**Enabling Agricultural Research and Innovation (EARI)**
**Accelerating Agricultural Innovation through Demonstration**

# Final Report- EARI14-091

1. *Project title and number*:
Implementation of Production Technologies for Season Extension Structures (coloured sweet peppers and grafted tomatoes grown in greenhouses and high tunnels).
EARI14-091

2. *Project leader and collaborators*:
Claude Berthélémé from the New Brunswick Department of Agriculture, Aquaculture and Fisheries (NBDAAF) is the project lead. He is the provincial Organic and Vegetable Specialist. Tara Scott from the Atlantic Canadian Organic Regional Network (ACORN), Charles Comeau and Patrick Toner from the NBDAAF collaborated.

3. *Summary:*

This demonstration project allowed several NB vegetable growers an opportunity to grow and evaluate ten top performing coloured sweet pepper cultivars and three grafted and non-grafted tomato cultivars. Through this project, the NBDAAF staff also monitored irrigation, fertilization program and inside and outside temperatures of four greenhouse and tunnel tomato production sites.

Eight growers from across the province grew the coloured sweet peppers and provided their assessment for each of the ten coloured pepper cultivars by completing a crop assessment survey. The project demonstrated that it is possible to successfully grow coloured sweet peppers in New Brunswick by selecting early to mid-season cultivars and by growing them in greenhouses and tunnels which allow for earlier ripening and less bacterial disease pressure. Based on the crop assessment surveys and comments received from growers, the following six cultivars appear to be the most interesting for NB vegetable producers who sell locally and direct to consumers: Triora, Carmen, Cupid, Catriona, Doe Hill and Red Wing.

Three greenhouse and one high tunnel tomato producers grew three tomato cultivars, Frederik, Sakura and Sweet Heart on their own roots (non-grafted treatment) and grafted onto a Maxifort rootstock (grafted treatment). The growers recorded the tomato yields from the six grafted and non-grafted tomato treatments. The grafted tomato plants demonstrated improved crop vigour, vegetative growth, height and often yield. At all sites, the grafted Frederik and Sweet Heart seemed to outperform the yield from the non-grafted plants by 9 to 50%. The Maxifort rootstock had a more robust and healthier root system than the ones produced by the non-grafted Sakura and Frederik. On one particular site, the benefit of grafting with the disease-resistant rootstock was evident. The non-grafted Frederik was severely infected by the corky root soil borne

disease caused by *Pyrenochaeta lycopersici,* while the Frederik plants grafted on the Maxifort rootstock did not show any signs of disease.

The same greenhouse and tunnel tomato growers were selected for the greenhouse monitoring component of the project. NBDAAF staff installed and monitored tensiometers and temperature data loggers to monitor indoor and outdoor air temperature. NBDAAF staff also conducted soil and plant tissue sampling to monitor the fertilization program of each farm through the season.

It was quickly determined that the tensiometers used to monitor soil moisture and manage irrigation were not effective for the sites because the soil moisture throughout the beds was not uniform enough to show coherent readings. Additional drip lines and more frequent watering were recommended in order to meet the tomato plant's water requirements.

Regarding fertilization, although the basic soil tests taken prior to planting indicated a high level of fertility in all sites, only one operation was able to supply enough nutrients to meet the plant's requirement. Soil and tissue test reports suggest that most growers need to apply additional nitrogen and potassium.

On several occasions during the season, the temperature in the greenhouses and tunnels at most sites reached the critical level for tomato production of 35° C indicating the need for improved ventilation. Also, because none of the sites used supplemental heat in their structures after the beginning of June, the inside night and early morning temperature was regularly below the critical level for tomato production of 15°C.

4. *Introduction:*

During the last 10 years, few vegetable research and demonstrations projects have been conducted in New Brunswick with the exception of the work carried out by AAFC's Sénateur Hervé J. Michaud Farm in Bouctouche. The vegetable sector has evolved greatly over the past 30 years. Fewer producers are now involved in the production and many of them have scaled down as wholesaling produce has not been very profitable to growers.

Although the overall acreage of vegetables grown in the province has diminished since the 80's, many new small scale operations have been established. These operations are involved with direct marketing and are benefiting from the renewed interest shown by consumers for locally produced fruit and vegetables. As a result, many of them are involved in season extension activities. Off-season prices associated with early and late season crops and the need to stretch the growing season to capture new markets are driving the interest for season extension. A recent vegetable farm tour to Quebec confirmed that NB growers must adopt several novel practices and techniques to maintain their competitiveness. Grafted tomato plants in greenhouses and tunnels, selecting earlier, more productive coloured sweet pepper cultivars and making use of basic tools such as tensiometers, thermometers and automated equipment are practices that NB growers need to adopt.

5. *Project Objective(s):*

Provide 8 NB vegetable growers with an opportunity to grow the top performing coloured sweet pepper cultivars (including cultivars evaluated in Québec in 2012-2014). Provide 4 NB vegetable growers with an opportunity to grow and compare the productivity of grafted and non-grafted tomato cultivars (Sakura, Sweet Heart and Frederik grafted on the Maxifort rootstock) in their greenhouses or tunnels.
Monitor the production of 4 greenhouse and tunnel tomato producers (including irrigation system design, watering practices, fertilization program, and inside/outside temperatures of the infrastructure).

6. *Project Deliverable(s):*

The seeds and transplants were ordered, grown, purchased and delivered to all collaborating farms in May and June 2015. Eight (8) NB vegetable growers grew the ten coloured sweet peppers and four (4) tomato producers grew the three grafted and non-grafted transplants. The same four greenhouse/tunnel tomato growers were selected for the greenhouse monitoring component of the project. Transplants were grown by Schurman Family Farm and Strawberry Hill Farm. The tomato growers collected yield data through the entire season and the NBDAAF staff monitored irrigation, fertilization program and inside and outside temperatures. Four of the eight producers who grew the coloured sweet peppers reported back to the project lead with their crop assessment surveys.

7. *Project details/methodologies*:

Coloured Sweet Pepper Demonstration: The eight producers grew the coloured sweet peppers in their greenhouses or tunnels using their normal production practices. Growers were asked to fill in the crop assessment sheets so the project lead could report all the relevant information. It is important to note that no yield data was collected from the coloured sweet pepper cultivars.

Grafted Tomato Demonstration: The four tomato producers grew the grafted and non-grafted cultivars in their greenhouses or tunnels (cv. Frederik, Sweat Heart and Sakura). At three sites the treatments were grown in the same row and under the same irrigation and fertilization conditions. Each cultivar was grown on grafted rootstocks and on their own roots for comparison with a total of six treatments per site. It is important to note that the grafted tomato demonstration did not include replications although the six treatments were grown on all four sites. Grafted and non-grafted plants were grown with twin heads by either pinching the seedling above the cotyledons or by allowing the sucker below the first cluster to grow.

Tomato monitoring: At each site, three tensiometers and two thermocouples (temperature data loggers) were installed to monitor irrigation and inside/outside air temperatures. Soil fertility was monitored at planting time with one Basic Soil Test and during the season with two Greenhouse Soil Tests (Satured Media Extract, SME) and with three Plant Tissue Tests. The Sakura cultivar was the only one monitored through Plant Tissue Testing.

*8. Results and discussion*:

According to the comments provided by the growers on the crop assessment surveys, the productivity of the coloured sweet peppers grown on the eight farms was extremely variable. The surveys also indicated that the following six cultivars appear to be the most interesting for NB vegetable producers who sell locally: Triora, Carmen, Catriona, Cupid, Doe Hill and Red Wing. Two informal group tasting events found the first 5 cultivars listed above to be the most flavourful ( Annex A). It should be noted that some of the growers (direct marketers) preferred the medium sized fruits over the large fruits because of the higher unit cost associated with the large fruits. Many growers sold the small pepper cultivars in mixtures and by containers instead of by weight.

On all four sites (Annex C), the grafted tomato plants provided improved crop vigour, vegetative growth and height (Annex D). On all sites, the grafted Frederik and Sweet Heart seemed to outperform the yield from the non-grafted plants by 9 to 50%. At three sites, the grafted Sakura seemed to provide more yield than the non-grafted Sakura. At one site, the grafted Sakura treatment was outperformed by the non-grafted treatment. However, it should be noted that the yield data obtained from that particular treatment may not be reliable because of trellis failure and harvesting issues (Annex F). The Maxifort rootstock grafted on Sakura and Frederik tended to have more robust and healthier root systems than the roots produced by the same fruiting cultivars (Annex E). The size of the root system from the Sweat Heart cultivar was very similar to the one from the Maxifort Rootstock. On one particular site, the benefit of grafting with the disease-resistant rootstock was evident. The non-grafted Frederik was severely infected by the corky root soil borne disease caused by *Pyrenochaeta lycopersici,* while the Frederik plants grafted on the Maxifort rootstock did not show any signs of disease. This may explain why the grafted Frederik seem to generate higher yields compared to the non-grafted Frederik. It is interesting to note that the tissue testing from one site seem to indicate that the grafted treatment was able to uptake more nutrients than the non-grafted treatment. This trend seemed more consistent for the uptake of micro-nutrients.

