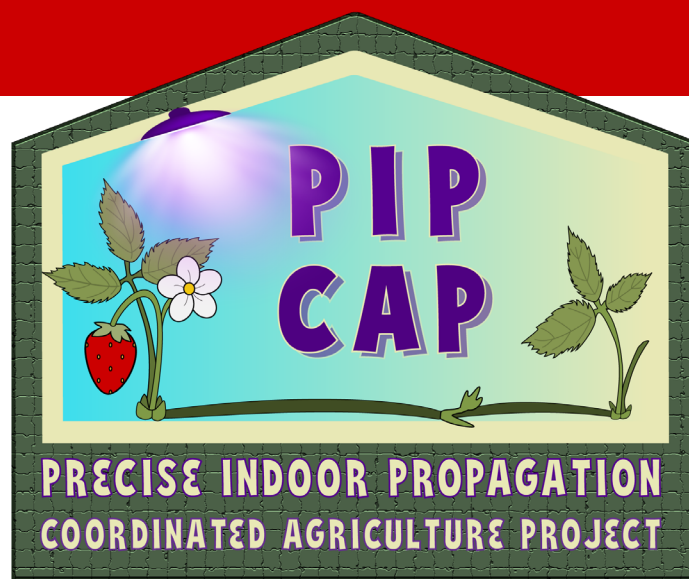


Award: 2021-51181-35857
Budget: \$5,294,195



Update Fumigation Alternative Meeting Ventura Co. 2024

Development and Integration of Next Generation Propagation Strategies to Increase the Resilience of the US Strawberry Supply Chain

Mark Hoffmann
Director PIP-CAP
Strawberry Extension Specialist
North Carolina State University

Soil-less Substrates



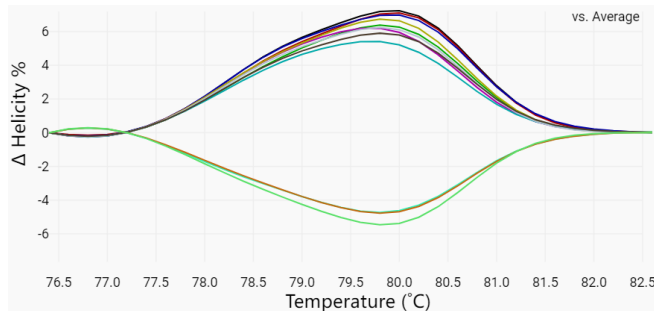
Dr. Brian Jackson
Brandan Shur (MS student)



Genomic Database



Dr. Zhongchi Liu
Dr. Caren Cheng
Dr. Xi Luo
Dr. Ibraheem Olasupo



Field Evaluation



Dr. Oleg Daugovich
Dr. Ibraheem Olasupo



09/2021-09/2026



Major expected outcomes:

- Resources, platform and guidelines for strawberry propagation in protected culture
- Genomic Database of high quality strawberry genomes



NC STATE
UNIVERSITY





Optimize Indoor Propagation



Optimize Plant
Conditioning

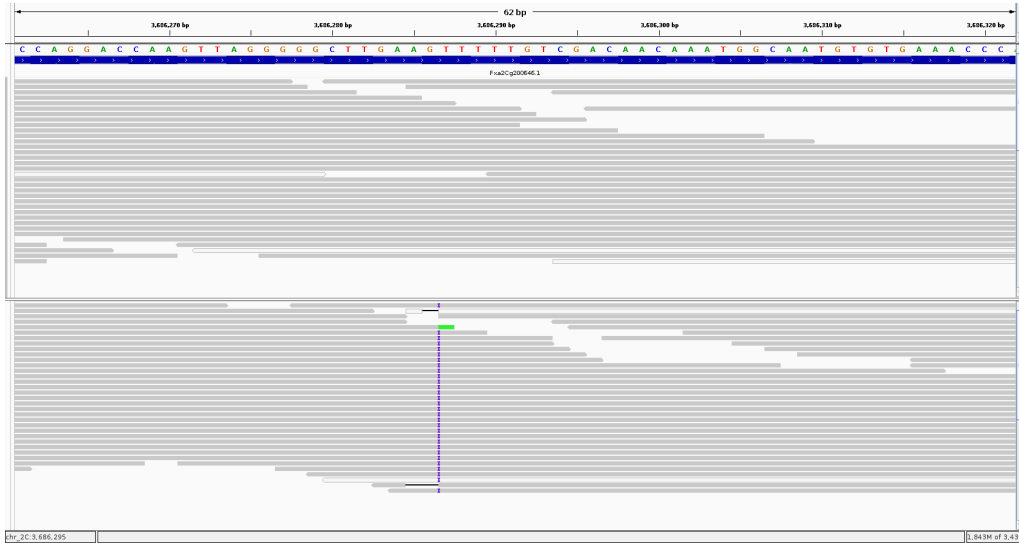


Evaluate Performance



Can we use simple tools to optimize propagation in open-field nurseries?

Fronteras Monterey



Can we target the genetic differences between cultivars?

Soil-less Substrates



Dr. Brian Jackson
Brandan Shur (MS student)



