Rit LbhÍ nr. 55

„Áhrif milliplöntunar, afblöðunar og grisjunar á vöxt, uppskeru og gæði gróðurhúsatómata“

FINAL REPORT

Christina Stadler

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Landbúnaðarháskóli Íslands

December 2014

Final report of the research project
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Abbreviations

DM	dry matter yield
DS	dry substance
E.C.	electrical conductivity
HPS	high-pressure vapour sodium lamps
kWh	kilo Watt hour
LAI	leaf area index
N	nitrogen
pH	potential of hydrogen
ppm	parts per million
W	Watt
Wh	Watt hours

Other abbreviations are explained in the text.

1 SUMMARY

In Iceland, winter production of greenhouse crops is totally dependent on supplementary lighting and has the potential to extend seasonal limits and replace imports during the winter months. Adequate guidelines for increasing yield are not yet in place for tomato production and need to be developed. The objective of this study was to test if interplanting, deleafing and pruning the clusters are affecting growth, yield and quality of tomatoes and to evaluate the profit margin.

Two experiments with grafted tomatoes (*Lycopersicon esculentum* Mill. cv. Encore) were conducted, the first (A) from October to the middle of January and the second (B) from the middle of January to the middle of June 2014, in the experimental greenhouse of the Agricultural University of Iceland at Reykir. Tomatoes were grown in pumice in four replicates with 2,66 tops/m^2 with two tops per plant under high-pressure vapour sodium lamps (HPS, 240 W/m^2) for a maximum of 18 hours light. The daytemperature was 21,5℃ and the night tempera ture 18℃, CO_2 800 ppm. Tomatoes received standard nutrition through drip irrigation.

In part A was the effect of pruning the clusters and deleafing tested and the profit margin calculated, in part B was the effect of interplanting and deleafing tested and the profit margin calculated.

Pruning of the clusters had an effect on marketable yield, the harvest was 10 % less. The average fruit weight was higher with pruning the clusters, but the amount of harvested fruits was lower. More fruits were classified as first class fruits after pruning the clusters and too small fruits were decreased.

Fruits from the treatment without interplanting were harvested about one week earlier and with longer growing period increased the yield (35 kg/m^2) more than with interplanting (30 kg/m^2), which was a significant difference. But, without interplanting could no fruits be harved during the time the old plants were moved out of the greenhouse and the new plants started to give the first harvest, which was about 8 weeks without harvest. However, with interplanting was no harvest break, but the first harvest was deleayed by one week compared with no interplanting. Therefore, was the additional harvest with interplanting about 7 weeks and gave about 14 kg/m^2 when calculated with 2 kg/m^2 per week. That means that the yield reached about 45 kg/m^2 with interplanting compared to 35 kg/m^2 without interplanting, which was statistically significant. The development of the yield over a longer time (2 years)

would be 15 % more with „interplanting“ if assumed that the tomatoes would be harvested for six months before new plants would be planted.

With interplanting and much deleafing increased the yield up to 10 % in addition: In part B was the yield with much deleafing more than 45 kg/m^2, but was about 5 kg/m^2 less with normal deleafing and statistically significant. The reason for the higher yield with much deleafing was an increased average fruit weight and more fruits in the 1st class. However, in part A was the yield 25 kg/m^2 with both treatments. The average fruit weight was the same and also the number of harvested fruits in 1st and 2nd class. The reason for the contrasting results was due to earlier and longer (also during the first part of harvest) deleafing in part B. The difference in yield was visible after 8 weeks after the first treatment and continued the time the treatment lasted. The shorter deleafing in part A did not increase the yield. Most fruits were classified as 1st class fruits with much deleafing and the amount in the 2nd classs was smaller than with normal deleafing.

Marketable yield was 85-86 % of total yield in part A and 91-94% in part B. In all treatments were eight fruits per cluster counted, except when clusters were pruned was about one fruit less was. Not pollinated fruits were few or about one fruits per two clusters. Nearly no unpolluninated fruit was counted when clusters were pruned (A) and less without interplanting than with interplanting (B).

Without pruning clusters increased the yield by 10 % and the profit margin by 1.100 ISK/m^2. When interplanting was done, increased the yield by 10 % (and by 15 % over a longer time) and the profit margin by 3.400 ISK/m^2. When much deleafing was done instead of normal deleafing increased the yield by 10 % and the profit margin by 1.400 ISK/m^2. A higher tariff did not change profit margin. Also, the position of the greenhouse (urban, rural) did not influence profit margin.

Possible recommendations for saving costs other than lowering the electricity costs are discussed. From an economic viewpoint it is recommended not to prune grafted tomatoes, to use interplanting (when no diseases are in the greenhouse) and start soon to deleaf much and continue with it longer than until the first harvest to be able to increase yield and profit margin.

YFIRLIT

Vetrarræktun í gróðurhúsum á Íslandi er algjörlega háð aukalýsingu. Viðbótarlýsing getur því lengt uppskerutímann og komið í stað innflutnings að vetri til. Fullnægjandi leiðbeiningar vegna ræktunar á tómötum eru ekki til staðar og þarfnast frekari þróunar. Markmiðin voru að prófa, hvort milliplöntun, afblöðun og grisjun hefðu áhrif á vöxt, uppskeru og gæði tómata og hvort það væri hagkvæmt.

Gerðar voru tvær tilraunir með ágrædda tómata (*Lycopersicon esculentum* Mill. cv. Encore), sú fyrri (A) október 2013 til miðs janúar 2014 og sú síðari (B) frá miðjum janúar til miðs júní 2014, í tilraunagróðurhúsi Landbúnaðarháskóla Íslands að Reykjum. Tómatarnir voru ræktaðir í vikri í fjórum endurtekningum með 2,66 toppa/m^2 með tvo toppa á plöntu undir topplýsingu frá háþrýsti-natríumlömpum (HPS, 240 W/m^2) að hámarki í 18 klst. Daghiti var 21,5℃ og nætur hiti 18℃, CO_2 800 ppm. Tómatarnir fengu næringu með dropavökvun.

Í hluta A voru áhrif grisjunar og afblöðunar prófuð og framlegð reiknuð út, í hluta B voru áhrif milliplöntunar og afblöðunar prófuð og framlegð reiknuð út.

Grisjun hafði áhrif á söluhæfa uppskeru, uppskerumagn var 10 % minna. Meðalþyngd aldina var eitthvað hærri með grisjun en fjöldi uppskorinna aldina var lægri. Fleiri aldin fara í fyrsta flokk eftir grisjun en þegar ekki var grisjað og lítil aldin voru fæst.

Í upphafi uppskerutímabils byrjaði meðferð án milliplöntunar einni viku fyrr að gefa uppskeru og þegar leið á vaxtartímabilið jókst uppskera mun meira en með milliplöntun. Þannig fengust 35 kg/m^2 án milliplöntunar en 30 kg/m^2 með milliplöntun sem var tölfræðilega marktækur munur. En án milliplöntunar var engin uppskera frá því að gömlu plöntunar eru teknar út úr húsi og þar til nýju plönturnar gáfu fyrstu uppskeru, sem var um 8 vikur án uppskeru. Við milliplöntun var alltaf uppskorið en fyrstu uppskeru seinkað um eina viku borið saman við enga milliplöntun, því var aukauppskeran með milliplöntun í um 7 vikur og gefur um 14 kg/m^2 ef reiknað er með 2 kg/m^2 á viku. Það þýðir að uppskera var um 45 kg/m^2 með milliplöntun borið saman við 35 kg/m^2 án milliplöntunar sem er tölfræðilega marktækt. Þróun uppskeru yfir lengra tímabil (2 ár) væri 15 % meiri með „milli-plöntun“ ef gert er ráð fyrir að tómatar séu uppskornir í sex mánuði áður en gróðursett er aftur.

Einnig var prófuð milliplöntun og mikill afblöðun og jókst þá uppskeran um allt að 10 % til viðbótar: Í hluta B var uppskeran við mikil afblöðun komin yfir 45 kg/m^2 en var um 5 kg/m^2 minna með hefðbundinni afblöðun, sem var marktækur munur. Ástæðan fyrir meiri uppskeru við mikil afblöðun var aukin meðalþyngd og fleiri aldin í 1. flokki. En í hluta A var uppskeran 25 kg/m^2 í báðum meðferðum. Meðalþyngd var hin sama og einnig fjöldi aldina í 1. og 2. flokki. Ástæðan fyrir andstæðum niðurstöðum var að fyrr var byrjað að afblaða og afblöðun stóð lengur og alveg fram yfir byrjun uppskeru í hluta B. Munurinn í uppskeru var sýnilegur um 8 vikum eftir fyrstu meðferð og hélst þann tíma sem meðferð stóð. En styttri afblöðun í hluta A jók uppskeru ekkert. Flest aldin fóru í 1. flokk við mikla afblöðun og hluti í 2. flokki tiltölulega lítill í samanburði við hefðbundna afblöðun.

Hlutfall uppskerunnar sem hægt var að selja var 85-86 % í hluta A og 91-94% í hluta B. Í öllum meðferðum fengust átta aldin af klasa nema fyrir grisjun sem var um einu aldini færra. Ófrjóvguð aldin voru fá eða tæplega eitt aldin á hverja tvo klasa. Nánast engin ófrjóvguð aldin voru við grisjun (A) og heldur færri við enga milliplöntun en með milliplöntun (B).

Þegar klasarnir eru ekki grisjaðir, þá jókst uppskera um 10 % og framlegð um 1.100 ISK/m^2. Þegar milliplöntun var notuð, þá jókst uppskera um 10 % (og um 15 % yfir lengri tíma) og framlegð um 3.400 ISK/m^2. Ef afblöðun fer úr hefðbundinni í mikla jókst uppskera um 10 % og framlegðin um 1.400 ISK/m^2. Hærri rafmagnsgjaldskrá breytir framlegð næstum ekkert. Það skiptir ekki máli hvort gróðurhús er staðsett í þéttbýli eða dreifbýli, framlegð er svipuð.

Möguleikar til að minnka kostnað, aðrir en að lækka rafmagnskostnað eru ræddir. Frá hagkvæmnisjónarmiði er mælt með því að grisja ágrædda tómata ekki, nota milliplöntun (ef sjúkdómar eru ekki í gróðurhúsi) og byrja snemma að afblaða mikið og gera það fram yfir byrjun uppskeru til að auka uppskeru og framlegð.

2 INTRODUCTION

The extremely low natural light level is the major limiting factor for winter greenhouse production in Iceland and other northern regions. Therefore, supplementary lighting is essential to maintain year-round vegetable production. This could replace imports from lower latitudes during the winter months and make domestic vegetables even more valuable for the consumer market.

The positive influence of artificial lighting on plant growth, yield and quality of tomatoes (*Demers* et al., 1998a), cucumbers (*Hao* & *Papadopoulos*, 1999) and sweet pepper (*Demers* et al., 1998b) has been well studied. It is often assumed that an increment in light intensity results in the same yield increase. Indeed, yield of sweet pepper in the experimental greenhouse of the Agricultural University of Iceland at Reykir increased with light intensity (*Stadler* et al., 2010). However, with tomatoes, a higher light intensity resulted not (*Stadler*, 2012) or in only a slightly higher yield (*Stadler*, 2013a). "Encore" is one of the most common tomato varieties that is grown in Iceland. So far, mostly ungrafted plants of „Encore" are planted. Only in few icelandic nurseries are grafted tomatoes used. However, in the literature is grafting considered as positive (e.g. *Kowalczyk* & *Gajc-Wolska*, 2011) and also first experiments in Iceland showed a yield increase by using grafted tomatoes compared to ungrafted tomatoes (*Stadler*, 2013b).

Environmental conditions and the tending strategy are expected to have an impact on the growth of the plants. Plants can be too vegetative or too generative often due to environmental conditions. Plants can be kept in balance or steered back in the required direction by changing light, temperature, humidity, CO_2, irrigation, nutrition and plant management. Plants become vegetative in favourable, mild growing conditions and generative in harsh growing conditions. Determining the plant balance requires accurate observation of the plants, which is reached by weekly crop registration (*Houter* et al., 2007a; *Houter* et al., 2007b). The amount of leaves on a plant and the growth stage when leaves are taken from the plant can influence the growth of the tomato plant and will therefore be further investigated.

It can also be expected that interplanting is influencing the growth of the plants. Interplanting is done with the purpose of never having a gap between harvests by planting the new plants in between the old plants. This is done about eight weeks before the old plants are stopping to give tomatoes. The young plants will be ready to give harvest when the harvest of the old tomato plants has ended. Interplanting is involving the risk of young plants staying in the shadow of the old plants and therefore getting less light and the young plants will not be able to get more light before the old plants are thrown out of the greenhouse. Therefore, it has to be tested if interplanting is giving a higher yield than without interplanting.

The last tomatoes on a cluster are oft staying small and are because of that classified as not marketable fruits (*Stadler*, 2013b). Therefore, the question is if the yield can be increased by pruning the clusters to eight tomatoes.

Incorporating interplanting, deleafing and pruning into a production strategy is an economic decision involving added costs versus potential returns. Therefore, the question arises whether these factors are leading to an appropriate yield of fruits. Also, the profit margin of the horticultural crop was considered.

The objective of this study was to test if (1) interplanting, the form of deleafing and pruning of clusters are affecting growth, yield and quality of tomatoes, if (2) these parameters are converted efficiently into yield, and if (3) the profit margin can be improved by interplanting, deleafing and pruning of clusters. This study should enable to strengthen the knowledge on the best method of growing tomatoes and give vegetable growers advice how to improve their tomato production by modifying the efficiency of tomato production.

3 MATERIALS AND METHODS

3.1 Greenhouse experiment

An experiment with grafted tomatoes (*Lycopersicon esculentum* Mill. cv. Encore), interplanting, different forms of deleafing and pruning of clusters was conducted at the Agricultural University of Iceland at Reykir.

Seeds of tomatoes were sown on 18.06.2013 in rock wool plugs. On 29.07 were four plants of ungrafted tomatoes planted into 18 l pots filled with pumice stones. Six pots were placed on each bed in two chambers. These plants were used to produce later shadow for grafted plants (sown on 14.08.2013, rootstock Maxifort, 2 tops/plant and 2 plants/pot) that were interplanted between these old plants on 02.10.2013. In addition, were plants also planted in an empty chamber.

Tomatoes were transplanted in rows in four 70 cm high beds (Fig. 1) with 2,66 tops/m^2. Beds were equipped with 6 pots respectively 24 tops. Four replicates, one replicate in each bed consisting of two pots (8 tops) acted as subplots for measurements. Other pots were not measured. Do to the weekly hanging down were all plants once at the end of the bed.

However, due to wrong settings of the different chambers did the interplanting plants not develop as planned. The plants were stretched and nearly now clusters had developed. Therefore, it was decided to continue only with the chambers with no interplanting until cluster 16 (middle of January) and repeat the chambers with interplanting. Then the old plants from two chambers were used in the interplanting chamber and new plants planted on 13.01.2014 between and also in one empty chamber for the treatment without interplanting. The old plants were topped 14 days before the interplanting was taking place and laid down under the tops of the new plants three days after interplanting. The old plants were deleafed two clusters higher than the cluster that is harvested from and the plants were removed after all fruits ripened. The experiment with the new plants ended in middle of June. That means, two experiments were conducted: In the first experiment (part A) was the effect of pruning and deleafing tested and in the second experiment (part B) the effect of interplanting and deleafing (see chapter “3.2 Treatments”).

Wires were placed in about 3,56 m height from the floor with each 90 cm distance between floors and beds. Bumblebees were used for pollination and hives were open from 11.00-14.00. Hives were replaced every two to three weeks.

The first 3-4 days was the temperature set on 21,5°C during day and 20℃ during night and later on 21,5 ℃ / 18 ℃ (day / night). C arbon dioxide was provided (800 ppm CO_2 with no ventilation and 400 ppm CO_2 with ventilation). A misting system was installed. Plant protection was managed by beneficial organisms and if necessary with insecticides.

Fig. 1: Experimental design of cabinets.

Tomatoes received standard nutrition consisting of "Pioner Basis 6-4-30 + Mg" (AZELIS) until 29.11.2013 according to the following fertilizer plan (Tab. 1a) and after that the fertilizer mixture in Tab. 1b was used.

Tab. 1a: Fertilizer mixture according to advice from Azelis.

Fertilizer (amount in kg)	Stem solution A (1000 l)		Stem solution B (1000 l)				Irrigation water		Runoff water
	Calcium nitrate	Nitrogen acid	Pioner Basis 6-4-30 + Mg	Magnesium sulphate	Pioner Iron Chelate EDDHA 6 %	Resistim (as required)	E.C. (mS/cm)	pH	pH
Planting – flower ing on 3. truss	100	as required	100	12,5		10	2,6-3,2	5,2-5,5	5,7-5,9
Flowering on 3. truss – topping	100	as required	125		0,5	10-20	2,4-3,0	5,2-5,5	5,7-5,9

Tab. 1b: Fertilizer mixture according to advice from Magnús.

Normal mixture in 200 l stem sulution (amount in kg, micronutrients in g)	Stem solution A (1000 l)					Stem solution B (1000 l)						
	Calciumnitrate	Potassium nitrate	Iron chelate 6 %	Potassium sulfate	Magnesium sulfate	Monopotassium phosphate	Potassium nitrate	Mangansúlfat	Borax	Koparsúlfat	Zinksúlfat	Natriummolybdat
Planting – flower ing on 3. truss	20	5	0,6	0	7,5	4	7,5	38	76	4	19	2,6
Flowering on 3. truss – 6. cluster	20	6	0,5	0	7,5	3,4	10	38	60	4	19	2,6
Flowering on 6. cluster – 9. cluster	17,5	6	0,5	1,6	7,5	3,4	10	38	60	4	19	2,6
Flowering on 9. cluster – topping	20	6	0,5	1,8	7,5	3,4	10	38	60	4	19	2,6
Topping – end	16	6	0,5	1,8	7,5	3,4	10	38	60	4	19	2,6

Plants were irrigated through drip irrigation (4 tubes per bucket). The watering was set up that the plants could root well down, which means a low amount of run off in the first 2-3 weeks. The pumice was watered with an E.C. of 3,5 in the beginning, E.C. 3,5-4,5 in the first 4 weeks and after that E.C. 2,6-3,5 depending on the E.C. of the runoff.

Only few information are available regarding the time of irrigation, the duration between irrigations and the duration of irrigation (see appendix).

3.2 Treatments

Tomatoes from Part A were grown from 02.10.2013 until 13.01.2014 and tomatoes from Part B from 13.01.2014 until 12.06.2014 under high-pressure sodium lamps (HPS) for top lighting in cabinets at the Agricultural University of Iceland in Reykir:

Part A:

1. HPS top lighting 240 W/m^2 + grafted Encore, no interplanting, normal deleafing, pruning of clusters
   normal deleafing, pruning of clusters
2. HPS top lighting 240 W/m^2 + grafted Encore, no interplanting, normal deleafing, no pruning of clusters
   normal deleafing, no pruning of clusters
3. HPS top lighting 240 W/m^2 + grafted Encore, no interplanting, much deleafing, no pruning of clusters
   much deleafing, no pruning of clusters

Part B:

1. HPS top lighting 240 W/m^2 + grafted Encore, interplanting, normal deleafing, no pruning of clusters
   interplanting, normal deleafing
2. HPS top lighting 240 W/m^2 + grafted Encore, no interplanting, normal deleafing, no pruning of clusters
   no interplanting, normal deleafing
3. HPS top lighting 240 W/m^2 + grafted Encore, interplanting, much deleafing, no pruning of clusters
   interplanting, much deleafing

All double clusters were taken away and in addition clusters were pruned to eight fruits (but the first three clusters only to six fruits) in the treatment "pruning of clusters".

"Normal deafing" means that 2-3 leafes were taken each week. All leaves below the 1st cluster were taken (in two steps) before the first harvest and all leaves below the 2nd cluster were taken when the 8th cluster flowered. "Much deleafing" means that leaves were taken as normal, but when the 3rd cluster flowered, one leaf behind this cluster was taken and two leaves from the bottom. When the 4th cluster flowered was the leaf behind that cluster taken and two leaves from the bottom. When the 5th cluster flowered was the leaf behind this cluster taken and two leaves from the bottom. When the 6th cluster flowered was the leaf behind this cluster taken and two leaves from the bottom and from then on the deleafing was decided depending on how the plants were looking.

HPS lamps for top lighting (600 W bulbs) were mounted horizontally over the canopy. Light (240 W/m^2) was provided for 0-18 hours, depending on solar irradiation and age of plants. Plants from part B received 18 h light from the beginning, shortened to 16 h in the middle of February und 14 h in the middle of March and 12 h in the middle of April. The lamps were automatically turned off when incoming illuminance was above the desired set-point.

3.3 Measurements, sampling and analyses

Soil temperature was measured once a week.

The amount of fertilization water (input and runoff) was measured every day and regularly analyzed for nutrients.

To be able to determine plant development, the height of plants was measured each week and the number of clusters was counted and the distance of clusters measured. In addition, in all cabinets were ten plants measured and regarding the growth (vegetative/generative) was acted on environmental factors and tending strategies. Measurements included diameter of head, length growth, leaf length, flowering cluster, total fruit on plant per stem, highest cluster and harvested cluster.