Irrigation: Based on irregular tensiometer readings and water circle observations, it was quickly determined that the tensiometers used to monitor soil moisture were not effective at these sites because the soil moisture throughout the bed was not uniform enough to show coherent readings. In all cases, growers needed to improve their irrigation system design and watering practices. The tensiometers were monitored occasionally; however, no data was collected.

Fertilization: The basic soil tests taken prior to planting indicate a high level of fertility at all sites; however, based on the SME soil and tissue test reports, only one farm site had adequate nitrogen levels in the soil and in the plant tissues during the full season (Annex G and H). All SME soil tests and some of the tissue tests indicated low levels of phosphorus, although no phosphorus deficiencies were observed on the crop. Growers participating in the project, tended to underestimate the tomato plant's need for potassium. According to SME soil and plant test reports, only one of the four farm sites had adequate levels of potassium in their soil and their crop over the full season.

Temperature: On several occasions, the temperature in the greenhouses or tunnels at most sites reached the critical high level for tomato production of 35° C during the season (Annex I). Since none of the sites used supplemental heat in the structures after the beginning of June, the inside temperature was regularly below the critical low level of 15°C.

9. *Conclusions and important things learned:*

Coloured Sweet Peppers:

It is possible to successfully grow coloured sweet peppers under NB conditions by selecting early to mid-season cultivars and by growing them in greenhouses and tunnels which allow for earlier ripening, extended season and less bacterial disease pressure (reduced leaf wetness). Collaborators and industry consultants agree that it is extremely important to grow robust and healthy transplants to obtain high yield. The pepper assessment summary sheet provides a detailed description of the ten (10) cultivars grown. Since the productivity of the pepper cultivars was extremely variable between sites, growers should conduct cultivar trials under their own growing conditions to determine which ones are better adapted to their operation.

Grafted Tomato Plants:

Based on the results of the 2015 project, most grafted tomato plants (treatments) grown in minimally heated greenhouses and unheated tunnels allowed for increased yield. It is generally recognized that growers who produce tomatoes in heated greenhouses or tunnels and in the soil with little or no crop rotation options should consider grafting their plants on disease resistant and vigorous rootstock. This is particularly true when soil-borne diseases have been identified. However, a number of recent studies from Quebec clearly show that grafting tomato plants will delay fruit production. Consequently, tomato grafting is more beneficial to greenhouse/tunnel growers who extend their season with supplemental heat. To mitigate the delayed harvest, growers are encouraged to manage their grafted indeterminate tomato crop on two heads and with intensive pruning. De-suckering and pruning will re-balance the crop from an excessively vegetative mode to a fruit setting mode (regenerative mode). It should; however, be noted that some varieties do not perform well when they are pruned heavily. Also, grafted tomato plants may not be suitable for growers looking for tomatoes for the early market.

Since grafted tomato plants generally provide increased plant vigour and vegetative growth, more pruning; therefore, improved management will be required. For this reason, novice growers may want to consider improving their tomato production skills before considering grafted tomato plants. However, some industry experts think differently, suggesting that the improved rootstock may offer more benefits when the crop is grown in less than adequate conditions (i.e. fertility, water and temperature stress). To make full use of a vigorous rootstock and for economic reasons, the scion (top part of the transplant and cultivar grown for its fruit) is often grown with two heads or leads. The scions should also be managed so they are not in contact with the soil to prevent them from developing roots. The roots from the scion do not have the soil-borne disease resistance that is offered by the selected rootstock. Furthermore, the suckers

from the rootstock should not be allowed to grow as they are generally not productive and their fruit of lower quality. Growers who make use of grafted tomato plants may need to adjust their irrigation practices and fertilization program.

More research will be required to determine which production systems are most suitable for grafted tomato plants and which are the most cost effective. Several questions remain: Should NB growers use grafted tomato plants in unheated season extension structures (short season) when soil-borne diseases are not present? Should growers use grafted tomato plants for field production? Should growers graft determinate type tomatoes? Should growers graft the more vigorous indeterminate and/or small fruited type tomatoes, and how should the various scions be managed (intensively pruned or not)? What is the best choice of rootstock (regenerative or vegetative) for the various types of tomatoes?

Greenhouse Tomato Production Monitoring:

Greenhouse tomato growers need to improve their irrigation system design and watering practices. The system should include at least 2 drip lines and preferably 3 to 4 lines for organic production. Additional lines allow for uniform watering of the entire bed width. Emitter spacing should not be too far apart (12 inches or less). To reduce evaporation and stimulate mineralization of the organic fertilizers applied on the surface of the soil, black or white on black plastic mulch should be used. The use of white on black plastic (non-buried) is of particular benefit to organic growers who need to lift their mulch in order to apply dry organic fertilizers during the season. Without any type of mulch, limited mineralization of the organic matter and organic fertilizers will occur at the surface of the soil because the conditions are too dry to support soil biological activity. Based on the observations made during the summer of 2015, diversified vegetable growers tend to under-irrigate their crop (watering is not frequent enough). To compensate for irregular watering, some growers will often over-irrigate (leaving the irrigation on for excessively long periods of time). Growers need to be more consistent in the watering frequencies and length of watering cycles. When the tomato plants are producing ripened fruit and when the conditions are sunny and hot, multiple short watering cycles should be used and overall water volume increased. Watering should be done between mid-morning and mid-afternoon. A period of soil dryness (aeration) is needed after the watering cycles. The period of aeration should occur during late day and night time. This encourages soil biological activity and optimal root growth. Tensiometers are valuable soil moisture monitoring tools that are used to manage the watering practices; however, for them to be useful, the irrigation system must be well designed to ensure uniform watering. Novice greenhouse operators should use tensiometers.

The fertilizers or amendments should be applied to the entire bed width to encourage optimal root development. Placing organic fertilizers in the plant hole before planting is not a recommended practice. Some references suggest that organic and conventional tomato growers should apply at least ½ of the nitrogen fertility to the soil prior to planting. The fertilizers or amendments used prior to planting must be incorporated lightly into the soil. Since only one farm site had adequate nitrogen levels in the soil and plants during the entire season, growers will need to add nitrogen

fertilizers during the season on top of the beds or through the drip irrigation system. Organic growers may want to use several sources of nitrogen to ensure a more consistent and longer lasting release of nitrogen. Since none of the crops have shown any phosphorus deficiencies, no corrections were required on any of the four sites. Low levels of soil and plant tissue phosphorus are often reported in organic tomato production. In general, growers tend to underestimate the tomato plant's need for potassium. Potassium should be applied prior to planting and during the season. According to plant tissue analysis, three of the farms should have added some potassium rich fertilizers during the season. The project demonstrated the usefulness of doing some basic soil tests prior to planting, in-season greenhouse soil tests and in-season tissue tests to monitor the fertilization program.

On several occasions, the temperature in the tomato greenhouses and tunnels of most sites reached the critical level of 35° C during the season. Growers who use season extension infrastructure need to better monitor inside temperatures and ventilate their structures before the temperature reaches excessively high levels. Horizontal air-flow (HAF) fans may be used to circulate the inside air, to eliminate hot spots. The warm air should be exhausted out of the structure by natural or forced air ventilation. Greenhouse and tunnel tomato plants will benefit from improved mid-day ventilation to reduce indoor temperature. Greenhouse tomato plants can withstand short periods of high temperature provided the irrigation is adequate and night temperature is back in the optimal range. Small tunnels and basic greenhouses are often not designed and equipped for optimal ventilation. Since none of the sites used supplemental heat in the structures after the beginning of June, the inside night and early morning temperature was regularly below the critical level of 15°C. Adding heat in early and late season should allow for higher fruit yield. It will also allow growers to optimize the benefit of the grafted plants which should be more productive over a longer period of time. For tomato production, it is best to keep the ambient temperature between 17°C and 25°C. The development of the tomato plants is jeopardized when the ambient temperature is outside the critical temperature levels. Adding early morning heat or ventilation would also reduce the relative humidity (RH) in the tunnels. This RH is responsible for morning condensation on the plants and higher incidence of disease.

10. Required next steps – The results and observations over the course of the season suggest that further greenhouse vegetable investigations are required. Growers need to improve their irrigation system designs, watering practices and fertilization programs. Growers should also purchase several crop production aids (e.i. better suited irrigation equipment, white on black plastic mulch, tensiometers, temperature monitoring, alarm devices and automated systems) as well as continue to invest in soil and tissue testing. The project lead and the partners are considering applying for additional funds in 2016-17. The application will be developed in February 2016 and will be submitted by early March 2016.