NC STATE
UNIVERSITY



Albion



PINDSTRUP

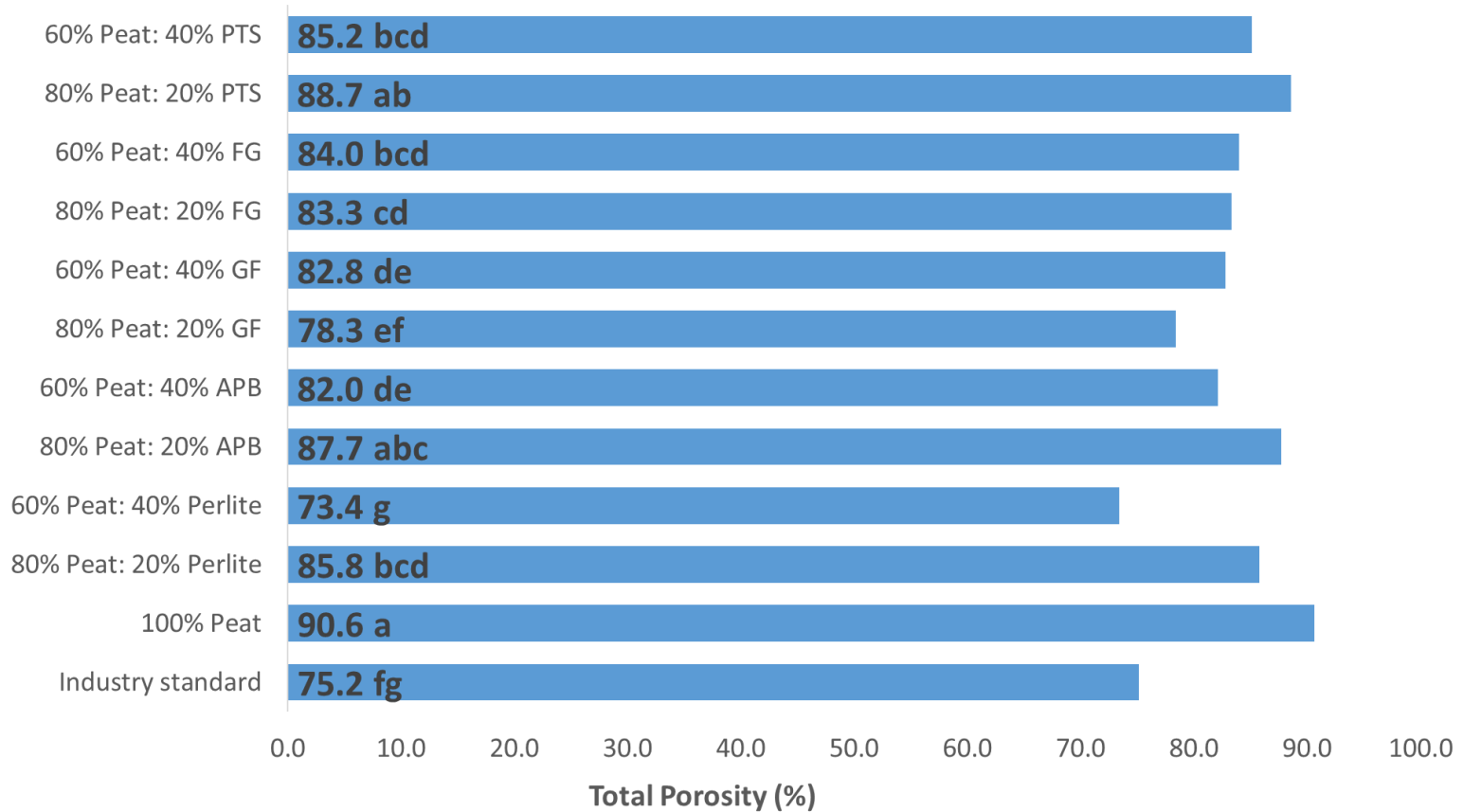
Substrate Sources

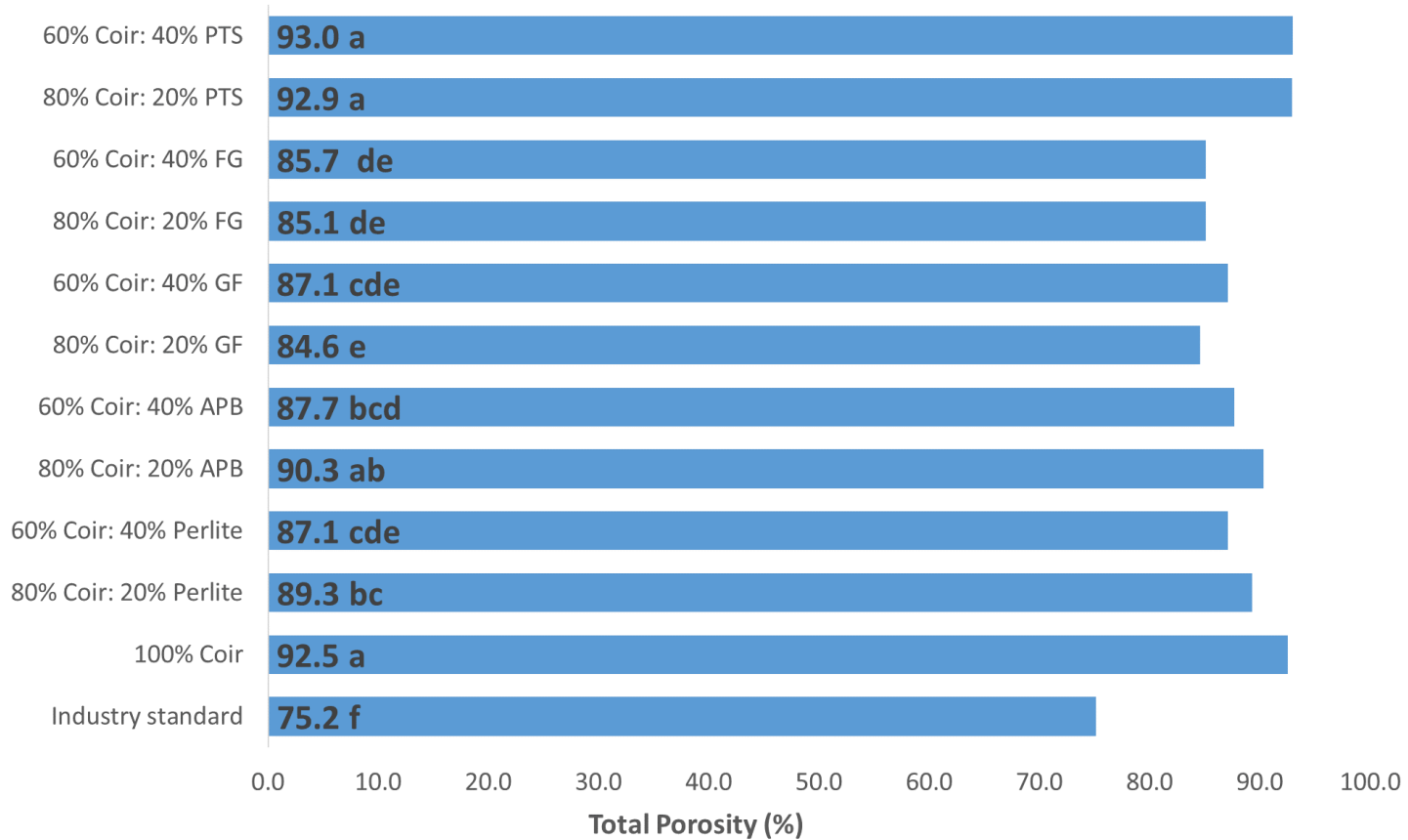
- Peat = Premier Pro-Moss
- ForestGold (**FG**) = Pindstrup
- GreenFibre (**GF**) = Klasmann-Deilmann
- Processed-tree-substrate (**PTS**) = NCSU
- Aged pine bark (**APB**) = Pacific Organics
- Coarse perlite = Supreme Perlite
- Industry Standard = 50% Coir/50% Peat



