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ZERO-WASTE

DELIVERABLE L1.1

REPORT ON ALTERNATIVE CULTIVATION TECHNIQUES FOR ZERO-WASTE CULTIVATION OF TOMATO, SWEET PEPPER AND CUCUMBER IN HIGH WIRE

The trials were conducted within the LA project Zero-Waste, with support from the Innovation & Enterprise Agency and the Flemish government's Agriculture and Fisheries Department.

CONTENTS

INTRODUCTION

When clearing a greenhouse, after substrate cultivation of fruiting vegetables such as tomatoes, peppers or cucumbers, a lot of operational waste is generated, consisting mainly of plant residues and substrate mats. Annually, for tomato, 30-50 tonnes of (wet) plant residues are cleared per hectare, amounting to a total of 16.5-27.5 kiloton for Belgium. As for cucumber and sweet pepper, these are 25-30 tonnes per hectare and 40 tonnes per hectare of plant residues respectively, accounting for 1.3-1.5 kiloton and 3.6 kiloton respectively for Belgium. These plant residues are classically shredded together with the plastic binding material, giving a mixed stream that is difficult to purify. This mixed stream is usually composted, but the contamination with plastic binding materials complicates composting. Moreover, a residual stream of non-compostable material remains, which has to be incinerated. Substrate mats mostly consist of mineral wool, which often cannot be put to a new use in horticulture after months of intensive use[1] . Consequently, the vast majority of this residual stream is processed in the production of bricks and a small percentage goes to incineration.

Growers have to pay to remove that waste from their farms and for this reason are looking for ways to reduce waste costs. Disposal costs are variable and depend on processor and pollution level of the waste streams. In 2021, a grower paid between 85 and 120 €/t (with twine and with/without clips) for disposal with notification (approval OVAM)[2] to the Netherlands for composting and up to 300 €/t for incineration in Flanders, with polypropylene binders. For organic biological waste licensed OBA composters in Flanders can also pre-treat and compost the shredded foliage (with ropes but without clips) at 70 to 105 €/tonne (2021)[1]. Also for the cultivation substrate, marketing prices vary widely depending on transportation and processors. These can be delivered in different depots, separating the rockwool slabs, plastic and material. Ultimately, about 1% of the substrate mat is incinerated or landfilled.

A ZERO-WASTE cultivation includes either binding materials that enable sustainable processing of the greenhouse foliage or a binding method that results in a pure vegetable waste stream. In addition, cultivation is only waste-free if the cultivation substrate also allows steps to be taken towards renewable raw materials that can be optimally reused in horticulture. In the case of used substrates based on peat and/or organic residues and fibres, composting is possible at OBA composters, licensed for organic biowaste. This report compiles research results and insights gained within the VLAIO-LA trajectory ZERO-WASTE (11/2021 - 10/2025), in the framework of WP1. In the course of 2021 and 2022, Inagro, Proefcentrum Hoogstraten (PCH) and Proefstation voor de Groenteelt (PSKW) carried out field trials in a cucumber, sweet pepper and tomato crop, respectively, with the aim of evaluating alternatives to current practices and translating them into advice for the sector. Details can be found inTable1.

Table1 : Cultivation details of the field trials conducted

	Cucumber	Tomato	Pepper

[1] Some growers steam and reuse the substrate. We do not have exact figures on this.
[2] Vlaco (2024). Final report Cmartlife C12.1

Race	BonPrima (Rijk Zwaan)	Rebelski (De Ruiter) grafted-topped on Maxifort (De Ruiter)	Mavera (Enza)
Location trial	Inagro (Agrotopia)	PSKW	PCH
Stem density	3.4 pcs/m²	2.5 pcs/m²	7.1 pcs/m²
Cultivation start date	09/02/2022	15/12/2021	06/12/2021
Cultivation end date	20/07/2022	14/11/2022	23/10/2022

BINDING MATERIALS AND METHODS

Situation

Fruiting vegetable plants such as tomato, sweet pepper and cucumber, are held in a vertical position with a tying system. Most growers use polypropylene (PP) ropes for this purpose because they are very flexible, possess considerable tensile strength and show little stretch or shrinkage. Moreover, PP availability is high which reduces the cost of reels. To guide the plants of vertical crops upwards, efforts are made to wind them around the rope. However, twisting in plants is not possible in many cases. Therefore, PP clips are often used to guide the plant along the rope and attach it to the rope. However, PP is not biodegradable. This severely limits the processing possibilities of a plant-rope-clip mixture. It is challenging to separate the plastic materials from the plant residues and the waste stream of rope and clip fragments can only be incinerated. Technological innovations that allow the ropes to be processed together with the plant residues or that produce a pure plant stream offer opportunities to make cultivation more sustainable.