11. *Communication*: The project lead and collaborators have presented the results at the ACORN conference (November 2015) and will be presenting it again at the NBSCIA Meeting as well as during the upcoming NBDAAF Crop Update and NBSCIA sessions. The presentation will be available on-line via the ACORN website.

Acknowledgements:
Thank you to the following project collaborators: Strawberry Hill Farm, Jemseg River Farm, Nature's Route Farm, Ferme Pouce Vert, Gore Farm, Pumpkin Lady Farm, Les serres à Eugène and Villeneuve Family Farm.
The project collaborators would also like to acknowledge and thank Johnny's Selected Seeds and Seminova for their technical support and seeds.

Annex A

**Description of Coloured Sweet Pepper Cultivars (as presented in seed catalogues):**

**Cupid, red mini (organic seeds, supplied by Johnny's)**
Early, red, sweet, mini bell. Fruits are blocky to slightly pointed, avg. 2" x 1 ¾" (51 g) and are particularly sweet when red. Large, well-branched plants protect the fruit from sunscald. The fruit is smoother and has better flavor than Mini Apple, which it replaced. Should be staked (4.5 ft).

**Triora, organic mini-medium (Rijk Zwaan, supplied by Seminova)**
Early orange mini-medium (113 g), 51 days, very attractive and very tasty, uniform quality fruit

**Doe Hill, mini yellow: (Supplied by Société des plantes):**
Small yellow pepper which would market well with Cupid (small red) and Triora (small orange). Very nice looking mini orange sweet peppers (66g). Thick skin, fragrant and sweet. Early and adapted. First cultivar to mature 65 days after transplanting. Good productivity on compact plants. Most productive/plant in Quebec trials. 45 cm. May lack in uniformity.

**Carmen, regular red (organic seeds, supplied by Johnny's)**
Best-tasting sweet Italian frying pepper. A beautiful pepper of the Italian "bull's horn" (corno di toro) type from Johnny's plant breeders Janika Eckert and Rob Johnston. Carmen has a lovely, sweet taste for salads and roasting, especially when partially or fully red-ripe. Tapered fruits avg. 6" long x 2 ½" wide, 5 oz. (142 gm), and ripen from green to deep carmine red. Maturity is early on an upright, medium-size plant. Suitable for outdoor or indoor production. AAS winner.

**Red wing, regular red (Rijk Zwaan, supplied by Seminova)**
Early to mid-season red pepper, high yielding, must be staked 4.5 ft, most attractive in Quebec trial, highest score in Quebec, uniform quality and size.

**Catriona, regular yellow (Enza Zaden Vitalis, supplied by Seminova)**
Early maturing yellow bell with robust disease resistance package. Compact plants are strong and upright. For open field or high tunnel production. Fruit sets well in a wide range of conditions. Intermediate resistance to Tomato Spotted Wilt Virus and Potato Virus Y. Upright habit 3.5 fruits.

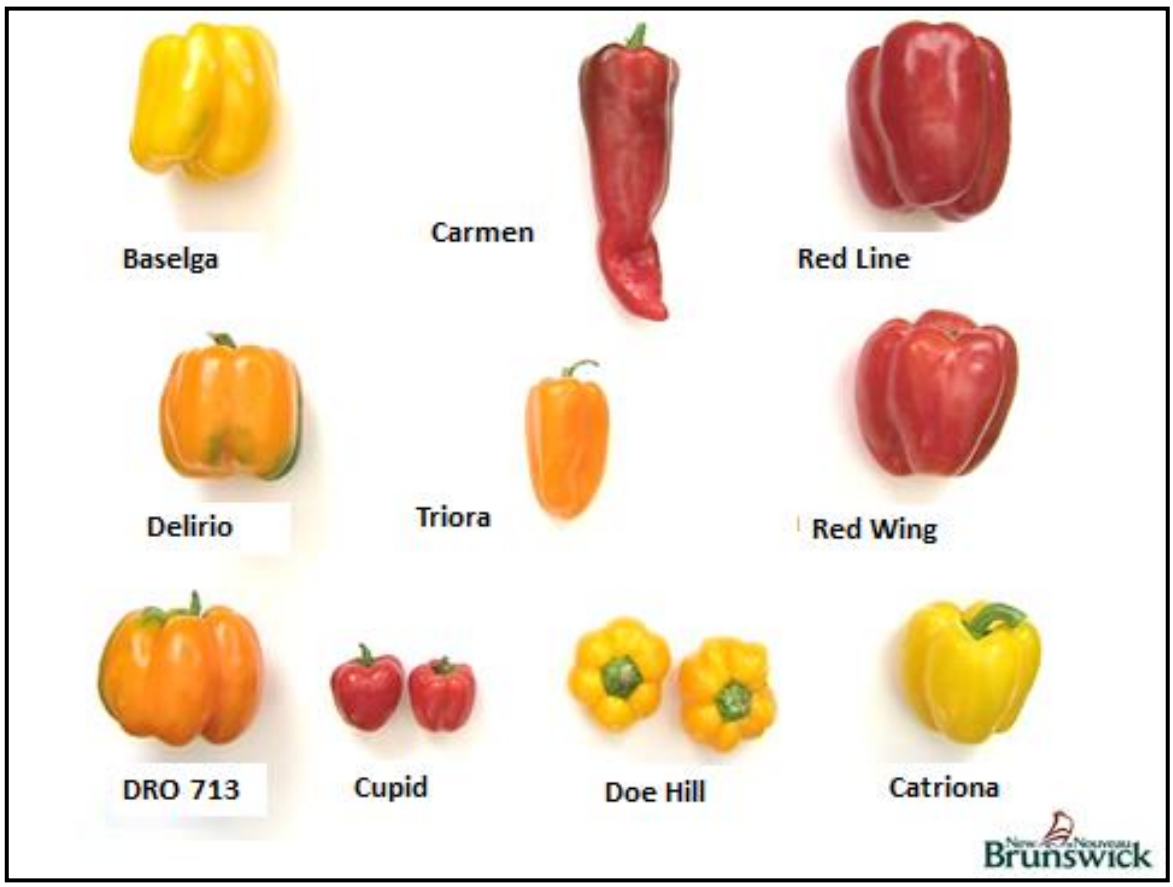
**Delirio, regular orange (lots of interest in Quebec, supplied by Stokes)**
Shiny dark orange, excellent TSW tolerance, blocky 4 lobe fruit average 4.25 inches. Offering a great production of firm and uniform fruits.
75 days, dark green to tangerine orange.

**DRO 713, regular orange, (DeRuiter, supplied by Seminova)**
New cultivar that does not have a description but should be of interest to NB growers. It should be on the market next year. According to the company rep, it should be early to mid-season.

**Baselga, regular yellow (Rijk Zwaan, supplied by Seminova)**
Baselga is the cultivar to choose when growing yellow peppers. It has the highest production of all yellow pepper cultivars by a high margin. The fruit size is large with a nice 4 lobed blocky shape and the colour stays very yellow even during the heat of the summer. Noted for its early production, strong growth and generative nature. Baselga is TM: 0-3 virus resistant for another added benefit.

**Red Line, regular red (Rijk Zwaan, supplied by Seminova)**
Mid-season red pepper, best tasting pepper in Quebec trial, less yielding than Red Wing, somewhat smaller than Red Wing (186 g).

