was used from the seed stage. The surveys were conducted in a phytotron in Norway and molecular analyses were performed by the Postdoc at the SLU facilities at SLU-Alnarp.

WP2: Yield potential in relation to spent mushroom compost (SMC) amendment

Mushroom and oyster cultivation are significant industries in Sweden that produce nutrient-rich waste products - spent compost from mushroom cultivation (SMC) and spent substrate from oyster production (SOS). Because these waste materials could be cheap and effective fertilizers, the impact of treatment with SMC and SOS on plant growth and flower development in tunnel-grown cv. Favori was evaluated using the experimental setup described in WP1 Step 1. In these experiments, the amount of added synthetic fertilizer (Calcinit and Kristalon superba red) was adjusted according to the

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amount of added SMC or SOS. Experiments were performed for six months using the following mixtures of SMC and SOS with peat: 100% peat, 30% peat: 70% SMC or SOS, 50% peat: 50% SMC or SOS and 70% peat: 30% SMC or SOS. Flower development and nectar content were monitored throughout the cultivation period. In addition, greenhouse experiments were conducted to evaluate the nutrient and microbial content of SMC; the results of these studies are presented in a student thesis (6).

WP3: Yield potential in relation to pollination
The impact of SMC on flower and yield potential, nectar content, pollination, and berry/product quality was evaluated using cv. Favori under commercial production conditions at the Eriksgården commercial strawberry farm in Sjöbo (Sweden) during 2021. Two substrates were tested: peat and coco coir. Coir was included because it is now used in commercial production and is the main growing media at Eriksgården. The SMC was mixed with these substrates in the following proportions: 100% peat or coir, 30% peat or coir: 70% SMC, 50% peat or coir: 50% SMC and 70% peat or coir: 30% SMC. For each berry, pollination deficits were scored on a scale of 0 (no deficits/malformations in fruit due to insufficient pollination) to 2 (multiple and obvious malformations), and the sum total of these scores was calculated per plant replicate. Nectar was collected from flowers using 0.5 µl microcapillary tubes and the difference between the fresh and dry weights of these tubes (after freeze-drying the water content) was taken as a measure of the sugar weight per sample.

WP4: Economic profitability
Efforts to evaluate growers' willingness and ability to adopt new technologies and tools were divided into two parts. First, the literature on the adoption of horticultural innovations was systematically reviewed to characterize horticultural producers' subjective evaluations of innovations, the influence of sustainability considerations on these evaluations, and the factors that may influence growers' decision-making processes. These variables were then investigated by conducting a structured interview survey of a small group of horticultural producers including growers not involved in berry production. This work was presented in an MSc thesis in horticultural science written by Lorière Borderie. Equations relating to the economics of strawberry production provided by the Swedish Board of Agriculture (2011) and HIR Skåne and Tillväxt Trädgård (2018) were adapted by modifying the input costs (mainly labor and substrate costs) and yield/revenue assumptions to predict the economic consequences of implementing different treatments. However, it was not possible to reliably estimate effects on profitability due to large uncertainties relating to the use of SMC (see results). Complementary interviews were conducted with personnel from a large strawberry producing firm to gather more information on the economic impact of new technologies and their potential adoption.

Results and discussion

Yield potential of different EB cultivars

All of the studied cultivars exhibited early flowering but 'Florentina' and 'Favori' achieved the earliest berry formation and maturation. The number of flower buds per plant was highest for 'Favori' followed by 'Florentina' and 'Furore', and lowest for Altess (Table 1).