Using alternative ropes

Natural fibres have been used to manufacture ropes for decades. Anno 2023 individuals often use sisal or jute for holding up plants in the vegetable garden. The disadvantage of natural ropes is that they absorb moisture more easily, making them more susceptible to rot and having to lose breaking strength. Nevertheless, organic fibres such as jute and cotton are frequently used for professional garden ropes, whether or not combined with viscose (also called rayon), a cellulose-based semi-synthetic fibre. Bringing materials together also provides a combined property towards tensile strength, stretchability, ..

There are also biodegradable plastic ropes on the market, made from the polymer PLA (poly lactic acid). These ropes are very similar to PP ropes, but break down when composted.

The environment in which the ropes will be used makes its demands. The ropes must be strong enough to last a year in the greenhouse, sometimes exposed to high temperatures, high humidity and direct sunlight. For a high-wire cucumber crop, where the plants hang in the greenhouse for five months never getting much heavier than 3 kg, a different (thinner) rope will be able to be used than for a beef tomato crop where nine months after commissioning a plant of > 5 kg is still hanging on the rope. That thickness is often expressed in m/kg where a high value indicates a thin rope. In sweet pepper, the ropes are knotted under the gutter and stretched tightly to the crop wire in order to remain hanging throughout the cultivation. For this crop, the degree of elongation and shrinkage is very important. For cucumber and tomato, the ropes are wound on reels either by the supplier or by the grower. Here, the ease of winding is important as well as the thickness of the rope because it determines the volume the reel will finally occupy above the crop and consequently the degree of shade it will cause in the crop. Finally, the material must be available and affordable. The additional cost of the rope should not exceed the savings from a reduced gate-fee, if the grower is also to receive an economic benefit.

A number of commercially available ropes were evaluated in ZERO-WASTE, shown in Table2 . No elongation or shrinkage problems were observed in the ropes tested, and no plant damage anywhere due to friction with the binder materials.

Table2 : Overview of ropes tested

TOUWEN				
Name	Material	Cucumber	Tomato	Pepper
Valent	PP	X	X	X
Twync cord Bio 800 m/kg	PLA			X
Biotwine 500 m/kg	PLA		X	
Biotwine 1,000 m/kg	PLA	X		
Jute Cordenka Twine 700 m/kg	jute+viscose (1+5)			X
Biobih 600 m/kg	jute+viscose (1+5)	X		
Corbeo Hortiray NR1	jute+viscose (1+4)	X		
Corbeo Hortiray KC6xR5N	cotton+viscose (6+5)		X	X
Biolor 635	cotton-viscose	X		
Royal Brinckman Jute 3	jute	X		
Cordenka Growth 250 AC1	viscose	X		
Cordenka Growth 360 AC1	viscose	X	X	X
Cordenka Growth 420 AC1	viscose		X	

In tomato and cucumber cultivation, all the ropes tested were found to be sturdy enough. In sweet pepper cultivation, 2 Hortiray ropes broke after 20 weeks of cultivation, but this could be attributed to drop formation on the rope located under the gutter

Also noteworthy was the slipperiness of the Cordenka viscose rope. This requires some extra attention when tying on the young cucumber, tomato and pepper plants, but is certainly not insurmountable. With fine, smooth viscose ropes it is important to choose clips or rings that clamp sufficiently so that the plant does not slide off the rope.

Winding jute-containing ropes runs a little harder. Jute also makes the reel a little bulkier which gives a little more shadowing on the crop. PLA rope has the advantage of being very similar to standard PP rope, which adds to its ease of use.

Using alternative clips

As with the ropes, a number of alternatives to PP clips were also tested (Table 3). A first alternative to PP clips are those same clips made of PLA. Virtually nothing has been changed to the design of the clip so that the PP clip can be replaced 1 on 1 by its biodegradable brother. Just as different diameters are available for PP depending on the crop in which they will be used, this is also the case for PLA.