**<u>Image of coloured sweet peppers cultivars</u>:**



# EARI 14-091 PROJECT- 2015 NBDAAF/ACORN Coloured Sweet Peppers Crop Assessment Summary

| | | | | | Score: 2= very low, 4= low, 6= medium, 8= high, 10= very high | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variety** | **Earliness (early, mid, late)** | **Height of plants (cm)** | **Fruit shape ribbed, blocky, horn-shaped, triangular, pumpkin, oval** | **Fruit taste (sweet, bitter, sour, hot, etc)** | **Fruit attractiveness score** | **Fruit size uniformity score** | **Yield score** | **Proportion of marketable fruit score** | **Shelf-life score** | **Fruit taste score** | **Comments from growers and collaborators:** disease incidence, insect damage, fruit size, colour uniformity, days to full maturity, other fruit characteristics, etc |
| **Carmen (regular red)** | Early | 71-80 | Bull-horn shaped | Sweet and flavourfull * | 9 | 9 | 9 | 9 | 9 | 8* | Heavy yield, thinning in early stages maybe beneficial, pick promptly or the fruit tips can go soft if in contact with ground. 153g/fruit/1 site, av.8 fruits/plant/1 site, av.17 fruits/plant/1 site, 40% lodging on 1 site, need staking, hard to pick when loaded. 1 grower did not like taste. |
| **Red Wing (regular red)** | Late | 66-80 | Very large blocky | Sweet | 9 | 9 | 8 | 8 | 9 | 6 | Huge fruit somewhat bigger than Red Line (according to seed supplier). Very interesting large and tasty fruit. 280g/fruit/1 site, av.5 fruits/plant/1 site, av.16 fruits/plant/1 site, 20% lodging on 1 site, 14% wilt or rot on 1 site. |
| **Red Line (regular red)** | Late | 60-70 | Very large blocky | Sweet | 9 | 7 | 8 | 8 | 9 | 6 | Huge fruit bigger than Red Wing (according to one grower). 340g/fruit/1 site, av.7 fruits/plant/1 site, av.13 fruits/plant/1 site, less than 10% lodging on 1 site, need staking. |
| **Catriona (regular yellow)** | Early-mid | 60-67 | Very large blocky | Sweet* | 9 | 9 | 9 | 8 | 7 | 7* | Amazing yellow colour. Pick promptly to avoid soft spots on fruit. A good variety. 233-250g/fruit/1 site, av.7 fruits/plant/1 site, av.10 fruits/plant/1 site, 7% wilt or rot on 1 site, 0% lodging on 1 site. |
| **Baselga (regular yellow)** | Late | 61-75 | Large pumpkin "ribbed" | Sweet | 7 | 8 | 8 | 9 | 8 | 6 | Thicker skin than Catriona. Lacked the consistent nice shape of Catriona. Fruits tended to be a bit shorter/rounder with more pronounced ribs than Catriona. 280-260g/fr/1 site, av.4 fr/plant/1 site, av.13 fr/plant/1 site, 7% wilt or rot on 1 site, 29% lodging on 1 site, need staking. |
| **Delirio (regular orange)** | Late | 60-81, variable | Large blocky | Sweet | 9 | 8 | 7 | 7 | 8 | 6 | Fruit shape and size were nice, but the plants lack vigour. Plant height was variable. 167-300g/fruit/1 site, av.7 fruits/plants/1 site, av.17 fruits/plant/1 site, 50% lodging on 1site, weak plants, need staking. |
| **DRO 713 (regular orange)** | Mid | 60-80 variable | Very large blocky | Sweet | 8 | 7 | 7 | 8 | 8 | 7 | Fruit shape and size were nice, but not really a productive variety. 200-300g/fruit/1 site, av.9 fruits/plant/1 site, av.13 fruits/plant/1 site, 38% lodging on1 site, poor germination, weak seedlings, non-uniform seedlings, need staking. |
| **Cupid (mini red)** | Early | 60-100, variable | Mini oval | Sweet * | 9 | 8 | 8 | 9 | 9 | 8* | Beautiful deep red. Very productive variety. This variety produces numerous fruits per plant. The height of the plants varied between sites. 37g/fruit/1 site, may need staking. Cupid and Doe Hill together make a nice mini pepper selection for selling in quarts. |
| **Triora (mini-medium-orange)** | Early -mid | 65-71 | Med. triangle | Very sweet and flavourful * | 9 | 9 | 9 | 8 | 9 | 9* | Good yielder, medium size fruit, gorgeous orange. Did consistently well on all sites. Top pick for one grower. 115g/fruit/1 site, no lodging with lots of fruit, av.14 fruits/plant/1 site, av.16 fruits/plant/1 site, need staking, pick promptly to avoid small cracks. |
| **Doe Hill (mini-yellow)** | Early | 50-64, variable | Small pumpkin "ribbed" | Very sweet and flavourful * | 7 | 7 | 8 | 7 | 9 | 9* | Plants typically produce numerous small fruits. 77g/fruit/1 site, prone to wilt and rot in field conditions but did well under cover. Some plants failed during the middle of the season. No lodging with lots of fruits, av.20 fruits/plant/1 site, av.20 fruit/plant/1 site, no staking needed. |

Data and observations from 8 New Brunswick sites (one year only). It is important to note that none of the collaborators have measured the exact yields.

All scores are based on visual observations and taste. Significant yield variations were observed between sites. Most cultivars should be staked.

* Top 5 best tasting peppers based on two group tasting events. Seed suppliers: Johnny's Selected Seeds, Veseys Seeds, Seminova, Stokes Seeds, La société des plantes

Annex B

**Description of tomato cultivars (as presented in seed catalogues):**

**Frederik:** Beef type from Johnny's, 76 days, New! High yields from a compact, vigorous plant, 7-9 oz., very good flavor. Deep round fruits and light ribbing. Short internode length results in a compact plant, which works well for greenhouses or tunnels with less height. Good greenhouse disease package, high resistance to fusarium wilt races 1, 2, fusarium crown and root rot, leaf mold, tomato mosaic virus; including intermediate resistance to powdery mildew. Indeterminate.

**Sweet Heart:** Grape type from Veseys, 68 days, bright red grape tomato, extra sweet and crack resistant, 1.5 in. fruit, very vigorous, indeterminate and requires support. One of Veseys favorite and appreciated by many Atlantic growers.

**Sakura:** Cherry type from Johnny's, 55 days, real sweet tomato flavor and firmness without being hard. One of the first varieties to ripen in our greenhouse, Sakura keeps going all season long because of its excellent disease resistance. Prolific yielder of bright red, shiny, medium-sized cherry tomatoes that average 15 grams. Excels in the greenhouse. High resistance to fusarium wilt races 1, 2, leaf mold, and tobacco mosaic virus; and intermediate resistance to nematodes . One of Johnny's favorite and grown by several growers in 2014.

**Maxifort:** Tomato rootstock from Johnny's used to add disease resistance and much improved plant vigor for an extended harvest. Maxifort adds a very high level of vigor. Also resistant to crown rot and corky root. Disease resistance is not transferred to the scion plant. NOTE: Maxifort should be used for rootstock only. If left to grow on its own, the fruit produced is small, stays green, and is not good for consumption.

Annex C

**Description of Four Greenhouse/Tunnel Tomato Farms**

Strawberry Hill Farm (SHF)

| | |
|---|---|
| Description of Season Extension Infrastructure | Minimal heated greenhouse, double layer plastic |
| Soil History | Greenhouse installed in 2011.<br>Frequent applications of compost have been made.<br>Also used for winter greens production.<br>Tomatoes are always grown in this greenhouse |
| Tomato Management Practice | String, clips, pruning (two heads/plant) and no deheading |
| Planting Date | May 20 |
| Crop Termination Date | October 5 |
| Plant Density | 16 145 plants/ha or 32,290 heads/ha |
| Fertility Available | 182 kg/ha (avail. N) + 151 kg/ha $P_20_5$ + 165 kg/ha $K_2O$<br>Actisol (chicken manure) and wood ashes at planting |
| Irrigation System | One drip line with 18 inches between emitters, no mulch |

Jemseg River Farm (JRF)

| | |
|---|---|
| Description of Season Extension Infrastructure | Moveable caterpillar tunnel, single layer of plastic |
| Soil Farm History | Tunnel installed in the spring.<br>Field used for various types of vegetables (good rotation)<br>Farm made compost applied annually |
| Tomato Management Practice | Weaving, some pruning (two heads/plant) and no deheading |
| Planting Date | May 20 |
| Crop Termination Date | October 20 |
| Plant Density | 15,947 plants/ha or 31,894 heads/ha |
| Fertility Available | 196 kg/ha (avail. N) + 112 kg/ha $P_20_5$ + 96 kg/ha $K_2O$<br>Crab meal at planting |
| Irrigation System | One drip line with 12 inches between emitters, black plastic mulch |

Nature's Route Farm (NRF)

| | |
|---|---|
| Description of Season Extension Infrastructure | Unheated greenhouse, double layer of plastic |
| Soil Farm History | Greenhouse installed in 2013<br>Heavy application of compost in year 1<br>Crab meal used as nitrogen rich amendment |
| Tomato Management Practice | String, clips, pruning (two heads/plant) and no deheading |
| Planting Date | May 26 |
| Crop Termination Date | Mid-October |
| Plant Density | 17,940 plants/ha or 35,880 heads/ha |
| Fertility Available | 107 **(+)** kg/ha (avail. N) + 92 kg/ha $P_20_5$ + 223 kg/ha $K_2O$<br>Crab meal and K-Mag prior to planting and granulated chicken manure during season |
| Irrigation System | One spaghetti emitter per plant, no mulch |

Ferme Pouce Vert (FPV)

| | |
|---|---|
| Description of Season Extension Infrastructure | Multi-Bay High Tunnel, single layer of plastic |
| Soil Farm History | High Tunnels installed in 2010<br>Heavy application of compost in year 1<br>Commercial chemical fertilizers used annually<br>Tomatoes are grown in rotation with cucumbers, peppers and lettuce (tomatoes once every 3 year) |
| Tomato Management Practice | String, clips, some pruning (two heads per plant) and no deheading |
| Planting Date | May 22 |
| Crop Termination Date | Mid-October |
| Plant Density | 14,351 plants/ha or 28,702 heads/ha |
| Fertility Available | 244 kg/ha (avail. N) + 122kg/ha $P_20_5$ + 300 kg/ha $K_20$<br>20-10-10 (in-row) and 0-0-60 (broadcast) prior to planting |
| Irrigation System | Two drip lines with 12 inch between emitters, black plastic mulch |