Yield (fresh and dry biomass) of seedlings and their N content was analyzed. During the growth period, fruits were regularly collected (2-3 times per week) in the subplots.

Total fresh yield, number of fruits, fruit category (A-class (> 55 mm), B-class (45-55 mm) and not marketable fruits (too little fruits (< 45 mm), fruits with blossom end rot) was determined. Additional samplings included samples from pruning during the growth period. At the end of the growth period on each plant from the subplots the number of immature fruits was counted. The aboveground biomass of these plants was harvested and divided into immature green fruits and shoots. For all plant parts, fresh biomass weight was determined and subsamples were dried at 105 ° C for 24 h for total dry matter yield (DM). Dry samples were milled and N content was analyzed according to the DUMAS method (varioMax CN, Macro Elementar Analyser, ELEMENTAR ANALYSENSYSTEME GmbH, Hanau, Germany).

The interior quality of fruits was determined. A brix meter (Pocket Refractometer PAL-1, ATAGO, Tokyo, Japan) was used to measure sugar content in fruits at the beginning, in the middle and at the end of the growth period. From the same harvest, the flavour of fresh fruits was examined in tasting experiments with untrained assessors.

Energy use efficiency (total cumulative yield in weight per kWh) and costs for lighting per kg yield were calculated for economic evaluation.

3.4 Statistical analyses

SAS Version 9.4 was used for statistical evaluations. The results were subjected to one-way analyses of variance with the significance of the means tested with a Tukey/Kramer HSD-test at $p \leq 0{,}05$.

4 RESULTS

4.1 Environmental conditions for growing

4.1.1 Solar irradiation

Solar irradiation was allowed to come into the greenhouse. Therefore, incoming solar irradiation is affecting plant development and was regularly measured. The natural light level decreased after transplanting into the cabinets continuously to < 5 kWh/m^2 and was staying at this value to the beginning of March 2014. However, with longer days solar irradiation increased naturally continuously to > 10 kWh/m^2 at the middle of April 2014 (Fig. 2).

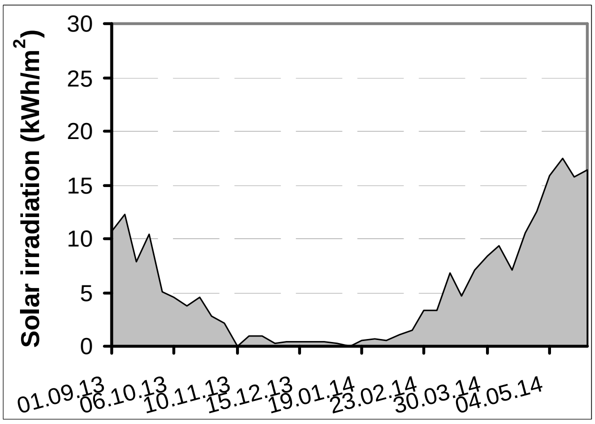


Fig. 2: Time course of solar irradiation. Solar irradiation was measured every day and values for one week were cumulated.

4.1.3 Soil temperature

Soil temperature was measured weekly at low solar radiation in the morning (at about 08.30). Soil temperature stayed most of the time between 20-22°C (Fig. 3).

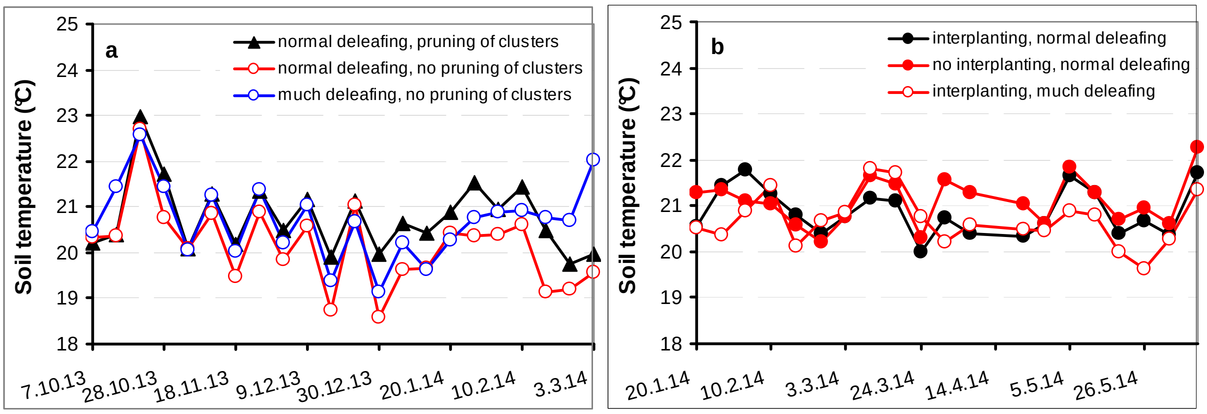


Fig. 3: Soil temperature for part A (a) and part B (b). The soil temperature was measured at little solar irradiation early in the morning.

4.1.4 Irrigation of tomatoes

The amount of applied water varied most of the time between 4 and 10 l/m^2 (Fig. 4). By calculating the daily applied water rate per months (Fig. 5) it is getting obvious that the treatment “interplanting, normal deleafing” was watered less than the other two treatments (Fig. 5b).

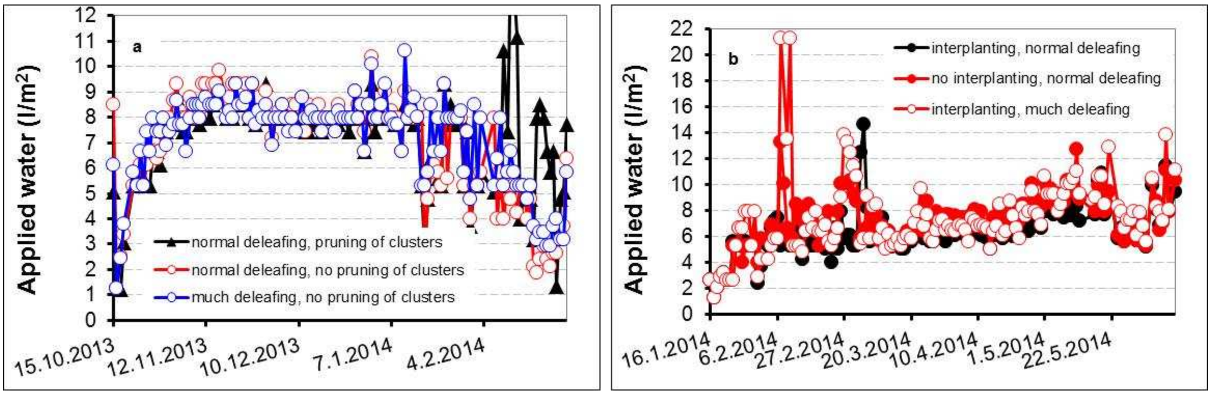


Fig. 4: Daily applied water for part A (a) and part B (b).

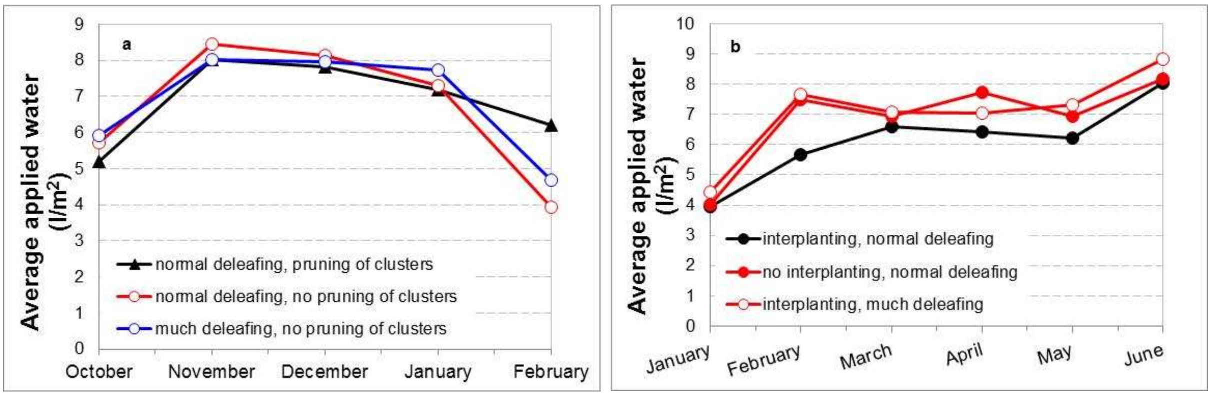


Fig. 5: Average daily applied water for part A (a) and part B (b).

E.C. and pH of irrigation water was fluctuating much (Fig. 6a, b). E.C. of applied water ranged most of the time between 2,4 and 3,8 and pH between 4,8 and 6,0.

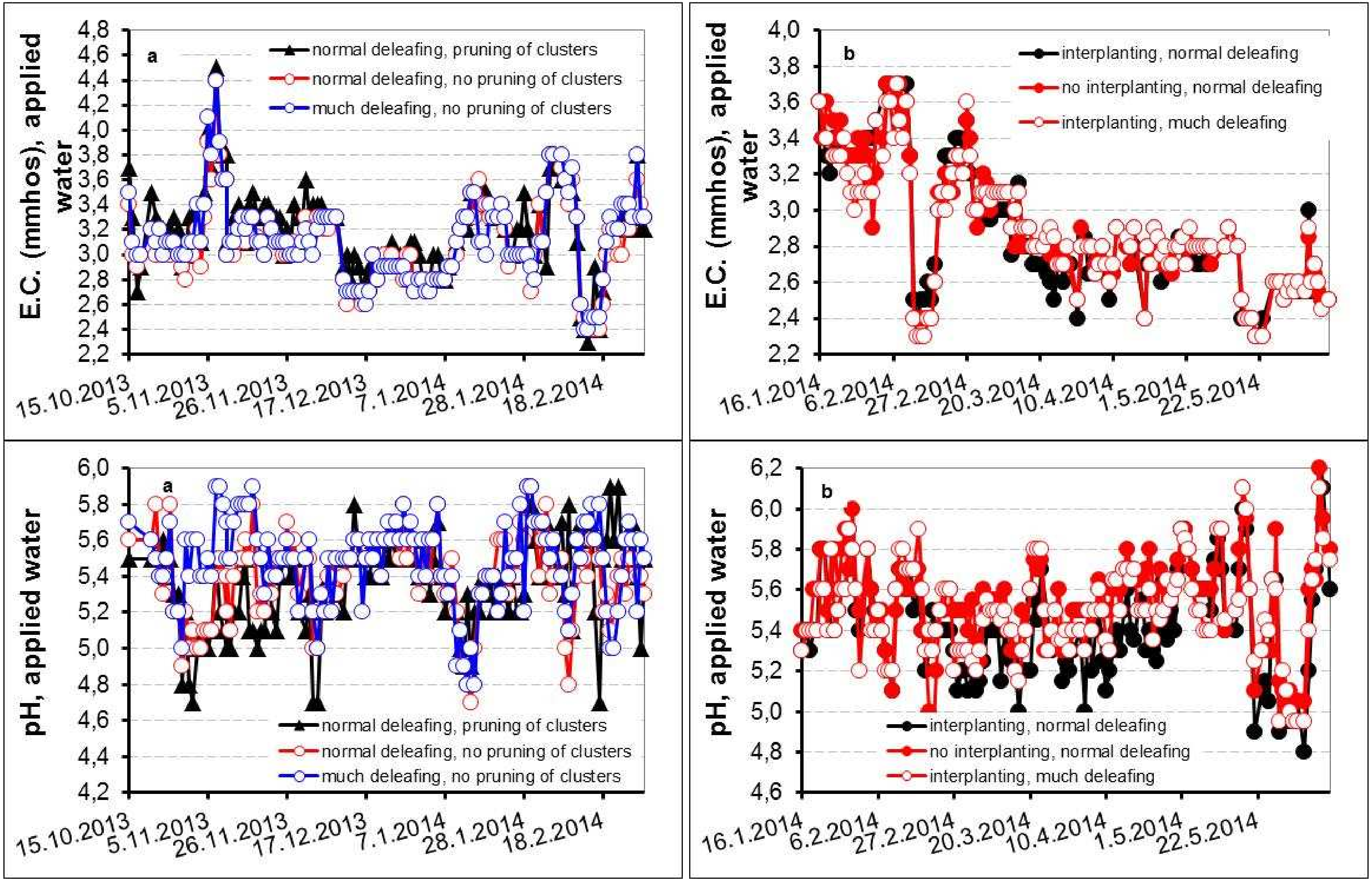


Fig. 6: **E.C. and pH of irrigation water for part A (a) and part B (b).**

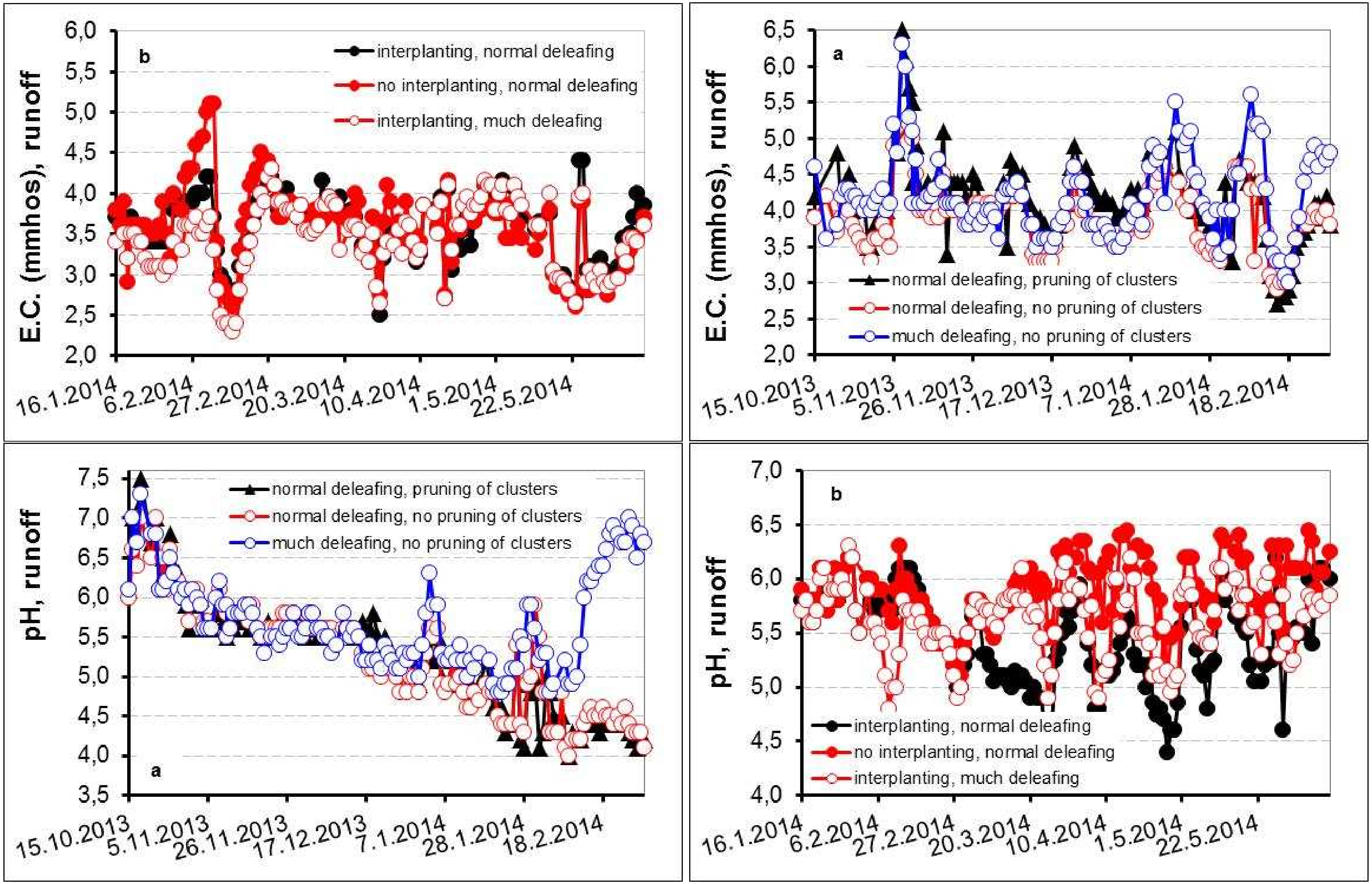


Fig. 7: **E.C. and pH of runoff of irrigation water for part A (a) and part B (b).**

E.C. of runoff stayed mostly between 3,0 and 5,5 and the pH of runoff most of the time between 4,5-5,5. In part A, the pH of runoff seems to decrease during the growth period from about 7,0 to 4,0, but for the treatment “much deleafing, no pruning of clusters” the pH increased at the end of the growth period (Fig. 7a). In part B, the pH of runoff seems to be highest for the treatment “no interplanting, normal deleafing” (Fig. 7b).

The amount of runoff from applied irrigation water was about 20-60 % (Fig. 8). It seems to be lowest at the end of the growth period for “much deleafing, no pruning of clusters” in part A (Fig. 8a).

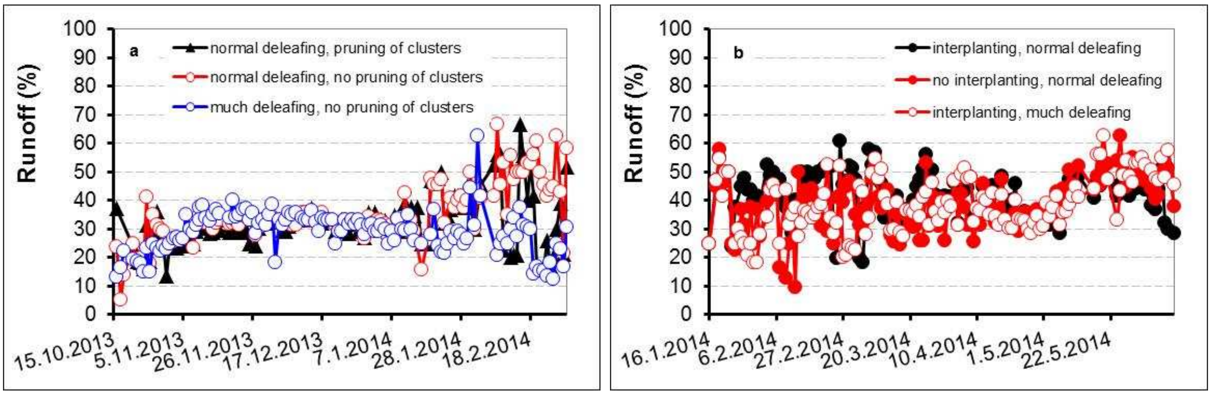


Fig. 8: Proportion of amount of runoff from applied irrigation water for part A (a) and part B (b).

Monthly taken water samples from the drip and the runoff water provide an information basis on which nutrients are close to the target of the drain water. In part A, all chambers showed a high Cu content on the 21.11.2013. In part B the treatment “no interplanting, normal deleafing” showed a low P content on 10.04.2014 (data not shown).

Plants took up to 8 l/m^2. It seems that plants took up less water in the treatment “interplanting, normal deleafing” (Fig. 9).

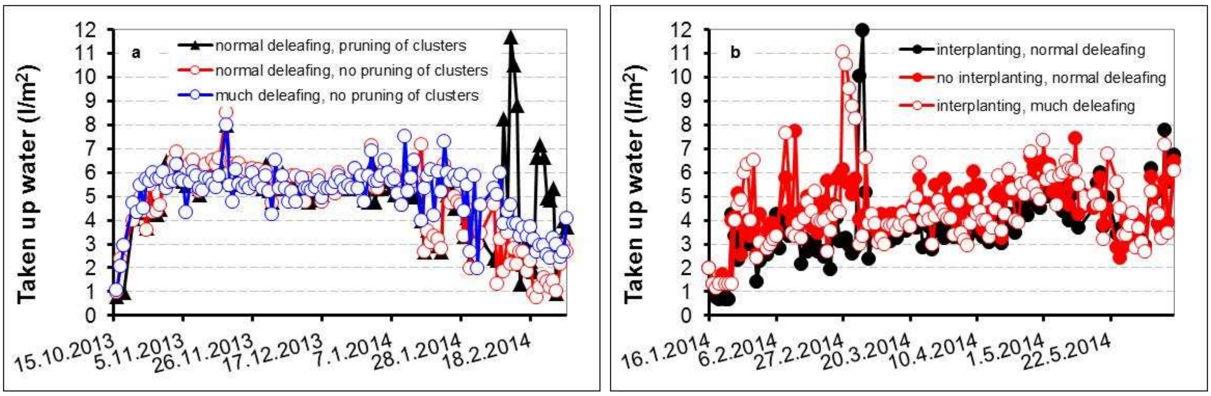


Fig. 9: Water uptake for part A (a) and part B (b).

