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Improving of the growing methods for Foamplant substrates.

Fig 1: Foamplant substrate

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Assessing the difference between lettuces growing methods with Foamplant substrates

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Summary

Preface:

I'm a French student studying plant production at Aeres university of applied science. To validate my bachelor, I'm currently doing an internship at the company Foamplant. This internship aims to allow me to write and present a research thesis based on an experimentation that I performed.

I would like in the first instance to acknowledge all the people to whom I feel grateful for helping me all along with this research.

I first would like to thank Barend Gehner, which is my colleague, teacher, thesis coach and who helped me to find my internship. He also took some times to introduce me to the company to make sure I would benefit as much as possible from this internship.

I would also like to thank my company tutor Martijn Beljaars for trusting and supporting me and for allowing me to do this internship.

Finally, I would like to thank all the teachers from France and the Netherland that gave us lessons over the last year, and that kept answering our question an helping us during this internship.

Summary

Hydroponic systems for lettuces production is a technique used more and more. However, this way of production is not free of environmental impact. The main substrate used today for the production is Rockwool substrate. However, Rockwool substrates are not biodegradable and generate pollution in their production cycle. The company foamplant designed a substrate biodegradable and cheap to produce. The aim of the thesis was to determine the optimal growing conditions to exploit the new substrate. The main question was: **What is the impact of different growing conditions on lettuce grown with Foamplant substrate?** Thus, the main objective of this research was to describe the lettuces growth in different conditions to determine the more adequate for large-scale production.

The results of this research showed that the optimal watering regime was 15 times per day with 1.5 cm of water level, to get the best germination rate and 8 times per day in order to limit the quantity of dead leaves, fungus, and parasite algae.

According to the results the Foamplant substrate can be a serious alternative to the Rockwool substrate. This would allow to produce lettuce with less impact on the environment and without impacting the performances.

1/ Introduction:

Nowadays in the world and especially in the Netherland hydroponic systems for food production are spreading and they are more and more used. However, this way of production brings issues. The substrates are hard to recycle and create waste or they are coming from unrecoverable peat sources. Finding a new type of substrate that could replace Rockwool or peat substrate is a challenge for the entire sector. Lettuce (*Lactuca sativa* L.) is one of the most important plant of our alimentation. The hydroponic and vertical growing methods are particularly adapted for the lettuce production.

Foamplant is a company designing and producing substrate. They designed a new type of substrate, made of foam. This innovation has a lot of advantages, it is biodegradable, its sturdy consistency allows it to be easily manipulated by automatized system and reduce risks of substrate particles ending up in the irrigation system. It does not affect the pH. It is cheap and clean to produce. The new substrate created by Foamplant is meant to grow crops within a hydroponic system. The company has noticed that these substrates dried quicker than traditional ones. That is why they want to know what the best watering regime is to use them efficiently. Some studies showed that far red can have a positive impact on roots development. We will try to observe if far red help lettuce growing on the new substrate.

The results of this study will be used by Foamplant to advice growers on how to use this substrate, to reach the best yields.

Theoretical framework:

The growing technique we used in this experiment is a hydroponic method. The substrate delivers the optimal supply of nutrients and oxygen to the roots, however Foamplant substrates appear to dry faster than usual substrates, according to the pieces of information and experiences from the company.

Water plays different roles in plants: it is used for the translocation and distribution of nutrients, it preserves the rigidity of plant organs, it is a chemical reaction medium and it is an essential component of the plant. photosynthetic process (Mengel et al., 2001).

In most of the hydroponic systems the lettuces grow for 2/4 weeks before going to a greenhouse. We will probably observe algae growth in the irrigation water, these algae can have a negative impact on lettuce growth (Schwarz, D., & Gross, W).

Increasing the watering regime has a positive impact on yields. Lettuces require a frequent irrigation to grow properly because of a lack of deep rooting system. Dry growing conditions increase chances of bolting for lettuces. (Tsabedze and Wahome, 2020).

The impact of far-red light on lettuce is well documented. It can regulate phytochrome-mediated morphological and physiological plant responses. Lettuce seed growing in an environment with a high R:FR light ratio will exhibit less thermoinhibition and photosensitivity when compared with lettuce growing with a lower R:FR light environment (JieZou et al.) Additional far-red can improve leaf area; the plant canopy is more open, it facilitates a better light interception and lead to higher plant radiation use efficiency, the

dry matter weight is also improved. (Zou et al., 2019). Additional FR radiation can also increase lettuce shoot weight and increase growth rate and reduce the relative specific chlorophyll content. The root dry weight is also increased with additional far-red light (Qingwu Meng and Erik S.Runkle, 2019).

The size of the trays and the size of the gap between the lettuce also have an impact on the growth. Lettuces seem to produce more with a bigger volume of tray's cells; however, there are no studies about the trays we will use in this experiment (Lima et al., 2018).

Blue and far-red light can inhibit fungus spore germination, so we can expect fewer fungal diseases (Calpouzos and Chang,1971).

Knowledge gap:

The impact of the watering regime has already been assessed in numerous studies; however, each watering system can have particularities such as water level, watering time, watering regime. Also, in this study we will mostly focus on Foamplant substrate, there is no public research about these substrates. We will try to find out if the available knowledge about hydroponic substrates is also relevant for Foamplant substrates.

Main question:

What is the impact of different growing conditions on lettuce grown with Foamplant substrate?

Sub questions:

Which watering regime fits better with Foamplant substrates?

Does light spectrum have an impact on the lettuce's response to watering regime?

What are the differences between rockwool substrate and Foamplant substrates?

Are there any differences between the 2 types of trays?

What is the optimal water level during the watering?

Objectives:

This experimental project takes place after the creation of a new type of substrate by the company Foamplant. This is a quantitative research since we compared the results between different growing methods. The functions of research are testing and exploring, we describe with numbers, compare, and evaluate the growing methods.

In this experiment, we grew lettuces on a vertical farming system with 2 levels. This study aims to find out the best growing conditions to use this new substrate. We mostly focused on the watering regime but the growing condition such as light spectrum and type of tray will also be assessed. Due to material restriction and in order to make the experiment easier to settle, we only assessed 2 watering regimes at the same time. Other experiments will be lead later in order to compare the efficiency of other watering regimes in the same conditions.

We compared the result with different trays, water level, light, substrate, and watering regime.

2/ Material and method

The first experimentation was realized with 2 types of substrates, Foamplant's substrate that we want to analyze and Rockwool which was used as a control treatment. We built 2 irrigation systems which watered with 2 different regimes. It was not possible to assess more watering regimes because then build an additional irrigation system would be requiered. We received 2 kinds of tray and we had not enough of each to use just one type of trays. Also, we had not enough Rockwool to fill 2 trays per danish bottom. With these constraints, the plan needed to be addapted. So, we have chosen to combine the Foamplant's substrate with tray 1, the Foamplant's substrate with tray 2, and the Rockwool substrate with tray 1. The trays were half filed up. It allowed us to observe the lettuce grows longer since there was more available space for the leaves.

Independent variable:

Watering regime:

-8 times/day

-15 times /day

Light:

-200 µmol Blue + Red

-200 µmol Blue + Red +far red

Type of substrate:

-Rockwool + tray 1 (A)

-New Foamplant substrate +tray 1 (B)

-New Foamplant substrate +tray 2 (C)

Fig 2: Tray 1

Fig 3: Tray 2

On the tray 1 the gap between each substrate is smaller than on the tray 2. we will seed 90 seeds on each tray 1 and 63 on each tray 2.

Dependant variables:

In order to have a global view of the advantages of each treatment we tried not only focus on yield but try to have a holistic approach. The aim of the study is to observe the overall development of the lettuces.

-Germination rate:

Measured 1 week after seedling, the missing seeds were not replaced to not impact the others results.

-Wet matter weight:

Measured with a scale at the end of the growth, just after the harvest. The lettuce is cut 0.5 cm above the substrate level, in order just to harvest the edible part.

-Dry matter weight:

Measured just after the wet weight. The lettuce will stay on the oven for 2 days at 70°C and then we will scale them.

-Dry matter percentage:

Obtained by calculating Wet matter/Dry matter

-Damaged leaves:

Measured after the first growing part and before the harvest. The notation protocol is based on the number of damaged leaves per plant and the quantity of damaged plant.