Annex D

**Grafted Tomato Images:**

Image of tomato transplant (rootstock and scion)

Image of some of the treatments (grafted treatments showing more growth)

Annex E

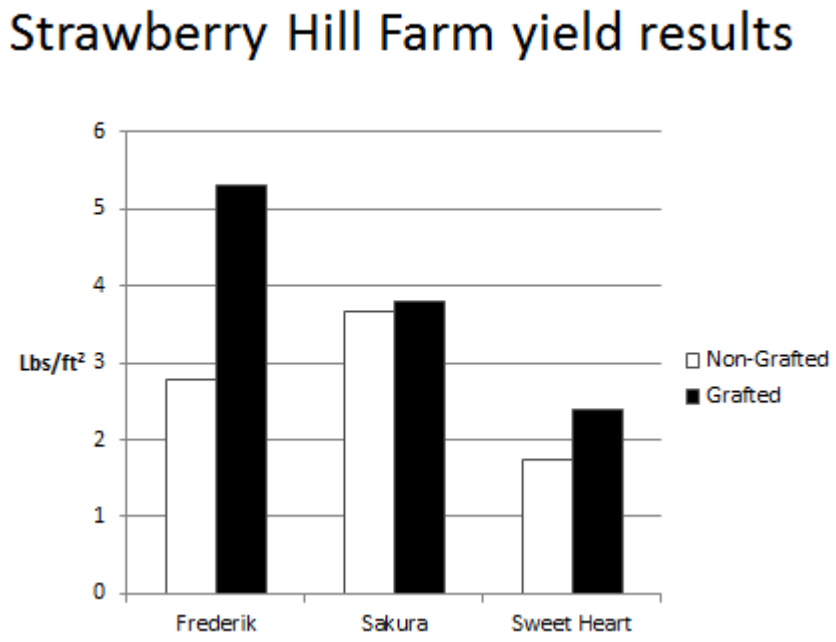
**Description of root system (cultivars versus Maxifort rootstock)**

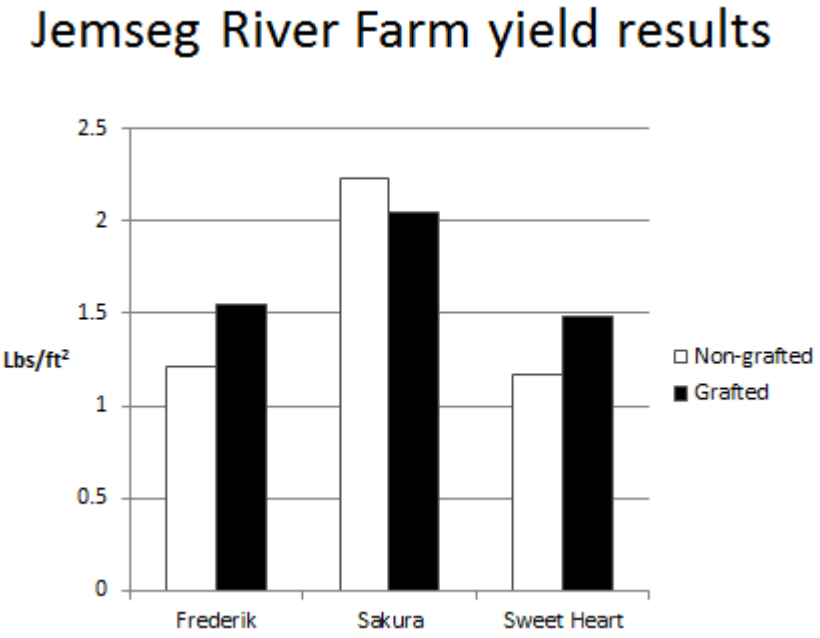
| Treatment (cultivar) | Observation (size of root system) | Treatment (Maxifort) |
|---|---|---|
| **Strawberry Hill Farm** | | |
| Sweet Heart | = | Grafted |
| Sakura | < | Grafted |
| Frederik | << | Grafted |
| **Jemseg River Farm** | | |
| Sweet Heart | >/= | Grafted |
| Sakura | < | Grafted |
| Frederik | </= | Grafted |
| **Nature's Route Farm** | | |
| Sweet Heart | < | Grafted |
| Sakura | < | Grafted |
| Frederik | < | Grafted |
| **Ferme Pouce Vert Farm** | | |
| Sweet Heart | >/= | Grafted |
| Sakura | < | Grafted |
| Frederik | < | Grafted |

Grafted Sakura and Frederik on Maxifort rootstock produced a more robust and healthier root system.

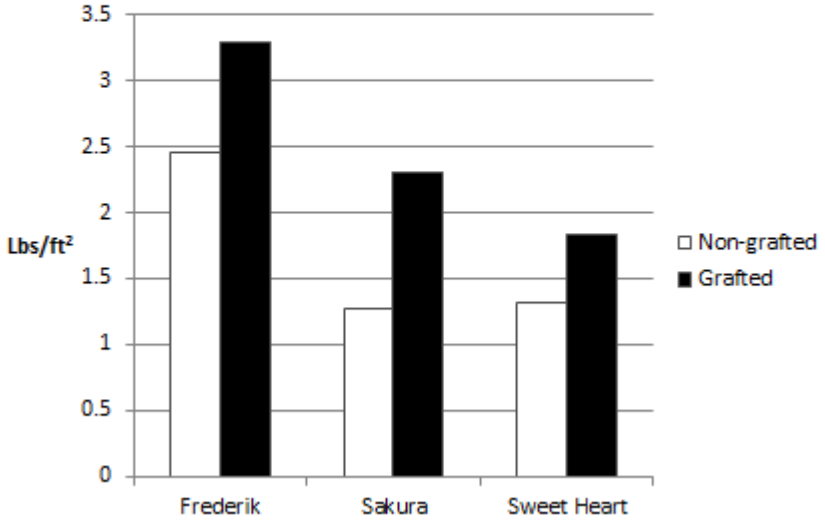
Annex F

**Grafted and non-grafted tomato yields from four farms**

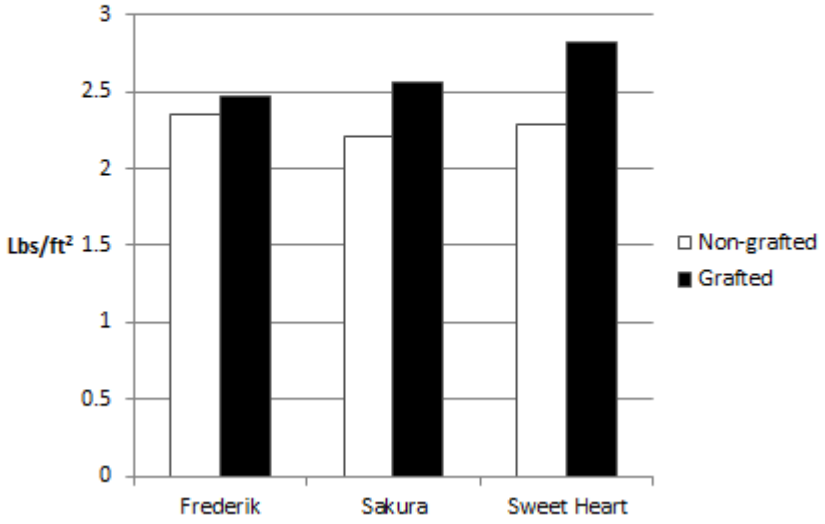


# Nature's Route Farm yield results




# Ferme Pouce Vert yield results



Annex G

## Basic Soil Test Results

| Farm | Organic Matter (%) | pH | Phosphate (ppm) | Potash (ppm) | Calcium (ppm) | Magnesium (ppm) | Boron (ppm) | Copper (ppm) | Zinc (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| **SHF** | 4 | 5.8 | 600 (H+) | 280 (H+) | 1550 | 133 | 0.7 | 2.8 | 5.8 |
| **JRF** | 5.7 | 6.3 | 585 (H+) | 235 (H+) | 1761 | 127 | 0.4 | 1.2 | 2.9 |
| **NRF** | 4.9 | 7.6 | 532 (H+) | 584 (H+) | 3875 | 422 | 5.1 | 8.6 | 4.5 |
| **FPV** | 3.7 | 7.9 | 837 (H+) | 143 (H) | 3197 | 115 | 1.3 | 0.6 | 2.2 |

| Farm | Sulfur (ppm) | Manganese (ppm) | Iron (ppm) | Sodium (ppm) | Aluminium (ppm) | Ca/Mg ratio | CEC (Meq/100g) | Total % Base Saturation |
|---|---|---|---|---|---|---|---|---|
| **SHF** | 58 | 31 | 272 | 91 | 1378 | 12:1 | 13 | 70.2 |
| **JRF** | 16 | 31 | 212 | 20 | 1270 | 14:1 | 12 | 89 |
| **NRF** | 505 | 82 | 108 | 175 | 978 | 9:1 | 25 | 96.9 |
| **FPV** | 18 | 39 | 157 | 42 | 1261 | 28:1 | 17 | 99 |