4.2 Development of tomatoes

4.2.1 Height

Tomato plants were growing about 2-4 cm per day and reached at the end of the experiment about 3 m (Fig. 10). Plants in the treatment “normal deleafing, pruning of clusters” were growing significantly taller than plants in the treatment “normal deleafing, no pruning of clusters” (Fig. 10a). There were no statistically differences in part B (Fig. 10b).

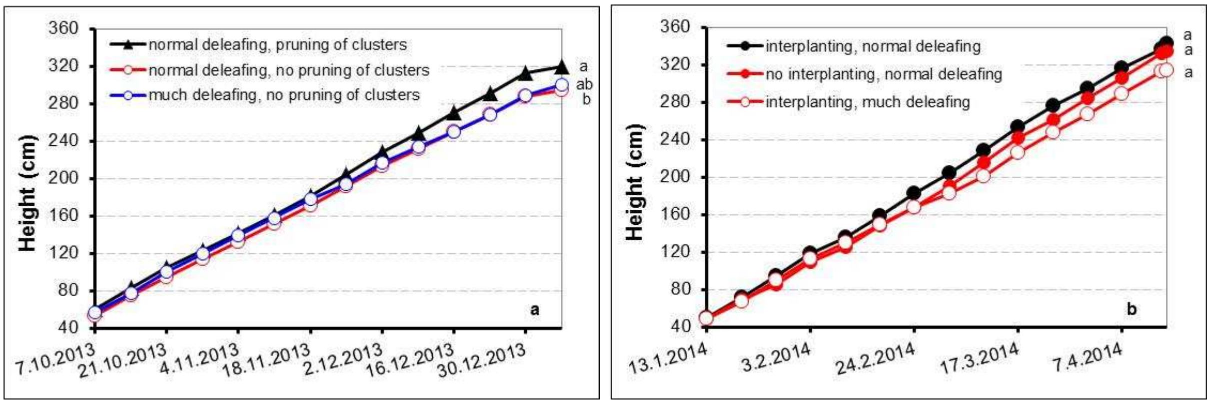


Fig. 10: Height of tomatoes for part A (a) and part B (b).

Letters indicate significant differences at the end of the experiment (HSD, $p \leq 0,05$).

4.2.2 Number of clusters

The number of clusters increased with approximately one additional cluster per week, with no statistically differences in the number of clusters between treatments (Fig. 11a, Fig. 11b).

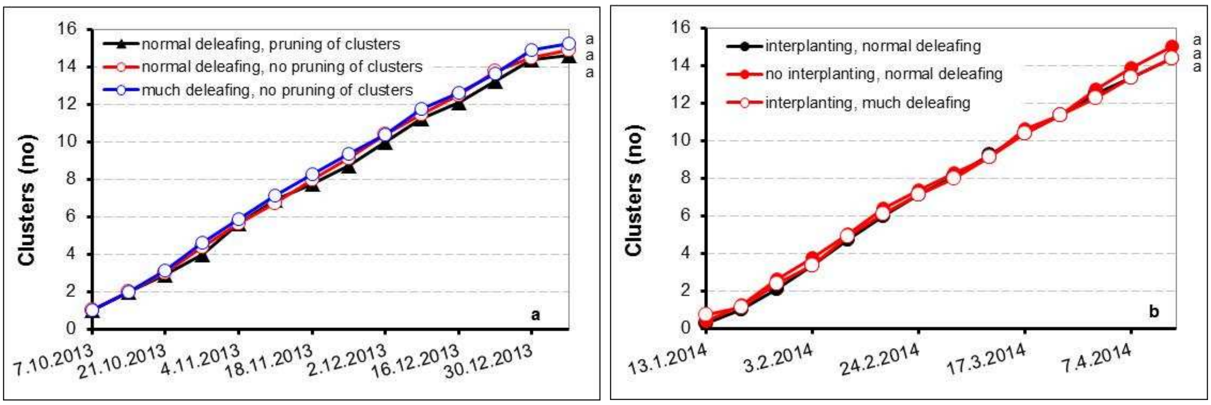


Fig. 11: Number of clusters for part A (a) and part B (b).

Letters indicate significant differences at the end of the experiment (HSD, $p \leq 0,05$).

4.2.3 Distance between clusters

The distance between clusters was regularly measured and stayed most of the time between 17-19 cm for part A and 18-21 for part B (Fig. 12).

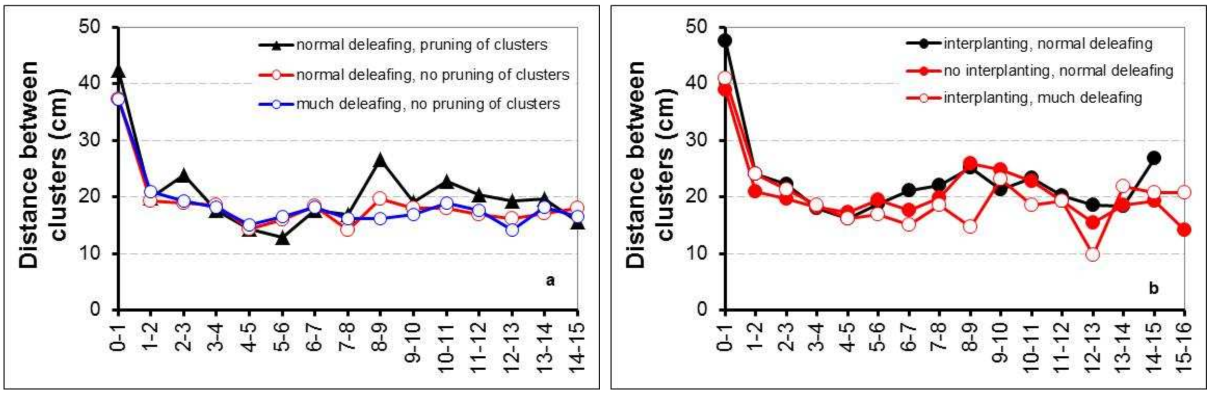


Fig. 12: Average distance between clusters for part A (a) and part B (b).

4.2.4 Fruits per cluster

Fruits per cluster fluctuated much (Fig. 13) and amounted 6-10. In average, plants that were pruned to six respectively eight fruits had about one fruit less compared to the other treatments (Fig. 13a).

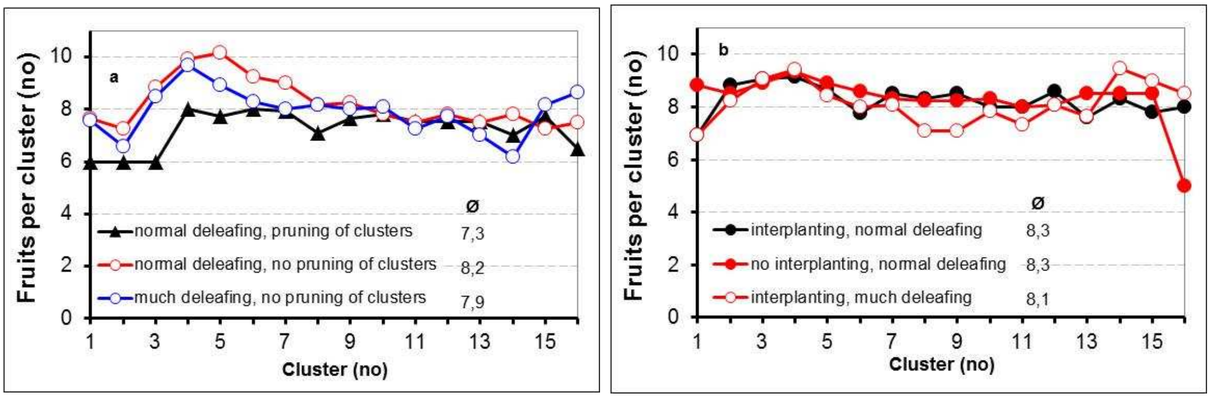


Fig. 13: Fruits per cluster for part A (a) and part B (b).

The number of not pollinated fruits per cluster was in general low. Less not pollinated fruits (nearly 0 fruits) were detected in the cabinet where fruits were pruned to six or eight fruits (Fig. 14a). It seems that interplanting increased the number of not pollinated fruits (Fig. 14b).

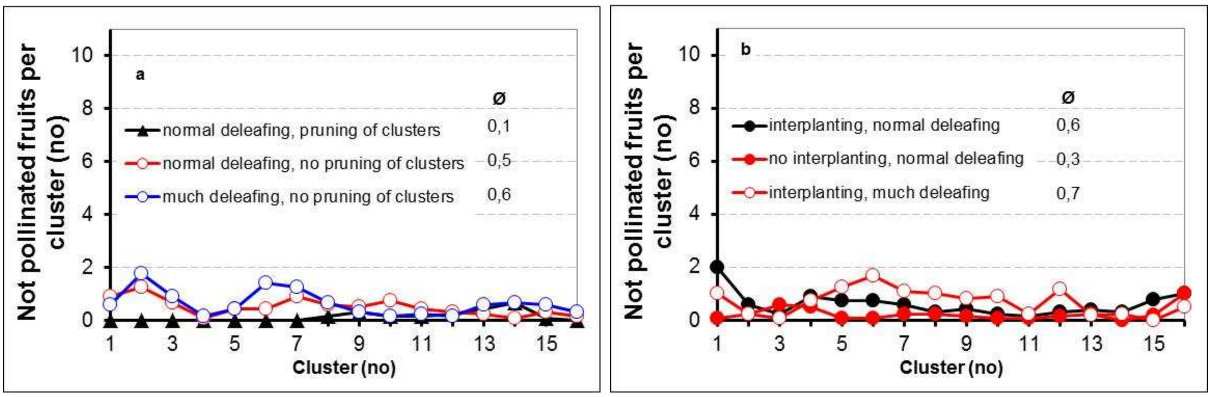


Fig. 14: Not pollinated fruits per cluster for part A (a) and part B (b).

4.2.5 Weekly measurements

Lengths of leaves decreased until the end of the experiment from about 44 to about 34 cm in part A (Fig. 15a). When leaves were taken early (treatment “much deleafing, no pruning of clusters”) length of leaves was decreased. However, this was not observed in part B, where the treatment “interplanting, much deleafing” seems to have even longer leaves compared to the treatment “interplanting, normal deleafing” (Fig. 15b).

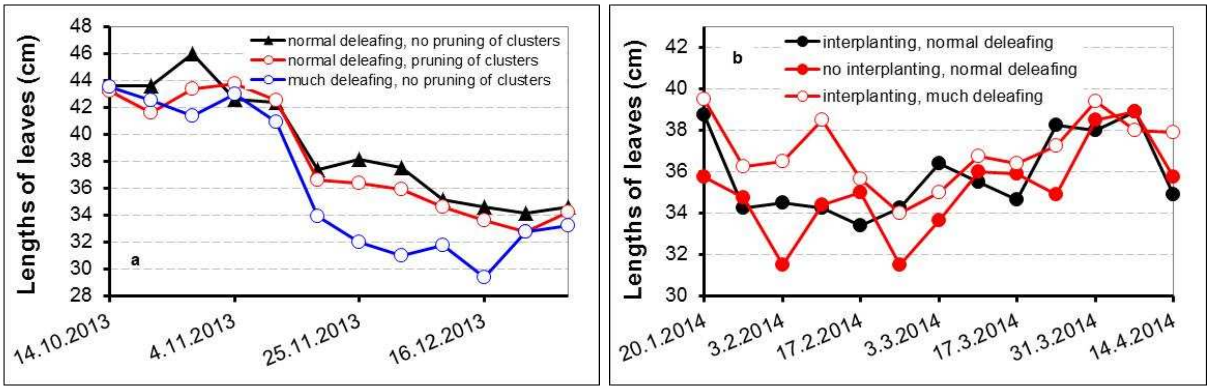


Fig. 15: Length of leaves for part A (a) and part B (b).

All treatments were growing each week in average 19-21 cm (Fig. 16). When the average is observed, no differences in the weekly growth of tomatoes were detected.

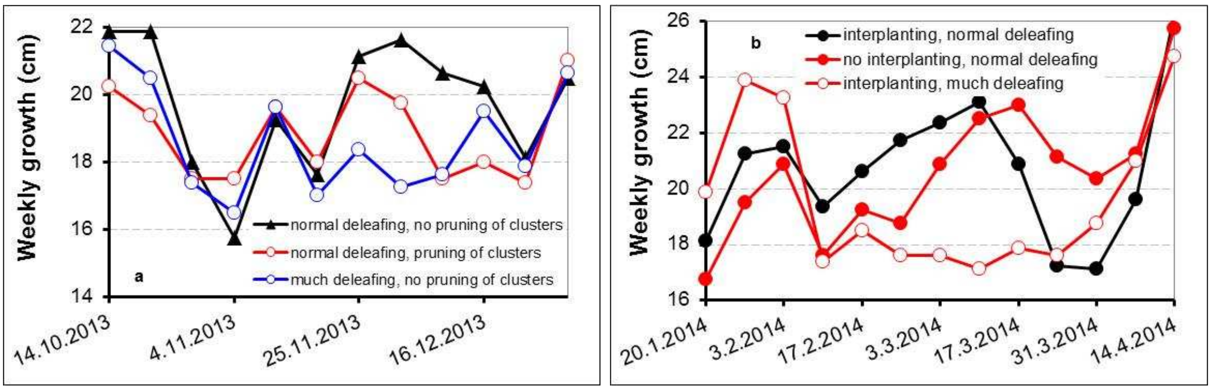


Fig. 16: Weekly growth for part A (a) and part B (b).

The number of flowers varied between 7 and 11 and was independent of the treatment (Fig. 17).

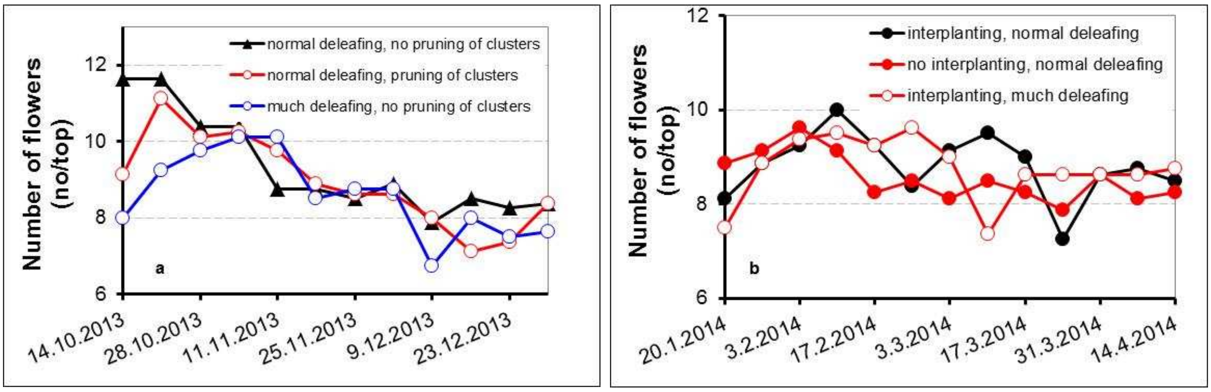


Fig. 17: Number of flowers for part A (a) and part B (b).

Stem diameter was varying from 0,6 to 1,0 cm in part A (Fig. 18a) and from 0,7 to 0,9 in part B (Fig. 18b), with no differences between treatments.

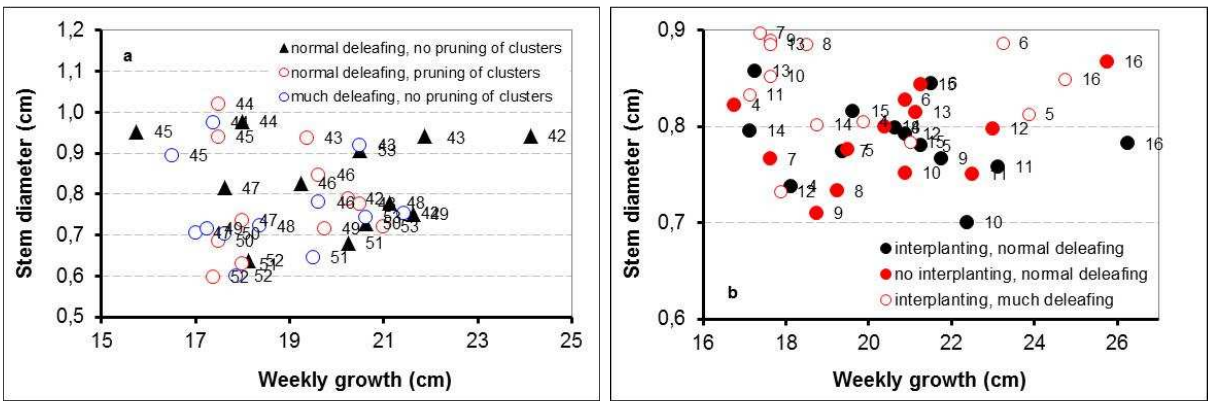


Fig. 18: Stem diameter and weekly growth for part A (a) and part B (b).
Numbers are representing the week number.

The quotient “lengths to top to stem diameter” was 19-20 for part A and 20-21 for part B with no differences between treatments. The treatments were getting more “little vegetative” with longer growing period (Fig. 19).

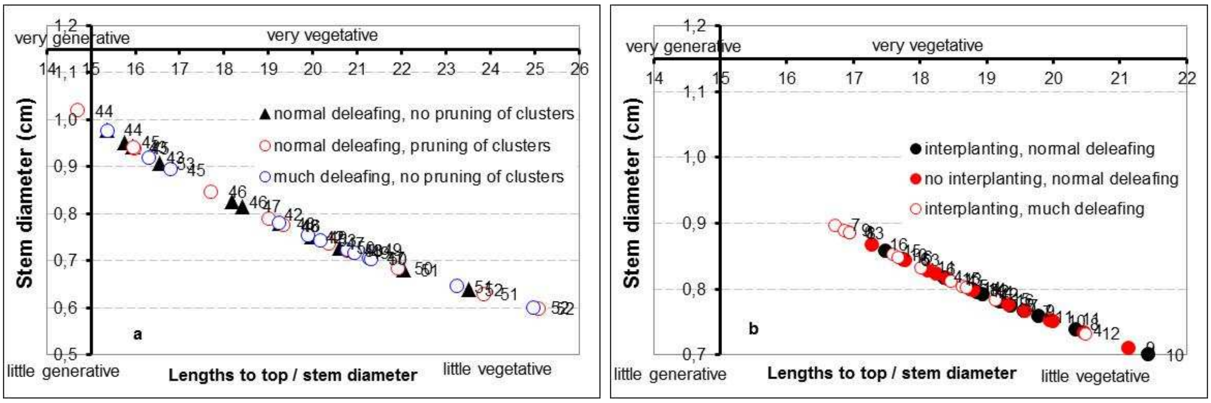


Fig. 19: Stem diameter and quotient lengths to top and stem diameter for part A (a) and part B (b).
Numbers are representing the week number.

The number of leaves on the plant was calculated according to the number of leaves that were taken and according to the number of clusters on a plant. It was assumed that five leaves were below the first cluster and three leaves between clusters. However, it is known that plants are not always developing according to this rule, but this calculation is giving an idea on how many leaves were on a plant, even though this number is not completely exact. Also, it has to be taken into account that new developed leaves are quite small and can therefore not really be counted as fully developed leaves. For part A the number of leaves on the plant was going in waves and increased from about 8 to about 18 in the middle of November to about 25 leaves at the end of the year and declined thereafter very fast down to 10 at the middle of January and down to three leaves at the end of the experiment (Fig. 20a). It was obvious that both part A and part B had something in common: During three weeks in November there were about four leaves less on the plant when much deleafing was done compared to normal deleafing (Fig. 20a). Again, for five weeks from the middle of February to the middle of March there were more than three leaves less on the plant when much deleafing was done compared to normal deleafing (Fig. 20b). However, later the amount of leaves on the plant was comparable, meaning that not really more leafes were taken, but the deleafing was done earlier (by taking the leaf behind the cluster when it was still small).

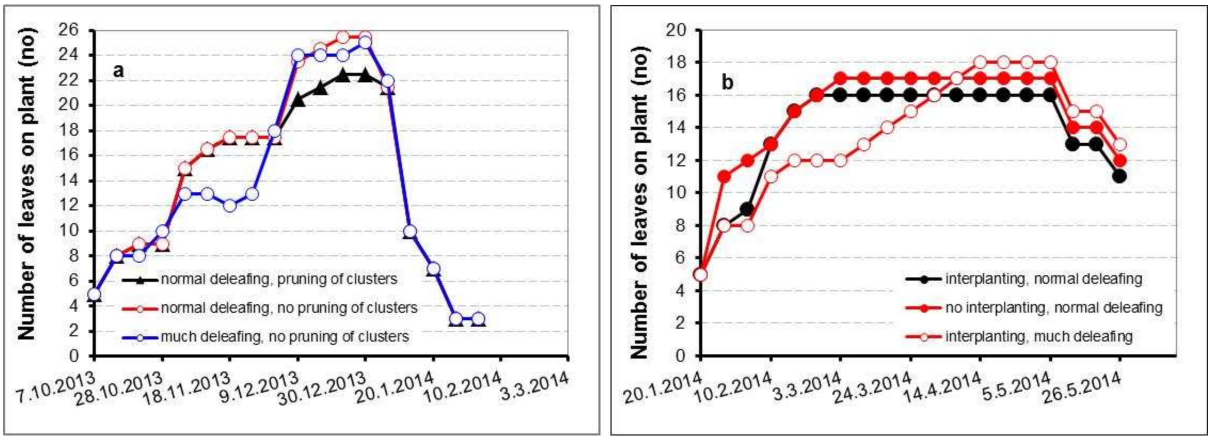


Fig. 20: Number of leaves on the tomato plant for part A (a) and part B (b).