0	1	2	3	4	5	6	7	8	9	10
0 plants dammaged	1 leaf >50 % of the plants	1 leaf <50 %	2 leaves >50 %	2 leaves <50 %	3 leaves >50 %	3 leaves <50 %	4 leaves >50 %	4 leaves <50 %	5 leaves >50 %	5 leaves <50 %

-Number of leaves:

Measured after 3 weeks of growth, we randomly selected 20 plants and write down the mean. The second measurement will be just before the harvest.

Materials:

2 Irrigation system (Pipes, gooses, connections, valves)

2 Pumps

Salad seeds (Batavia)

8 danish bottoms

16 trays type 1

8 trays type 2

4 led light (red + blue)

4 led light (red + blue + far red)

Heating system

Substrates

2 water tanks (200 L)

Time and budget:

The lettuces growth started the 05/10/20 after we finished the crafting of the irrigation system. We observed the growth of the lettuces on a daily base, we observed the lettuces development until 18/12/20. Each measure took approximately 3 hours. The times spent on observation was fluctuating depending on the stage of growth.

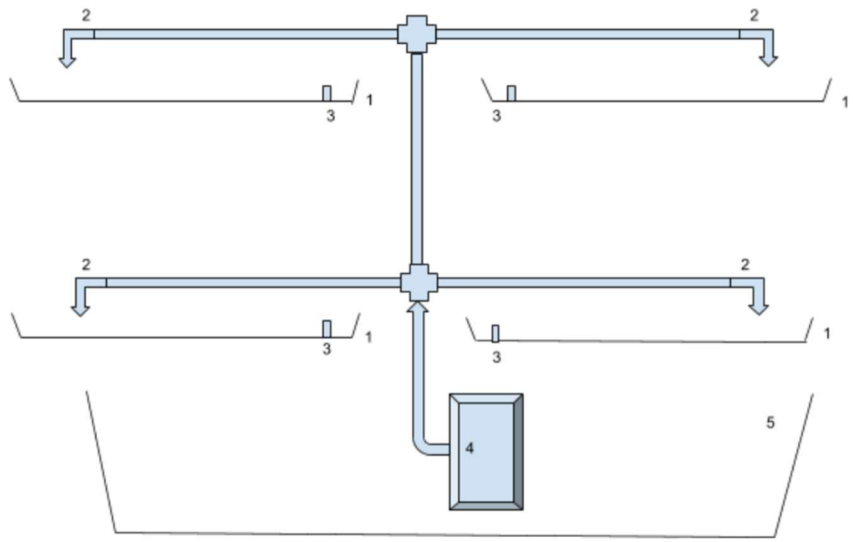
The building of the full irrigation System cost around 100 €, the rest of the equipment is provided by the AERES farm and the company Foamplant.

Limit of the research:

The lack of repetition is the main issue of this experiment (explanation in the experimental plan part). Also, the door of the container is situated close to the part of the experimentation receiving water 8 times a day, this proximity could potentially impact the growth.

The duration of this experimentation could also be restricting, indeed in order to assess different watering regimes and repeat the experiment, we would have needed more time. Due to the actual sanitary crisis we had to shorten the length of the internship.

Scheme of the irrigation system:



1: danish bottom

Each danish bottom has a hole to let the water evacuate, this hole connects to a goose which lead the water to the water tank.

2: valve

The water flow is determined by the valves.

3: level pipe

The level pipe is used to complete the valve to control the water level. It is fixed on the danish bottom hole. The water is evacuated when the level reaches the top of the tube. There is also space in between the pipe and the danish bottom where the water can evacuate with a low debit so when the pump is off the water does not stagnate. This part has been added after 1 Month of growth to resolve issues with the water level. It also allows to vary the water level to assess the differences between differences.

4: pump

Each pump is linked to 4 danish Bottom.

5: water tank

Each water tank contains 200L of water.

Fertilisation:

A	quantity	concentration
calcium nitrate	1,7L	1.5Kg/L
calcium chloride	0,2L	1,3Kg/L
iron	55,8g	6%
manganese	4.28g	12,80%
zinc	4.41g	14,80%
copper	0.86g	14,80%

B	quantity	concentration
phosphoric acid	0.35L	1,42Kg/L
magnesium sulfate	1.4L	1,23Kg/L
sapletric acide	1.35L	1,24Kg/L
potasium hydroxide	0.9L	1,5Kg/L
borax	6.7g	11,30%
so molybd	0.24g	39,60%

Fig 3: nutrient recipe

We put all the macro element with calcium on the jerrycan A as well as most of the micro elements. The nutrient solution was then diluted 100 times in order to be assimilated by the plants.

Experimental site:

fig 4: Aeres farm location:

fig 5: Foamplant location

fig 6: Picture of the container

The company is located in Groningen; however, the experimentation took place in the aeres farm in Dronten. The lettuces grew in a hermetic container, no sun light could reach the plants, there was only one entry.

Temperature:

There is no way to precisely change and uniformize the temperature in the container. It was measured to see if there is area with different temperature.

There was no heating system, the temperature inside used to rise because of the heat coming from the LEDs. Between the 2 levels of the experiment, we observed a difference of 2°C.

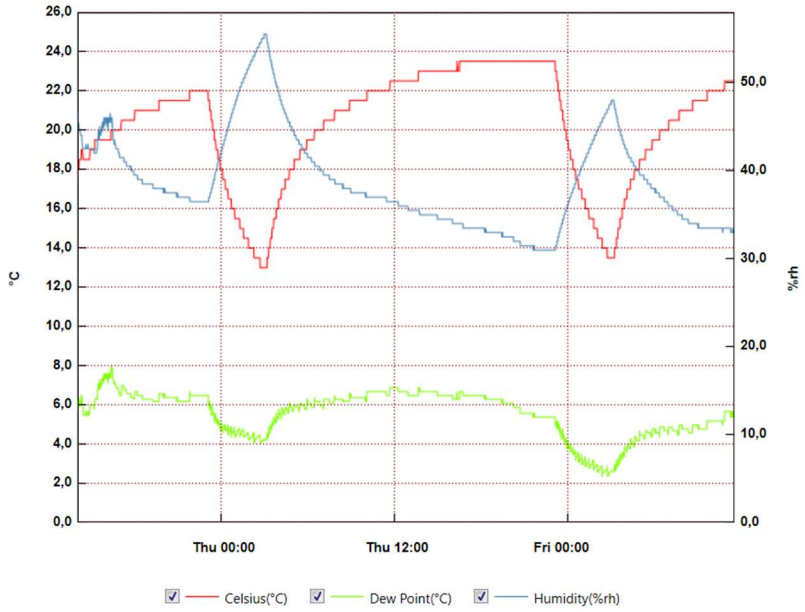


Fig 7: level 1 temperature, humidity and dew point graph

Max Temperature	23.5
Min Temperature	13
Average temperature	20.2

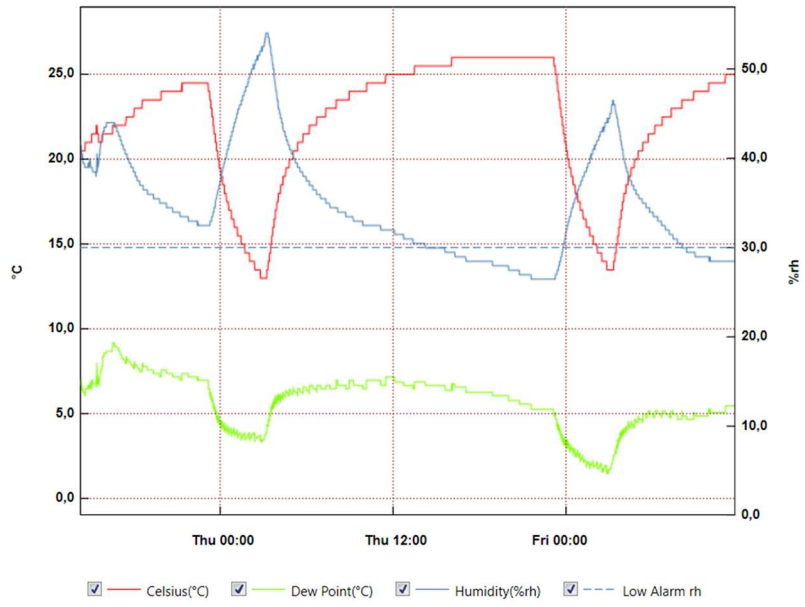


Fig 8: level 2 temperature, humidity and dew point graph

Max Temperature	26°C
Min Temperature	13°C
Average temperature	22.3°C

Relative humidity

Max relative humidity	55.5%
Min relative humidity	31%
Average relative humidity	38.7%

The relative humidity is quite low however it was no available way to change it. It was rising in the night when the led were off. It was no watering in the night, keeping a high relative humidity at this moment was important.