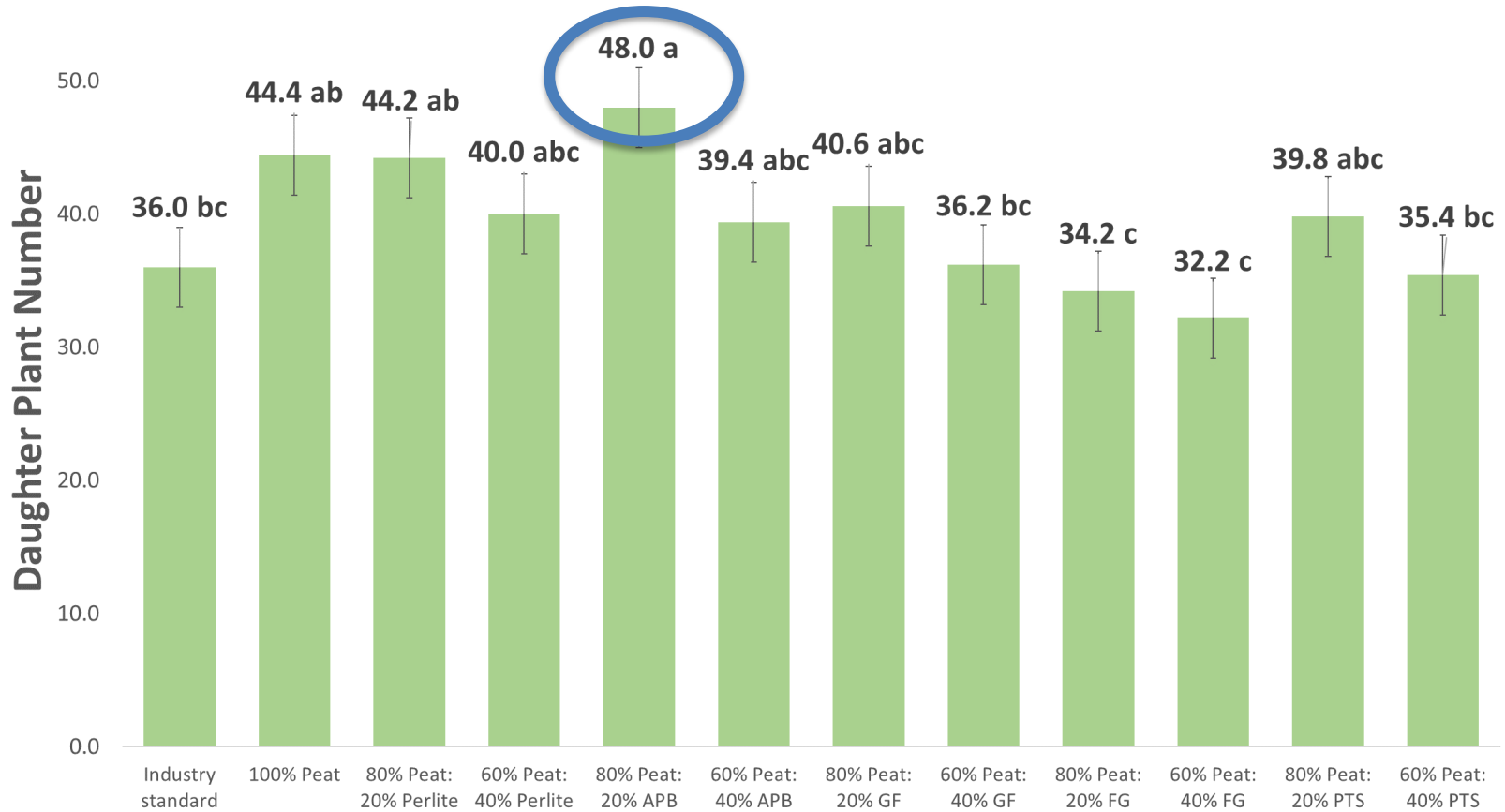
we make it grow







70 days



70 days



Industry standard

S₁₀₀

S₈₀P₂₀

S₆₀P₄₀

S₈₀B₂₀

S₆₀B₄₀



S₈₀GF₂₀

S₆₀GF₄₀

S₈₀FG₂₀

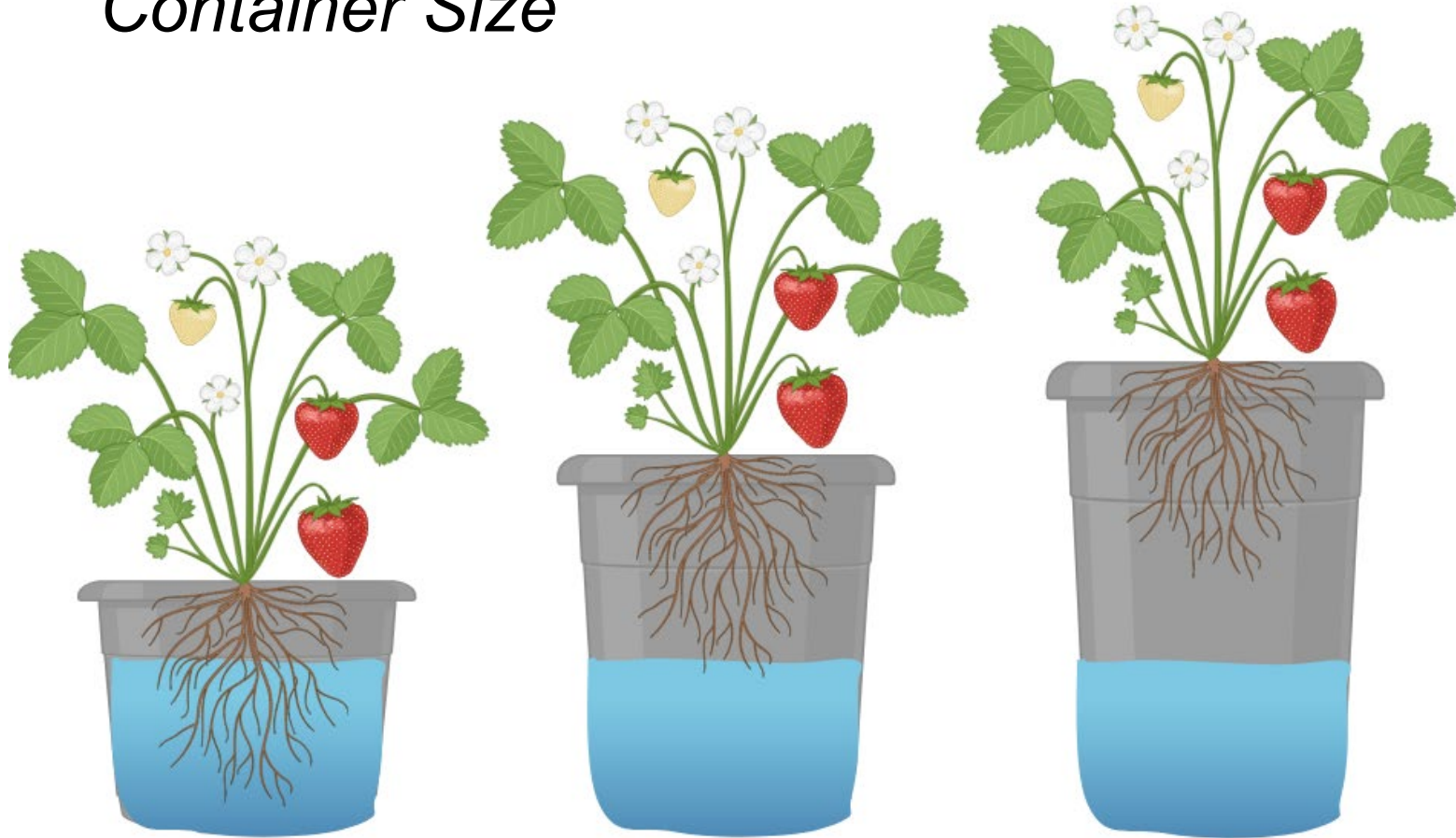