4.3 Yield

4.3.1 Total yield of fruits

The yield of tomatoes included all harvested red fruits at the end of the growth period. The fruits were classified in 1. class (> 55 mm), 2. class (45-55 mm) and not marketable fruits (too little fruits (< 45 mm), fruits with blossom end rot, flawed, cracked and not well shaped fruits).

Cumulative total yield of tomatoes ranged between 26-29 kg/m^2 for part A (Fig. 21a) and 33-36 kg/m^2 for part B (Fig. 21b). Pruning of the clusters decreased total yield significantly. Interplanting decreased total yield significantly when in addition normal deleafing was done. However, “interplanting, much deleafing” did not affect total yield.

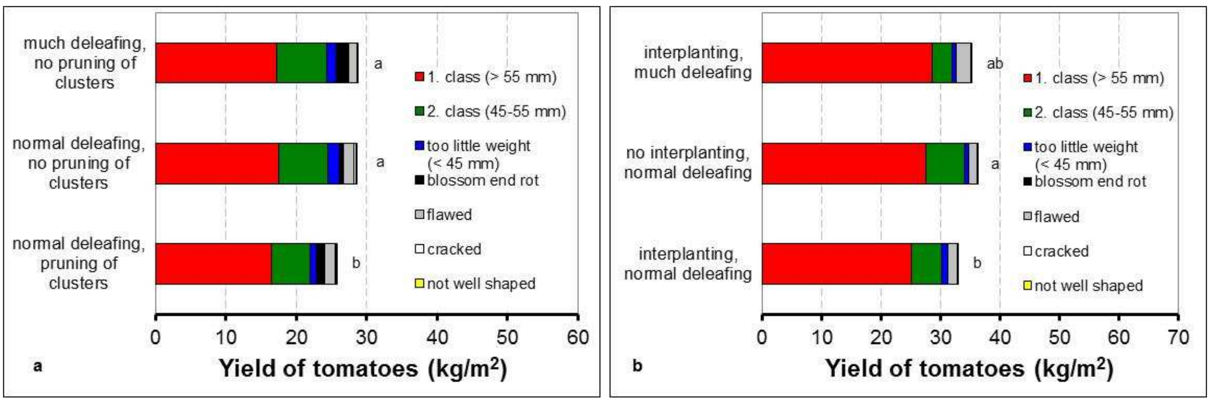


Fig. 21: Cumulative total yield for part A (a) and part B (b).
Letters indicate significant differences at the end of the experiment (HSD, p ≤ 0,05).

4.3.2 Marketable yield of fruits

For part A, at the end of the harvest period amounted yield of grafted tomatoes 22-24 kg/m^2 (Fig. 22a). No significant yield differences between the treatments were observed. However, the marketable yield was tendentially lower when clusters were pruned. It seems that the yield increase in the treatment with much deleafing was decreased compared to the other treatments during January while it increased again in February.

In part B, was a tomato yield of 30-34 kg/m^2 measured. With „no interplanting, normal deleafing" was a significantly higher yield reached compared to „interplanting, normal deleafing". However, when in the interplanting treatment also much deleafing was done, was the yield level comparable to „no interplanting, normal deleafing" (Fig. 22b, first letters). It seems that the increase of the treatment, where much deleafing was done, was getting less from the beginning of May and onwards compared to the treatment „no interplanting, normal deleafing".

Without interplanting were tomatoes harvested about one week earlier. However, that means also that there was no yield for about eight weeks (time for cleaning + time from planting to 1. harvest). The one week delayed harvest with interplanting means that the interplanting chambers had an additional harvest of seven weeks with nearly 13 kg for "interplanting, normal deleafing" and 15 kg for "interplanting, much deleafing" when calculated with an average weekly marketable yield. Thus, with interplanting a significant higher yield was reached compared to the treatment without interplanting. When much leaves are taken, an even significantly higher yield compared to normal deleafing can be reached (Fig. 22b, second letters).

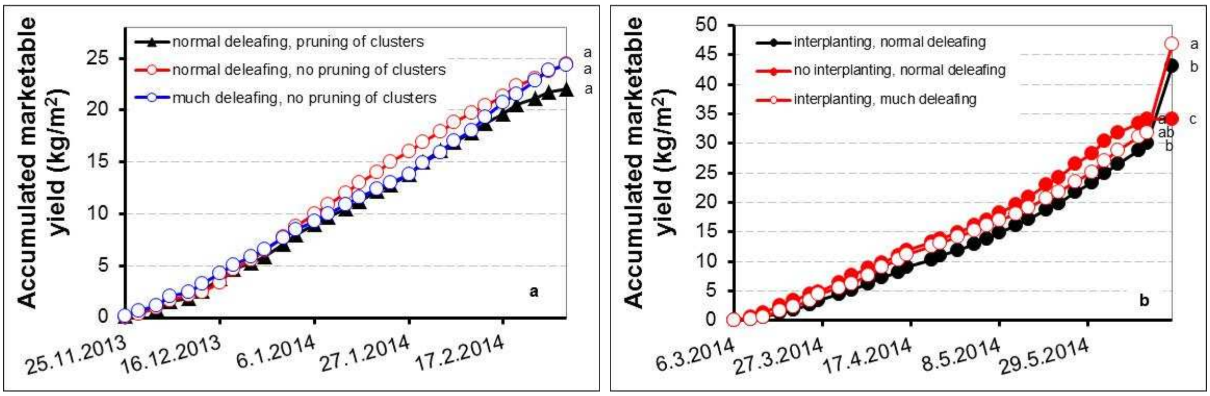


Fig. 22: Time course of accumulated marketable yield (1. and 2. class fruits) of tomatoes for part A (a) and part B (b).

Letters indicate significant differences at the end of the experiment (HSD, p ≤ 0,05).

For part A had all treatments a high 1. class yield at the beginning of the harvest period. However, at the end of January decreased 1. class yield (Fig. 23a) and increased 2. class yield (Fig. 24a) and thus, decreasing the proportion of 1. class yield on total yield. In contrast, for part B increased 1. class yield with a longer harvest period (Fig. 23b) and decreased 2. class yield (Fig. 24b).

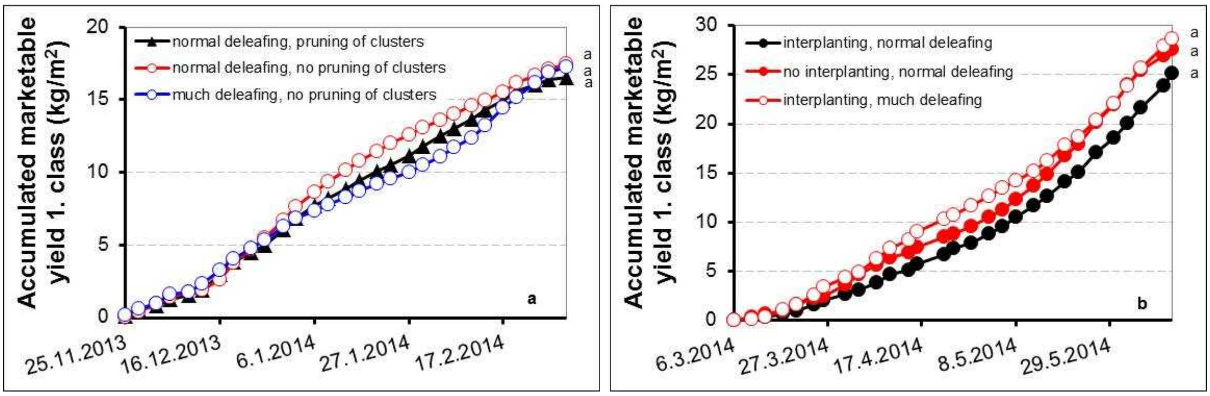


Fig. 23: Time course of marketable 1. class yield for part A (a) and part B (b).
Letters indicate significant differences at the end of the experiment (HSD, $p \leq 0{,}05$).

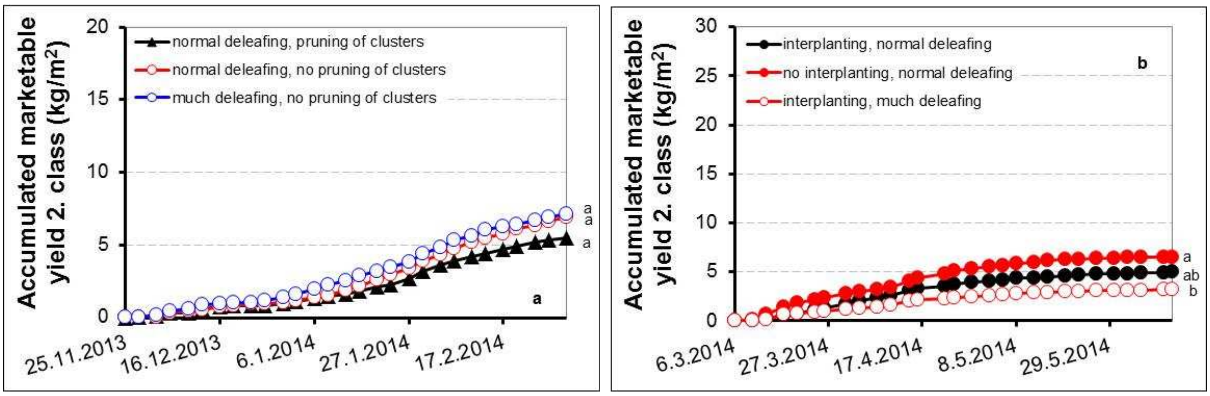


Fig. 24: Time course of marketable 2. class yield for part A (a) and part B (b).
Letters indicate significant differences at the end of the experiment (HSD, $p \leq 0{,}05$).

For part A was weekly harvest of first class fruits between 1-2 kg/m^2 in the middle of the harvest period, but at the beginning and end of the harvest period lower (Fig. 25a). For part B increased weekly harvest with higher solar irradiation up to 4 kg/m^2 (Fig. 25b).

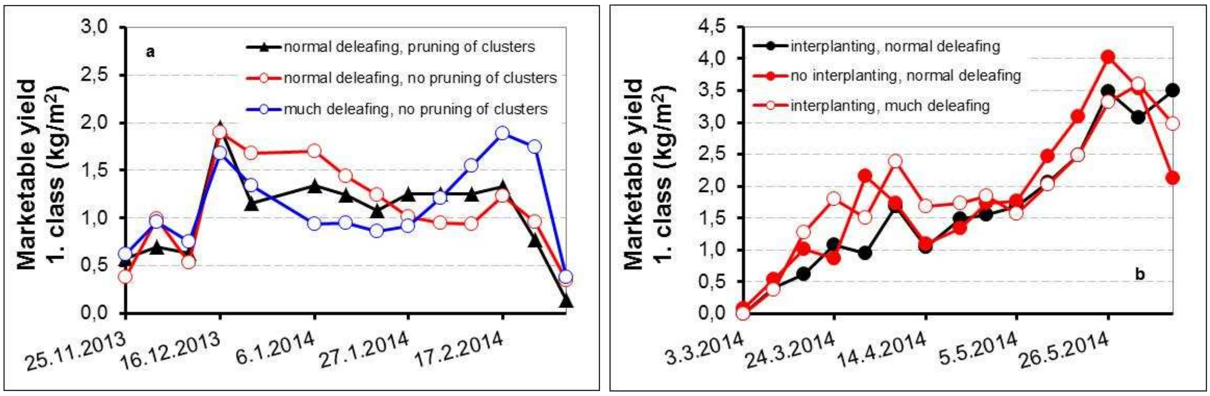


Fig. 25: Time course of marketable yield for part A (a) and part B (b).

The deleafing strategy had an effect on yield, which is shown by the relationship between the number of leaves and the harvest (Fig. 26). As mentioned before, was in part A much deleafing done for three weeks and was finished when the harvest started. Eight weeks after the first treatment, where much deleafing was done, was a lower harvest measured and continued a bit longer than three weeks, which was the time that the much deleafing treatment lasted. In part B, was much deleafing done for five weeks and lasted longer than the beginning of the harvest. Eight weeks after the first treatment, where much deleafing was done, was an increase in yield measured and the increase continued for five weeks, which was the time that the treatment lasted. Summarized can be said that much deleafing had a positive effect on yield when the treatment started early and continued longer than the first harvest, while a late and short treatment had no positive effect. An increase can be seen after eight weeks and as long as the treatment was done.

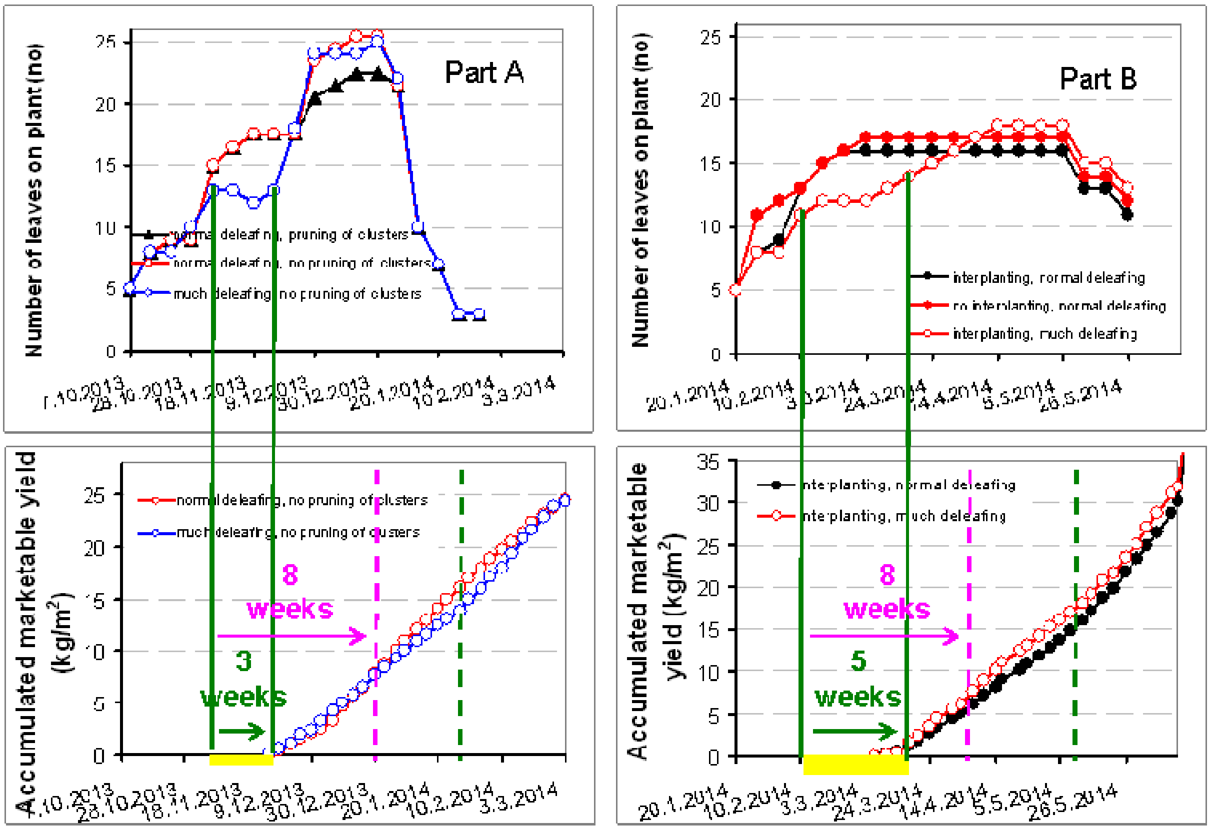


Fig. 26: Relation between number of leaves and harvest at normal and much deleafing for part A (a) and part B (b).

Normally tomatoes are grown longer than the experiment lasted. Therefore, it was also calculated how the yield would have developed over a longer time, like after two years. In this calculations was a six months harvest period assumed before new plants were planted. Used were numbers from the experiment and when time exceeded the experimental time, average numbers from each treatment were used. With no interplanting was always a waiting period of eight weeks before harvest started, while the harvest in the interplanting chambers continued without a break. After six month harvest reached the yield in the treatment with no interplanting the harvest of the interplanted treatments. But with longer time increased the difference between “interplanting” and “not interplanting”. After renewing the plants three times in the not interplanted treatment and four times in interplanted treatments was the yield after two years 15 % more with interplanting. Among that was it possible to increase the yield by further 10 % when much deleafing was done (Fig. 27).

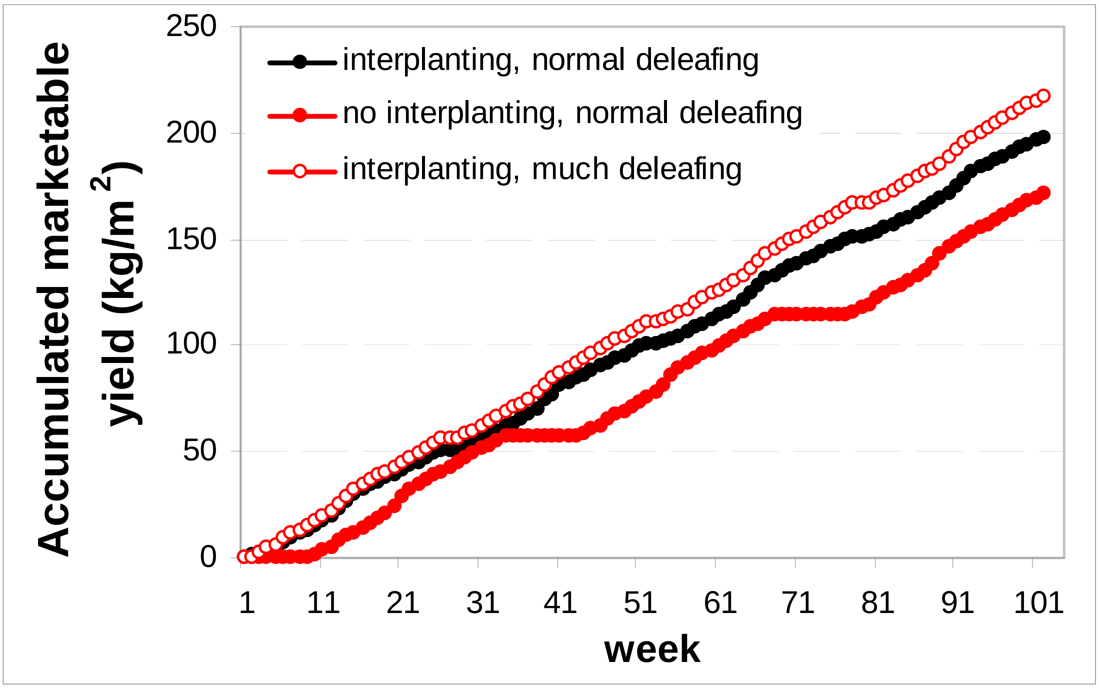


Fig. 27: Accumulated marketable yield after 2 years for part B.

Number of 1. class and 2. class fruits was not different between treatments for part A (Tab. 2). For part B it seems that the number of 1. class fruits was tendentially decreased for the treatment “interplanting, normal deleafing” (Tab. 2). The number of 2. class fruits was decreased in the treatment “interplanting, much deleafing” compared to “no interplanting, normal deleafing”. Additional fruits of the interplanting chamber during the time the chamber without interplanting chamber had no yield were not taken into account.

Tab. 2: Cumulative total number of marketable fruits for part A and part B.

Treatment	**Number of marketable fruits**	
	1. class	2. class
Part A		
normal deleafing, pruning of clusters	152 a	70 a
normal deleafing, no pruning of clusters	163 a	89 a
much deleafing, no pruning of clusters	160 a	92 a
Part B		
interplanting, normal deleafing	206 a	62 ab
no interplanting, normal deleafing	232 a	81 a
interplanting, much deleafing	227 a	41 b

Letters indicate significant differences (HSD, $p \leq 0{,}05$).

Average fruit size of first class tomatoes was varying between 107-109 g / fruit for part A (Fig. 27a) and between 109-118 g / fruit for part B (Fig. 28b). With higher solar irradiation increased average weight of tomatoes up to 150 g / fruit. The treatment "interplanting, much deleafing" was during the whole harvest period with the biggest tomatoes. However, much deleafing did not result in bigger fruits in part A (Fig. 28a).