***Table 1**. Growth parameters related to yield potential in four strawberry cultivars. Different letters indicate significant differences between treatments (P < 0.001) according to one-way ANOVA.*

Strawberry cultivar	Number of flower buds	Number of flowers per plant and week	Number of berries per plant and week
Florentine	4.5[b]	21[b]	12[b]
Favori	4.8[a]	15[a]	20[a]
Furore	2.6[c]	10[c]	7[c]
Altess	1.3[d]	9[c]	5[d]

The number of flowers and berries per cultivar, plant and week during the cultivation period were also highest in 'Favori' followed by 'Florentina', 'Furore' and 'Altess'. These results show that the studied cultivars differ with respect to yield and bud formation during the cultivation period, possibly due to differences in flower initiation during propagation. These are important factors for growers to consider when selecting strawberry cultivars.

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Yield potential in relation to temperature and photoperiod

As reported in the first publication arising from this project (4), the EB cultivar Florentina had significantly more vegetative (S3) than generative (>S5) meristems under all three temperature regimes (20, 25 and 30 °C), while ‘Favori’ had significantly more generative than vegetative meristems at 25 °C and 30 °C (Figure 2). Favori also exhibited superior growth and berry yields at 25 °C and 30 °C, whereas ‘Florentina’ grew best at 20 °C. These results show that meristem dissection can be used to determine the effects of temperature and photoperiod on meristem development, occurrence of cropping peaks, and yield potential. They also indicate that cv. ‘Favori’ has a more stable yield potential at high temperatures of 25 °C and 30 °C than cv. ‘Florentina’, which is important when considering the impact of extreme weather conditions on EB cultivars’ growth and yields.

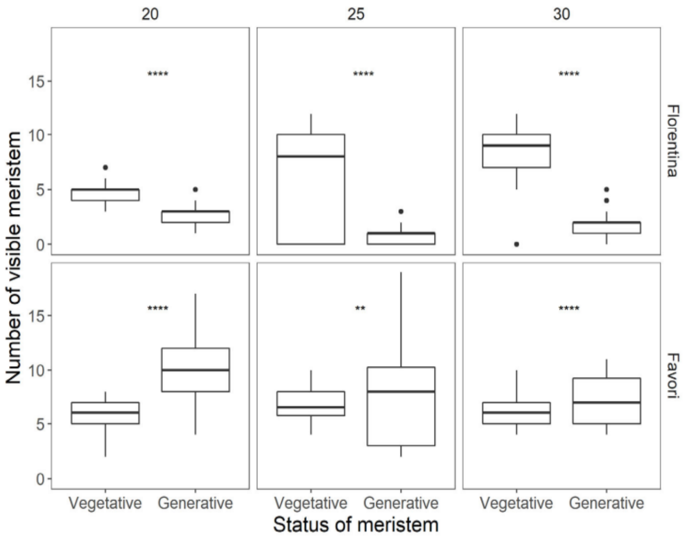

Figure 2. *Differences in the status of plant meristems at the end of the 15-week temperature treatments for each cultivar. Statistically significant differences between the vegetative and generative stages were identified by ANOVA and are indicated by asterisks (* p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001)*

Our molecular analyses (7) confirmed that environmental changes can affect the genetics and architecture of strawberry plants even after induction. We also found that long-day conditions can initiate flowering and gene expression in EB cultivars at both high and low temperatures.

Yield potential in relation to SMC or SOS amendment

The SMC screening studies reported in the previously mentioned student thesis (6) revealed that SMC needed to be mixed with a conventional substrate due to its high pH and electrical conductivity (EC). It also revealed that SMC can host beneficial bacteria including *Pseudomonas* and *Bacillus* species known for their potential antagonism of plant pathogens.