Figure 1 : Bato 15mm clip (PLA) in cucumber cultivation

A second alternative are metal rings from the TomSystem. These rings are clamped around the rope using a handheld device (Figure 2). The clamping strength is adjustable (1-5), allowing the rings to be attached to ropes of different thicknesses. The advantage of the metal rings is that they oxidize away during a properly performed composting process.

The rings proved compatible with every rope tested, but are not recommended in combination with thin, smooth (viscose) ropes. To prevent the Tomsystem rings from sliding, they had to be squeezed extra hard on the smooth ropes. This led to a few cases of fibre breakage, but without much consequence, as rope breakage never occurred.

Figure 2 : The metal rings of the TomSystem are clamped around the rope and tomato plant with a handheld device.

Table 3 : Overview of clips tested

CLIPS				
Name	Material	Cucumber	Tomato	Pepper
Paskal 15 mm 554kc-bio	PLA	X		
Paskal 23 mm 550kdbio-8	PLA	X	X	
Bato 15 mm	PLA	X		
Bato 19 mm	PLA	X	X	
Classic ARaymond	PP		X	
TomSystem	Metal	X	X	

All clips and rings tested were found suitable for use in tomato or cucumber cultivation. Sometimes clipping with the PLA clips in tomato cultivation was a bit more difficult because the clips did not close properly, but that was due to the design and not the raw material.

Ringing is slightly slower at first, as you have to master the use of the device first. Sometimes the rope is missed, but as the operation is performed more often it becomes faster than classical clipping (10% faster at the end of cucumber growing). Whereas in classical clipping it is also possible to prune in between, this

is more difficult in ringing. After all, you hold the ringing device in one hand. Pruning and ringing are ideally done in two passes. With fruiting vegetables, it is important to ring in the right place. This prevents an ovary from getting trapped inside the ring and fusion finding place. The ongoing development of smaller rings for cucumber may further reduce this risk.

The use of 'ropeless' tying systems

The firm 'Pellikaan' developed a cultivation system in which cucumber and tomato plants (Table 4) are suspended from a metal hook (PlanthooQ) with metal clips (Qliprs). In the first weeks, the plant grows along a jute rope (to be removed later) up to the PlanthooQ that spans half the distance between the crop wire and the gutter. Once the plant reaches the hook, it is clamped to it with a Qlipr into which a plant-protective foam piece is inserted. As the plant grows further upwards, a second (cucumber and tomato) and a third (only for heavy tomato plants) Qlipr is added with the aim of properly distributing the plant weight. Crop maintenance takes a different form from classical clipping. With the Qlipr system, both lowering, fixing and horizontal shifting of the plant and trimming of the fruits/trusses are carried out in a single pass.

Table 4 : Overview of the ropeless tying systems tested

ROPELESS WINDING SYSTEMS				
Name	Material	Cucumber	Tomato	Pepper
Qliprs + PlanthooQ - Pellican	metal	X	X	

Figure 3 : Rope-free tying system Qlipr (Pellikaan), attaching a Qlipr to the PlanthooQ

The experience from the field trials was that the Qliprs did indeed firmly attach the plant to the PlanthooQ without damaging the plant stem. No sap flow was ever obstructed or fungal attack occurred at the attachment location of the Qlipr.

The learning curve to master the Qlipr system cannot be underestimated. In the cucumber trial, the Qlipr system required significantly more time at the start, but at the end of cultivation, a 10% saving in labour

expenditure could be demonstrated compared to the classic combination of clipping, pruning and reeling, shifting. The reason why was mainly because less frequent Qlipr attachments should be done (Qlipr interval of 5 days instead of 3-4 in cucumber). In tomato cultivation, Qlipr seemed to require more time until the end of the crop, partly because there the Qlipr interval could only be increased to 10 days until April, but Qlipr attachment was still needed every 7 days, just as in a conventional crop. Qlipr attachment also requires concentration because it is a slightly more complex clamping movement and all other actions have to be done in the same working passage.