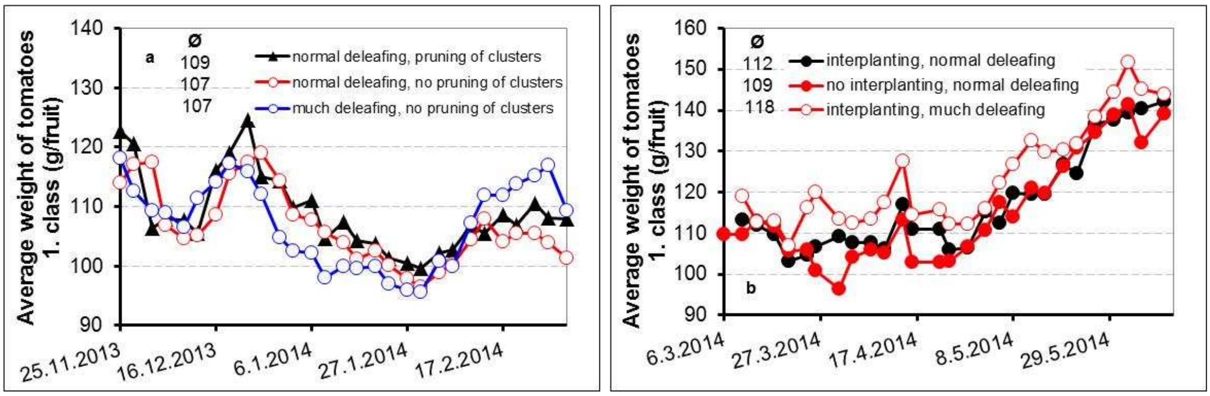


Fig. 28: Average weight of tomatoes (1. class fruits) for part A (a) and part B (b).

To observe the success of flowering until harvest, the flowering was classified and the number of "fruits total" (fruits that were supposed to be harvested later) was registered. When a cluster was harvested, the total number of "fruits harvested" was counted. The number of "lost fruits" is the difference between the number of fruits that were registered at flowering (fruits total) and the number of harvested fruits. "Lost fruits" might have been aborted or did not develop well and stayed small. However, for the treatment "normal deleafing, pruning of clusters" the number of lost fruits might have been high due to the fact that pruning has not yet been done when "fruits total" were counted. The number of "fruits total" was in average one fruit less for the treatment "much deleafing, no pruning of clusters" (Fig. 29a). However, much deleafing did not cause less fruits in the interplanted treatment (Fig. 29b). In part A, the number of harvested fruits was highest with in average 9,1 at "normal deleafing, no pruning of clusters" and lower for "normal deleafing, pruning of clusters" (average 7,2) and "much deleafing, no pruning of clusters" (average 7,6). In part B, the number of harvested and lost fruits was in average 0,5 fruits lower for the treatment "interplanting, normal deleafing" (Fig. 29b).

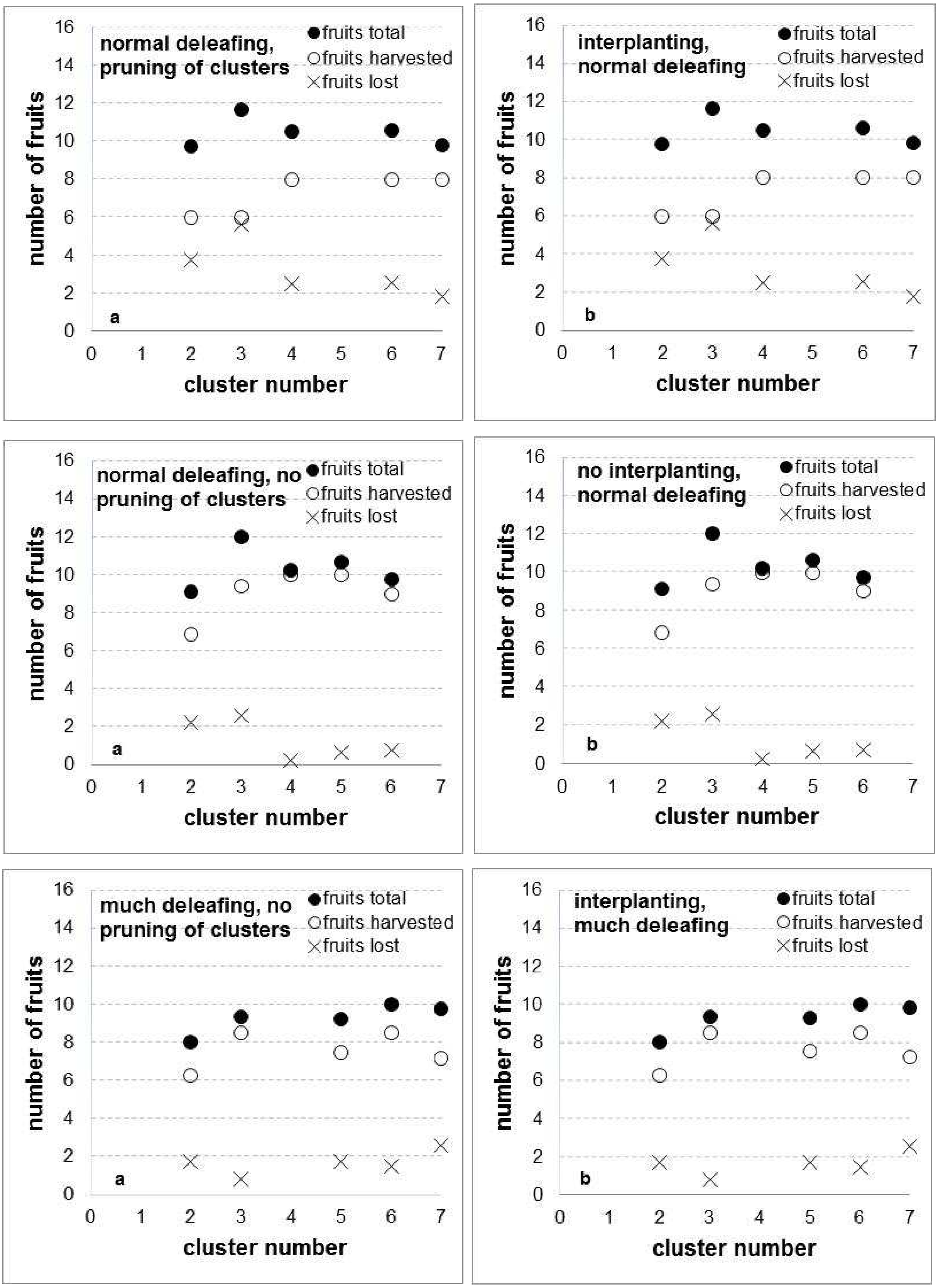


Fig. 29: Number of fruits at setting and harvest for part A (a) and part B (b).

4.3.3 Outer quality of yield

Marketable yield was about 85 % for part A and 91-94 % for part B (Tab. 3). The amount of too little fruits was decreased by pruning the clusters. The number of blossom end rot fruits was quite high due to a problem in plant nutrition during the beginning of the growth period. Interplanting and the amount of deleafing did not effect the amount of marketable and unmarketable yield.

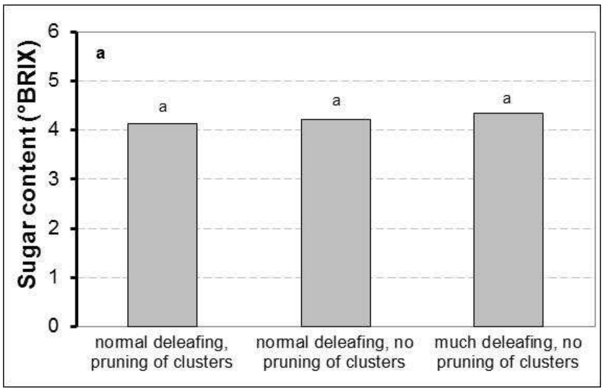
Tab. 3: Proportion of marketable and unmarketable yield for part A and part B.

Treatment	Marketable yield		Unmarketable yield				
	1. class	2. class	too little weight	blossom end rot	flawed	cracked	not well shaped
Part A							
normal deleafing, pruning of clusters	64	22	3	4	6	1	0
normal deleafing, no pruning of clusters	62	24	6	2	5	1	0
much deleafing, no pruning of clusters	60	25	5	6	4	0	0
Part B							
interplanting, normal deleafing	77	15	3	0	5	0	0
no interplanting, normal deleafing	76	18	2	0	4	0	0
interplanting, much deleafing	82	9	2	0	7	0	0

4.3.4 Interior quality of yield

4.3.4.1 Sugar content

Sugar content of tomatoes was measured once during the harvest period (part A: 9.12.2013, part B: 07.04.2014) and was around 4 with no differences between treatments (Fig. 30).



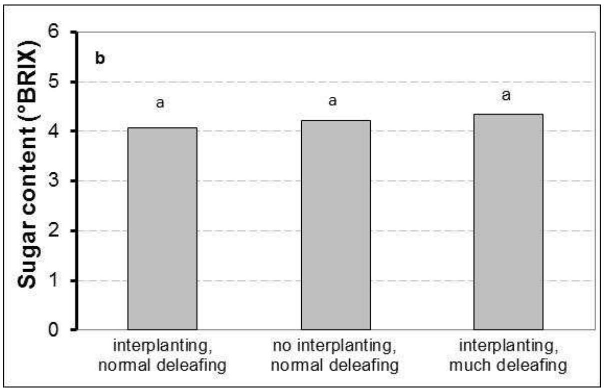


Fig. 30: Sugar content of fruits for part A (a) and part B (b).

Letters indicate significant differences at the end of the experiment (HSD, $p \leq 0,05$).

4.3.4.2 Taste of fruits

The taste of tomatoes, subdivided into sweetness, flavour and juiciness was tested by untrained assessors on 10.12.2013 for part A and on 14.04 for part B. The rating within the same sample was varying very much and therefore, same treatments resulted in a high standard deviation. It seems that without pruning the clusters at normal deleafing, tomatoes were less sweet, whereas this effect was not observed at much deleafing (Fig. 31a). Between the other treatments were no obvious differences observed (Fig. 31).

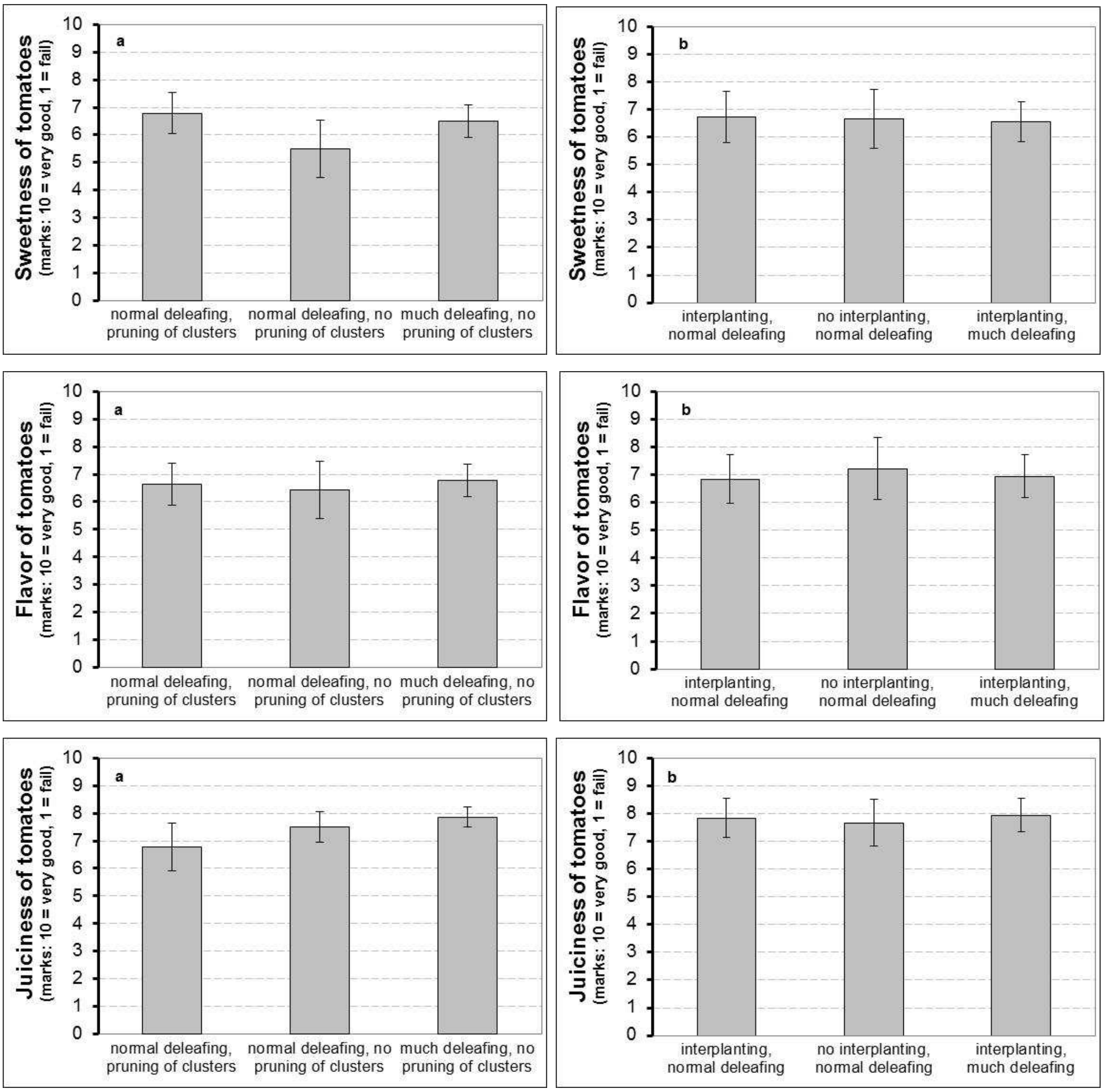


Fig. 31: Sweetness, flavour and juiciness of fruits for part A (a) and part B (b).

4.3.4.3 Dry substance of fruits

Dry substance (DS) of fruits was measured once during the harvest period and amounted less than 5 % (Fig. 32). It seems that the treatment “no interplanting, normal deleafing“ had a slightly higher dry substance content (Fig. 32b).

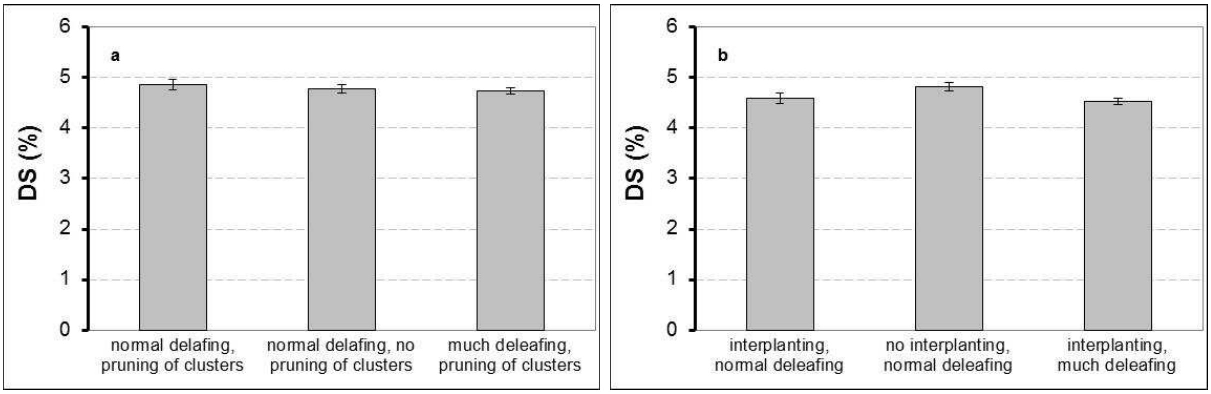


Fig. 32: Dry substance of fruits for part A (a) and part B (b).

4.3.5.4 Nitrogen content of fruits

N content of fruits was measured and was between 2,3-2,8 % (Fig. 33).

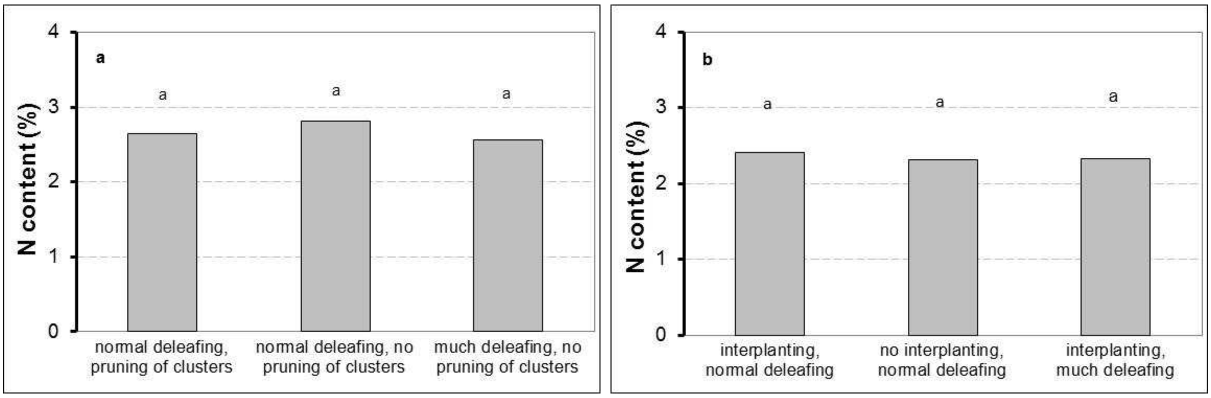


Fig. 33: N content of fruits for part A (a) and part B (b).

4.3.5 Dry matter yield of stripped leaves

During the growth period, leaves were regularly taken off the plant and the cumulative DM yield of these leaves was determined. No differences between treatments were measured (Fig. 34).

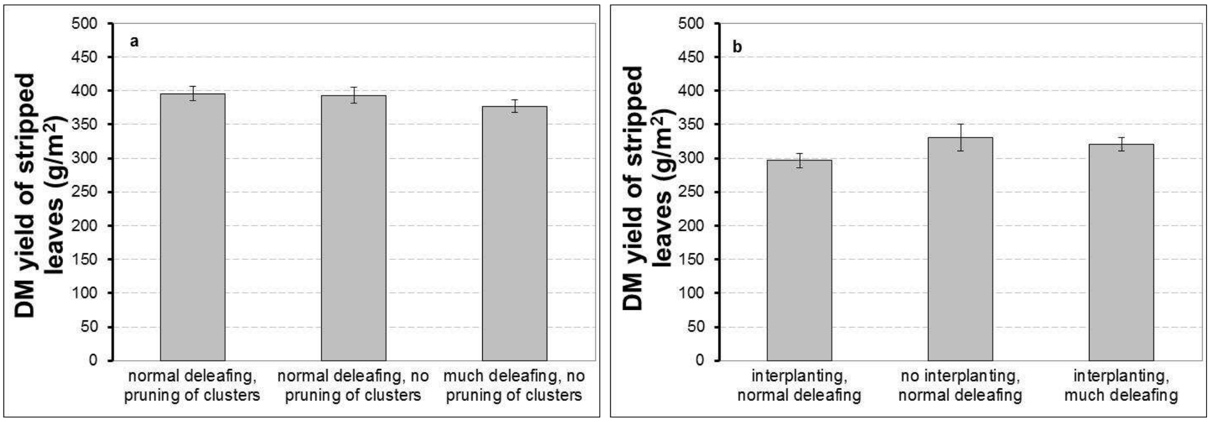


Fig. 34: Dry matter yield of stripped leaves for part A (a) and part B (b).

Error bars indicate standard deviations and are contained within the symbol if not indicated.

4.3.6 Cumulative dry matter yield

The cumulative DM yield included all harvested red fruits, the immature fruits at the end of the growth period, the stripped leaves during the growth period and the shoots. The cumulative DM yield did not differ between treatments (Fig. 35). The ratio fruits to "shoots + leaves" was 60 % for part A and 70 % for part B, with no differences between treatments.

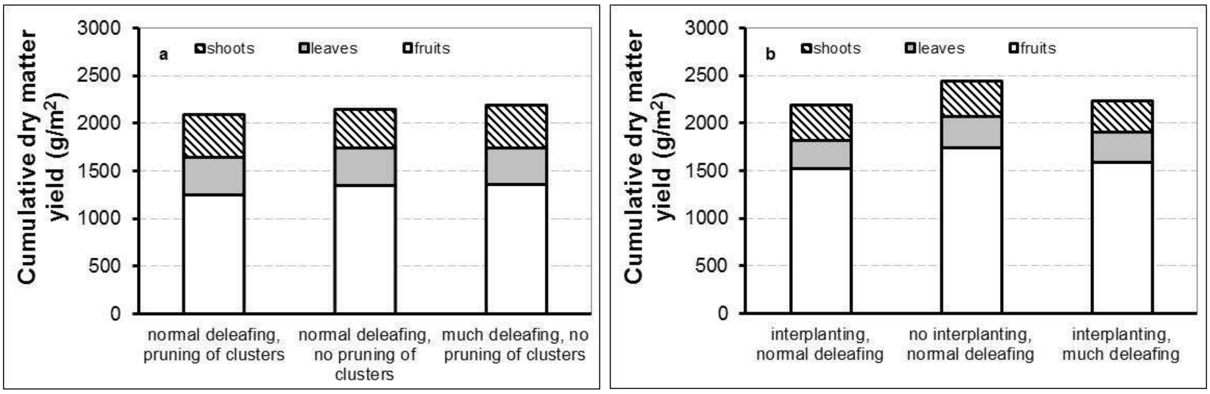


Fig. 35: Cumulative dry matter yield for part A (a) and part B (b).