## Saturated Media Extract Soil Test Results

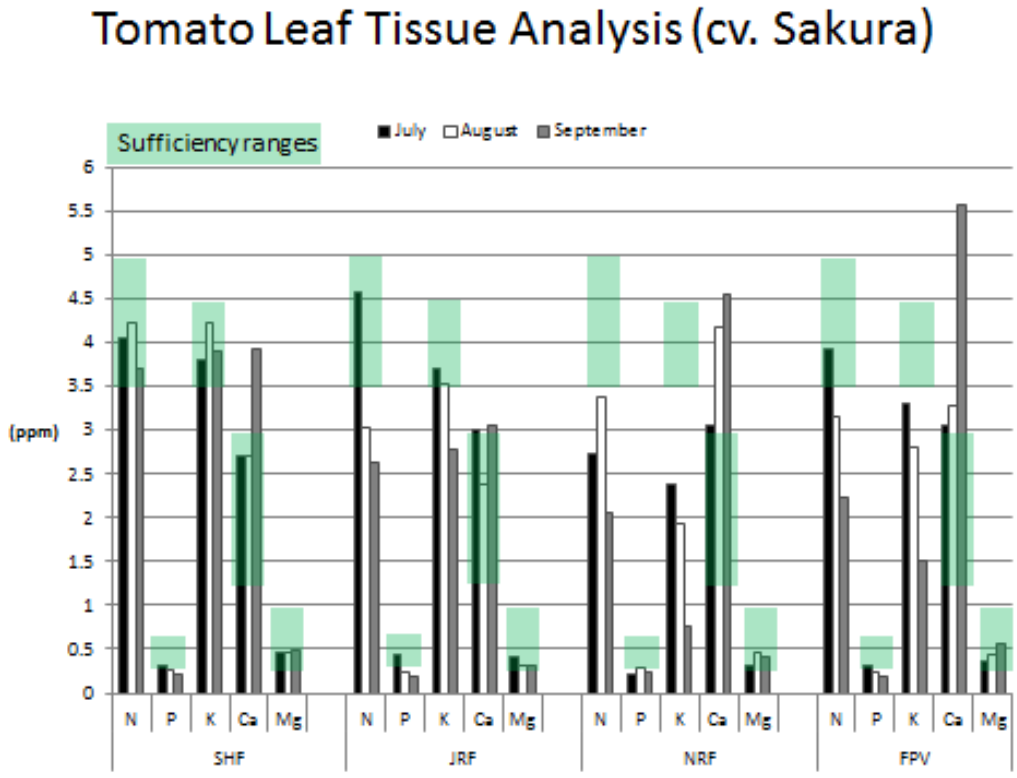
| | Soluble salt (mS/cm) | | | pH | | | Nitrate-N (ppm) | | | Phosphorous (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farm | June | July | Trend | June | July | | June | July | | June | July | |
| SHF | 5.2 | 3.4 | ↓ | 7.0 | 7.2 | ↑ | 602 | 386 | ↓ | 1.3 | 0.9 | ↓ |
| JRF | 1.7 | 1.8 | ↑ | 8.0 | 8.0 | – | 147 | 187 | ↑ | 1.2 | 1.0 | ↓ |
| NRF | 5.5 | 1.9 | ↓ | 7.9 | 8.1 | ↑ | 288 | 63 | ↓ | 0.8 | 0.5 | ↓ |
| FPV | 7.5 | 2.4 | ↓ | 7.3 | 7.9 | ↑ | 684 | 216 | ↓ | 0.4 | 0.3 | ↓ |

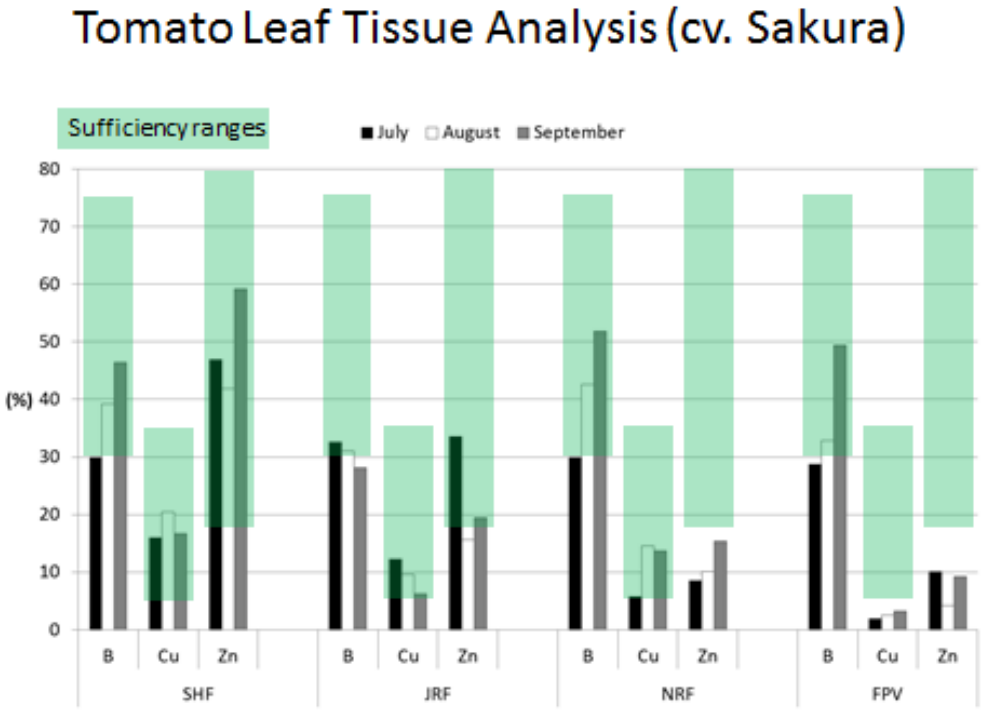
| | Potassium (ppm) | | | Ca (ppm) | | | Mg (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm | June | July | | June | July | | June | July | |
| SHF | 196 | 61 | ↓ | 571 | 402 | ↓ | 108 | 78 | ↓ |
| JRF | 21 | 13 | ↓ | 84 | 131 | ↑ | 14 | 21 | ↑ |
| NRF | 201 | 18 | ↓ | 647 | 311 | ↓ | 192 | 62 | ↓ |
| FPV | 158 | 17 | ↓ | 899 | 281 | ↓ | 75 | 26 | ↓ |