Using the Qlipr system in a cucumber crop comes with an added challenge. Because the plants form suture tendrils that snake around the PlanthooQ, some resistance is encountered when sliding down the plant. However, damaging the suture tendrils during this process never led to adverse consequences for the plant. Keeping an extra stem on also comes with a protocol. Whereas otherwise a new rope is led to the base of the new shoot and attached to it, now the new shoot must already be fairly long to cover the distance to the next PlanthooQ. Just after holding on, it is important that when lowering, mother and daughter plants are carefully manipulated together.

Furthermore, there are concerns among growers about an increased risk of disease transmission. Because the lower Qlipr is removed first and then placed back on top of the same plant after being moved downwards, the risk of transmission of pathogens between plants is limited. There are also reservations about the reusability of the material, especially the foam pieces. The metal parts should be hygienized (e.g. steamed or foamed) after each cultivation. No research was conducted into the effectiveness of hygienization of the foam pieces. The foam pieces are easily removed from the Qliprs and should ideally be replaced at every crop change. This process is very labour-intensive.

Cost-benefit analysis

Switching to alternative strapping systems can become a financial challenge or opportunity for the company. In the Cmartlife project (action C12.1) Boerenbond, in collaboration with Vlaco, PSKW and PCH, built a cost-benefit analysis to outline the potential impact[3] . A grower can fill out his own situation in an Excel file. Overall, a number of conclusions were drawn: the alternatives of bio ropes with metal rings or the Qlipr system can be financially beneficial for (meat) tomato cultivation and high wire cucumber. The use of bio-plastic clips currently represents a significant material premium in a crop where many clips are needed. Twisting in bio ropes is financially interesting in greenhouse crops of cucumber (traditional), aubergine and courgette. For tomatoes and peppers, GMO support is needed to break even when turning in (with at most 1 clip).

[3] Subproject C12.1 - reducing plastic contamination in greenhouse foliage of various fruit vegetables (2020-2023) | Vlaco

SUBSTRATE MATS

For fruit crops in substrate mats, the plants are traditionally placed on a growing medium into which all nutrients are dripped in the form of a nutrient solution. This medium is preferably inert (EC and pH control are smooth and predictable), pathogen-free, with an easy installation and clearing, of high quality (preservation of structure and optimal balance between water and air, etc.) and must be usable for a full year of production. For tomato and sweet pepper, we still see a lot of use of rock wool substrate; cucumber is mainly grown on perlite. Both are inert, mineral substrates with a high energy demand during the production phase: rockwool is spun from basalt at 1500°C, perlite is puffed volcanic rock created when heated past 1000°C. They are usually not[4] reused in cultivation and cannot be returned to nature after use in cultivation due to their mineral nature. Several recycling options exist, but even these require quite a lot of energy; a limited proportion of perlite is steamed and reused, rockwool is collected and shredded and made into bricks. To reduce the ecological impact of substrates, one could look at renewable raw materials that are easier to give a second life after usage.

Renewable raw materials

In the cucumber, tomato and pepper trial, different organic mats were compared with the references rockwool and/or perlite. Each mat was irrigated in a specific way, based on previous experience. Based on expectations linked to the composition, substrate mats were grouped on a specific tap area. During cultivation, sensors measuring EC and water content in the substrates were used to control watering. An overview is shown inTable 5 . The results of this trial are reported below and can also be found in Trial Garden News[5] (2023).

[4] Some (pepper) growers reuse their rockwool substrate. Some steam first others do not. In tomato, this is less applicable for fear of ToBRFV transmission.

[5] https://www.proeftuinnieuws.be/wp-content/uploads/2023/03/Organische-substraten-kunnen-wedijveren-met-steenwol-en-perliet.pdf

Table 5 : Overview of the substrate mats tested and the irrigation strategy applied (cucumber: perlite and Grow Bag; tomato: rockwool, perlite and Growbag Advanced; sweet pepper: rockwool, Mosswool and Sioen medium).