Experimental set up:

All along the experimentation, the experimental plan evolved in order to adapt to the current needs. In the results part the experimental plan used will be indicated.

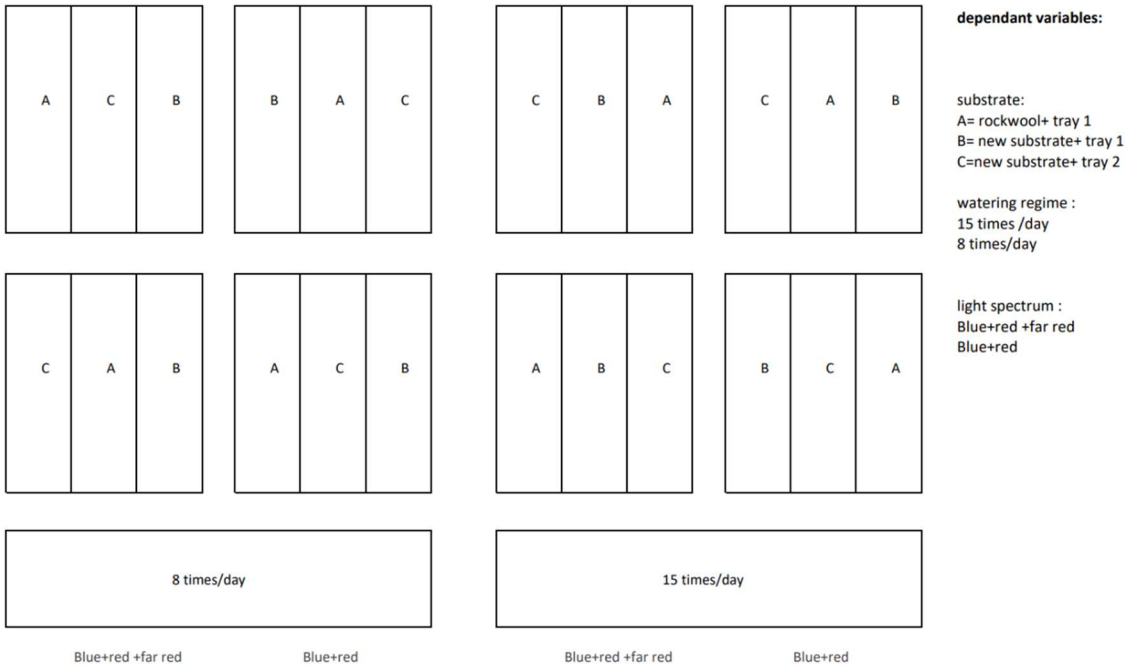


Fig 9: 1st experimental set up

The experiment is divided into 2 parts main part, the left gets water 8 times a day when the right gets water 15 times a day. Each watering last 15 min. Then each side is divided between light with or without far-red. Each Danish bottom had different growing conditions and each of them contains the 3 different growing bases described on the diagram up. Randomization was effectuated inside of each danish bottom. Having more

repetition could have been interesting however we had some constraints. Making 3 repetitions inside each danish bottom is quite complicated and it would not be very useful since all the repetitions would undergo the same variation. We could remove a variable to replace it with a repetition, but the watering regime is my main variable and the light spectrum of the led cannot be changed. In this part of the experiment, we only had 2 repetitions. Also, the 2 repetitions are not equal they have a 2°C average temperature difference this was problematic for the statistical accuracy.

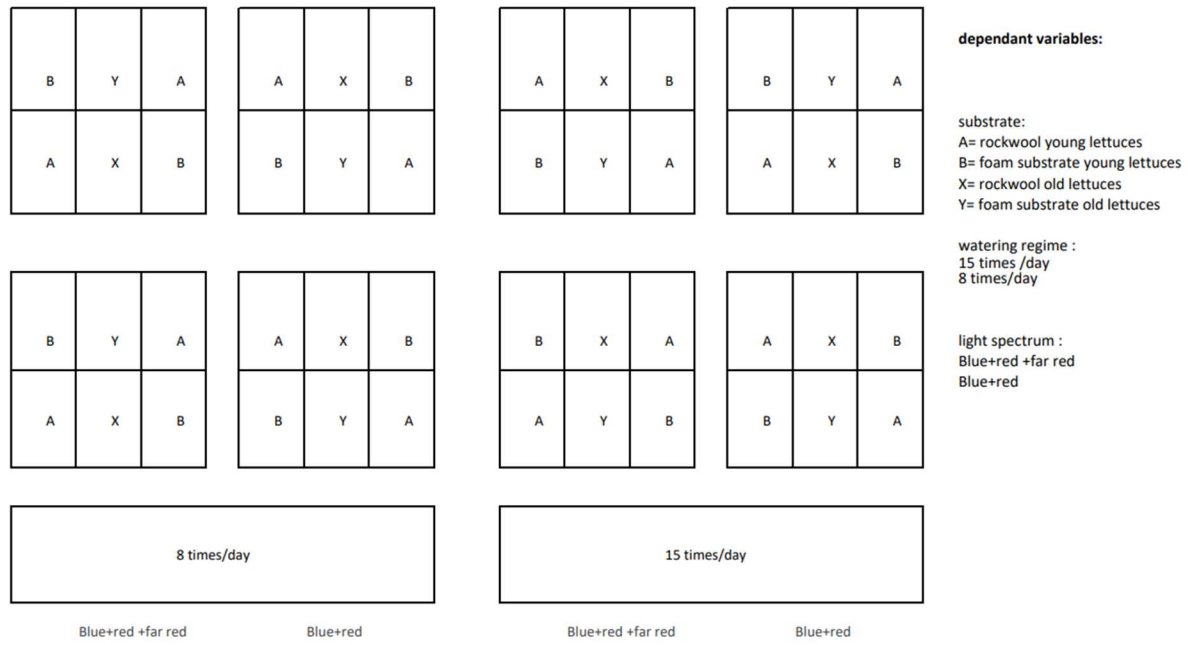


Fig 10: 2nd experimental set up

When the lettuces were developed enough, half of the best plant growing in trays 1 with Rockwool substrates and half of the best plant growing in trays 1 with foam substrates were selected and grouped together into tray 2. In a nutshell, A and B from the first part of the experiment became X and Y. The plant coming from C from the first experiment were thrown away. Finally, new lettuces were seeded in the 2 remaining trays (trays 1) which became the new A and B. The trays were divided into 2 parts which allowed to solve the repetitions issue. However, the repetitions are in the same danish bottom, therefore they are very likely to undergo the same variation.

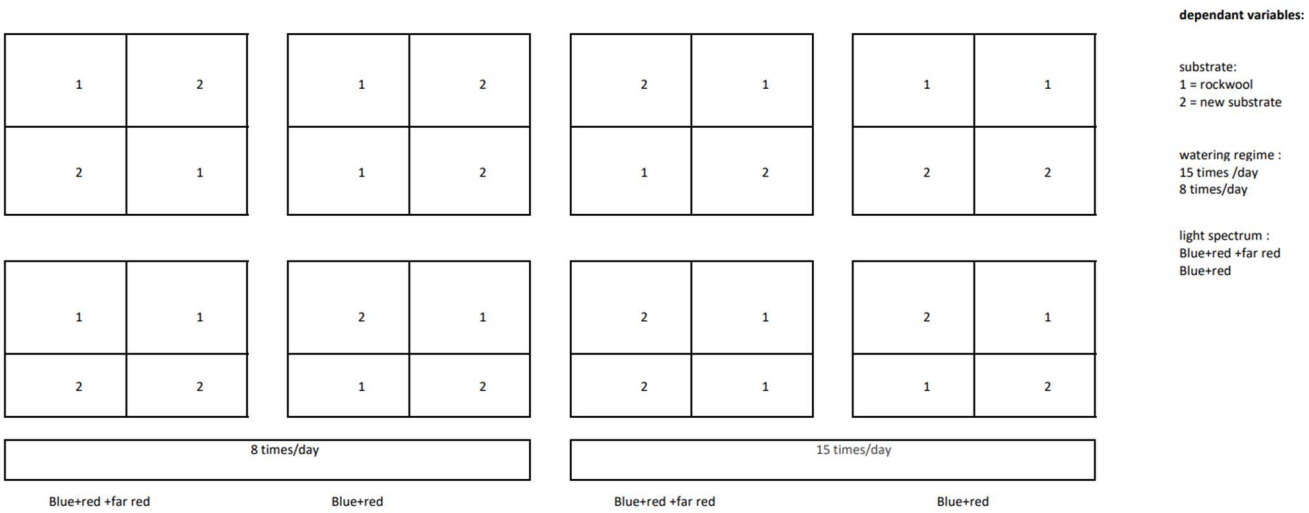


Fig11: 3rd experimental set up

The 3rd part of the experiment was simplified. It is basically the same as the second experiment but without the bigger trays (X and Y).