| |
|---|
| Very High |
| High |
| Optimum |
| Acceptable |
| Low |

Annex H

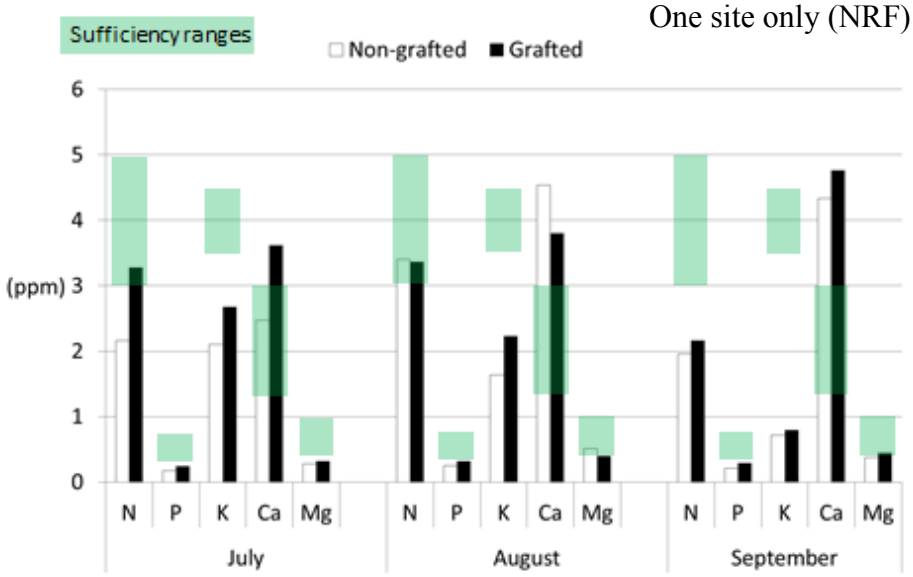
**Tomato Tissue Test Results:**



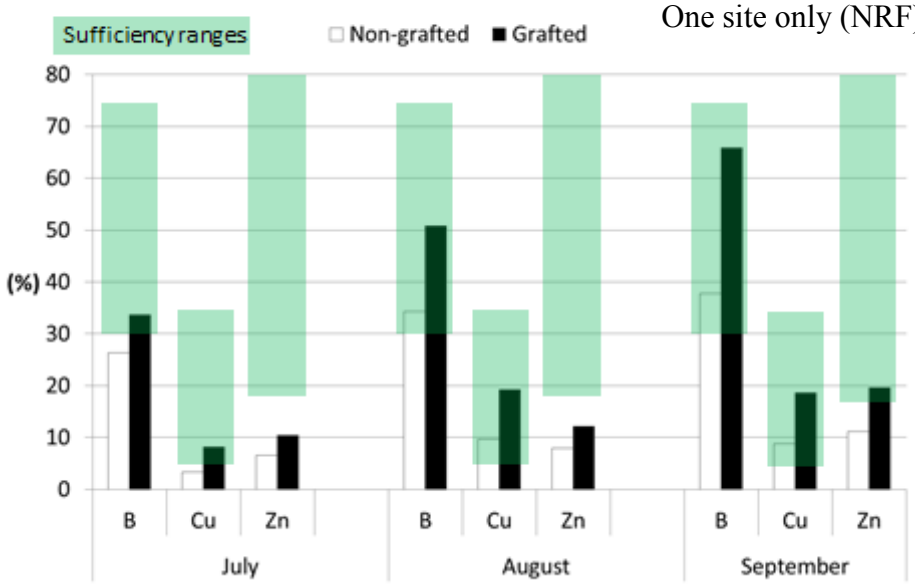
## Tomato Leaf Tissue Analysis (cv. Sakura)

One site only (NRF)




## Tomato Leaf Tissue Analysis (cv. Sakura)

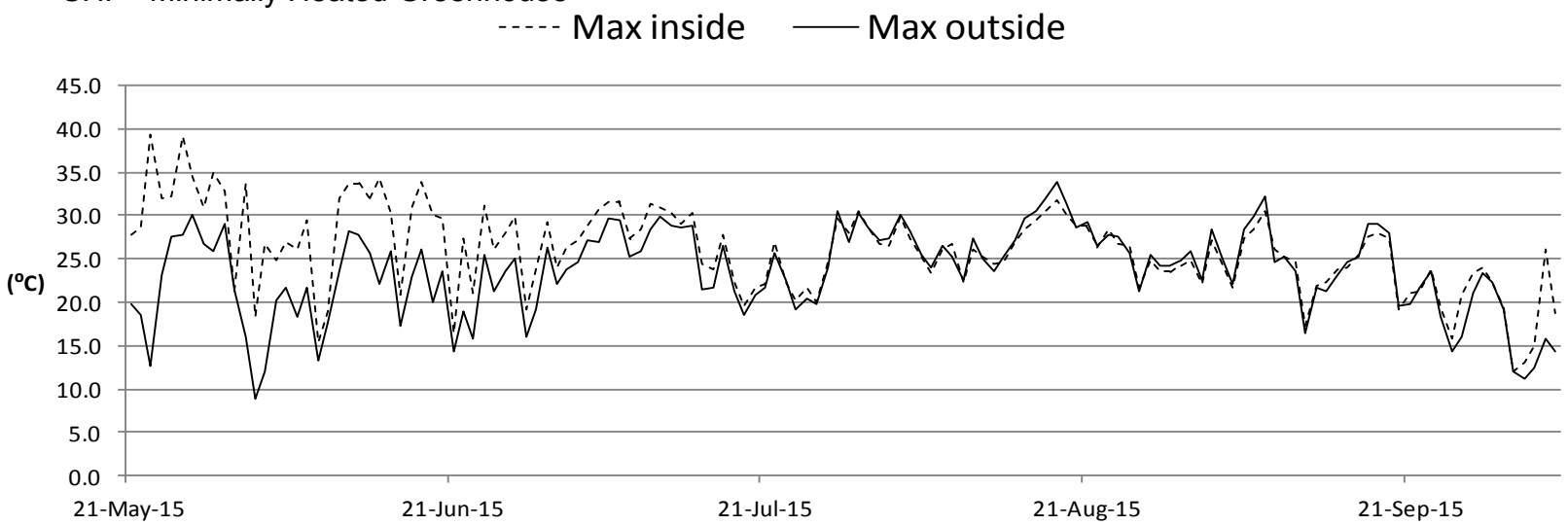
One site only (NRF)

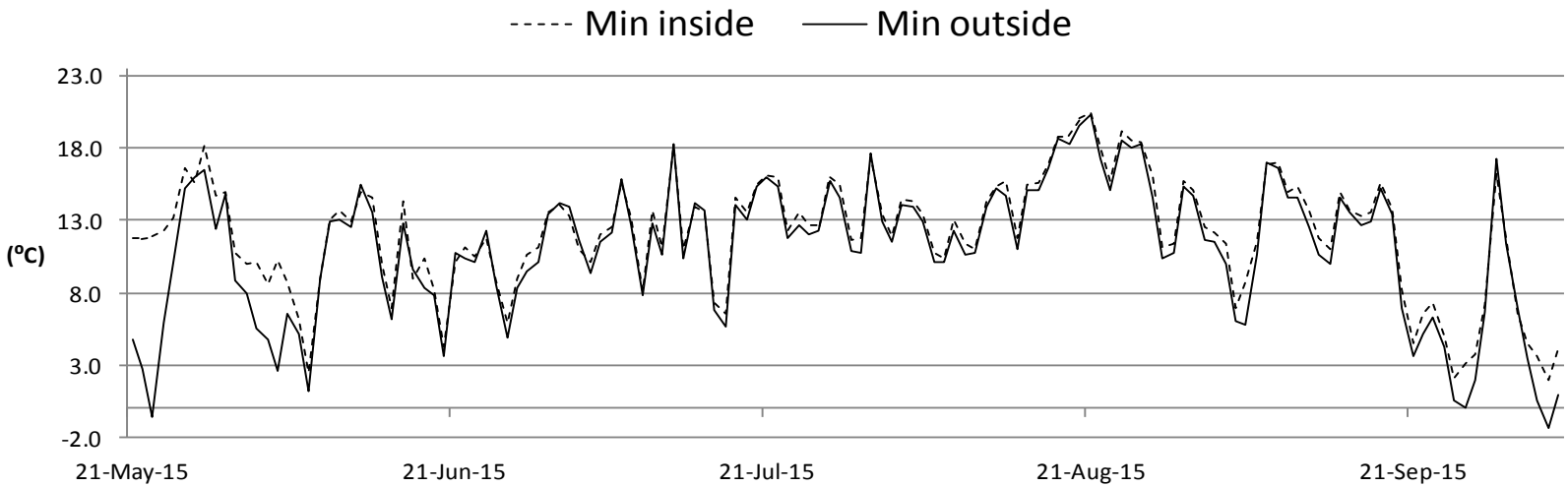


Annex I

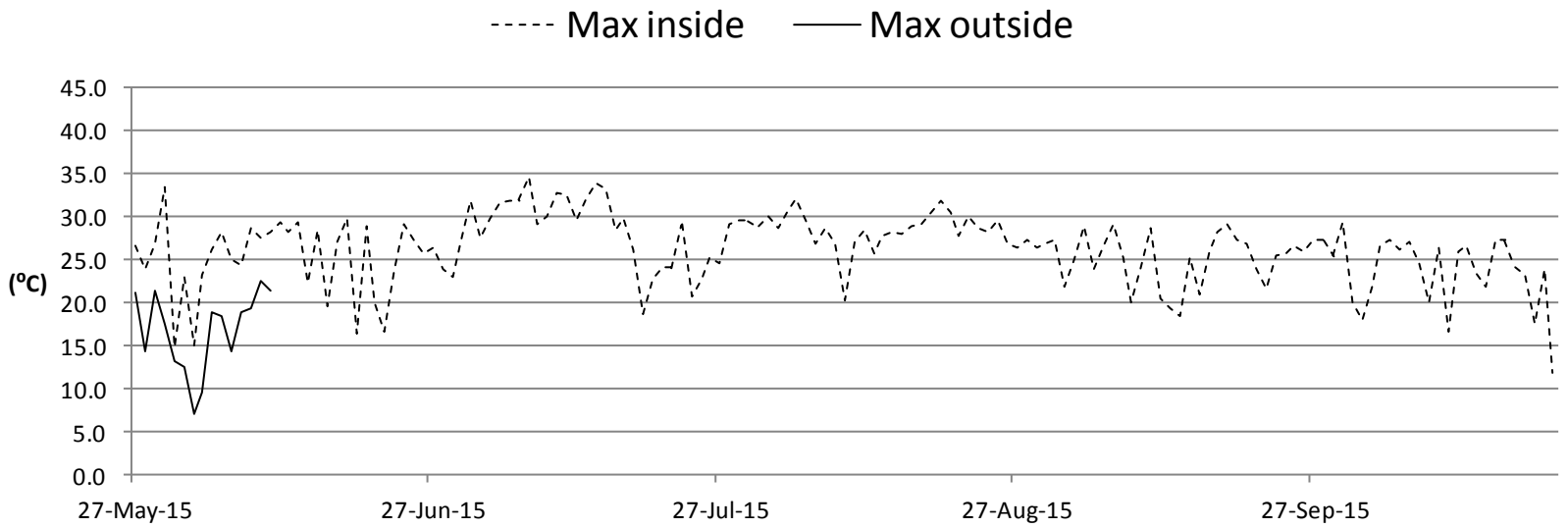
**Inside and Outside Temperature Trends on the Four Farms:**