4.4 Nitrogen uptake

The cumulative N uptake included N uptake of all harvested fruits, the immature fruits at the end of the growth period, the stripped leaves during the growth period and the shoots. The fruits contributed with 60 % for part A and nearly 70 % for part B much more than the leaves and shoots to the cumulative N uptake (Fig. 36). It seems that the N uptake with "no interplanting" was higher than with "interplanting".

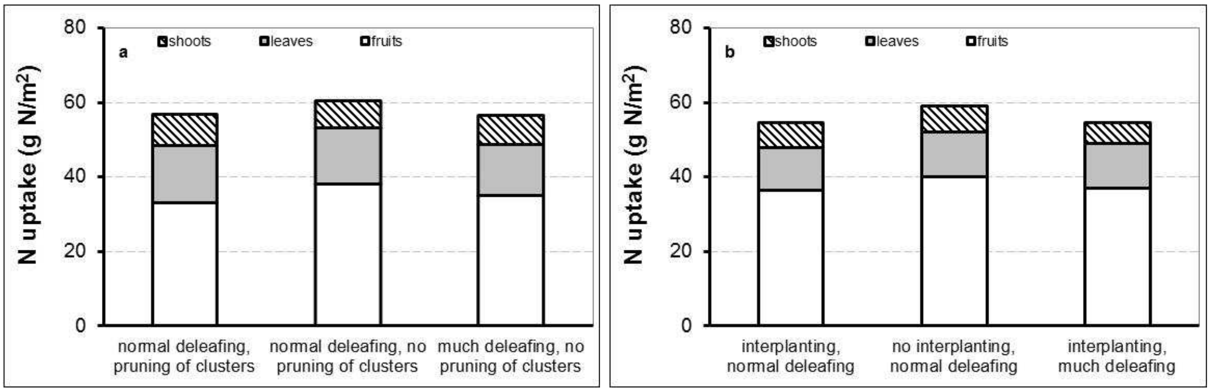


Fig. 36: Cumulative N uptake of tomatoes for part A (a) and part B (b).

4.5 Economics

4.5.1 Lighting hours

The number of lighting hours is contributing to high annual costs and needs therefore special consideration to consider to decrease lighting costs per kg marketable yield. The total hours of lighting during the growth period of tomatoes were both simulated and measured with dataloggers.

The simulated value was calculated according to the lighting hours written down. However, there it was not adjusted for automatic turn off, when incoming solar radiation was above a set-point (Tab. 4). The calculation of the power was lower for the measured values than for the simulated ones, because lights at the outer beds were also partly contributing to lighten the shelter belt. For calculation of the power, different electric consumptions were made, because the actual consumption is higher

Tab. 4: Lighting hours, power and energy in the cabinets for part A and B.

Treatment	Hours	Power	Energy	Energy/m^2
	h	W	kWh	kWh/m^2
Part A				
Measured values	2.456	288	35.372	707
Simulated values				
0 % more power consumption (nominal)	3.610	240	43.320	866
6 % more power consumption	3.610	254	45.919	918
10 % more power consumption	3.610	264	47.652	953
Part B				
Measured values	1.627	288	23.433	469
Simulated values				
0 % more power consumption (nominal)	3.436	240	41.232	825
6 % more power consumption	3.436	254	43.706	874
10 % more power consumption	3.436	264	45.355	907

than the nominal value of the bulb: one was based on the power of the lamps (nominal Watts, 0 % more power consumption), one with 6 % more power consumption and one for 10 % more power consumption.

4.5.2 Energy prices

Since the application of the electricity law 65/2003 in 2005, the cost for electricity has been split between the monopolist access to utilities, transmission and distribution and the competitive part, the electricity itself. Most growers are, due to their location, mandatory customers of RARIK, the distribution system operator (DSO) for most of Iceland except in the Southwest and Westfjords (*Eggertsson*, 2009).

RARIK offers basically three types of tariffs:

a) energy tariffs, for smaller customers, that only pay fixed price per kWh,
b) "time dependent" tariffs (tímaháður taxti, Orkutaxti TT000) with high prices during the day (09.00-20.00) at working days (Monday to Friday) but much lower during the night and weekends and summer, and
c) demand based tariffs (afltaxti AT000), for larger users, who pay according to the maximum power demand.

In the report, only afltaxti is used as the two other types of tariffs are not economic. Since 2009, RARIK has offered special high voltage tariffs ("VA410" and "VA430") for large users, that must either be located close to substation of the transmission system operator (TSO) or able to pay considerable upfront fee for the connection.

Costs for distribution are divided into an annual fee and costs for the consumption based on used energy (kWh) and maximum power demand (kW) respectively the costs at special times of usage. The annual fee is pretty low for "VA210" and "VA230" when subdivided to the growing area and is therefore not included into the calculation. However, the annual fee for "VA410" and "VA430" is much higher. Growers in an urban area in "RARIK areas" can choose between different tariffs. In the report only the possibly most used tariffs "VA210" and "VA410" in urban areas and "VA230" and "VA430" in rural areas are considered.

The government subsidises the distribution cost of growers that comply to certain criteria's. Currently 87 % and 92 % of variable cost of distribution for urban and rural areas respectively. This amount can be expected to change in the future.

Based on this percentage of subsidy and the lighting hours (Tab. 5), for the cabinets the energy costs per m^2 during the time of the experiment for the growers were calculated (Tab. 5).

Tab. 5: Costs for consumption of energy for distribution and sale of energy for part A and part B.

	Costs for consumption							
	Energy ISK/kWh				**Energy costs with subsidy per m^2** ISK/m^2			
Treat-ment	Part A		Part B		Part A		Part B	
	real	calculated	real	calculated	real	calculated	real	calculated
				DISTRIBUTION				
RARIK Urban					87 % subsidy from the state			
VA210	0,47	0,45	0,66	0,46	333	387 411 426	310	376 399 414
VA410	0,38	0,36	0,57	0,37	272	313 331 344	268	305 323 335
RARIK Rural					92 % subsidy from the state			
VA230	0,48	0,46	0,65	0,46	338	395 419 435	304	383 406 421
VA430	0,33	0,32	0,47	0,32	236	275 291 302	219	267 283 293
				SALE				
Afltaxti	5,17	4,86	6,45	4,95		4.210		4.080
Orkutaxti	8,25	6,23	7,28	6,35	3.659	4.463	2.952	4.324
						4.631		4.487

Comments: The first number for the calculated value is with 0 % more power consumption, the second value with 6 % more power consumption and the last value with 10 % more power consumption.

Prices are from April 2014.

The energy costs per kWh for distribution after subsides are around 0,45-0,65 ISK/kWh for „VA210“ and „VA230“, around 0,35-0,6 ISK/kWh for „VA410“ and 0,3-0,5

ISK/kWh for „VA430“. The energy costs for sale are for „Afltaxti“ around 4,9-6,5 ISK/kWh and for „Orkutaxti“ around 6,2-8,3 ISK/kWh.

Cost of electricity was higher for the calculated values (Tab. 6). In general, tariffs for large users rendered lower cost.

4.5.3 Costs of electricity in relation to yield

Costs of electricity in relation to yield for wintergrown tomatoes were calculated (Tab. 6a, 6b).

Tab. 6a: Variable costs of electricity in relation to yield for part A.

	Variable costs of electricity per kg yield ISK/kg					
Treatment	normal deleafing, pruning of clusters		normal deleafing, no pruning of clusters		much deleafing, no pruning of clusters	
Yield/m²	22,0		24,4		24,4	
	real	calculated	real	calculated	real	calculated
Urban area (Distribution + Sale)						
VA210	181	209 221 230	163	188 199 207	164	188 200 207
VA410	179	205 218 226	161	185 196 204	161	185 196 204
Rural area (Distribution + Sale)						
VA230	182	209 222 230	164	189 200 207	164	189 200 208
VA430	177	204 216 224	159	184 195 202	160	184 195 202

While for the distribution several tariffs were possible, for the sale only the cheapest tariff was considered. The costs of electricity increased by more than 10 % with pruning the clusters (“normal deleafing, pruning of clusters” compared to “normal deleafing, no pruning of clusters”) due to a lower yield (Tab. 6a).

Tab. 6b: Variable costs of electricity in relation to yield for part B.

	Variable costs of electricity per kg yield ISK/kg					
Treatment	interplanting, normal deleafing		no interplanting, normal deleafing		interplanting, much deleafing	
Yield/m²	43,0		34,1		46,8	
	real	calculated	real	calculated	real	calculated
Urban area (Distribution + Sale)						
VA210	76	104 110 114	96	131 138 144	70	95 101 105
VA410	75	102 108 112	94	129 136 141	69	94 99 103
Rural area (Distribution + Sale)						
VA230	76	104 110 114	95	131 139 144	70	95 101 105
VA430	74	101 107 111	93	127 135 140	68	93 98 102

The costs of electricity increased by more than 20 % with interplanting (“interplanting, normal deleafing” compared to “no interplanting, normal deleafing”) due to a higher yield because no harvest gap is between planting of new plants and harvest. Even more than 5 % lower costs of electricity could be reached by taking many leaves (compare “interplanting, much deleafing” with “interplanting, normal deleafing”) due to the higher yield (Tab. 6b).

4.5.4 Profit margin

The profit margin is a parameter for the economy of growing a crop. It is calculated by substracting the variable costs from the revenues. The revenues itself, is the product of the price of the sale of the fruits and kg yield. For each kg of tomatoes, growers are getting about 400 ISK from Sölufélag garðyrkjumanna (SfG) and in addition 77,26 ISK from the government. Therefore, the revenues increased with more yield (Fig. 37).

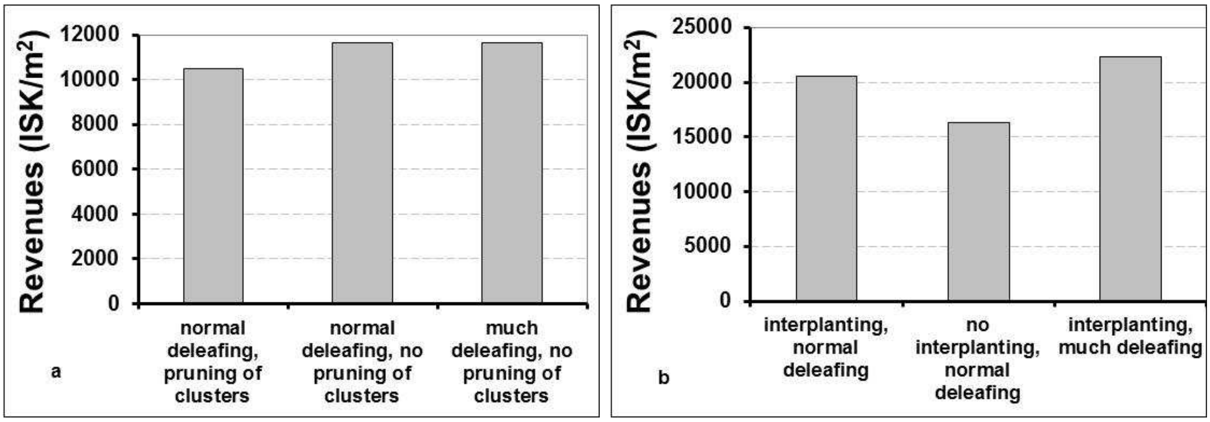


Fig. 37: Revenues at different treatments for part A (a) and part B (b).

When considering the results of previous chapter, one must keep in mind that there are other cost drivers in growing tomatoes than electricity alone (Tab. 6). Among others, this are e.g. the costs for seeds and seedling production (≈ 300 ISK/m^2) and transplanting (≈ 400 ISK/m^2), costs for plant nutrition (≈ 300 ISK/m^2), CO_2 transport (≈ 300 ISK/m^2), liquid CO_2 (≈ 1.300 ISK/m^2), the rent of the tank (≈ 500 ISK/m^2), the rent of the green box (≈ 250 ISK/m^2), material for packing (≈ 700 ISK/m^2), packing costs with the machine from SfG (≈ 400 ISK/m^2) and transport costs from SfG (≈ 330 ISK/m^2) (Fig. 38).

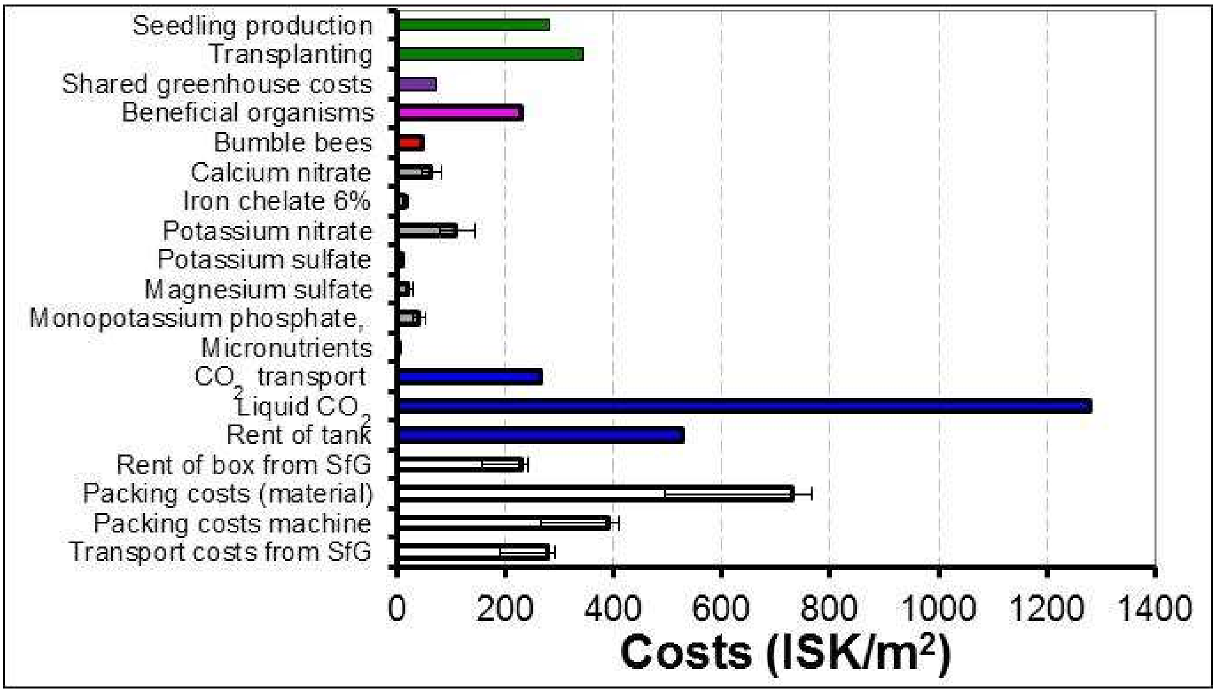


Fig. 38: Variable and fixed costs (without lighting and labour costs).

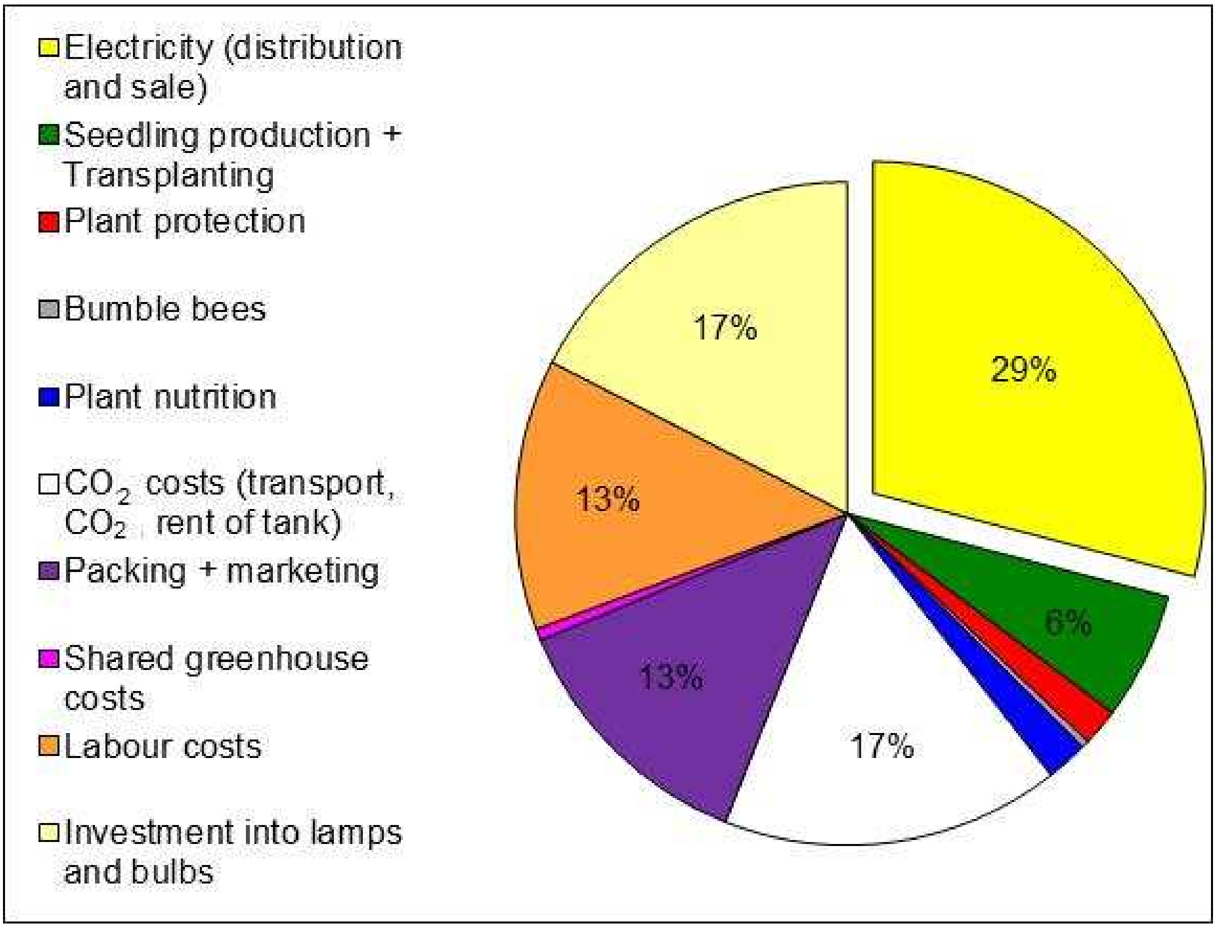


Fig. 39: Division of variable and fixed costs.

However, in Fig. 38 three of the biggest cost drivers are not included and these are investment in lamps and bulbs, electricity and labour costs. These costs are also included in Fig. 39 and it is obvious, that especially the electricity and the investment in lamps and bulbs as well as the labour costs are contributing much to the variable and fixed costs beside the costs for packing and marketing and CO_2 costs.

A detailed composition of the variable costs at each treatment is shown in Tab. 7.

Tab. 7: Profit margin of tomatoes at different treatments (urban area, VA210).