3) Results

I) Germination rate

(1st experimental set up)

Means:

Tray/ watering regime	A/8	B/8	C/8	A/15	B/15	C/15
Average Germination rate	0.952	0.958	0.940	0.975	0.98	0.97

Fig 12: mean of the tray and watering regime combined groups

Light/ watering regime	R+B+FR/8	R+B/8	R+B+FR/15	R+B/15
Average Germination rate	0.933	0.967	0.987	0.970

Fig 13: mean of the light and watering regime combined groups

Far red =FR; Red=R; Blue=B

light	R+B+FR	R+B
Average Germination rate	0.960	0.968

Fig 14: mean of the light groups

A) Light color impact on the germination rate:

Test of normality:

light	Statistic test value	Shapiro-wilk sig.	distribution
Red+ Blue	0.913	0.233	Normally distributed
Far red + Red+ Blue	0.932	0.401	Normally distributed

Fig 15: normality test of the light groups

The shapiro-wilk sig is superior to 0.05 which means that both groups of data are normally distributed, so we are using a parametric test. We are only comparing the results of one independent variable, so we are using an independent t-test.

Independent t-test:

H0: There are no differences on germination rate between lettuces grew under different type of light.

H1: There are differences on germination rate between lettuces grew under different type of light.

Pvalue= 0.05

Statistical test value t= -0.684

Asymp. Sig. = 0.501

Pvalue > 0.05 so we can't reject the null hypothesis

B) Impact of the watering regime and tray on the germination rate

Test of normality:

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.913	0.236	Normally distributed
15	0.849	0.035	Not normally distributed

Fig 16: normality test of the watering regime groups

Trays	Statistic test value	Shapiro-wilk sig.	distribution
A	0.940	0.607	Normally distributed
B	0.762	0.011	Not normally distributed
C	0.941	0.623	Normally distributed

Fig 17: normality test of the tray groups

One group is not normally distributed, so we must use a non-parametric test. We can not analyse 2 independent variables together with a non-parametric test. We will use a variable with 6 levels Instead of 2 independent variables with 2 and 3 levels. The new independent variable is a combination of the 2 previous variables.

Trays/watering regime	Statistic test value	Shapiro-wilk sig.	distribution
A/8	0.895	0.406	Normally distributed
B/8	0.744	0.034	Not normally distributed
C/8	0.982	0.911	Normally distributed
A/15	0.971	0.850	Normally distributed

B/15	0.945	0.683	Normally distributed
C/15	0.848	0.220	Normally distributed

Fig 18: normality test of the *tray and watering regime combined groups*

One group is not normally distributed, so we must use a non parametric test. We are going to use a Kruskal-Wallis test.

Kruskal-Wallis test:

H0 : There are no differences on germination rate between lettuces grew with different tray and watering regime.

H1 : There are differences on germination rate between lettuces grew with different tray and watering regime.

Pvalue =0.05

Khi-square = 8.588

Asymp. Sig 0.0127

Pvalue < 0.05 so we can reject the null hypothesis

Now that we know that there is a difference among the groups, we are going to use a Mann-Whitney test to compare groups by pair. By doing so we will be able to know which groups are different.

Mann-Whitney test:

H0: There are no differences in germination rate between lettuces grew with tray A and 8 watering per day and lettuces grew with tray A and 15 watering per day.

H1: There are differences in germination rate between lettuces grew with tray A and 8 watering per day and lettuces grew with tray A and 15 watering per day.

Pvalue=0.05

Statistycal test value Z= -1.637

Asymp. Sig. = 0.102

Pvalue > 0.05 so we can not reject the null hypothesis

H0: There are no differences on germination rate between lettuces grew with tray B and 8 watering per day and lettuces grew with tray B and 15 watering per day.

H1: There are differences on germination rate between lettuces grew with tray B and 8 watering per day and lettuces grew with tray B and 15 watering per day.

Pvalue=0.05

Statistycal test value Z= -2.084

Asymp. Sig. = 0.037

pvalue < 0,05 so we reject the null hypothesis.

Lettuces grown on Foamplant substrate in tray 1 receiving water 15 times per day show a higher germination rate.

H0: There are no differences on germination rate between lettuces grew with tray C and 8 watering per day and lettuces grew with tray C and 15 watering per day.

H1: There are differences on germination rate between lettuces grew with tray C and 8 watering per day and lettuces grew with tray C and 15 watering per day.

Pvalue=0.05

Statistycal test value Z= -1.162

Asymp. Sig. =0.245

Pvalue > 0.05 so we can't reject the null hypothesis

H0: There are no differences on germination rate between lettuces grew with tray B and 15 watering per day and lettuces grew with tray C and 15 watering per day.

H1: There are differences on germination rate between lettuces grew with tray B and 15 watering per day and lettuces grew with tray C and 15 watering per day.

Pvalue=0.05

Statistycal test value Z= -1.176

Asymp. Sig. =0.240

Pvalue > 0.05 so we can't reject the null hypothesis

C) Impact of watering regime and light type on the germination rate:

Normality test:

One group is not normally distributed, so we must use a non-parametric test. We can not analyse 2 independent variables together with a non-parametric test. We will use a variable with 4 levels Instead of 2 independent variables with 2 levels. The new independent variable is a combination of the 2 previous variables.

Light/watering regime	Statistic test value	Shapiro-wilk sig.	distribution
Red+ Blue/8	0.988	0.984	Normally distributed
Far red + Red+ Blue/8	0.942	0.673	Normally distributed
Red+ Blue/15	0.809	0.070	Normally distributed
Far red + Red+ Blue/15	0.896	0.0352	Normally distributed

Fig 19: normality test of the light and watering regime combined groups

All 4 groups of data are normally distributed, so we are using a parametric test. We are comparing the result of one independent variable with more than 3 levels, so we are using a one-way Anova.

One-way Anova:

H0: there is no differences between lettuces grew with different watering regime and type of light.

H1: there is no differences between lettuces grew with different watering regime and type of light.

pvalue = 0.05

F = 5.386

Sig general = 0.007

Pvalue < 0.05 so we can reject the null hypothesis.

Tab of significance (Tukey test):

Light/watering regime	**Red+ Blue/8**	**Far red + Red+ Blue/8**	**Red+ Blue/15**	**Far red + Red+ Blue/15**
Red+ Blue/8	/	0.098	0.004	0.062
Far red + Red+ Blue/8	/	/	0.478	0.995
Red+ Blue/15	/	/	/	0.617
Far red + Red+ Blue/15	/	/	/	/

Fig 20: tukey tab of significance

The only significant difference is between Red+ Blue with 15 watering per day and Red+ Blue with 8 watering per day.

H0: There are no differences on germination rate between lettuces grew with Red+ Blue and 8 watering per day and lettuces grew with tray Red+ Blue and 15 watering per day.

H1: There are differences on germination rate between lettuces grew with Red+ Blue and 8 watering per day and lettuces grew with tray Red+ Blue and 15 watering per day.

Pvalue=0.05

Sig=0.004

pvalue < 0,05 so we reject the null hypothesis.

There are differences on germination rate between lettuces grew with Red+ Blue and 8 watering per day and lettuces grew with tray Red+ Blue and 15 watering per day. Plants receiving more water show a higher germination rate.