S₆₀FG₄₀

S₈₀PTS₂₀

S₆₀PTS₄₀



Container Size



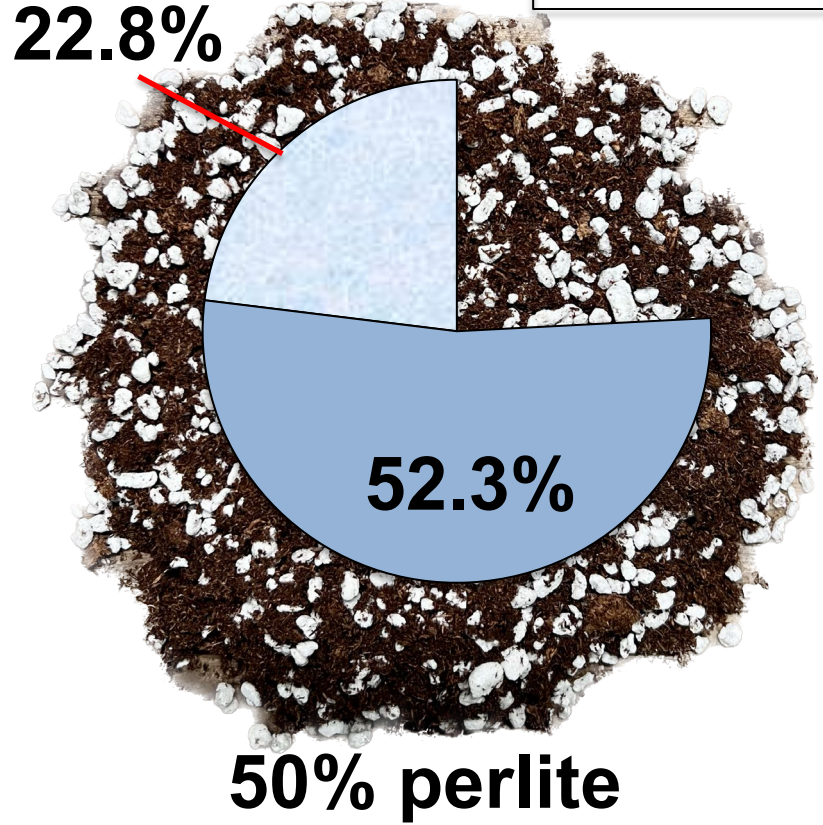
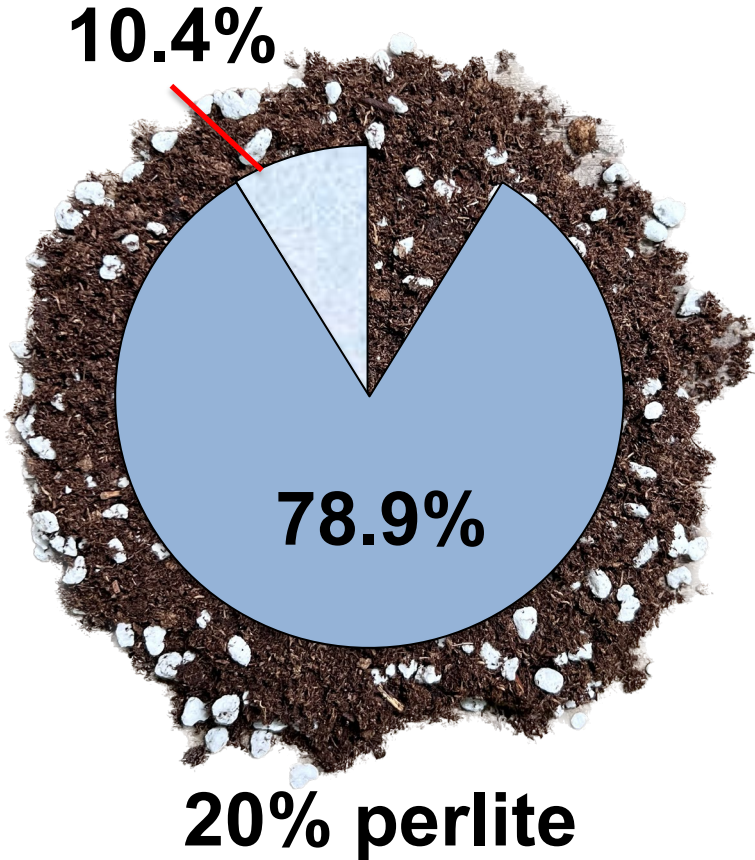
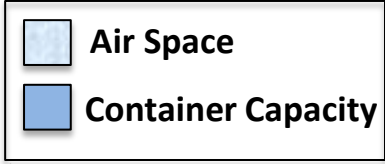
Materials and Methods

Experimental Substrates:

1. 80% coir: 20% perlite
2. 50% coarse perlite:
25% peat: 25% coir



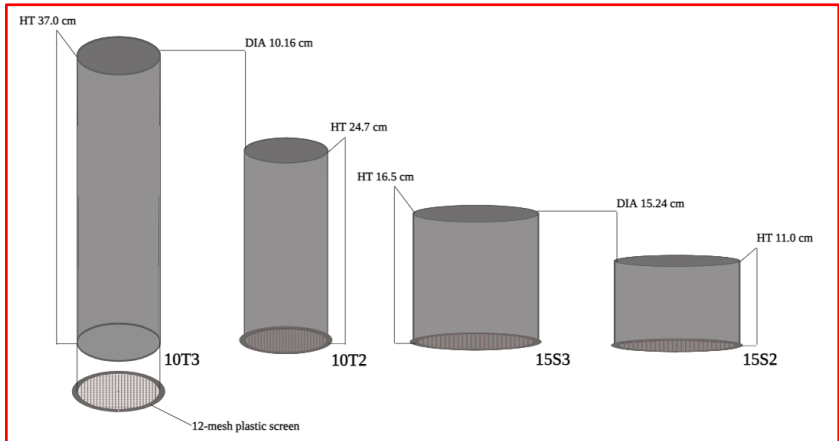
Physical Properties



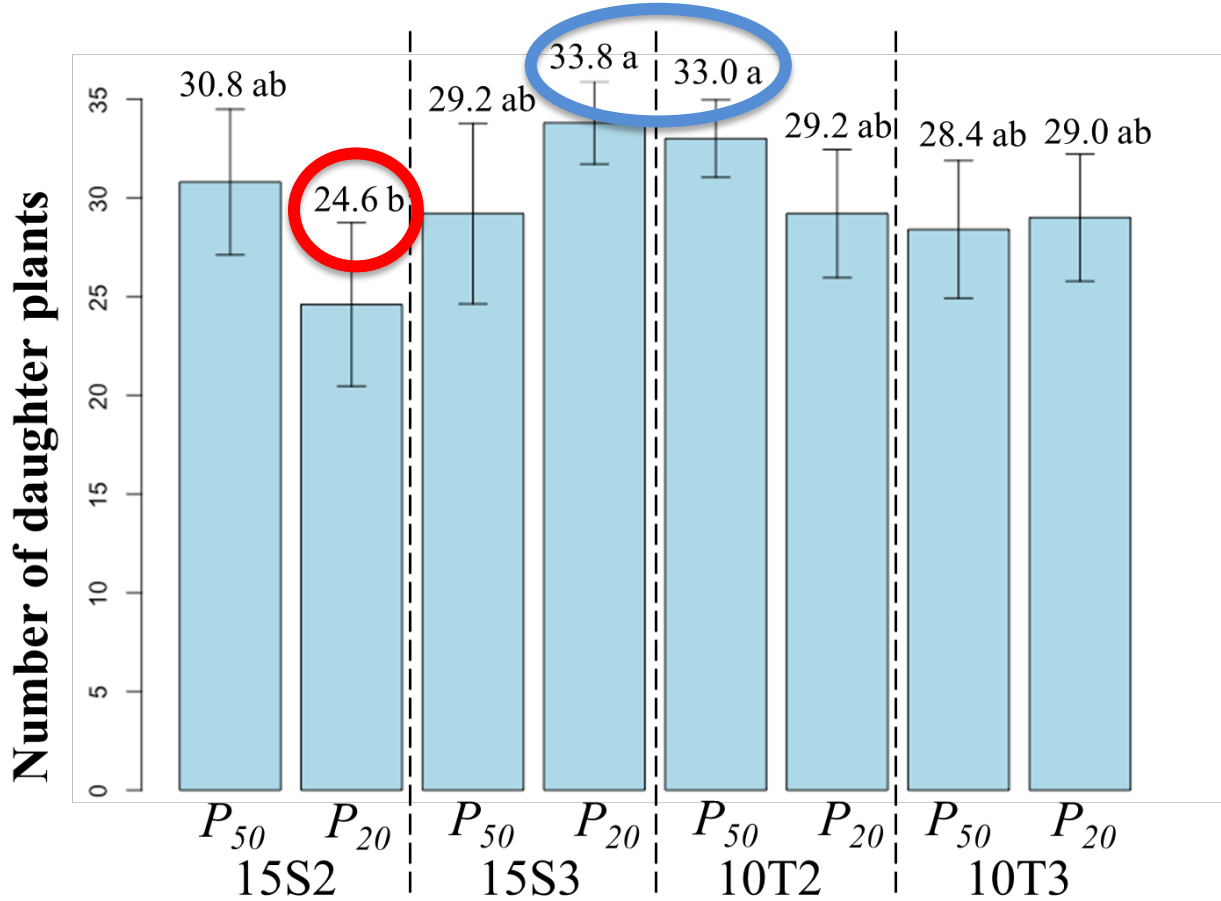
Materials and Methods

Containers were made from Schedule 40 PVC pipe:

1. 10.16 x 37.0-cm (3L)
2. 10.16 x 24.7-cm (2L)
3. 15.24 x 16.5-cm (3L)
4. 15.24 x 11.0-cm (2L)



$P = 0.024$



Summary

- *80% Coir- 20% Perlite and 80% Peat – 20% APB: highest daughter plant numbers*
- *Very generally: substrates that low airspace, more container capacity provide more daughter plants.*
- **2L – TALL - HIGH AIRSPACE & 3L – SHORT - LOW AIRSPACE** led to more daughter plant production.



- **Dr. Brian Jackson**
Professor, NCSU
Director Soil-Less Substrate Lab
Department Horticultural Science

Brandan Shur
MS, NCSU
MS-Graduate Soil-Less Substrates
Department Horticultural Science