Table 2. *Scoring of meristem stages (see Figure 1 for details of scoring system) of strawberry plants cultivated in peat amended with either spent mushroom compost (SMC) or spent oyster substrate (SOS) during a 15-week (W) cultivation period. Statistically significant differences between treatments were identified by ANOVA and are indicated by asterisks * (p < 0.05).*

Treatments	W0	W3	W6	W12	W15
100% Peat	S4	S4	S5	S5	S9
50% Peat:50%SMC	S4	S5*	S7*	S7*	S9
70% Peat:30%SMC	S4	S5*	S7*	S7*	S9
50% Peat:50%SOS	S4	S4	S5	S4	S9
70% Peat:30%SOS	S4	S4	S5	S4	S9

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The SMC also had a high nutrient content, necessitating optimization of fertilization strategies in treatments including it. Scoring of meristem stages (Table 2) in treatments with SMC or SOS mixed with peat revealed earlier development of generative conditions in plants grown on peat-SMC mixed substrates when compared to peat alone or peat amended with SOS. SMC amendment may thus promote flower development in addition to vegetative growth, leading to higher yields.

The SMC-containing treatments had the highest numbers of flowers and fruits as well as the heaviest fruits, confirming the potential of SMC to promote growth and yield (Figure 3). SMC is rich in nutrients that could directly promote vegetative and generative growth (3). Its high microbe content could also increase yields because microorganisms have important effects on nutrient availability (8). Overall these results show that SMC warrants further evaluation under commercial conditions.

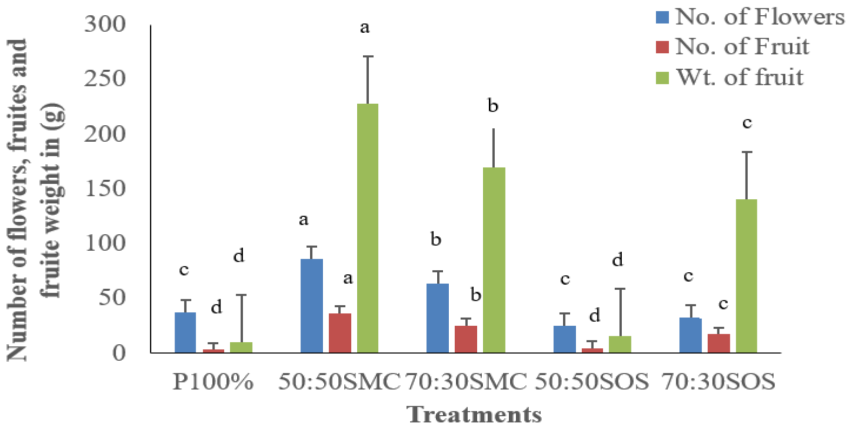

***Figure 3**. The effect of spent mushroom compost (SMC) and spent Oyster substrate (SOS) blended with peat on number of flowers and number and weight of fruits of cv. Favori cultivated in tunnels for 15 weeks. Different letters indicate significant differences between treatments (P < 0.001; one-way ANOVA).*

Effects of SMC amendment on yield potential and pollination in commercial production systems
Scoring of meristem stages (Figure 1) in treatments using peat or coco coir amended with SMC showed that plants cultivated on coco coir and SMC reached the generative stage (> S5) faster than those cultivated on peat and SMC. This may indicate that SMC amendment can promote flower growth (and thus increase yields) as well as vegetative growth when coco coir is used as the growth substrate. Plants cultivated in coco coir amended with SMC also displayed higher yield potentials than those cultivated on peat and SMC (Figure 4). These results clearly demonstrate that substrate choice and SMC amendment can strongly affect the growth and development of EB cultivars.