II) Average number of leaves per lettuce after 20 days

(1st experimental setup)

Means:

	A/8	**B/8**	**C/8**	**A/15**	**B/15**	**C/15**
Average number of leaves	4.9	4.9	4.35	5.25	5.575	5.225

Fig 21: mean of the tray and watering regime combined groups

	FR/8	**RB/8**	**FR/15**	**RB/15**
Average number of leaves	4.75	4.68	5.43	5.26

Fig 22: mean of the light and watering regime combined groups

	RB+FR	**RB**
Average Germination rate	5.09	4.975

Fig 23 mean of the light groups

A) Light impact on the average number of leaves:

Normality test:

light	Statistic test value	Shapiro-wilk sig.	distribution

Red+ Blue	0.851	0.037	Not normally distributed
Far red + Red+ Blue	0.978	0.973	Normally distributed

Fig 24: normality test of the light groups

Both groups of data are normally distributed, so we are using a parametric test. We are only comparing the result of one independent variable, so we are using an independent t-test.

Independant t-test :

H0 : There are no differences on average number of leaves between lettuces grew with red + blue and lettuces grew with red + blue + far red.

H1 : There are differences on average number of leaves between lettuces grew with red + blue and lettuces grew with red + blue + far red.

Pvalue=0.05

Statistycal test value t= -0.869

Asymp. Sig. = 0.385

pvalue > 0,05 so we cannot reject the null hypothesis

B) Light and watering regime impact on the average number of leaves:

Normality test :

watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.974	0.946	Normally distributed
15	0.936	0.443	Normally distributed

Fig 25: normality test of the watering regime groups

One group is not normally distributed, so we must use a non-parametric test. We can't analyse 2 independent variables together with a non-parametric test. We will use a variable with 4 levels Instead of 2 independent variables with 2 levels. The new independent variable is a combination of the 2 previous variables.

Light/watering regime	Statistic test value	Shapiro-wilk sig.	distribution
Red+ Blue/8	0.981	0.958	Normally distributed

Far red + Red+ Blue/8	0.961	0.824	Normally distributed
Red+ Blue/15	0.920	0.505	Normally distributed
Far red + Red+ Blue/15	0.930	0.577	Normally distributed

Fig 26: normality test of the light and watering regime combined groups

All 4 groups of data are normally distributed, so we are using a parametric test. We are comparing the result of one independent variable with more than 3 levels, so we are using a one-way Anova.

One-way Anova :

H0 : There are no differences on average number of leaves between lettuces grew with different light and watering regime.

H1 : There are differences on average number of leaves between lettuces grew with different light and watering regime.

Pvalue=0.05

Statistical test value F= 3.029

Asymp sig = 0.053

pvalue > 0,05 so we can not reject the null hypothesis

C) Light and tray impact on the average number of leaves:

Normality test :

tray	Statistic test value	Shapiro-wilk sig.	distribution
A	0.813	0.039	Not normally distributed
B	0.904	0.311	Normally distributed
C	0.874	0.166	Normally distributed

Fig 27: normality test *of the tray groups*

One group is not normally distributed, so we must use à non-parametric test. We can't analyse 2 independent variables together with a non-parametric test. We will use a variable with 4 levels Instead of 2 independent variables with 2 levels. The new independent variable is a combination of the 2 previous variables.

Tray/watering regime	Statistic test value	Shapiro-wilk sig.	distribution
A/8	0.729	0.024	Not normally distributed
B/8	0.959	0.773	Normally distributed
C/8	0.911	0.488	Normally distributed
A/15	0.854	0.240	Normally distributed
B/15	0.935	0.625	Normally distributed
C/15	0.920	0.538	Normally distributed

Fig 28: normality test of the tray and watering regime combined groups

One group is not normally distributed, so we have to use à non-parametric test. We are going to use a Kruskal-Wallis test to know if there are differences among the groups.

Kruskal-Wallis test:

H0: There are no differences on average number of leaves between lettuces grew with different tray and watering regime.

H1: There are differences on average number of leaves between lettuces grew with different tray and watering regime.

pvalue=0,05

Chi-square= 10.130

Asymp. Sig. = 0.72

pvalue > 0,05 so we cannot reject the null hypothesis.

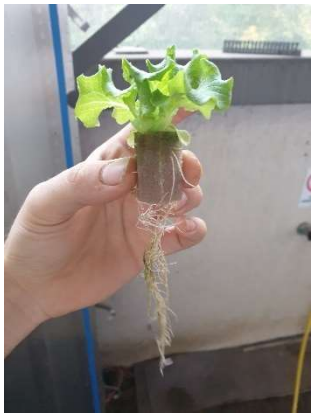


Fig 29: lettuce after 20 days of growth

III) Quantity of dead leaves:

(1st experimental setup)

Means:

	A/8	B/8	C/8	A/15	B/15	C/15
Quantity of dead leaves	2.25	2.75	3	4.5	4.5	4.25

Fig 30: mean of the tray and watering regime combined groups

	FR/8	RB/8	FR/15	RB/15
Quantity of dead leaves	2.16	3.16	4.5	4.33

Fig 31: mean of the light and watering regime combined groups

A) Tray and watering regime impact on the Average number of dead leaves per tray

Normality test:

watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.877	0.080	Normaly distributed
15	0.894	0.133	Normaly distributed

Fig 31: normality test of the watering regime groups

tray	Statistic test value	Shapiro-wilk sig.	distribution
A	0.871	0.156	Normaly distributed
B	0.934	0.557	Normaly distributed
C	0.912	0.366	Normaly distributed

Fig 32: Normality test of the tray groups

All the variables are normally distributed, so we are using a parametric test. We are comparing 2 independent variables, so we are using an Anova.

Anova:

variable	dof	F	Sig	difference
Watering regime	1	18.123	0.000	Significantly different
tray	2	0.164	0.850	Not Significantly different
tray/ Watering regime	2	0.493	0.619	Not Significantly different

Fig 33: results of the Anova

The only significant difference is between the 2 watering regimes.

H0: There are no differences on average number of l dead eaves between lettuces grew with different watering regime.

H1: There are differences on average number of dead leaves between lettuces grew with different watering regime.

Pvalue = 0.05

F=18.123

Sig=0.000

pvalue <0,05 so we reject the null hypothesis.

There are more dead leaves among lettuces receiving more water.

IV) Fungus development

2nd experimental setup

Means:

Substrate/watering regime	**Rockwool/8**	**Foamplant/8**	**Rockwool/15**	**Foamplant/15**
Fungus development	0	0	19	3

Fig 34: *means of the substrate and watering regime combined groups.*

Light/watering regime	**FR+RB/8**	**RB/8**	**FR+RB/15**	**RB/15**
Fungus development	0	0	1	21

Fig 35: means of the light and watering regime combined groups

Watering regime	**8**	**15**
Fungus development	0	22

Fig 36: means of the watering regime groups

light	**FR+RB**	**RB**
Fungus development	1	21

Fig 37: means of the light groups

A) Watering regime and substrate impact on the fungus development

Normality test:

There is no fungus development with 8 watering per day so, there is no data for the distribution.

watering regime	**Statistic test value**	**Shapiro-wilk sig.**	**distribution**

8	///	///	Not normally distributed
15	0.581	0.000	Not normally distributed

Fig 38: normality test of the watering regime groups

substrate	Statistic test value	Shapiro-wilk sig.	distribution
Rockwool	0.510	0.000	Not normally distributed
Foamplant	0.418	0.000	Not normally distributed

Fig 39: normality test of the substrate groups

None of the group are normally distributed, so we must use à non-parametric test. We can't analyse 2 independent variables together with a non-parametric test. We will use a variable with 4 levels Instead of 2 independent variables with 2 levels. The new independent variable is a combination of the 2 previous variables.

Substrate/watering regime	Statistic test value	Shapiro-wilk sig.	distribution
Rockwool/8	///	///	Not normally distributed
Foamplant/8	///	///	Not normally distributed
rockwool/15	0.730	0.024	Not normally distributed
Foamplant/15	0.630	0.001	Not normally distributed

Fig 40: normality test of the substrate and watering regime groups

None of the groups are normally distributed so we are using a non-parametric test. We will use a Kruskal-Wallis test in order to compare the effect of the watering regime combined with the substrate.