SUBSTRATES					
			Applied irrigation strategy[1]		
Supplier	Substrate name	Material	Cucumber	Tomato	Pepper
Cutilene	Exxellent x-fibre	Rock wool			Rock wool
Grodan	GT-Master	Rock wool	Perlite	Rock wool	
Willems Perlite	Perlite - fraction 2	Perlite	Perlite	Perlite	
Novarbo	Mosswool	Sphagnum moss, peat and wood fibre	Grow Bag	Growbag Advanced	Mosswool
Sioen	Hard type	Coconut and jute fibre			Sioen medium
	Type medium		Grow Bag	Perlite	Sioen medium
	Type soft				Sioen medium
Klasmann-Deilmann	Growbag Advanced	Wood and coconut fibre	Perlite and Grow Bag	Growbag Advanced	
Agaris	Grow Bag	Bark, wood and coconut fibre	Grow Bag	Growbag Advanced	

[1] It was not possible to provide a separate irrigation strategy for each substrate, per cultivation there were two (cucumber) or three (tomato, sweet pepper) tap areas. Therefore, substrates with the most similarities were grouped in the same tap area. The choice was made to control according to the needs of one substrate rather than an intermediary control. Each tested substrate received an optimal irrigation strategy in at least one cultivation (except 'Sioen type hard' and 'Sioen type soft', as these were very similar to 'Sioen type medium').

Rock wool sets the bar

The widely used rock wool substrate is achieving good results in different crops. In tomato cultivation, the rock wool mat started with a production backlog. This was made up for during the cultivation so that rock wool achieved average yields over the entire growing season (Table 6). Rebelski's plants were vigorous and looked reasonably vegetative. Limited root mortality (10-20%) and browning were observed.

In the cucumber crop, the trial was conducted with the Bonprima variety. Here, the rockwool mat also performed well, despite the steering based on measurements in the perlite mats (Table 7). A mistake in the fertigation control in early April, with too few waterings, exposed a known pain point being the limited rewetting capacity. The mat drybacked slightly and could not recover. Despite this, there was no negative effect of this on the yield.

In sweet pepper, rockwool was the only reference and Mavera achieved good production on these mats (Table 8). The first harvest fell in week 12.

A good report for perlite

In the cucumber cultivation, the perlite mat presented an excellent report. On this mat, slightly larger watering sessions were given than in the organic mats, because of the smooth drainage. Perlite also achieved high production in tomato cultivation. This generative substrate ensured that the plants came

into production a week earlier than in rockwool. Perlite achieved a high overall yield despite a small production drop in summer. The tomato plants were slightly less vigorous but held on through the summer. A generative substrate like perlite together with a vegetative variety like Rebelski is a good combination .[6]

Good results with Mosswool from Novarbo provided adjusted steering

Novarbo's Mosswool substrate is a mat based on wood fibre, white peat and peat moss. This mat held water well, resulting in a nice dense root web that spread uniformly over the full height of the mat. This made the substrate a clear vegetative substrate. On these substrates, vigorous plants grew and produced well, except for tomato. In this crop, vegetative growth came at the expense of generative growth, mainly during spring. Provided separate water control and a generative variety, Novarbo's Mosswool substrate could achieve good performances. Cucumbers cope well with high moisture levels. Combined with the strong root web, this resulted in a vigorous crop with good yield results. In tomato, the combination of the wet, vegetative substrate with the Rebelski vegetative variety resulted in an overly vegetative plant and consequently lower production. Only in sweet pepper could the watering also be specifically adapted to the needs of Mosswool. There, this substrate achieved the highest production and number of fruits/m². The drainage holes were made larger to promote plant settlement. Due to strong vegetative growth, this substrate was disadvantaged in spring. In summer, there was a catch-up with good final results. During a hot and sunny summer, like in 2022, vegetative substrates like Mosswool are at an advantage.

Sioen is the most generative substrate

Sioen's substrates consist of fairly dry mats with vertically oriented jute and coconut fibres. This is the most generative substrate in the trial. A major advantage of dry substrates is that the grower can easily change the dryback (difference between minimum and maximum moisture content in the mat), which makes steering easier. Full dripping of this substrate did not occur as with the other mats because the fibres have a somewhat hydrophobic nature. As a result, the top of the substrate remained dry while there was free water at the bottom of the mat. The timing for making additional drain holes therefore has a major impact on the volume of water the mat can buffer. Sioen has three types: a dry (Sioen hard), intermediate (Sioen medium) and wetter (Sioen soft) substrate. Mould growth was observed in the three crops but did not affect plant growth.