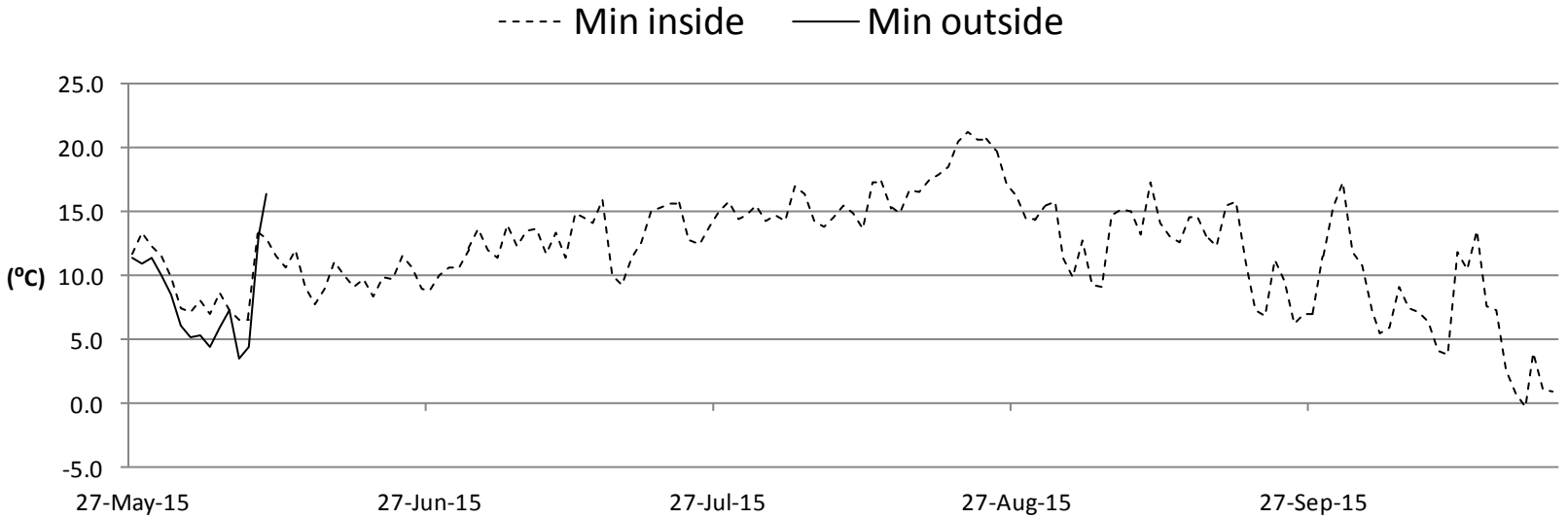
SHF– Minimally Heated Greenhouse



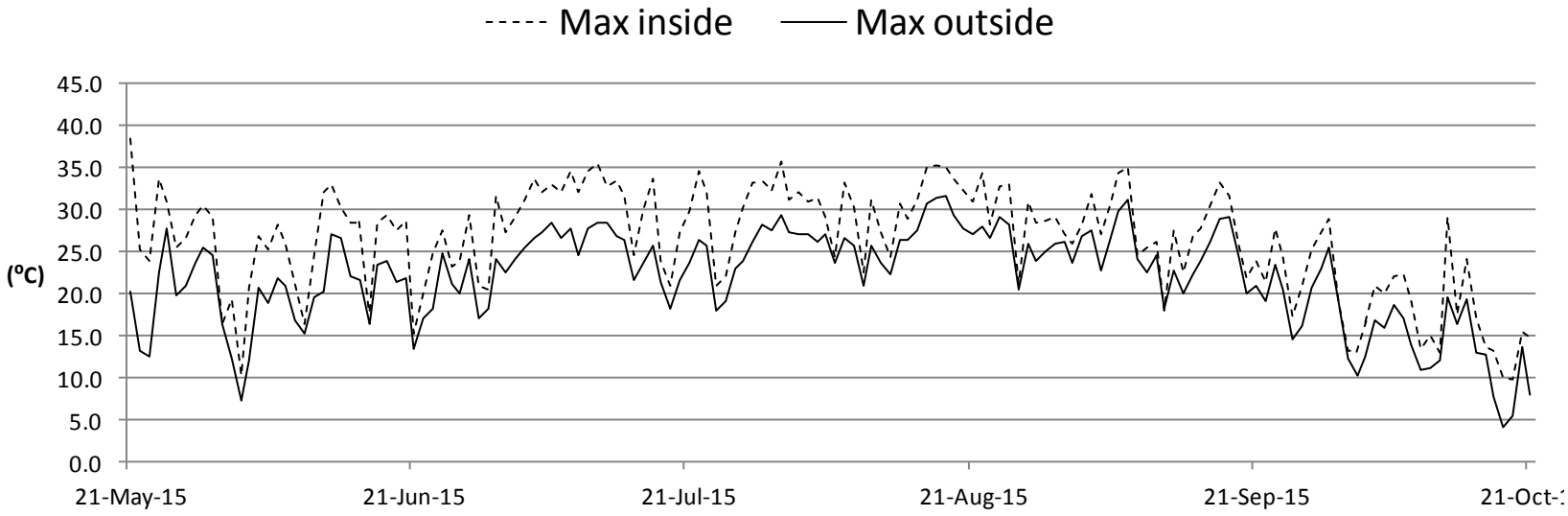



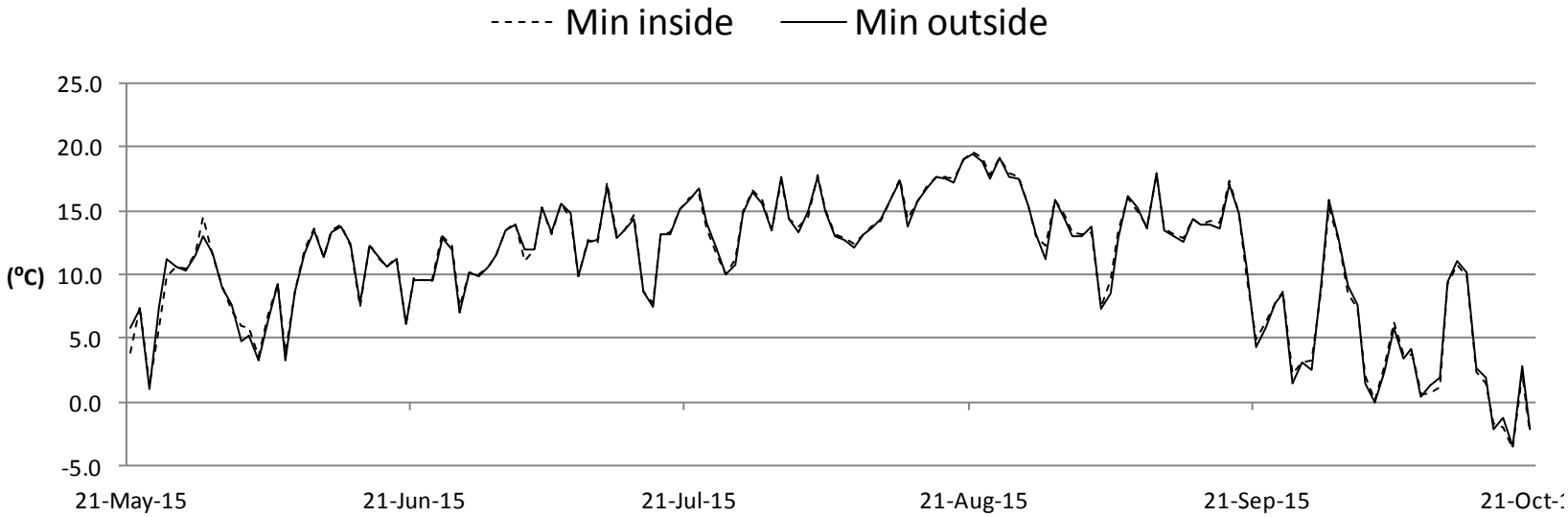
NRF– Unheated Greenhouse



JRF – Moveable Caterpillar Tunnel



FPV – Multi-Bay High Tunnel