Kruskal-Wallis test:

H0: there is no difference in fungus development between the 2 different substrates with 8 and 15 watering per day.

H1: there is a difference in fungus development between the 2 different substrates with 8 and 15 watering per day.

Pvalue= 0.05

Khi-square = 7.015

Asymp. Sig= 0.071

pvalue > 0,05 so we cannot reject the null hypothesis

There is no significative results, this may be because of the too small number of results. We are going to use a Mann-Whitney (non-parametric) test to compare the 2 watering regimes regardless of the substrate. By doing this we have less groups and more results.

Mann-Whitney:

H0 : there is no difference in fungus development between 8 and 15 watering per day

H1 : there is no difference in fungus development between 8 and 15 watering per day

Pvalue = 0.05

Statistical test value Z=-2.208

Asymp. Sig.=0.027

pvalue < 0,05 so we reject the null hypothesis

There is more fungus development with 15 watering per day.

B) lights impact on fungus development with 15 watering per day

We are only focussing on the lettuces receiving 15 watering per day since there is no fungus development with 8 watering per day.

Normality test:

light	Statistic test value	Shapiro-wilk sig.	distribution
Red+ Blue	0.630	0.001	Not normally distributed
Far red + Red+ Blue	0.785	0.078	Normally distributed

Fig 41: normality test of the light groups

One group is not normally distributed, so we are using a non-parametric test. We are using a Mann-Whitney test.

Mann-Whitney test:

H0: there is no difference between lettuces grew under red + blue with 15 watering per day and lettuces grew under red + blue + far red with 15 watering per day.

H1: there is difference between lettuces grew under red + blue with 15 watering per day and lettuces grew under red + blue + far red with 15 watering per day.

pvalue=0,05

Statistical test value Z= -1.692

Asymp. Sig. = 0.091

pvalue > 0,05 so we cannot reject the null hypothesis

Fig 42: fungus on lettuce

V) Wet matter yields:

2nd experimental setup

Means:

Substrate/watering regime	**rockwool/8**	**Foamplant/8**	**Rockwool/15**	**Foamplant/15**
Wet matter yield	0.446	0.445	0.467	0.496

Fig 43: means of the substrate and watering regime combined groups

Light/watering regime	**FR+RB/8**	**RB/8**	**FR+RB/15**	**RB/15**
Wet matter yield	0.455	0.436	0.49	0.46

Fig 44: means of the light and watering regime combined groups

light	**FR+RB**	**RB**
Wet matter yield	**0.471**	**0.449**

Fig 45: means of the light groups

Normality test:

light	Statistic test value	Shapiro-wilk sig.	distribution
Red + blue	0.973	0.921	Normally distributed
Red + blue +far red	0.961	0.961	Normally distributed

Fig 46: normality test light groups

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.949	0.702	Normally distributed
15	0.963	0.847	Normally distributed

Fig 47: normality test watering regime groups

substrate	Statistic test value	Shapiro-wilk sig.	distribution
Rockwool	0.934	0.585	Normally distributed
Foamplant	0.984	0.980	Normally distributed

Fig 48: normality test substrate groups

All the variables are normally distributed, so we are using a parametric test. We are comparing 3 independent variables, so we are using an Anova.

Anova:

variable	dof	F	sig	difference
water	1	1.353	0.283	Not statistically different
light	1	0.120	0.739	Not statistically different
substrate	1	0.003	0.955	Not statistically different
water/light	1	0.033	0.861	Not statistically different
water/substrate	1	0.004	0.950	Not statistically different
light/substrate	1	6.749	0.036	Statistically different

Fig 49: Anova results

The only significant effect come from the interaction between the light and the substrate (p=0.05)

VI) Dry matter yields:

2nd experimental setup

Means:

Substate/watering regime	rockwool/8	Foamplant/8	Rockwool/15	Foamplant/15
Dry matter yield (g)	0.0155	0.0121	0.023	0.021

Fig 50: means of the substrate and watering regime combined groups

Light/watering regime	FR+RB/8	RB/8	FR+RB/15	RB/15
Dry matter yield (g)	0.0164	0.0169	0.0253	0.0213

Fig 51: means of the light and watering regime combined effect

light	FR+RB	FR
Dry matter yield (g)	0.0181	0.0187

Fig 52: means of the light groups

Normality test:

light	Statistic test value	Shapiro-wilk sig.	distribution
Red + blue	0.996	1.000	Normally distributed
Red + blue +far red	0.886	0.214	Normally distributed

Fig 53: normality test of the light groups

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.988	0.991	Normally distributed
15	0.945	0.683	Normally distributed

Fig 54: normality test of the watering regime groups

substrate	Statistic test value	Shapiro-wilk sig.	distribution
Rockwool	0.874	0.201	Normally distributed
Foamplant	0.977	0.947	Normally distributed

Fig 55: normality test of the substrate groups

All the variables are normally distributed, so we are using a parametric test. We are comparing 3 independent variables, so we are using an Anova.

Anova:

variable	dof	F	sig	difference
water	1	3.295	0.107	Not statistically different
light	1	0.302	0.598	Not statistically different
substrate	1	0.514	0.494	Not statistically different
water/light	1	0.067	0.802	Not statistically different
water/substrate	1	1.802	0.216	Not statistically different
light/substrate	1	3.753	0.089	Not statistically different

Fig 56: Anova results

There is no significant difference between all the groups (P=0.05)

Fig 57: Lettuces before going to the oven

VII) percentage of dry matter:

2nd experimental setup

Means:

Substrate/ Watering regime	rockwool/8	Foamplant/8	Rockwool/15	Foamplant/15
Dry matter yield	3.85	3.62	4.07	4.39

Fig 58: mean of the substrate and watering regime combined groups

Light/watering regime	FR+RB/8	RB/8	FR+RB/15	RB/15
Dry matter yield	3.74	3.73	4.41	4.14

Fig 59: means of the light and watering regime groups

light	FR+RB	FR
Dry matter yield	4.035	3.984

Fig 60: means of the light groups

Normallity test:

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.797	0.051	Not normally distributed
15	0.895	0.303	Normally distributed

Fig 61: normality test of the watering regime groups

substrate	Statistic test value	Shapiro-wilk sig.	distribution
Rockwool	0.894	0.297	Normally distributed
Foamplant	0.726	0.072	Normally distributed

Fig 62: normality test of the substrate groups

light	Statistic test value	Shapiro-wilk sig.	distribution
Red + blue	0.889	0.269	Normally distributed
Red + blue +far red	0.824	0.052	Normally distributed

Fig 63: normality test of the light groups

All the groups are normally distributed, so we need to use a parametric test. We are using an Anova to compare the independent variables together.

Anova:

variable	dof	F	sig	difference
Watering regime	1	4.208	0.079	Not statistically different
light	1	0.280	0.613	Not statistically different
substrate	1	0.000	1,000	Not statistically different
water/light	1	0.065	0.266	Not statistically different
water/substrate	1	0.759	0.413	Not statistically different
light/substrate	1	0.027	0.109	Not statistically different

Fig 64: Anova results

There are no differences among the groups (p=0.05)

H0 : The dry matter percentage is not different for lettuce grew with different watering regime, light and substrate.

H0 : The dry matter percentage is not different for lettuce grew with different watering regime, light and substrate.

Pvalue= 0.05

pvalue > 0,05 so we cannot reject the null hypothesis.

VIII) Germination Rate with 2 cm water level

2nd experimental setup

Means:

Tray/watering regime	rockwool/8	Foamplant/8	Rockwool/15	Foamplant/15
Germination rate	0.9025	0.896	0.838	0.871

Fig 65: means of the substrate and watering regime combined groups

Light/watering regime	FR+R+B/8	R+B/8	FR+RB/15	R+B/15
Germination rate	0.89	0.905	0.853	0.856

Fig 66: means of the *light and watering regime combined groups*

light	FR+R+B	R+B
Germination rate	0.89	0.86

Fig 67: means of the light groups

Watering regime	8	15
Germination rate	0.899	0.855

Fig 68: means of the watering regime groups

Normality test:

substrate	Statistic test value	Shapiro-wilk sig.	distribution
rockwool	0.961	0.673	Normally distributed
foamplant	0.963	0.724	Normally distributed

Fig 69: normality test of the substrate groups

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.914	0.137	Normally distributed
15	0.965	0.761	Normally distributed

Fig 70: normality test of the watering regime groups

light	Statistic test value	Shapiro-wilk sig.	distribution
Red + blue	0.923	0.190	Normally distributed
Red + blue +far red	0.944	0.396	Normally distributed

Fig 71: normality test of the light groups

All the groups are normally distributed so we can use a parametric test. We are using an Anova to compare the independent variables together.