Genomic Database

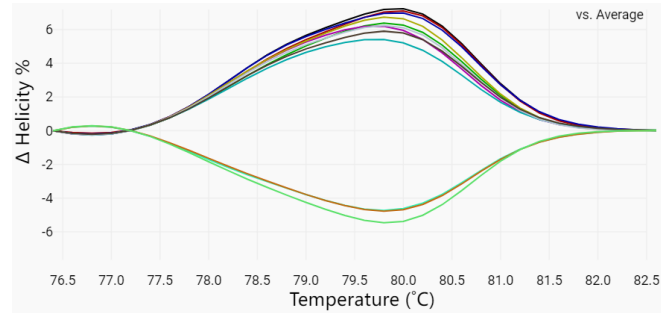


Dr. Zhongchi Liu

Dr. Caren Cheng

Dr. Xi Luo

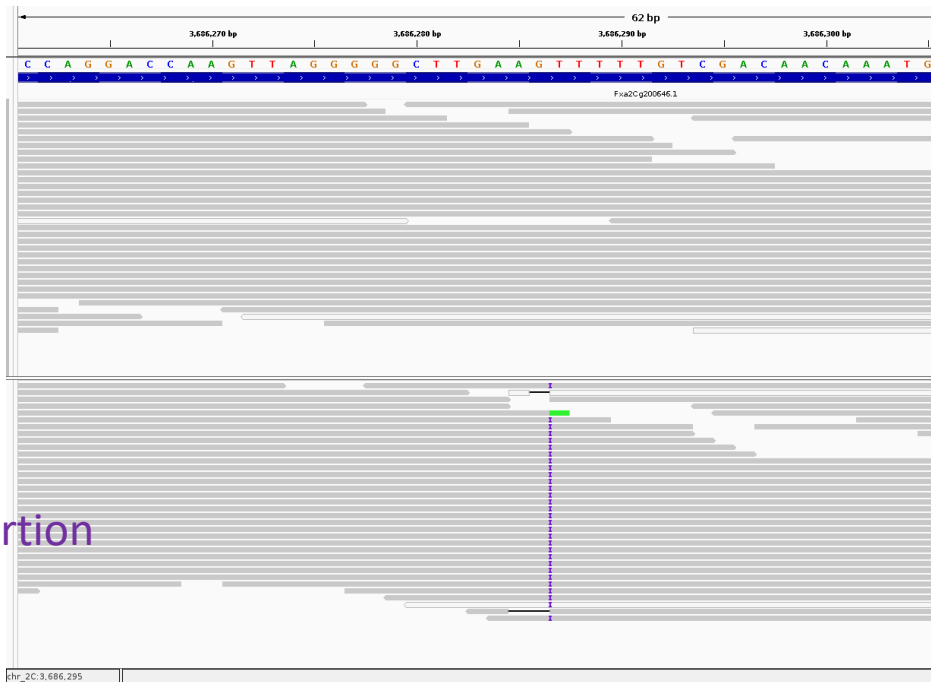
Dr. Ibraheem Olasupo



Visualization of ***GA20ox4*** in subgenome C of 'Monterey' and 'Fronteras'

Monterey
no mutation

Fronteras
has a 1 bp insertion
GT to GAT



We have deep-sequenced and aligned genomes of 13 strawberry cultivars

Cultivars	Reads (Million)	Bases (Billion)	Q30 bases (%)
Albion	246.45	36.81	94.17%
Brilliance	205.10	30.62	93.87%
Cabrillo	222.13	33.14	93.75%
Camarosa	214.25	32.00	93.42%
Chandler	214.03	31.94	93.44%
Finn	225.94	33.72	93.61%
Fronteras	233.60	34.89	93.61%
Monterey	224.13	33.48	93.62%
Moxie	204.68	30.56	94.10%
Portola	210.50	31.41	93.44%
Radiance	223.81	33.44	94.13%
Ruby June	214.21	32.01	93.94%
Sensation			

- **High quantity:** ~ 35 billion bases each cultivar, which equals **145×** coverage on average
- **High quality:** Q30 bases >93%

Note: Q30 means the sequence error rate is 1/1000 bases

Web interface

Cultivated Strawberries Genomic Resource (Beta)

The default view shows the region for gene "Fxa1Ag100002" located in chr_1A:7507..8881.

Search by gene name. You can try with this one: Fxa5Ag201159

Search by gene name.

chr_1A

chr_1A 7,600 7,700 7,800 7,900 8,000 8,100 8,200 8,300 8,400 8,500 8,600 8,700 8,800

Reference sequence (farr1)

farr1 GFF Ref

Gene Query:

Gene ID	Chromosome	Start	End	Description	Arabidopsis homolog	Gene name
---------	------------	-------	-----	-------------	---------------------	-----------

Input gene ID

**Display genome region
Zoom in/out**

**Output Tracks
(genome/
annotation/
cultivars)**

Gene search function

Input (three ways)

1. Type in the Gene ID

3. Search for the gene ID

Cultivated Strawberries Genomic Resource (Beta)

The default view shows the region for gene "Fxa1Ag100002" located in chr_1A:7507..8881.

Search by gene name. You can try with this one: Fxa5Ag201159

Search by gene name. Hit "View"

2. Type in the coordinates

chr_1A:7,507..8,881

Gene Query:

Gene ID	Chromosome	Start	End	Description	Arabidopsis homolog	Gene name

Gene ID search function

Hit "Search"

Type in the key word, eg. "gibberellin"

Gene ID	Chromosome	Start	End	Description	Arabidopsis homolog	Gene name
Fxa1Ag100377	chr_1A	2182048	2183230	2OG-Fe(II) oxygenase superfamily	AT4G21690.1	gibberellin 3-oxidase 3
Fxa1Ag102548	chr_1A	17039291	17042576	2-OXOGLUTARATE (2OG) AND FE(II)-DEPENDENT OXYGENASE SUPERFAMILY PROTEIN-RELATED	AT1G02400.1	gibberellin 2-oxidase 6
Fxa1Bg200370	chr_1B	1994178	1995358	Fe(2+) 2-oxoglutarate dioxygenase domain	AT4G21690.1	gibberellin 3-oxidase 3
Fxa1Bg202414	chr_1B	17556771	17559629	GIBBERELLIN 2-BETA-DIOXYGENASE 6	AT1G02400.1	gibberellin 2-oxidase 6
Fxa1Cg100335	chr_1C	1911087	1912269	Fe(2+) 2-oxoglutarate dioxygenase domain	AT4G21690.1	gibberellin 3-oxidase 3
Fxa1Cg102589	chr_1C	18966372	18969239	GIBBERELLIN 2-BETA-DIOXYGENASE 6	AT1G02400.1	gibberellin 2-oxidase 6
Fxa1Dg200345	chr_1D	2093910	2095092	Fe(2+) 2-oxoglutarate dioxygenase domain	AT4G21690.1	gibberellin 3-oxidase 3
Fxa1Dg202383	chr_1D	18238370	18241781	non-haem dioxygenase in morphine synthesis N-terminal	AT1G02400.1	gibberellin 2-oxidase 6
Fxa2Ag102726	chr_2A	20089613	20091976	2-OXOGLUTARATE (2OG) AND FE(II)-DEPENDENT OXYGENASE SUPERFAMILY PROTEIN-RELATED	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Ag102973	chr_2A	21632268	21648119	Isopenicillin N synthase-like	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Ag103422	chr_2A	24188644	24190414	2OG-Fe(II) oxygenase superfamily	AT5G07200.1	gibberellin 20-oxidase 3
Fxa2Bg202804	chr_2B	22081722	22083039	2-OXOGLUTARATE (2OG) AND FE(II)-DEPENDENT OXYGENASE SUPERFAMILY PROTEIN-RELATED	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Bg202805	chr_2B	22084119	22086180	Fe(2+) 2-oxoglutarate dioxygenase domain	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Bg202806	chr_2B	22091514	22092808	2OG-Fe(II) oxygenase superfamily	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Bg202809	chr_2B	22102888	22104713	2OG-Fe(II) oxygenase superfamily	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Cg200646	chr_2C	3685056	3686825	Isopenicillin N synthase-like	AT5G07200.1	gibberellin 20-oxidase 3
Fxa2Cg201084	chr_2C	7005848	7018759	Fe(2+) 2-oxoglutarate dioxygenase domain	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Dg202421	chr_2D	20757596	20758201	Isopenicillin N synthase-like	AT4G21690.1	gibberellin 3-oxidase 3
Fxa2Dg202583	chr_2D	21940497	21943122	Isopenicillin N synthase-like	AT1G15550.1	gibberellin 3-oxidase 1
Fxa2Dg202585	chr_2D	21947535	21949344	Isopenicillin N synthase-like	AT1G15550.1	gibberellin 3-oxidase 1