Treatment	normal deleafing, pruning of clusters	normal deleafing, no pruning of clusters	much deleafing, pruning of clusters	inter-planting, normal deleafing	no inter-planting, normal deleafing	inter-planting, much deleafing
Marketable yield/m^2	22,0	24,4	24,4	43,0	34,1	46,8
Sales						
SfG (ISK/kg) [1]	400	400	400	400	400	400
Government (ISK/kg) [2]	77,26	77,26	77,26	77,26	77,26	77,26
Revenues (ISK/m^2)	**10.509**	**11.659**	**11.646**	**20.544**	**16.280**	**22.353**
Variable and fixed costs (ISK/m^2)						
Electricity distribution [3]	333	333	333	310	310	310
Electricity sale	3.659	3.659	3.659	2.952	2.952	2.952
Seeds [4]	157	157	157	157	157	157
Seedling production	280	280	280	280	280	280
Grodan small [5]	11	11	11	11	11	11
Grodan big [6]	43	43	43	43	43	43
Pumice [7]	209	209	209	209	209	209
Predatory bug [8]	55	55	55	55	55	55
Parasitic wasps [9]	173	173	173	173	173	173
Bumble bees [10]	46	46	46	46	46	46
Calcium nitrate [11]	48	45	47	72	82	83
Iron chelate 6 % [12]	11	10	11	16	18	19
Potassium nitrate [13]	86	79	83	124	141	143
Potassium sulfate [14]	8	8	8	10	11	11
Magnesium sulfate [15]	16	15	16	24	27	28
Monopotassium phosphate [16]	31	28	30	46	52	53
Micronutrients [17]	2	1	2	2	3	3
CO_2 transport [18]	264	264	264	264	264	264
Liquid CO_2 [19]	1.279	1.279	1.279	1.279	1.279	1.279
Rent of CO_2 tank [20]	528	528	528	528	528	528
Strings	80	80	80	80	80	80
Rent of box from SfG [21]	156	173	173	305	242	332
Packing material [22]	495	549	548	967	766	1.052
Packing (labour + machine) [23]	264	293	293	517	409	562
Transport from SfG [24]	188	209	209	368	292	400
Shared fixed costs [25]	71	71	71	71	71	71
Lamps [26]	1.429	1.429	1.429	1.429	1.429	1.429
Bulbs [27]	762	762	762	762	762	762
∑ variable costs	**10.680**	**10.786**	**10.793**	**11.095**	**10.688**	**11.332**
Revenues -∑ variable costs	**-172**	**873**	**853**	**9.449**	**5.592**	**11.021**
Working hours (h/m^2)	0,97	0,91	0,96	1,62	1,27	1,73
Salary (ISK/h)	1.352	1.352	1.352	1.352	1.352	1.352
Labour costs (ISK/m^2)	1.307	1.226	1.292	2.187	1.715	2,340
Profit margin (ISK/m^2)	**-1.479**	**-353**	**-440**	**7.262**	**3.877**	**8.681**

[1] price winter 2013/2014: 400 ISK/kg
[2] price in October for 2014: 77,26 ISK/kg
[3] assumption: urban area, tariff "VA210", no annual fee (according to datalogger values)
[4] 15.988 ISK / 250 Encore seeds; 26.600 ISK / 1.000 Maxifort
[5] 36x36x40mm, 900 ISK / 220 Grodan small
[6] 27/35, 32 ISK / 1 Grodan big
[7] 8.696 ISK/m^3 (2,6 m^3 big pumice, 0,65 m^3 small pumice)
[8] 5.901 ISK / unit predatory bug (*Macrolophus caliginosus*)
[9] 9.383 ISK / unit parasitic wasps (*Encarsia formosa*)
[10] 6.540 ISK / unit bumble bees
[11] 2.125 ISK / 25 kg Calcium nitrate
[12] 17.050 ISK / 25 kg Iron chelate 6 %
[13] 4.175 ISK / 25 kg Potassium nitrate
[14] 3.550 ISK / 25 kg Potassium sulfate
[15] 1.700 ISK / 5 kg Magnesium sulfate
[16] 7.050 ISK / 25 kg Monopotassium phosphate
[17] 33.900 ISK / 5 kg micronutrients
[18] CO_2 transport from Rvk to Hveragerði / Flúðir: 7,0 ISK/kg CO_2
[19] liquid CO_2: 33,90 ISK/kg CO_2
[20] rent for 6 t tank: 66.000 ISK/month, assumption: rent in relation to 1.000 m^2 lightened area
[21] 85 ISK / 12 kg box
[22] packing costs (material):
costs for packing of big tomatoes (0,75 kg): platter: 15 ISK / 0,75 kg,
plastic film: 5 ISK / 0,75 kg,
label: 2 ISK / 0,75 kg
[23] packing costs (labour + machine): 12 ISK / kg
[24] transport costs from SfG: 8,55 ISK / kg
[25] 94 ISK/m^2/year for common electricity, real property and maintenance
[26] HPS lights: 30.000 ISK/lamp, life time: 8 years
[27] HPS bulbs: 4.000 ISK/bulb, life time: 2 years

The profit margin was dependent on the treatment (Fig. 40). For part A, the profit margin was with about -1.400 ISK/m^2 lowest at "normal deleafing, pruning of clusters". However, the profit margin rose to -400 ISK/m^2, when clusters were not pruned. That means, not pruning the clusters increased the profit margin by about 1.000 ISK/m^2. For part B, was the profit margin lowest with about 4.000 ISK/m^2 with the treatment "no interplanting, normal deleafing". When instead of "no interplanting" interplanting was done, increased profit margin to more than 7.000 ISK/m^2. That means interplanting increased the profit margin by more than 3.000 ISK/m^2. By taking many leafes (treatment "interplanting, much deleafing" compared to "interplanting, normal deleafing) can the profit margin even be increased by further 1.500 ISK/m^2 and up to nearly 9.000 ISK/m^2. For both, part A and part B, a larger use (higher tariff: "VA 410" compared to "VA 210", "VA 430" compared to "VA 230"), did not influence the profit margin. Also, it did not matter if the greenhouse is situated in an urban or rural area, the profit margin was comparable. However, at a higher tariff there was a surprisingly small advantage of rural areas due to the state subsidies (Fig. 40).

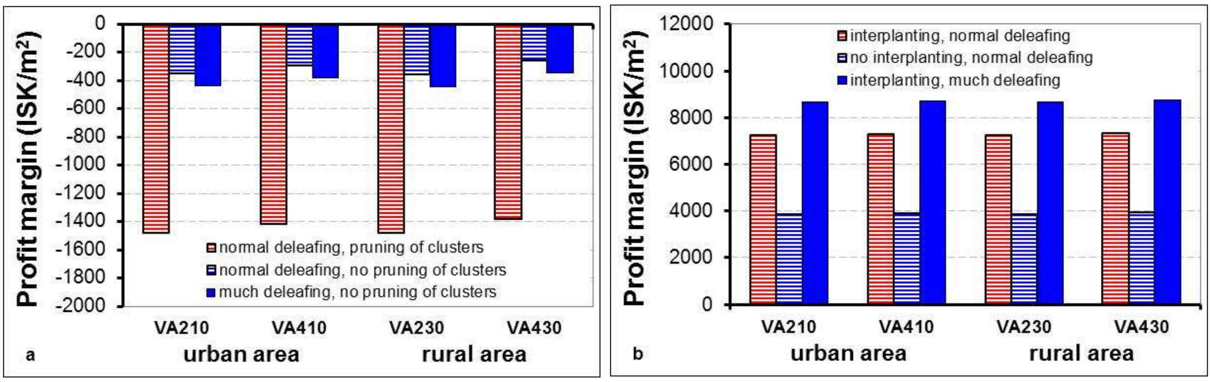


Fig. 40: Profit margin in relation to tariff and treatment for part A (a) and part B (b).

5 DISCUSSION

5.1 Yield in dependence of pruning the clusters

The yield of tomatoes was compared with and without pruning the clusters. The results show that pruning decreased the marketable yield by 10 % (Fig. 41) because of less harvested fruits due to a lower number of fruits on each cluster. However, one aim with pruning the clusters was to get bigger tomatoes and more marketable tomatoes, which was confirmed in a slightly higher average weight and in a higher first class yield, while fruits with too less weight were decreased.

In contrast, fruits on clusters that were pruned, got in the tasting experiment higher marks for the sweetness than fruits on unpruned clusters. However, this could not be confirmed when the sugar content was tested.

When clusters were not pruned, among yield also the profit margin increased (Fig. 41). Therefore, pruning the clusters of grafted tomatoes can not be recommended. However, pruning of clusters might have a positive effect on yield when ungrafted plants are used.

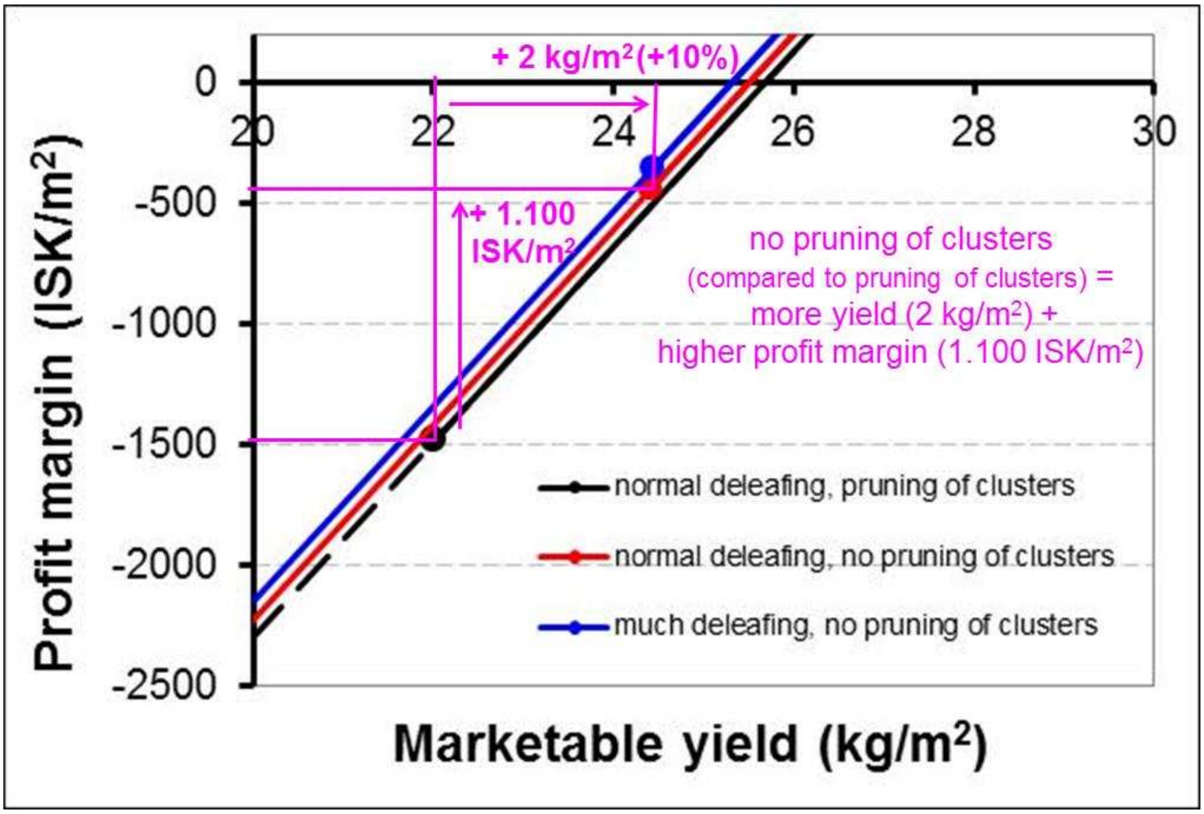


Fig. 41: Profit margin in relation to yield with pruning and no pruning the clusters– calculation scenarios (urban area, VA210).

5.2 Yield in dependence of the planting strategy (interplanting / no interplanting)

The yield with interplanting was about 15 % higher than without interplanting. This was due to no waiting period between harvesting from the old and new plants. However, also negative effects with interplanting can take place: In the beginning are the new plants getting less light in the shadow of the old ones. That means that there is also less air circulation that can increase fungal diseases. Fungal diseases and aphids can be in general a problem because there is no cleaning in between the transplanting's. To avoid negative effects with interplanting is it necessary that the growth of the old plants is controlled at the right time which means to top them and to hang them down under the top of the young plants. It has to be taken into account that interplanting is accompanied with more work. In addition, is this work also more difficult because extra care needs to be taken that the young plants are not damaged which is especially at the beginning a risk as the old plants are in the way. Also, were in the present study more not polluninated fruits with interplanting counted.

5.3 Yield in dependence of the form of deleafing (normal deleafing / much deleafing)

In a long-season glasshouse tomato crop, it is standard commercial practice to remove old leaves up to the picking truss. The main reasons for the removal of these leaves are to prevent disease, to hasten fruit ripening, and to make the harvest easier (*Heuvelink* et al., 2005). Some tomato growers remove young leaves in order to control vegetative vigour. The removal of young leaves reduces the total vegetative sink-strength and favours assimilate partitioning into the fruit (*Heuvelink* et al., 2005). A good tool to create a more open and generative plant habit is to take out a top leaf behind the flowering cluster, when twisting the plants (onces a week). Depending on the condition of the crop, it is common to start taking out a top leaf when the third truss is flowering (*Enza Zaden Export BV*, 2014). That improves light penetration and air circulation and that is preventing fungal diseases and aphids. In addition, it helps to direct nutrients to the growing tip and fruit.

Xiao et al. (2004) simulated what might happen if tomato cultivars were to have two instead of three leaves between each truss. The vegetative sink-strength was reduced by one-third, and seven fruits per truss were assumed. They predicted that photoassimilate partitioning to fruit would increase from 66 % to 74 %, but that the yield would increase by only 1,5 % due to the reduced LAI. However, if the LAI was maintained at 2,3 by retaining more old leaves, yields were predicted to increase by 12,8 %. Simulations by *Heuvelink* et al. (2005) included the effect of removing one, two, or three young leaves out of six, where the sink-strength of the leaves was reduced proportionally. Removing one in every three leaves was predicted to reduce yield by 5 %, although, if the removal of old leaves was delayed in order to maintain the LAI at approx. 2,9, the yield increased by 7 %. Indeed, when it was started early to take the leaf behind the upper newly developed cluster and continued with that longer than the start of the harvest, the yield of tomatoes in the presented study could be increased by 10 %. This number is fitting well to the predicted numbers from the authors.

In a glasshouse experiment, *Xiao* et al. (2004) found that removing one in every three young leaves did result in a 4% yield loss, even though this was not any significant loss in yield where the LAI was reduced from 2,9 to 2,4. Conversely, a significant (17 %) increase in yield was found when the LAI was increased using a higher plant density; however, in this case the LAI was 24 % greater than that of the controls, and there were more fruits per m^2, as all trusses were pruned to six fruits. Similarly, *Andriolo* et al. (2001) compared the effects of leaving one, two, or three leaves between trusses by removing young leaves from an indeterminate cultivar in a non-heated polyethylene greenhouse. They found no difference in terms of cumulative fruit dry weight per plant, despite the fact that the LAI values were 2,4, 3,0 and 4,3 for treatments with one, two, or three leaves between trusses, respectively.

In contrast, *Valdés* et al. (2010) measured an 8 % yield loss, due to a reduction in the average number of fruits set per truss and mean fruit weight, when the final LAI was reduced from approx. 4,1 to 2,9 after removing one in every three young leaves (after the canopy was established).

In the present experiment resulted taking the leaf behind the cluster after the third cluster had established and for a shorter time (stopping directly when the harvest started) in no positive influence on the yield. Therefore, the timing of when the deleafing strategy started and also how long it was proceeded had a big influence on the yield. Taking a leaf behind the cluster can be recommended when it is done not later than when the third cluster has developed and continued also at the beginning of the harvest. Also, *Verheul* (2012) concluded that manipulation of plant density in combination with leaf removal can be used to increase yield. However, the controversy results for part A and B with much deleafing can also be related to the lengths of the leaves. The length of leaves was higher at much deleafing compared to normal deleafing for part B, while in part A were leaves even shorter with much deleafing. The size of the leaves is linked to the LAI. The bigger leaves in part B were contributing to a LAI that seems to have been over the critical value and resulted therefore in a positive effect on yield, while in part A the LAI might have been under the critical value due to smaller leafes and with that no positive effect on yield was reached.

Among by increasing the yield with interplanting an additional yield increase of 10 % could be reached by much deleafing, that resulted also in an about 1.400 ISK/m^2 higher profit margin (Fig. 42). Therefore, also much deleafing can be recommended.

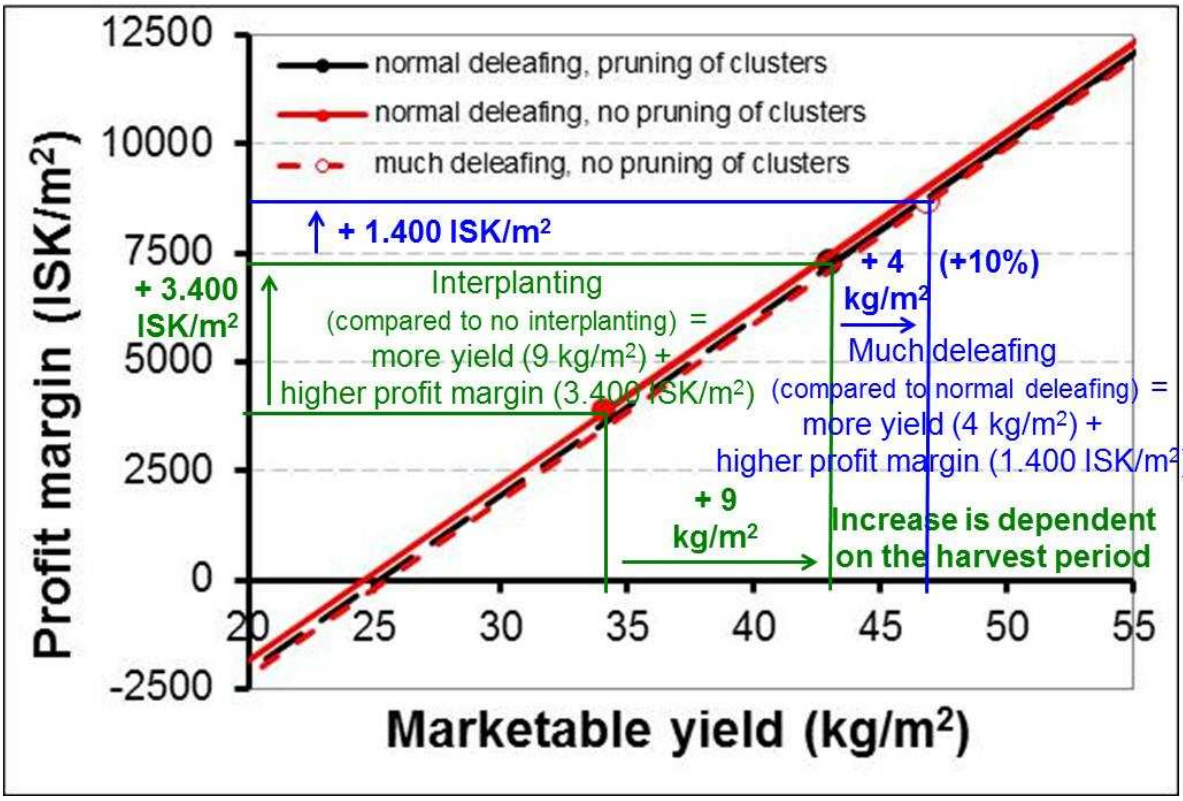


Fig. 42: Profit margin in relation to yield with interplanting and no interplanting and much and normal deleafing the clusters– calculation scenarios (urban area, VA210).

5.4 Future speculations concerning energy prices

In terms of the economy of lighting – which is not looking very promising from the growers' side – it is also worth to make some future speculations about possible developments. So far, the lighting costs are contributing to about 1/3 of the production costs. In the past and present there have been and there are still a lot of discussions concerning the energy prices. Therefore, it is necessary to highlight possible changes in the energy prices (Fig. 42). The white columns are representing the profit margin according to Fig. 40. Where to be assumed, that growers would get no subsidy from the state for the distribution of the energy, that would result in a profit margin of -2.500 to -4.000 ISK/m^2 for part A and for part B of 2.000 ISK/m^2 for the chamber without interplanting and 5.000-6.500 ISK/m^2 for chambers with interplanting (black columns, Fig. 43). Without the subsidy of the state, probably less Icelandic grower would produce tomatoes over the winter months. When it is assumed that the energy costs, both in distribution and sale, would increase by 25 %, but growers would still get the subsidy, then the profit margin would range between -1.500 and -2.500 ISK/m^2 for part A and for part B, 3.000 ISK/m^2 for the chamber without interplanting and 6.500-8.000 ISK/m^2 for chambers with interplanting (dotted columns). When it is assumed, that growers have to pay 25 % less for the energy, the profit margin would increase to -500 and +500 ISK/m^2 for part A and for part B 4.500 ISK/m^2 for the chamber without interplanting and 8.000-9.500 ISK/m^2 for chambers with interplanting (gray columns). From these scenarios it can be concluded that from the grower's side it would be preferable to get subsidy to be able to get a higher profit margin and grow tomatoes over the winter.

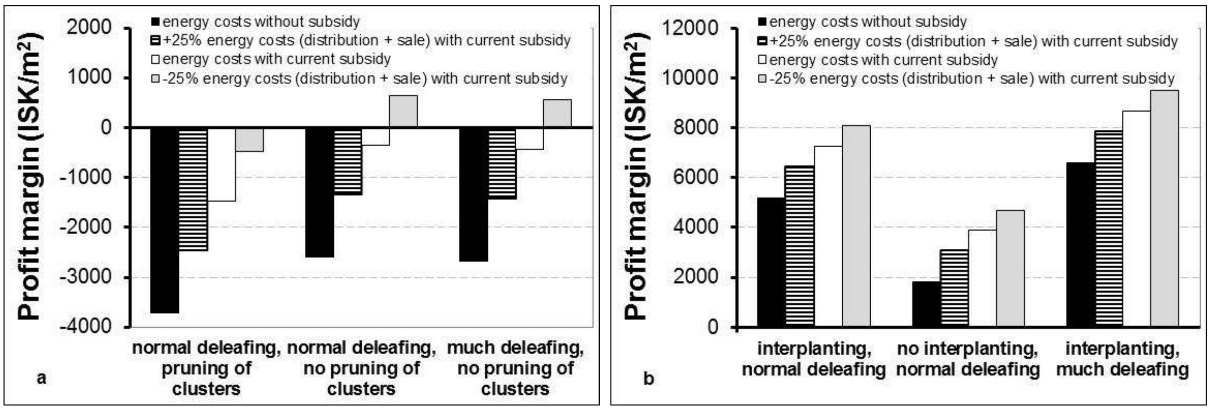


Fig. 43: Profit margin in relation to treatment – calculation scenarios (urban area, VA210).