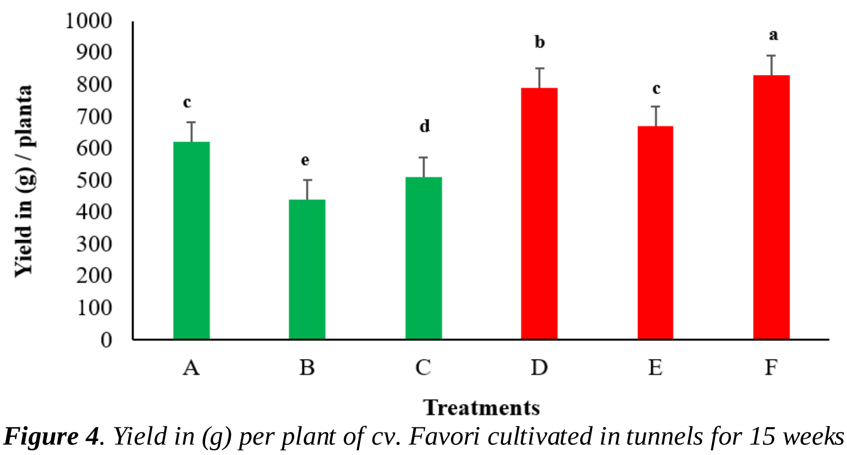

***Figure 4**. Yield in (g) per plant of cv. Favori cultivated in tunnels for 15 weeks when grown in A 100% peat, B 50% peat: 50% SMC, C 70% peat: 30%SMC, D 100% coir, E 50% coir: 50% SMC, and F 70% coir: 30%SMC. Different lowercase letters indicate significant differences between treatments (P < 0.001; one-way ANOVA).*

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Berries cultivated on SMC-amended coco coir (Table 4) had higher sugar contents than those cultivated on peat and SMC. Fruits grown on a 70% peat: 30% SMC substrate also had higher sugar contents than those grown in other peat treatments. Additionally, peat + SMC treatments yielded higher ascorbic acid contents than coir + SMC treatments, and coir treatments without SMC yielded higher ascorbic acid contents than those including SMC. Finally, berries grown on coir with SMC had higher total phenol contents than those grown on peat. SMC amendment of coir substrates thus increased the sugar and total phenols content of the fruits while reducing their ascorbic acid content.

***Table 4**. Quality parameters (contents of total phenols, ascorbic acid, and sugar) for strawberries cultivated on A = 100% peat, B = 50% peat: 50% SMC, C = 70% peat: 30% SMC, D = 100% coir, E = 50% coir: 50% SMC, and F = 70% coir: 30% SMC. Different letters indicate significant differences between treatments (P < 0.001, one-way ANOVA).*

Treatments	Total phenols in (mg/ g DW)	Ascorbic acid in (mg/100g FW)	Sugar in (g/ml)
A	24,9 [d]	74,1 [a]	2,3 [e]
B	30,6 [c]	72,3 [a]	2,9 [d]
C	25,1 [d]	71,6 [b]	3,6 [c]
D	31,7 [c]	59,8 [c]	3,7 [c]
E	42,6[a]	44,9 [e]	4,8 [b]
F	38,7 [b]	51,9 [d]	5,6 [a]

The pollination and nectar analyses revealed more extensive pollination and higher nectar sugar contents in treatments with coir alone and those using mixtures of 70% coir or peat with 30% SMC (Figure 5A). This may indicate that the beneficial effects of SMC amendment on the nectar sugar content are maximized when the SMC content is limited to 30%. However, the increased sugar content in the 30% SMC: 70% coir treatment could also be due to substrate effects rather than the SMC amendment per se. Treatments featuring 50% SMC amendment with coir or peat showed no improvement in nectar sugar content (Figure 5B). Nectar sugar contents were higher in coco coir treatments than in peat treatments (Table 4), which is partly consistent with the finding . This is partly in agreement with the nectar content with respect to coir but not with peat treatment of 30%SMC:70% peat.