Anova:

variable	dof	F	sig	difference
Watering regime	1	48.010	0.000	Statistically different
substrate	1	4.200	0.057	Not statistically different
light	1	6.943	0.018	Statistically different
Watering regime/substrate	1	9.152	0.008	Statistically different
Watering regime/light	1	0.467	0.504	Not statistically different
light/substrate	1	0.010	0.923	Not statistically different

Fig 72: Anova results

Pvalue=0.05

H0: The watering regime doesn't have an impact on the germination rate for lettuces grew with 2 cm of water level.

H1: The watering regime has an impact on the germination rate for lettuces grew with 2 cm of water level.

pvalue < 0,05 so we can reject the null hypothesis

H0: The type of substrate doesn't have an impact on the germination rate for lettuces grew with 2 cm of water level.

H1: The type of substrate has an impact on the germination rate for lettuces grew with 2 cm of water level.

pvalue > 0,05 so we cannot reject the null hypothesis

H0: The type of light doesn't have an impact on the germination rate for lettuces grew with 2 cm of water level.

H1: The type of light has an impact on the germination rate for lettuces grew with 2 cm of water level.

pvalue < 0,05 so we can reject the null hypothesis

H0: The watering regime and substrate combine effect don't have an impact on the germination rate for lettuces grew with 2 cm of water level.

H1: The watering regime and substrate combine effect have an impact on the germination rate for lettuces grew with 2 cm of water level.

pvalue < 0,05 so we can reject the null hypothesis

H0: The watering regime and light combine effect don't have an impact on the germination rate for lettuces grew with 2 cm of water level.

H1: The watering regime and light combine effect have an impact on the germination rate for lettuces grew with 2 cm of water level.

pvalue > 0,05 so we cannot reject the null hypothesis

H0: The substrate and light combine effect don't have an impact on the germination rate for lettuces grew with 2 cm of water level.

H1: The substrate and light combine effect have an impact on the germination rate for lettuces grew with 2 cm of water level.

pvalue > 0,05 so we cannot reject the null hypothesis

IIX) Germination rate with 1.5cm water level

(3rd experimental setup)

Means:

Substrate/watering regime	**rockwool/8**	**Foamplant/8**	**Rockwool/15**	**Foamplant/15**
Germination rate	0.927	0.902	0.902	0.9875

Fig 73: Means of the *substrate and watering regime combined groups*

Light/watering regime	**FR+RB/8**	**RB/8**	**FR+RB/15**	**RB/15**
Germination rate	0.911	0.915	0.945	0.952

Fig 74: means of the light and watering regime combined groups

Light	**FR+R+B**	**R+B**
Germination rate	0.928	0.933

*Fig 75: me*ans of the light groups

Watering regime	**8**	**15**
Germination rate	0.913	0.948

Fig 76: means of the watering regime groups

A) Light impact on the germination rate:

Normality test:

light	Statistic test value	Shapiro-wilk sig.	distribution
Red + blue	0.925	0.200	Normally distributed
Red + blue +far red	0.860	0.190	Normally distributed

Fig 77: normality test of the light groups

Both groups are normally distributed so we will use an independent t-test (parametric test)

Independent t-test:

H0: There are no differences on germination rate between lettuces grew under far red + red + blue and lettuce grew under red + blue.

H1: There are differences on germination rate between lettuces grew under far red + red + blue and lettuce grew under red + blue.

pvalue=0,05

Statistical test value t= -1.528

Asymp. Sig. = 0.137

pvalue > 0,05 so we cannot reject the null hypothesis

B) Impact of watering regime and substrate type on the germination rate:

Normality test:

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.880	0.039	Not normally distributed
15	0.884	0.044	Not normally distributed

Fig 77: normality test of the watering regime groups

substrate	Statistic test value	Shapiro-wilk sig.	distribution
rockwool	0.861	0.020	Not normally distributed
foamplant	0.885	0.046	Normally distributed

Fig 78: normality test of the substrate groups

Some groups are not normally distributed, so we must use à non-parametric test. We can't analyse 2 independent variables together with a non-parametric test. We will use a variable with 4 levels Instead of 2 independent variables with 2 levels. The new independent variable is a combination of the 2 previous variables.

Substrate/watering regime	**Statistic test value**	**Shapiro-wilk sig.**	**distribution**
Rockwool/8	0.782	0.018	Not normally distributed
Foamplant/8	0.907	0.334	Normally distributed
Rockwool/15	0.939	0.600	Normally distributed
Foamplant/15	0.843	0.082	Not normally distributed

Fig 79: Normality test of the of the substrate and watering regime combined groups

2 groups are not normally distributed, so we are going to use a Kruskal-Wallis test.

Kruskal-Wallis test:

H0= There are no impact of the watering regime and the type of substrate on the germination rate.

H1= There are impact of the watering regime and the type of substrate on the germination rate.

Pvalue= 0.05

Khi-square=23.805

Dof=3

Asymp. Sig=0.000

pvalue > 0,05 so we can reject the null hypothesis

We want to know which groups are different, so we are using a Man-Whitney test

Mann-Whitney test:

H0: There are no differences on germination rate between lettuces grew with 8 watering per day with Foamplant substrate and lettuces grew with 8 watering per day with rockwool.

H1: There are differences on germination rate between lettuces grew with 8 watering per day with Foamplant substrate and lettuces grew with 8 watering per day with rockwool.

pvalue=0,05

Statistical test value Z= -2.891

Asymp. Sig. = 0.004

pvalue < 0,05 so we can reject the null hypothesis.

Lettuces grew with rockwool substrate have a higher germination rate under 8 watering per day.

Mann-Whitney test:

H0: There are no differences on germination rate between lettuces grew with 8 watering per day with Foamplant substrate and lettuces grew with 15 watering per day with Foamplant.

H1: There are differences on germination rate between lettuces grew with 8 watering per day with Foamplant substrate and lettuces grew with 15 watering per day with Foamplant.

pvalue=0,05

Statistical test value Z= -3.383

Asymp. Sig. =0.001

pvalue > 0,05 so we can reject the null hypothesis.

Lettuces grew with Foamplant substrate have a higher germination rate under 15 watering per day

Mann-Whitney test:

H0: There are no differences on germination rate between lettuces grew with 15 watering per day with Foamplant substrate and lettuces grew with 15 watering per day with rockwool.

H1: There are differences on germination rate between lettuces grew with 15 watering per day with Foamplant substrate and lettuces grew with 15 watering per day with rockwool.

pvalue=0,05

Statistical test value Z= -3.381

Asymp. Sig. = 0.001

pvalue < 0,05 so we can reject the null hypothesis

Under 15 watering per day lettuces grew with Foamplant substrate have a higher germination rate.

X) Comparison 1.5 cm and 2 cm water level

3rd experimental setup

In order to assess the differences between the 2 levels of water we are going to use the datas from the previous experiments

Normality test:

Watering regime	Statistic test value	Shapiro-wilk sig.	distribution
8	0.953	0.177	Normally distributed
15	0.908	0.010	Not normally distributed

Fig 80: normality test of the watering regime goups

substrate	Statistic test value	Shapiro-wilk sig.	distribution
R	0.903	0.007	Not normally distributed
F	0.888	0.003	Not normally distributed

Fig 81: normality test of the substrate groups

Water level	Statistic test value	Shapiro-wilk sig.	distribution
1.5	0.907	0.0090	Not normally distributed
2	0.948	0.125	Normally distributed

Fig 82: normality test of the watering regime groups

Some groups are not normally distributed so we must use à non-parametric test. We can't analyse 3 independent variables together with a non-parametric test. We will use a variable with 8 levels Instead of 2 independent variables with 2 levels. The new independent variable is a combination of the 2 previous variables.