5.5 Recommendations for increasing profit margin

The current economic situation for growing tomatoes necessitate for reducing production costs to be able to heighten profit margin for tomato production. On the other hand side, growers have to think, if tomatoes should be grown during low solar irradiation and much use of electricity.

It can be suggested, that growers can improve their profit margin of tomatoes by:

1. Getting higher price for the fruits

   It may be expected to get a higher price, when consumers would be willing to pay more for Icelandic fruits than imported ones. Growers could also get a higher price for the fruits with direct marketing to consumers (which is of course difficult for large growers).

2. Decrease plant nutrition costs

   Growers can decrease their plant nutrition costs by mixing their own fertilizer. When growers would buy different nutrients separately for a lower price and mix out of this their own composition, they would save fertilizer costs.

   At low solar irradiation, watering with a scale can save up to 20 % of water – and with that plant nutrition costs – with same yield when compared to automatic irrigation (*Stadler*, 2013a). It is profitable to adjust the watering to the amount of last water application (*Yeager* et al., 1997).

3. Lower CO_2 costs

   The costs of CO_2 are pretty high. Therefore, the question arises, if it is worth to use that much CO_2 or if it would be better to use less and get a lower yield but all together have a possible higher profit margin. The CO_2 selling company has currently a monopoly and a competition might be good.

4. Decrease packing costs

   The costs for packing (machine and material) from SfG and the costs for the rent of the box are high. Costs could be decreased by using less or cheaper packing materials. Also, packing costs could be decreased, when growers would due the packing at the grower’s side. They could also try to find other channels of distribution (e.g. selling directly to the shops and not over SfG).

5. Efficient employees

   The efficiency of each employee has to be checked regularly and growers will have an advantage to employ faster workers. Growers should also check the user-friendliness of the working place to perform only minimal manual operations. Very often operations can be reduced by not letting each employee doing each task, but to distribute tasks over employees. In total, employees will work more efficiently due to the specialisation.

6. Decrease energy costs

   - Lower prices for distribution and sale of energy (which is not realistic)
   - Growers should decrease artificial light intensity at increased solar irradiation, because this would result in no lower yield (*Stadler* et al., 2010).
   - Also, growers could decrease the energy costs by about 6 % when they would lighten according to 100 J/cm^2/cluster and 100 J/cm^2 for plant maintenance (*Stadler*, 2012). This would mean that especially at the early stage after transplanting, plants would get less hours light. Also at high natural light, lamps would be turned off. In doing so, compared to the traditional lighting system, profit margin could be increased by about 10 % (assuming similar yield).
   - Light during nights and weekends from the beginning of November to the end of February is not recommended due to the lower yield and lower profit margin (*Stadler*, 2012).
   - Growers should check if they are using the right RARIK tariff and the cheapest energy sales company tariff. Unfortunately, it is not so easy, to say, which is the right tariff, because it is grower dependent.
   - Growers should check if they are using the power tariff in the right way to be able to get a lowered peak during winter nights and summer (max. power -30 %). It is important to use not so much energy when it is expensive, but have a high use during cheap times.
   - Growers can save up to 8 % of total energy costs when they would divide the winter lighting over all the day. That means growers should not let all lamps be turned on at the same time. This would be practicable, when they would grow in different independent greenhouses. Of course, this is not so

easy realisable, when greenhouses are connected together, but can also be solved there by having different switches for the lamps to be able to turn one part of the lamps off at a given time. Then, plants in one compartment of the greenhouse would be lightened only during the night. When yield would be not more than 2 % lower with lighting at nights compared to the usual lighting time, dividing the winter lighting over all the day would pay off. However, the last experiment showed that the yield was decreased by about 15 % when tomatoes got from the beginning of November to the end of February light during nights and weekends (*Stadler*, 2012). This resulted in a profit margin that was about 18 % lower compared to the traditional lighting system and therefore, normal lighting times are recommended.

- For large growers, that are using a minimum of 2 GWh it could be recommended to change to “stórnotendataxti” in RARIK and save up to 35 % of distribution costs.
- It is expected, that growers are cleaning their lamps to make it possible, that all the light is used effectively and that they are replacing their bulbs before the expensive season is starting.
- *Aikman* (1989) suggests to use partially reflecting material to redistribute the incident light by intercepting material to redistribute the incident light by intercepting direct light before it reaches those leaves facing the sun, and to reflect some light back to shaded foliage to give more uniform leaf irradiance.

6 CONCLUSIONS

The tomato yield was negatively influenced by pruning the clusters of grafted tomatoes and can therefore be recommended. However, pruning the clusters might be recommended for ungrafted plants.

Much deleafing was more and more difficult work and can be a problem when illnesses and aphids are in the greenhouse. But it is possible to increase the yield by 15 % when interplanting is done. Therefore interplanting of tomatoes can be highly recommended in case there is no requirement to clean the greenhouse. An additional increase of the yield by 10 % could be reached by much deleafing when it is started early and continued to harvest. The time of the first deleafing and how long the deleafing continues is deciding if the effect on yield is positive or not. After eight weeks after the first deleafing is an effect visible and it continues the time that the treatment was done. From the economic side it seems to be recommended to interplant grafted tomatoes, leave the clusters unpruned and start with the deleafing behind the cluster early and continue with it to the harvest.

Growers should pay attention to possible reduction in their production costs for tomatoes other than energy costs.

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8 APPENDIX

	Part A: normal deleafing, pruning of clusters Part B: interplanting, normal deleafing		Part B: no interplanting, normal deleafing		Part A: normal deleafing, no pruning of clusters Part B: interplanting, much deleafing		Part A: much deleafing, no pruning of clusters		
Date	**tasks**	**observations problems**	**tasks**	**observations problems**	**tasks**	**observations problems**	**tasks**	**observations problems**	**phone calls or email with Magnús**
2.okt									
3.okt									
4.okt									
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17.okt									
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20.okt									
21.okt									
22.okt									
23.okt									
24.okt									
25.okt									
26.okt									
27.okt									
28.okt									
29.okt									
30.okt									
31.okt									
1.nóv									
2.nóv									
3.nóv									
4.nóv									
5.nóv									

6.nóv						leaves showing P deficiency (high pH?), tops are stressed		blossom end rot, too little watering	
7.nóv									
8.nóv									
9.nóv		white flies in tops, Encarcia				white flies in tops, Encarcia		white flies in tops, Encarcia	
10.nóv									
11.nóv		blossom end rot increased				blossom end rot increased		blossom end rot increased	no deleafing above 1. cluster until cluster is turning red
12.nóv									
13.nóv	deleafing: 1-2 leafes				deleafing: 1-2 leafes		deleafing: leaf behind cluster 6		
14.nóv	new hives				new hives		new hives		
15.nóv									
16.nóv									
17.nóv									
18.nóv	deleafing: 2 leafes	top leaves are getting yellow			deleafing: 2 leafes	top leaves are getting yellow	deleafing: 3 leafes	top leaves are getting yellow	
19.nóv									
20.nóv							deleafing (leaf behind cluster 7)		
21.nóv	pruning clusters to 8 fruits								
22.nóv									
23.nóv									
24.nóv									
25.nóv	1. harvest, deleafing: 3 leafes	top leaves are still yellow			1. harvest, deleafing: 3 leafes	top leaves are still yellow	1. harvest, deleafing: 2 leafes	top leaves are still yellow, leaves are getting shorter	
26.nóv	deleafing: 2nd cluster naked	wateranalysis: macronutrients are too high			deleafing: 2nd cluster naked	wateranalysis: macronutrients are too high	deleafing: 2nd cluster naked,no leaf taken behind cluster	wateranalysis: macronutrients are too high	no deleafing behind the cluster this week and the next
27.nóv									
28.nóv	harvest				harvest		harvest		
29.nóv	changing fertilizer					changing fertilizer	changing fertilizer		
30.nóv									
1.des									
2.des	harvest	top leaves are still yellow, white flies			harvest	top leaves are still yellow,white flies,one plant with fungus	harvest	top leaves are still yellow,white flies, one plant with fungus	

3.des	deleafing: 3 leafes, sprayed with ROVRAL				deleafing: 3 leafes, sprayed with ROVRAL		deleafing: 2 leafes, sprayed with ROVRAL		
4.des									
5.des	harvest, new hives (Koppert)	Macrolophus			harvest, new hives (Koppert)	Macrolophus	harvest, new hives (Koppert)	Macrolophus	
6.des									
7.des									
8.des									
9.des	harvest, sprayed with ROVRAL	fungi at one plant in bed B			harvest, sprayed with ROVRAL		harvest, sprayed with ROVRAL		no deleafing in any chamber and no leaf behind the cluster
10.des									
11.des	new hives (Koppert), setup adjusted to the other chambers, decreased light to 16 h	tops are looking curly and yellow			new hives (Koppert), decreased light to 16 h	tops are looking curly and yellow	new hives (Koppert), decreased light to 16 h	tops are looking curly + yellow, interesting how plants are responding to taking many leafes and how they change again when normal de-leafing is done	E.C. down to 3.0, change fertilizer to more kalí, no deleafing this week, deleafing only normal from bottom, no deleafing behind cluster next 2 weeks
12.des	harvest, temp. changed according to light				harvest, temp. changed according to light		harvest, temp. changed according to light		
13.des									
14.des									
15.des									
16.des	harvest	brown spots on fruits			harvest	brown spots on fruits	harvest	most brown spots on fruits	
17.des									
18.des									
19.des	harvest, Encarsia, new hives (Koppert)	many leaves on plant			harvest, Encarsia, new hives (Koppert)	many leaves on plant	harvest, Encarsia, new hives (Koppert)	many leaves on plant	
20.des	changing night temp. from 16℃ to 18℃ for one week, deleafing: 2 leaves				changing night temp. from 16℃ to 18℃, deleafing: 2 leaves		changing night temp. from 16℃ to 18℃, deleafing: 3 leaves		
21.des									
22.des									
23.des	harvest, new hives, deleafing: 2 leafes				harvest, new hives, deleafing: 2 leafes		harvest, new hives, deleafing: 3 leafes		
24.des									

25.des									
26.des	harvest, changed watering from 30 to 25 min	low pH /drain (4,8)			harvest, changed watering from 30 to 25 min	low pH /drain (4,8)	harvest, changed watering from 30 to 25 min	low pH /drain (4,8)	
27.des	changing night temp. back from 18 to 16℃				changing night temp. back from 18 to 16℃		changing night temp. back from 18 to 16℃		
28.des									
29.des									
30.des	harvest				harvest		harvest		
31.des									
1.jan									
2.jan	harvest, deleafing: 3 leaves				harvest, deleafing: 3 leaves		harvest, deleafing: 2 leaves		
3.jan	topping				topping		topping		
4.jan									
5.jan									
6.jan	harvest				harvest		harvest		
7.jan									
8.jan	deleafing: 4 leaves				deleafing: 4 leaves		deleafing: 2-3 leaves		
9.jan	harvest, new hives				harvest, new hives		harvest, new hives		
10.jan									
11.jan									
12.jan									
13.jan	harvest, deleafing: 5-6 leaves, interplanting changing night temperature to 16℃, 18 h light		planting changing night temperature to 16℃, 18 h light		harvest, deleafing: 5-6 leaves, interplanting changing night temperature to 16℃, 18 h light		harvest, 5-6 leaves changing night temperature to 16C		take more leafes (14-15 leaves on plant), use Topsin 2 times before picking, change night to 16℃, on Monday to 17℃, than to 18℃
14.jan									
15.jan	deleafing: 6 leaves				deleafing: 6 leaves				
16.jan	harvest, old plant layed down under tops of young plants	new plants are lighter than not interplanted ones			harvest, old plant layed down under tops of young plants	new plants are lighter than not interplanted ones	harvest,old plants plants layed down		
17.jan									
18.jan									
19.jan									
20.jan	harvest, changing night temp. to 17℃	watering too much	changing night temp. to 17℃		harvest, changing night temp. to 17℃	watering too much	harvest changing night temp. to 17℃, 18 h light		
21.jan	new hives		new hives		new hives				
22.jan	deleafing				deleafing		deleafing		
23.jan	harvest, changing night temp. to 18℃		changing night temp. to 18℃		harvest, changing night temp. to 18℃		harvest changing night temp. to 18℃		
24.jan	watering changed		watering changed		watering changed				

	from 2h to 1,5h 3min. per watering		from 2h to 1,5h 3min. per watering		from 2h to 1,5h 3min. per watering				
25.jan									
26.jan									
27.jan	harvest, Topsin applied (4ml topsin/5l H_2O /100ml per cube)	leaves from young plants are looking yellow and curly	harvest, Topsin applied (4ml topsin/5l H_2O/100ml per cube)		harvest, Topsin applied (4ml topsin/5l H_2O /100ml per cube)	leaves from young plants are looking yellow and curly	harvest		
28.jan	deleafing old plants: 4 leaves, new hives		new hives		deleafing old plants: 4 leaves, new hives		deleafing old plants: 4 leaves		
29.jan									
30.jan	harvest, Encarsia		Encarsia		harvest, Encarsia		harvest		
31.jan	change watering from 1,5h and 3 min to 1h and 2,5 min		change watering from 1,5h and 3 min to 1h and 2,5 min		change watering from 1,5h and 3 min to 1h and 2,5 min				
1.feb									
2.feb									
3.feb	harvest, deleafing: 2 leaves		deleafing: 2 leaves		harvest, deleafing: 2 leaves, leaf behind 3rd cluster		harvest		
4.feb	new hive		new hive		new hive				
5.feb	deleafing: down to 6 leaves on old plant				deleafing: down to 6 leaves on old plant		deleafing: down to 6 leaves on old plant		
6.feb	harvest				harvest		harvest		
7.feb									
8.feb									
9.feb									
10.feb	harvest				harvest, deleafing: leaf behind 4th cluster	deleafing delayed because of different development of clusters	harvest		
11.feb	time between waterings: 40 min, new and old plants layed down, EC for applied water changed to 2,4, additionall 3 waterings beween: 5.00 and 6.00 with 20 min in between	temp.too high between 5.00 and 6.00	time between waterings: 40 min, new and old plants layed down, EC for applied water changed to 2,4, additionall 3 waterings beween: 5.00 and 6.00 with 20 min in between		time between waterings: 40 min, new and old plants layed down, EC for applied water changed to 2,4, additionall 3 waterings beween: 5.00 and 6.00 with 20 min in between	temp.too high between 5.00 and 6.00	time between waterings: 40 min, new and old plants layed down, EC for applied water changed to 2,4, additionall 3 waterings beween: 5.00 and 6.00 with 20 min in between	temp.too high between 5.00 and 6.00	
12.feb	new hives		new hives		new hives				

13.feb	harvest, watering changed to 35 min, lighting changed to 16 h	deleafing delayed due todifferent development of clusters	watering changed to 35 min, lighting changed to 16 h	deleafing delayed due to different development of clusters different deleafing	harvest, watering changed to 35 min, lighting changed to 16 h		harvest, watering changed to 35 min, lighting changed to 16 h		
14.feb	deleafing: 2 leafes		deleafing: 2 leafes		deleafing: 2 leafes				
15.feb									
16.feb									
17.feb	harvest				harvest		harvest		
18.feb	new hives, deleafing: up to 1st cluster	6th cluster flowering	new hives, deleafing: up to 1st cluster, 0-3 leaves	6th cluster flowering, except for plants that are looking bad	new hives, deleafing: up to 1st cluster, leaf behind 5th cluster	6th cluster flowering,			
19.feb	watering changed to 1.35 min, every 30 min watered, night temperature, changed to 16℃, speed from night to day 3℃/h, from day to night 4-6C°/h		watering changed to 1.40 min, every 30 min watered, night temperature changed to 16℃, speed from night to day 3℃/h, from day to night 4-6℃/h		watering changed to 1.35 min, every 30 min watered, night temperature changed to 16℃, speed from night to day 3℃/h, from day to night 4-6℃/h		night temperature changed to 16℃, speed from night to day 3℃/h, from day to night 4-6℃/h		
20.feb	harvest			plants are looking better	harvest		harvest		
21.feb									
22.feb									
23.feb									
24.feb	harvest				harvest		harvest		chamber 2: deleafing 2 leaves, chamber 3: differently chamber 4: 2 leaves on bottom + 1 leaf behind cluster 6 increase watering in chamber 3
25.feb									
26.feb									
27.feb	harvest				harvest		harvest		
28.feb									
1.mar									
2.mar									
3.mar	last harvest old plants	starting to flower on cluster 8		fruits starting to colour! starting to	last harvest old plants	starting to flower on cluster 8	last harvest old plants		

				flower on cluster 8					
4.mar	deleafing: 3 leafes		deleafing: 2 leafes		deleafing: 3 leafes				
5.mar									
6.mar	irrigation changed to 35 min between irr. and to 3 min		first harvest from new plants, irrigation changed to 35 min between irr. and to 3 min		irrigation changed to 35 min between irr. and to 3 min				
7.mar									
8.mar									
9.mar									
10.mar	first harvest from new plants	cluster 9 and 10 starting to flower	2nd. harvest, drain was over 50 %, irrigation changed to 45 between and 2,5 min each time	cluster 9 and 10 starting to flower	first harvest from new plants	cluster 9 and 10 starting to flower			no deleafing behind cluster 9 but only the 2 lowest leaves, wait with further deleafing behind clusters.
11.mar	new hives, deleafing: 3 leafes		new hives, deleafing: 3 leafes		new hives, deleafing: 2 leafes				
12.mar									
13.mar	harvest		harvest		harvest				
14.mar									
15.mar									
16.mar									
17.mar	harvest, suppl. light changed from 16 h to 14 h	leaves starting to turn little yellow (magnesium deficiency)	harvest, suppl. light changed from 16 h to 14 h	leaves starting to turn little yellow (mag-nesium deficiency)	harvest, suppl. light changed from 16 h to 14 h	leaves starting to turn little yellow (magnesium deficiency)			
18.mar	deleafing: 3 leafes		deleafing: 3 leafes		deleafing: 2 leafes				
19.mar									
20.mar	harvest		harvest		harvest				
21.mar									
22.mar									
23.mar									
24.mar	harvest, N:ammoniumfree	white flies increasing	harvest, N:ammoniumfree	white flies increasing	harvest N:ammoniumfree	white flies increasing			
25.mar	new hives		new hives		new hives				
26.mar	harvest, 16 h light, night 16°C, deleafing: 3 leafes		harvest, 16 h light, night 16C, deleafing: 3 leafes		harvest, 16 h light, night 16C, deleafing: 2 leafes				4-5 h hives open, 10 pieces Encarcia/m^2/week and double when many white flies, increase pH + Mg
27.mar									

28.mar									
29.mar									
30.mar									
31.mar	harvest	tops more light green	harvest	tops more light green	harvest	tops more light green			
1.apr									
2.apr	new Encarsia, deleafing: 3 leafes		new Encarsia, deleafing: 3 leafes		new Encarsia, deleafing: 2 leafes				
3.apr	harvest, again Ammonium fertilizer		harvest, again Ammonium fertilizer		harvest, again Ammonium fertilizer				
4.apr	night temperature back to 16℃		night temperature back to 16℃		night temperature back to 16℃				
5.apr									
6.apr									
7.apr	harvest		harvest		harvest				
8.apr	new hives, deleafing: 3 leafes		new hives, deleafing: 3 leafes		new hives, deleafing: 2 leafes				
9.apr									
10.apr	harvest		harvest		harvest				
11.apr									
12.apr									
13.apr									
14.apr	harvest		harvest		harvest				
15.apr	deleafing: 3 leafes		deleafing: 3 leafes		deleafing: 2 leafes				
16.apr	harvest		harvest		harvest				
17.apr									
18.apr	topping		topping		topping				
19.apr									
20.apr									
21.apr									
22.apr	harvest, new hives		harvest, new hives		harvest, new hives				
23.apr									
24.apr	harvest		harvest		harvest				
25.apr									
26.apr									
27.apr									
28.apr	harvest		harvest		harvest				
29.apr									
30.apr									
1.maí	harvest		harvest		harvest				
2.maí									
3.maí									
4.maí									
5.maí	harvest		harvest		harvest				
6.maí									
7.maí									

8.maí	harvest		harvest		harvest				
9.maí									
10.maí									
11.maí									
12.maí	harvest		harvest		harvest				
13.maí	deleafing		deleafing		deleafing				
14.maí									
15.maí	harvest		harvest		harvest				
16.maí									
17.maí									
18.maí									
19.maí	harvest		harvest		harvest				
20.maí									
21.maí	no deleafing this week	small spots on tomatos due too much calcium = stop using calcium sulphate	no deleafing this week	small spots on tomatos due too much calcium = stop using calcium sulphate	no deleafing this week	small spots on tomatos due too much calcium = stop using calcium sulphate			
22.maí	harvest		harvest		harvest				
23.maí									
24.maí									
25.maí									
26.maí									
27.maí									
28.maí	deleafing: 2 leaves		deleafing: 2 leaves		deleafing: 2 leaves				
29.maí									
30.maí									
31.maí									