My gene of interest is "gibberellin 20-oxidase 3". Its gene ID is "Fxa2Cg200646"

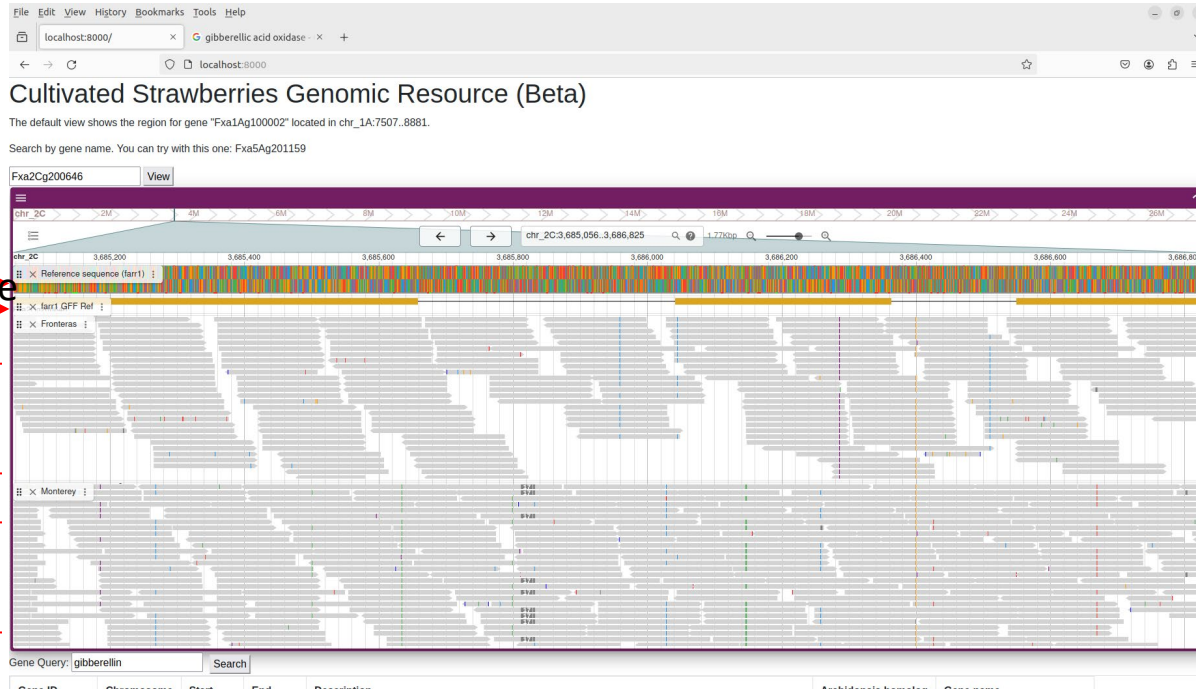
Check the track for display (13 cultivars)

The screenshot displays the Cultivated Strawberries Genomic Resource (Beta) interface. The main content area shows a genomic track for the gene "Fxa1Ag100002" located on chromosome 1A at position 7507,888. Below the track, there is a search bar with the query "gibberellin" and a table of gene entries. An "Available tracks" dialog box is overlaid on the page, showing a list of tracks that can be displayed. The "Cultivar - alignments" track is highlighted, and a red arrow points from the text "Check the track for display (13 cultivars)" to this track. The dialog box also shows other tracks like "Reference sequence (tarr1)", "Genes", and "tarr1 GFF Ref".

Gene ID	Chromosome	Start	End	Description	Gene name
Fxa1Ag100377	chr_1A	2182048	2183230	ZOG-F...	gibberellin 3-oxidase 3
Fxa1Ag102548	chr_1A	17039291	17042576	2-OXO...	gibberellin 2-oxidase 6
Fxa1Bg200370	chr_1B	1994178	1995358	Fe(2+)	gibberellin 3-oxidase 3
Fxa1Bg202414	chr_1B	17556771	17559629	GIBBE...	gibberellin 2-oxidase 6
Fxa1Cg100335	chr_1C	1911087	1912269	Fe(2+)	gibberellin 3-oxidase 3
Fxa1Cg102589	chr_1C	18966372	18969239	GIBBE...	gibberellin 2-oxidase 6
Fxa1Dg200345	chr_1D	2093910	2095092	Fe(2+)	gibberellin 3-oxidase 3
Fxa1Dg202383	chr_1D	18238370	18241781	non-ha...	gibberellin 2-oxidase 6
Fxa2Ag102726	chr_2A	20089613	20091976	2-OXOG...	gibberellin 3-oxidase 1
Fxa2Ag102973	chr_2A	21632268	21648119	Isopenicillin N synthase-like	gibberellin 3-oxidase 1
Fxa2Ag103422	chr_2A	24188644	24190414	ZOG-Fe(II) oxygenase superfamily	gibberellin 20-oxidase 3
Fxa2Ba202804	chr_2B	22081722	22083039	2-OXOG...	gibberellin 3-oxidase 1

Output

- Gray means sequences are identical to the reference.
- Colors indicates SNPs or INDELS.
- Their positions on a gene can be decided in parallel with the annotation track



Reference sequence →
Gene annotation →

Reads from cv.
"Fronteras"
aligned to this
gene

Reads from cv.
"Monterey"
aligned to this
gene

If you have your own cultivar being sequenced, which is not in this database, it possible to do comparison by add your tracks locally

The screenshot shows the Cultivated Strawberries Genomic Resource (Beta) web application. The main interface displays genomic tracks for the gene "Fxa1Ag100002" located on chromosome 1A. A modal window titled "Available tracks" is open, showing a list of tracks and cultivars. The "Cultivar - alignments" section is expanded, showing a list of cultivars with checkboxes. A blue arrow points from the text "Activate tracks" to a yellow "+" button in the bottom right corner of the modal. Another blue arrow points from the text "Add tracks" to the "Add track" button below the "+" button.

Available tracks

- Filter tracks
- Tracks
- Reference sequence (tarr1) ...
- Genes
- tarr1 GFF Ref ...
- Cultivar - alignments
- Abilion ...
- Brilliance ...
- Cabrillo ...
- Cammarosa ...
- Chandler ...
- Finch ...
- Fronteras ...
- Monterey ...
- Moxie ...