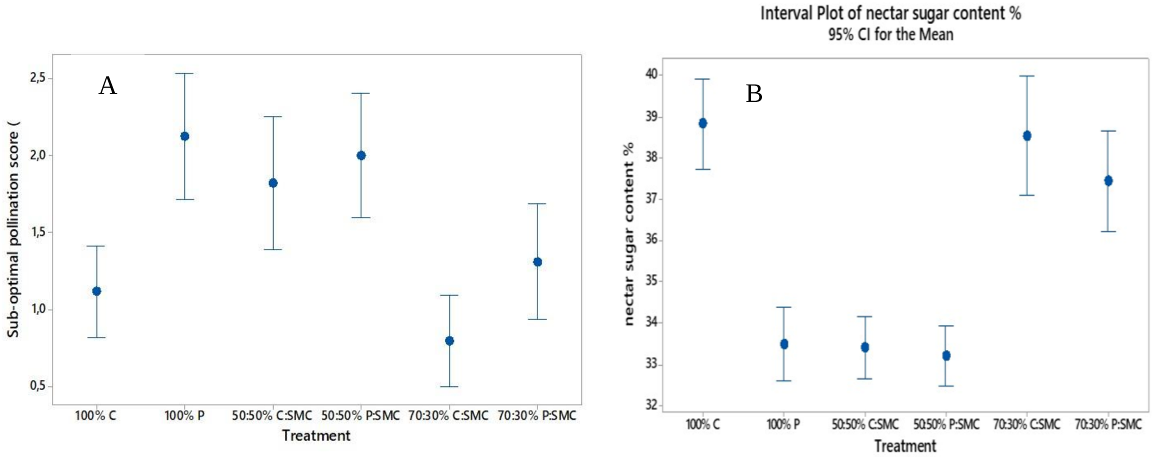

***Figure 5**. (A) Pollination and (B) nectar sugar content in the Favori strawberry cultivar cultivated in tunnels for 15 weeks after cultivation in 100% peat, 50% peat: 50% SMC, 70% peat: 30% SMC, 100% coir, 50% coir: 50% SMC, and 70% coir: 30%SMC. Significant differences between treatments were identified by one-way ANOVA.*

However, growth on SMC-amended coco coir also affected the size and shape of the fruit: fruits grown on such substrates were large and irregularly shaped (Figure 6). Further research is therefore needed to optimize fruit quality in relation to SMC amendment and pollination.

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Figure 6. *Strawberries collected from the 50% coir: 50% SMC (left) and 70% coir: 30% SMC (right) treatments.*

Economical profits

Growers' ability to adopt new technologies or tools

The review identified five main categories of decision factors: 1) individual background factors (e.g., experience, culture, education, and technical knowledge); 2) benefits of the innovation (relating to, e.g., productivity, profitability, affordability, o maintenance costs); 3) trialability and observability (e.g. technological awareness and access); 4) compatibility with current systems and global challenges (e.g. market demands, labels, workload, infrastructure); and 5) complexity (e.g., need to adapt infrastructure and acquire new information, knowledge, and/or management skills). The interviews showed that risk, in particular economic risk, was the largest barrier to adopting new technologies. Both formal and informal information sources affected decisions, but informal ones (for example neighbors or other farmers) appeared to be more important. Opportunities to directly observe the potential benefits of new technologies were particularly valued. This should be taken into account when deciding how to promote new technologies and communicate with producers.

SMC and economic outcomes

Because commercial production requires predictable and stable output fruit quality in terms of berry size, texture, taste, and shape, we cannot yet determine how the use of SMC-containing substrates would affect the profitability of strawberry production. Further work on this topic is therefore needed to ensure that the output quality reaches the market's demand. Accordingly, no reliable profitability analysis can be offered at this point. However, it is possible to reason on the economic potential:

1. Since labor costs exceed substrate costs, it is preferable to use a substrate for two years (coir, or coir-SMC mixtures) than one that lasts for only one year (peat or peat-SMC mixtures).
2. Some treatments using coir:SMC mixtures can increase yields. In particular, the 1:1 mixture strongly increased flower induction as well as the number of fruits and their weight.
3. If a new substrate costs no more than those used currently and can be used for two years (which remains to be determined), it will probably increase profitability and thus be attractive to users. This increases its likelihood of adoption in practice.
4. Further work on coir and SMC mixtures is needed to consistently obtain berries whose quality meets commercial requirements concerning fruit size, shape, taste and texture. Market acceptability of the produce should be assessed along with buyers' willingness to pay for produce not fully compliant with existing standards.