In tomato, the medium mat was tested. Despite a lower fruit weight, this substrate had good spring production. This good production at the beginning of the season was due to an earlier production start and a higher number of fruits harvested. The plants were less vigorous but held out through the summer. In summer, we saw more shrinkage cracks on the fruits. This indicates greater dynamics in fruit swelling and shrinkage caused by the variation of moisture content throughout the day in these mats. The Brix value was slightly higher in this object. In cucumber, Sioen's medium mat was also tested. In terms of production, this mat was able to keep pace from 7 March to 21 April, but dropped 10 kg/m² in the following 50 days. In the last month, this slab caught up again, but could not make up the shortfall with narrowly significant differences in the final result. The roots formed mainly in the bottom 3 centimetres of the mat.

[6] In pepper, perlite was not included as a reference, rockwool was.

In sweet pepper, Sioen's three different substrate types were tested. Despite the fact that the summer of 2022 was less optimal for generative substrates, no significant loss of production was observed for the hard and soft types. One advantage is the early production of these two substrates; initial production was double that on rockwool. These early fruits did show a remarkably high number of shrinkage cracks. On Sioen hard and soft, these were present in 33% and 30% of the fruits assessed, respectively, while on rockwool they were present in 4%. The medium substrate achieved a lower number of fruits (114) than with rockwool (121). It is possible that this substrate was at a disadvantage due to its smaller volume; the medium substrate was 4 cm narrower compared to the other mats.

Beautiful rooting in Growbag Advanced from Klasmann-Deilmann

Klasmann-Deilmann's Growbag Advanced is a substrate based on wood and coconut fibre. Rooting in this substrate went well with a nice veining of the entire substrate. In both tomato and cucumber cultivation, spring fruit weight was high. In tomato, this trend did not continue, resulting in a slightly lower total yield compared to rockwool. Only in the cucumber crop, this mat lay in both the mineral control of the perlite mats and the more organic control according to Agaris' Grow Bag. In both objects, particularly good results were achieved. There were slightly more cucumbers with lower fruit weight in the mineral steering. With the mineral steering, we noticed a lower dryback rate than with rockwool. In organic steering, it was similar to the values of Mosswool (Novarbo) and Grow Bag (Agaris). In tomato, the dryback rate was also lower than in rockwool. Water content decreased very slowly after the last watering. Klasmann-Deilmann's Growbag Advanced thus possesses quite vegetative properties and organic steering with fewer but larger turns seems appropriate.

Grow Bag by Agaris is moist but has a good dryback rate

Agaris' Grow Bag is an organic substrate based on bark, wood and coconut fibre that is reasonably moist but has a good dryback rate. This makes the substrate neither distinctly vegetative nor generative. The volume of the mat decreased steadily as cultivation progressed, presumably because the organic components began to decompose. Physical properties were similar to Klasmann-Deilmann's Growbag Advanced. Roots were well distributed throughout the substrate mat but fewer roots were present compared to the other objects.

Agaris' Grow Bag scores well for tomato and cucumber in the first half of cultivation. In summer, there is a drop in production. This drop has no negative impact on the total yield for tomato, but for cucumber, one of the four parallels scores poorly as a result, lowering the average for this substrate.

Table 6 : Tomato production results (18/3/22 - 14/11/22)

TOMATO			
Substrate	Production (kg/m²)	Fruit weight (g)	Number of fruits/m²
Rock wool	59.51 a	230 a	259 a
Perlite	60.25 a	225 b	268 a
Mosswool	57.52 a	226 b	255 a
Sioen medium	60.43 a	229 a	263 a
Growbag Advanced	57.80 a	225 b	256 a
Growbag	59.02 a	224 b	264 a

Table 7 : Production results cucumber. Both mineral and organic steerings were followed for Klasmann-Deilmann's Grow Bag.

CUCUMBER			
Substrate	Production (kg/m²)	Fruit weight (g)	Number of fruits /m²
Rock wool	46.47 a	437 a	106 a
Perlite	47.95 a	447 a	106 ab
Mosswool	47.00 a	445 a	106 ab
Sioen medium	38.48 a	439 a	88 b
Growbag Advanced (mineral)	46.00 a	438 a	105 ab
Growbag Advanced (organic)	47.50 a	447 a	106 a
Growbag	44.00 a	443 a	99 a

Table 8 : Pepper production results.