Activate tracks →
"+ " button →
"Add tracks"



- **Dr. Caren Chang**
Professor, University of Maryland
Department of Cell Biology & Molecular Genetics



- **Dr. Ibraheem Olasupo**
Post-Doc, NCSU
Department of Horticultural Science

- **Dr. Zhongchi Liu**
Professor, UoM
Department of Cell Biology & Molecular Genetics



- **Dr. Xi Luo**
Post-Doc, UoM
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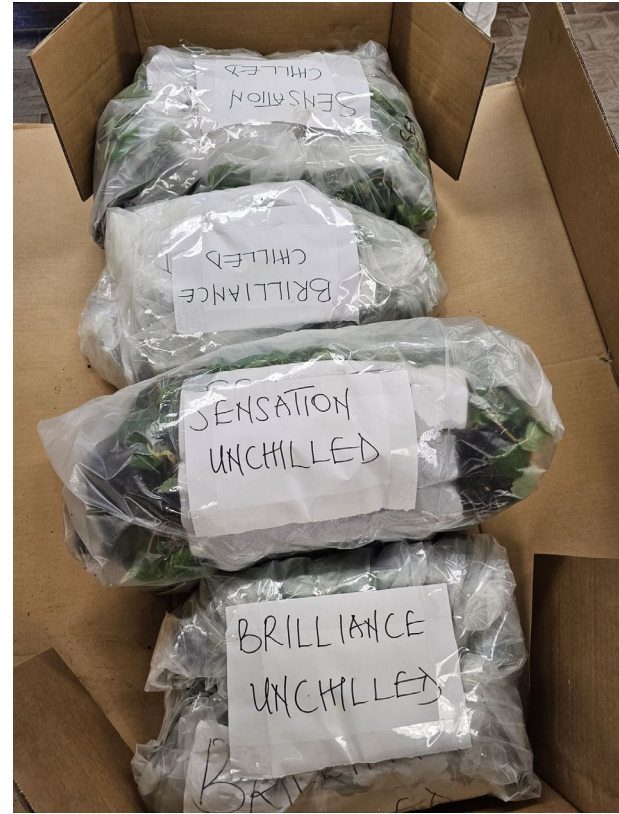


Field Evaluation



Dr. Oleg Daugovich
Dr. Ibraheem Olasupo





Cultivar	Chilling hours	Field planting location
Brilliance and Sensation (SD)	350	Florida
Monterey (LD)	350	SLO
Fronteras (SD)	450	Ventura Co.
Chandler (SD) and Camarosa	450	North Carolina

Chilling temperature: 39.2 ° F

Photoperiod: 16 h

Fertigation: Bottle-fed with our strawberry nutrient recipe

Fertigation regime: Every other day

2023-2024



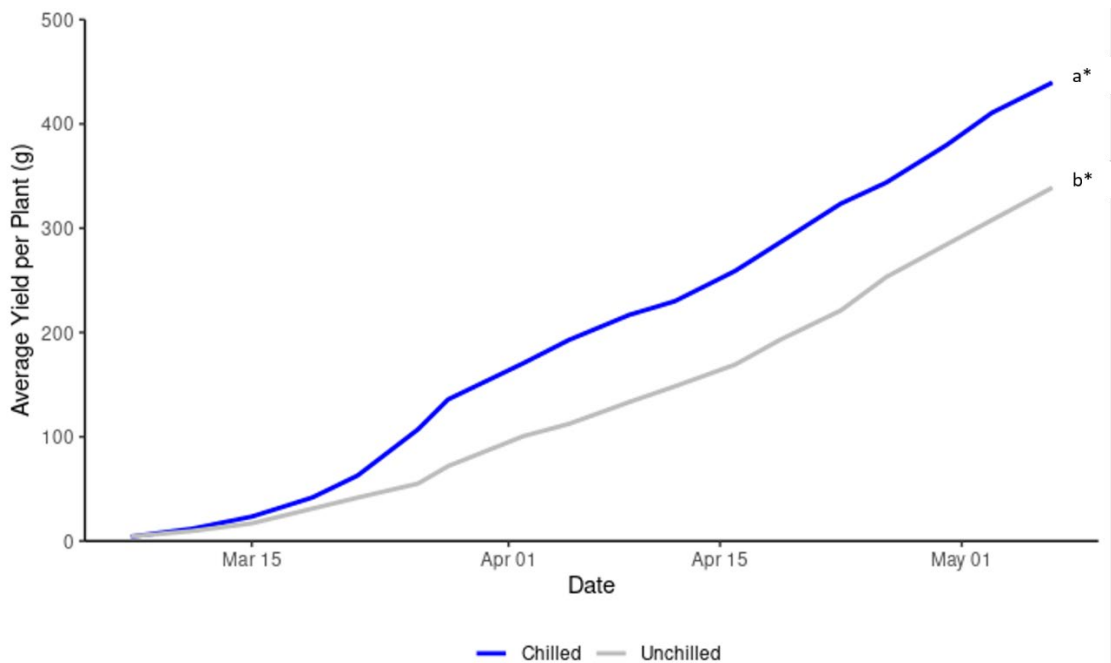


Chilled 'Fronteras', April 24.



Unchilled 'Fronteras', April 24.

Treatment	Yield Mean (g/plant)	Yield st. dev.
Chilled Fronteras	472.2407	24.28586
Unchilled Fronteras	406.2940	22.27653





- ***Dr. Oleg Daugovich***
Strawberry and Vegetable Crop Advisor
Cooperative Extension Ventura Co.

- ***Dr. Ibraheem Olasupo***
Post-Doc, NCSU
Department of Horticultural Science

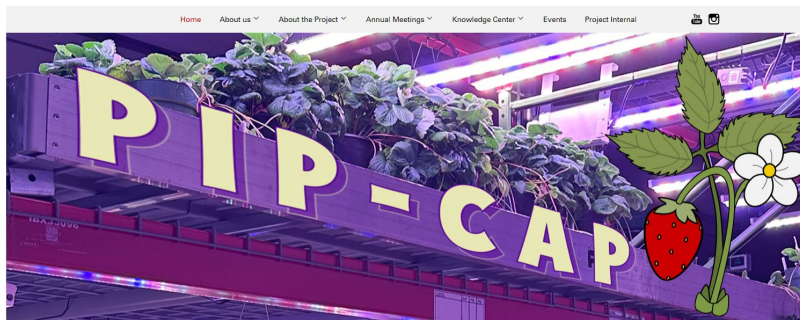




Dutch Garden Center



Strawberry Precise Indoor Propagation



Welcome to the PIP-CAP website, a cutting-edge project funded by USDA-NIFA through theSCRI-CAP initiative from 2021-2025. Our vision is to revolutionize strawberry propagation in the US by harnessing Controlled Environment Technology, with a mission dedicated to creating indoor propagation protocols for various strawberry cultivars. Join us on this journey to diversify and enhance the methods of strawberry propagation.

*SCRI-CAP = Specialty Crop Research Initiative – Coordinated Agricultural Project



<https://strawberries-pip.cals.ncsu.edu/>



USDA-NIFA Award: 2021-51181-35857

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