Flower counting and economic outcomes

Interviews revealed little firm-level interest in flower counting *in situ*: it was felt that such analysis would provide no economic gain, whether conducted at the farm or at external laboratories, and that investing in the necessary competence development and equipment would not pay off. Moreover, it would be difficult to adjust the harvesting workforce because employees are typically seasonal and cannot be hired for shorter periods of time. Harvest predictions can already be obtained from sellers of strawberry plants, so growers know roughly how many employees will be needed for harvesting and when it should begin. However, flower counting could be useful for assessing the impact of changes in production parameters such as the temperature or the introduction of new substrates or varieties.

Conclusions

From the results described above, we can conclude that

- The yield potential of cold-stored (Frigo) plants of strawberry cultivars commonly used in commercial production varied over the cultivation season.

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- Cv. Favori is a good EB cultivar for commercial production with high yield potential at high temperatures when using optimized fertilization strategies
- Flower mapping using the meristem growth scale developed in this work can be a useful tool for growers because it can predict the timing of the first harvest peak and its dependence on environmental factors (e.g. temperature), long/short day treatments and fertilization.
- Amending growth substrates with spent mushroom compost (SMC) has a positive effect on plant growth and yield as well as the content of beneficial microorganisms in the substrate
- When mixed with SMC, coco coir is a better substrate than peat in terms of product quality: adding SMC to coir increased the sugar and total phenols content of the obtained strawberries
- Further research on fruit quality parameters is needed to identify optimal conditions for SMC amendment and pollination
- Pollination and nectar sugar content can be improved by growing strawberries on a substrate consisting of 30% SMC and 70% peat or coir.
- The use of SMC-containing substrates increases the potential for circularity in strawberry cultivation and therefore increases sustainability.
- Technologies using SMC mixtures in strawberry production will probably be acceptable to growers if product quality can be made predictable and the risk is perceived to be low.
- Use of coir-SMC mixtures could increase the profitability of strawberry production but further studies are needed to improve the predictability of production output in terms of quality.
- Opportunities to observe trials and evaluate the ease of use of new amended substrates could facilitate knowledge dissemination and adoption of new technologies by growers.

Relevance and recommendations

The results provide industrial strawberry growers with:

- Information on the yield potential of different everbearing strawberry cultivars
- A scale that growers, advisors, and breeders can use to evaluate the vegetative and generative status of everbearing strawberry cultivars and thereby assess their flowering potential
- Strategies to enhance pollination and yield potential based on the selection of optimal cultivars, substrates, and temperatures in relation to flowering and fertilizer amendment.

In addition, the following recommendations can be made:

- Further work with the coco coir and SMC mixtures is needed to consistently obtain products that satisfy commercial requirements concerning fruit size, shape, taste and texture.
- Market acceptability of the produce should be assessed along with buyers' willingness to pay for produce deviating from existing commercial standards.

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Dissemination of results:

Scientific publications, *published*	*Samia Samad, Denis Butare, Salla Marttila, Anita Sønsteby and Sammar Khalil, 2021. Effects of Temperature and Photoperiod on the Flower Potential in Everbearing Strawberry as Evaluated by Meristem Dissection, Horticulturae 7, 484. https://doi.org/10.3390/horticulturae7110484