Water level/watering regime/substrate	Statistic test value	Shapiro-wilk sig.	distribution
1.5/15/R	0.939	0.600	Normally distributed
1.5/15/F	0.843	0.082	Normally distributed
1.5/8/R	0.782	0.180	Normally distributed

1.5/8/F	0.907	0.334	Normally distributed
2/8/R	0.865	0.135	Normally distributed
2/8/F	0.934	0.557	Normally distributed
2/15/R	0.817	0.044	Normally distributed
2/15/F	0.932	0.350	Normally distributed

Fig 83: normality test of the watering regime, substrate and water level groups

All the groups are normally distributed, so we can use a parametric test. We are going to use a one-way Anova.

One-way Anova:

H0: There is no differences between lettuces grew with different water level, substrate and watering regime

H1: There is differences between lettuces grew with different water level, substrate and watering regime

Pvalue= 0.05

Dof =7

F=53.305

Sig=0.000

pvalue > 0,05 so we can reject the null hypothesis

Tab of significance (Tukey test):

	1.5/15/R	**1.5/15/F**	**1.5/8/R**	**1.5/8/F**	**2/15/R**	**2/15/F**	**2/8/R**	**2/8/F**
1.5/15/R	/	0.000	0.072	1.000	0.000	0.009	1.000	0.995
1.5/15/F	/	/	0.000	0.000	0.000	0.000	0.000	0.000
1.5/8/R	/	/	/	0.072	0.000	0.000	0.072	0.009
1.5/8/F	/	/	/	/	0.000	0.009	1.000	0.995
2/15/R	/	/	/	/	/	0.009	0.000	0.000
2/15/F	/	/	/	/	/	/	0.009	0.072
2/8/R	/	/	/	/	/	/	/	0.995
2/8/F	/	/	/	/	/	/		/

Fig 84: Tukey tab of significance

When the sig is below 0.05 there is a difference between the 2 groups.

Statistical groups:

Group number	**1**	**2**	**3**	**4**	**5**
group	2/15/R	2/15/F 2/8/F	2/8/F 1.5/15/R 1.5/8/F 2/8/R	1.5/15/R 1.5/8/F 2/8/R 1.5/8/R	1.5/15/F

Fig 85: groups significantly equal

Thanks to the tukey test we can identify groups of data close enought to be considered as statistically identical. The lettuces with 2 cm of water level receiving water 15 times a day and growing in rockwool substrates showed the lowest germination rate. The best germination rate was obtained with lettuces grew with 1.5cm of water 15 watering per day in Foamplant substrates.

4) Discussion

Discussion of the results

As a reminder, this research aims to describe the lettuces growth, on a hydroponics system with Foamplant substrates, when exposed to different variations. The main objective is to determine the optimal watering regime and to find out the overall condition that favours a good optimization of the watering regime.

In the first experiment, Foamplant substrate in tray 1 receiving water 15 times per day showed a higher germination rate than Foamplant substrate in tray 1 receiving water 8 times per day. With 1.5 cm of water, lettuces grew with Foamplant substrate had a higher germination rate under 15 watering per day. With 8 watering per day, the germination rate seems to be lower for Foamplant substrate. However, there were more dead leaves among lettuces receiving water 15 times per day and a higher fungal development was observed. The substrates do not have enough time to dry, allowing the fungus to develop easily. Most of the fungus were found on the same trays, they developed on Rockwools substrates and then started spreading even on the Foamplants substrates. Without Rockwool substrates it is probable that the Foamplant substrates would never have developed fungal diseases. There are no significant differences in the number of leaves after 20 days of growth nor in the yields after 1 month. Some differences could be observed but without statistically significant differences. The high frequency of watering seems to be interesting only for the germination process, beyond this step it does not give significant advantages and may even increase the risks of diseases. Finally, we observed a consequent quantity of algae on the tray receiving water 15 times per day. The light reached the water more frequently and was absorbed by the algae.

Rockwool substrates reacted differently to the variation in the watering regime. They showed better results in germination with a low frequency of watering regime. Lettuces grew with Rockwool substrates had a higher germination rate than Foamplant substrates with 8 watering per day and 1.5 cm of water level and Foamplant showed a higher germination rate with 15 watering per day with 1.5 cm of water level. The difference can be explained because of Rockwool ability to stay wet. However, the overall best results were obtained with Foamplant and 15 watering per day.

No differences were found between the types of trays even though we expected the highest result with the tray 2, because of the bigger gaps between the substrates. (Lima et al., 2018)

The lettuces grew with Red+ Blue showed a lower germination rate than lettuces grew with tray Red+ Blue +far red. However, no combined effect was found between the watering regime and the light wavelength. It seems like the lettuce growing with additional far-red were less impacted than the others. This is confirmed by a study that demonstrated that Blue and far-red light could inhibit fungus spore germination. (Calpouzos and Chang,1971). However, the result obtained was not statistically significant it is therefore not possible to confirm this affirmation.

The water level had a quite significant impact on the overall lettuce's development. With a water level of 2 cm, the higher germination rate was obtained with 8 watering per day. This may be because the water level was high enough to cover the seeds and reduce oxygen availability. The lettuces receiving water 8 times per day may have been less affected by this issue.

The lettuces with 2 cm of water level receiving water 15 times a day and growing in Rockwool substrates showed the lowest germination rate. The best germination rate was obtained with lettuces grew with 1.5cm of water, 15 watering per day, and Foamplant substrates.

According to the available results, the best watering regime is 15 watering per day with 1.5 cm of water level, to get the best germination rate and 8 watering per day to limit the risks of diseases without impact on the total number of leaves.

Critical reflexion on the experiment

The relevance of this study lies in the fact it highlighted differences between different growing conditions. The company Foamplant is leading multiple other experiments and will keep assessing other growing conditions to establish a substantial data base. This study was the first step to determine the optimal growing condition to use Foamplant's substrates. However, some of the tests carried out did not show significant results.

The lack of repetition was certainly the main reason. However, having 3 repetitions inside each tray would not have been very useful since all the repetitions would undergo the same variation. Removing a variable to replace it with a repetition was not possible because of logistics issues explained in the experimental plan part. Also, the 2 repetitions are not identical they have a 2°C average temperature difference. This was problematic for the statistical accuracy even though no statistical differences were observed between the 2 levels.

The relative humidity also appears to be quite low. During the experiment, data logger were introduced in the container the average value was 38.7% this may have had an impact on the lettuce's growth.

The duration of this experimentation could also be restricting, indeed to assess different watering regime and repeat the experiment we would have needed more time. Due to the actual sanitary crisis, we had to shorten the length of the internship.

As a result of the methodology and the limits of this research, here are improvements that can be done for new research next year:

-The best option would have been to modify the growing structure to have 3 levels, but this would require buying new led lights.

-The experiment inside of the container should be stopped after 3 weeks to observe more lettuce cycle.

-The experiment should be carried out in a greenhouse after 3 weeks in the container, this would allow to see if the starting material impact the final harvest quality

-using only one type of light would allow more repetition however, this would require buying more led lights.

-The experiment should compare more water level since we observed a strong impact of this parameter

-Comparing more type of substrate with Foamplant would allow to have a better understanding of Foamplant's relative qualities.

Thus, with these improvements more data would be measured, and this would increase the reliability of the repetitions. These improvements could allow more reliable results and conclusions compared to this research.

5)Conclusion and recommendation

Conclusion

This writing was a research thesis about substrate in hydroponics production. The subject of the thesis was determining the optimal growing condition to exploit the new substrate produced by the company Foamplant. The main question was: What is the impact of different growing conditions on lettuce grown with Foamplant substrate? Thus, the main objective of this research was to describe the lettuces growth with different growing condition in order to determine the more adequate for large-scale production.

The results of this research showed that the optimal watering regime was 15 per day with 1.5 cm of water level, to get the best germination rate and 8 times per day to limit the quantity of dead leaves fungus, and parasite algae.

According to the results, the Foamplant substrate can be a serious alternative to the Rockwool substrates. This would allow to produce lettuce with less impact on the environment and without impacting the performances.

Recommendation

The hypothetical best recommendation would then be to reduce the frequency of watering after the seed's germination in order to benefit from all the advantages from both watering regimes. Despite Foamplant substrates requiring a high frequency of watering, the results are encouraging. This experimentation was only a first step, others watering regime and general growing condition need to be assessed to have a large vision of the substrate capacity.

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