PEPPER			
Substrate	Production (kg/m²)	Fruit weight (g)	Number of fruits/m²
Rock wool	24.30 ab	201 a	121 ab
Mosswool	25.21 a	190 a	133 a
Sioen hard	23.91 ab	200 a	119 bc
Sioen soft	24.84 a	203 a	123 ab
Sioen medium	22.81 b	200 a	114 c

Adjusted irrigation required

An optimal irrigation strategy can be created for each type of mat. This is necessary to exploit the full potential of the mat. Depending on the crop, rockwool (tomato, pepper) or perlite (cucumber) is taken as a reference resulting in the control of new types of substrate mats being less optimal. Mats that easily retain moisture offer robustness. The irrigation frequency here may be slightly lower and the duration slightly longer. A concern with this type of mats is that sufficient dryback is achieved during the night. Therefore watering can be stopped earlier in the afternoon. For mats that retain moisture less well, a high frequency of smaller turns is recommended. In order not to let the dryback overnight become too large, watering is often done a little longer or an extra night turn given. In this case a failure of the system or an error in control will more likely lead to economic damage. Our tests showed that the risk of damage was higher with underdosing than with overdosing. Consequently, mat types that buffer well tend to perform better than mats that retain moisture less well and quickly suffer from underwatering.

Substrates as a generative or vegetative tool to balance the plant

The mats tested here possess different properties that can be an advantage or disadvantage for cultivation, depending on conditions. To balance the crop, a wide range of factors (including cultivation, variety, irrigation strategy, irrigation system...) must be taken into account. Here, substrate choice could also be an interesting tool; for example, combining a vegetative variety with a drier substrate makes it easier to balance the plant. Mats with a high water buffering capacity can always meet the water needs of the plants. In this respect, no drought stress occurs to the plant. To achieve good root quality and nutrient uptake, it is also important that the air/water balance in the mat is in equilibrium. Too much water in that respect can also lead to plant stress. In general, we noticed that plants on mats with good water buffering in a tap area with rockwool-based irrigation can invest a lot of energy in growth. These types of mats guarantee a vigorous crop with many and sturdy green parts (thick stem, vigorous head, large leaves). However, in combination with vegetative varieties, such substrates also tend to have lower production because there is less investment in fruit. These types of mats come into their own when combined with a variety that grows more generatively or in drier periods with high water consumption (hot summers).

Mats that drain smoothly run the risk of just failing to meet the crop's water demand at times and thus triggering a stress response. In plants, stress is associated with a higher investment in fruit at the expense of the photosynthetic apparatus. The plants look more sparse and seem to have lost some of their vigour.

CONCLUSION

In ZERO-WASTE, it was shown that alternative substrates and materials and techniques for binding plants and substrates are available that are not based on polypropylene (PP). Biodegradable binding materials, which are similar in appearance and properties to standard PP materials, offer potential as it does not require any other operation from the user and therefore does not affect labour requirements. To know whether the switch is profitable, the grower should weigh the higher cost against the savings in disposal

cost. GMO support can also be included in the calculation. This may vary from supplier/customer/region to region.

Metal rings instead of clips require an initial adjustment to cultivation operations, but can eventually reduce labour for tying up. Together with an easier to handle plant flow (if combined with biodegradable ropes), ringing plants can make cultivation more sustainable.

The Qlipr system requires a thorough redesign of the labour profile on a farm. Moreover, workers are asked to combine several operations in one passage. This is not suitable for every type of farm. Nevertheless, the rope-less system can produce a clean residual flow and the investment cost is affordable thanks to a lower disposing cost and potential labour savings (after learning curve).

The market offers organic substrates capable of growing a crop with yields and quality that can match the references rockwool or perlite. Each type of slab has its specific physical properties that must be taken into account in the irrigation strategy. For dry type slabs, it is important to adjust irrigation frequency and duration so that the dynamics in moisture content in the slab do not become too extreme and the plant does not experience drought stress. Moisture sensors can give an indication during the first experiences and indicate if/when/how much adjustment is needed

Additional research is needed to further and holistically explore the potential of promising alternative materials. For instance, wetter (organic) substrates could potentially cause more disease in the presence of root diseases. On the other hand, the alternative materials may have additional benefits that were not explored in this project. For instance, organic substrates may have positive effects on microbial balance and better establishment of biological control organisms in the root environment and then potentially provide more resilient plants. The sustainability of the various alternative and common materials was also not explored in this project, which is a complex question requiring thorough life-cycle analyses