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	*Samia Samad, Rodmar Rivero, Pruthvi Balachandra Kalyandurg, Ramesh Raju Vetukuri, Ola M. Heide, Anita Sønsteby and Sammar Khalil, 2022. Characterization of Environmental Effects on Flowering and Plant Architecture in an Everbearing Strawberry F1-Hybrid by Meristem Dissection and Gene Expression Analysis, Horticulturae 8, 626. https://doi.org/10.3390/horticulturae8070626
Scientific publications, *submitted*	*Sammar Khalil, Preeti Panda, Farideh Ghadamgahi, Ana Barreiro, Anna Karin Rosberg, Maria Karlsson, Linda-Maria Dimitrova Mårtensson, Madeleine Uggla and Ramesh Vetukuri, 2022. Microbial and biochemical quality of spent mushroom compost and spent oyster substrate in relation to disease suppression and plant growth Submitted to MDPI Microorganisms?
Scientific publications, *manuscripts in preparation*	*Sammar Khalil, Paul Egan, Johan A. Stenberg, Salla Marttila, Anita Sønsteby, Samia Samad, 2023. Impact of spent mushroom compost on growth and yield potential of everbearing strawberry
	*Sammar Khalil, Johan A. Stenberg, Salla Marttila, Anita Sønsteby, Paul Egan, 2023. Yield and Pollination of everbearing strawberry as interacted by substrate and amendment of spent mushroom compost
	*Fernqvist, F., Spendrup, S., Thörning, R. 2023. The adoption of novel technologies in strawberry production, the case of Sweden
Conference publications/ presentations	*Sammar Khalil, Madeleine Uggla, Giovana Prado, Julia Forsbacka, Ramesh Vetukuri. Disease suppression in the circular economy using spent mushroom compost. International symposium on innovative technologies and production strategies for sustainable controlled environment horticulture (S06), Angers, France, 14-20 August 2022. (https://www.ihc2022.org/)
Other publications *media etc.*	*Sammar Khalil, Madeleine Uggla and Samia Samad. 2021. Biocirkulär ekonomi i trädgårdsnäringen med svampkompost i jordgubbsodling, LTV-fakultetens faktablad Fakta från Biosystem och teknologi 2021:4
	*SVT report: https://svt.se/nyheter/lokalt/skane/jordgubbar-kan-fa-egna-livvakter-mot-mogel
	*Sammar Khalil, Paul Egan, Johan Stenberg, Salla Marttila, Anita Sønsteby. Flower mapping or score for meristem development- a tool to be used for flower prediction. To be submitted to Viola in 2022/2023.
	*Sammar Khalil, Paul Egan, Johan Stenberg, Salla Marttila, Anita Sønsteby. Pollination and nectar content in relation to SMC amendment. To be submitted to Viola in 2023.
	*Fernqvist, F., Khalil, S. & Borderie, L. (in progress) Faktablad: Hållbara innovationer i hortikulturella produktionssystem. LTV-Fakultet faktabladsserie. To be finalized in 2023.
Oral communications *to industry, students, etc.*	*Jordgubbsodling i cirkulärt tänkande- användning av svampkompost i substrat, 2021/ 24 – 25 november. Hooks bärkonferens med LRF, bärodlare, rådgivare och andra aktörer inom bärsektor.
	*Remonterande jordgubbssorter i varierande odlingsförhållande 2022/ 13 – 14 december, Hooks bärkonferens med LRF, bärodlare, rådgivare och andra aktörer inom bärsektor.
Student theses	*Master's thesis - Butare, Denis, 2020. Effect of temperature on plant growth and yield in everbearing strawberry *Fragaria* x *ananassa*, cv. Florentina. (https://stud.epsilon.slu.se/15942/)
	*Master's thesis - Elaamer, Hani, 2020. The effect of spent mushroom (A*garicus bisporus)* compost on the indigenous rhizosphere microbiota in strawberry cultivation (https://stud.epsilon.slu.se/16095/)
	*Master's thesis (Erasmus Program, Università Degli Studi di Padov) - Prado, Giovana, 2020. Effect of spent mushroom compost on strawberry plant growth, yield and on Phytophthora crown rot disease
	*Master's thesis in Horticultural Science - Loriène Borderie, 2021. Sustainable innovations in horticultural production systems: evaluating the decision-making process of the adoption of new practices. (https://stud.epsilon.slu.se/17514/)
Other including Patents	*Patents, book chapters, reference group meetings etc.*