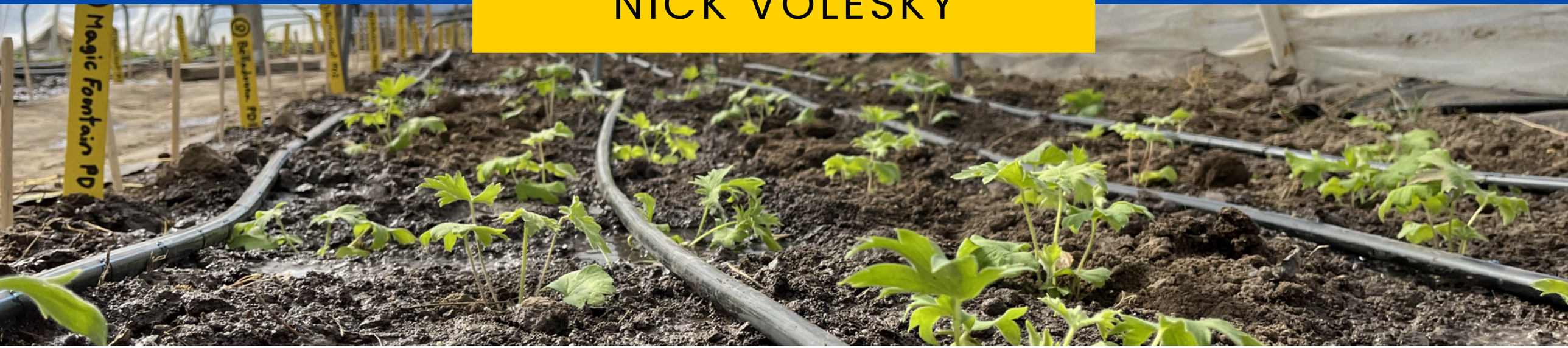
OPTIMIZING DELPHINIUM AND LARKSPUR THROUGH TIMING AND PROTECTED CULTIVATION METHODS FOR CUT FLOWER PRODUCTION

NICK VOLESKY



Extension
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SMALL FARMS LAB

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USDA NIFA
WESTERN SARE Sustainable Agriculture Research & Education

REGIONAL PRODUCTION CHALLENGES

- Growers favor warm-season annuals, challenges with cool-season crops[3]
- High elevation and microclimates bring late snow, a short 89–135 day season, >20 °C temp swings, and intense solar radiation[1] [4]
- By late spring:
  - heat, pests, and disease rise[5]
  - water restrictions[5]
- Most guidelines from other production regions, don’t address Utah’s conditions—local solutions needed

SOURCES

1. UTAH CLIMATE CENTER 2024
2. GILLIES AND RAMSEY 2009
3. ARMITAGE AND LAUSHMAN 2003
4. RAUTER ET AL 2022
5. PRATT ET AL 2019

PROTECTED CULTIVATION

- High tunnels (HT) increase stem length, yield, and harvest timing[1] [2] [5] [7] [8]
- In northern Utah, they advanced:
  - Peony[9], anemone[10], snapdragon[11], ranunculus[12] by 34–56 days
- Air temps can be up to 30 °C warmer unvented, 10 °C vented, but only 1–3 °C warmer at night vs outside[5] [6]
- Shade cloth in cut flowers reduces surface temperature, and can increase stem length[3] [6]

SOURCES

1. BLOMGREN AND FRISCH 2007
2. KNEWTSON ET ALL 2010
3. HUNTER ET AL. 2012
4. WIEST ET AL. 1976
5. WIEN 2009
6. ARMITAGE 1991
7. BOTH ET AL. 2007
8. WIEN ET AL. 2008
9. LEWIS ET AL. 2003
10. RAUTER ET AL. 2022
11. LEWIS ET AL. 2021
12. RAUTER ET AL. 2002A

WHY DELPHINIUM AND LARKSPUR?

- Delphinium and Larkspur are cool-season cut flowers within Ranunculaceae with strong market potential[3]
- Local demand exceeds supply in Utah[1]
- 2022 survey of 62 UT growers:
  - 72% grow delphinium & larkspur[2]
  - 21% interested but not yet producing[2]
- Research is needed to develop reliable production methods that extend harvest and boost yields

SOURCES

1. S. WORKMAN PERSONAL COMM. 2024
2. VOLESKY AND STOCK, UNREPORTED SURVEY 2022
3. ARMITAGE AND LAUSHMAN 2003

DELPHINIUMS

OVERVIEW

- Short-lived cool-season perennials (1-3 years)[5–11]
- Optimal temperatures: 65 to 75 ºF Day/ 58 to 61 ºF Night [4] [12–18]
- Unique shades of blue and tall racemes offer vertical structure and balance in floral arrangements[1] [3]
- Elatum-types *(Delphinium elatum)*
  - 5 stem bunches, $2.40 - $3.20[1] [3]
- Belladonna-types (*Delphinium* × *belladonna*)
  - 10 stem bunches, $1.20 - $1.60[1] [3]
- No current regional production guidelines

SOURCES

1. S. WORKWMAN PERSONAL COMM.
2. PICKLINQ 2024
3. H. GRIFFITHS, PERSONAL COMM.
4. GARNER ET AL. 1997
5. TAMURA 1993
6. TAKHTAJAN 1997
7. BAILEY AND BAILEY 1976
8. HONDA AND TSUTSUI 1997
9. BEDFORD 2005
10. USDA 1961
11. HOLCOMB AND BEATTIE 1988/1990
12. SYNGENTA FLOWERS 2023
13. PANAMERICAN SEED 2024
14. SAKATA SEED AMERICA 2003
15. HANKS 2016
16. PACIFIC PLUG & LINER 2024
17. DELPHINIUM SOCIETY 2024
18. WANG AND WARNOCK 2001

EARLY TRANSPLANT AND HIGH TUNNELS INCREASE PRODUCTION

Lincolnshire, UK (Zone 7b, 204 freeze-free days)[1]:

- Late March transplants had the greatest yields at 45 stems/m²
- Staggered planting late Mar to mid-May yielded stems 29 Jun–26 Oct (17 weeks)

  Ithaca, NY (Zone 6a, 144 freeze-free days)[2]:
- High tunnel (HT) yields: 1.7–4.6 stems/plant vs field: 0.9–2.8 stems/plant
- HT advanced harvest by 11–14 days

SOURCES

1. HANKS 2016
2. WIEN 2005

OBJECTIVES

Assess both High Tunnel and Field systems for bloom timing, yield, and stem quality of first- and second-year plants by testing:

- two spring transplant dates per system
  - Late March (LM) and Mid-April (MA) in HT
  - Early May (EM) and Mid-May (MM) in F
- three series (Elatum and Belladonna types) with three color selections each
- 30% shade cloth use in field production and its effect on stem quality

Delphinium elatum

Magic Fountain Series

Dark Blue with Dark Bee

White with White Bee

Mid Blue with White Bee

Delphinium elatum

Pacific Giant Series

Summer Skies

Galahad

Blue Bird

Delphinium × Belladonna

Belladonna Series

Cliveden Beauty

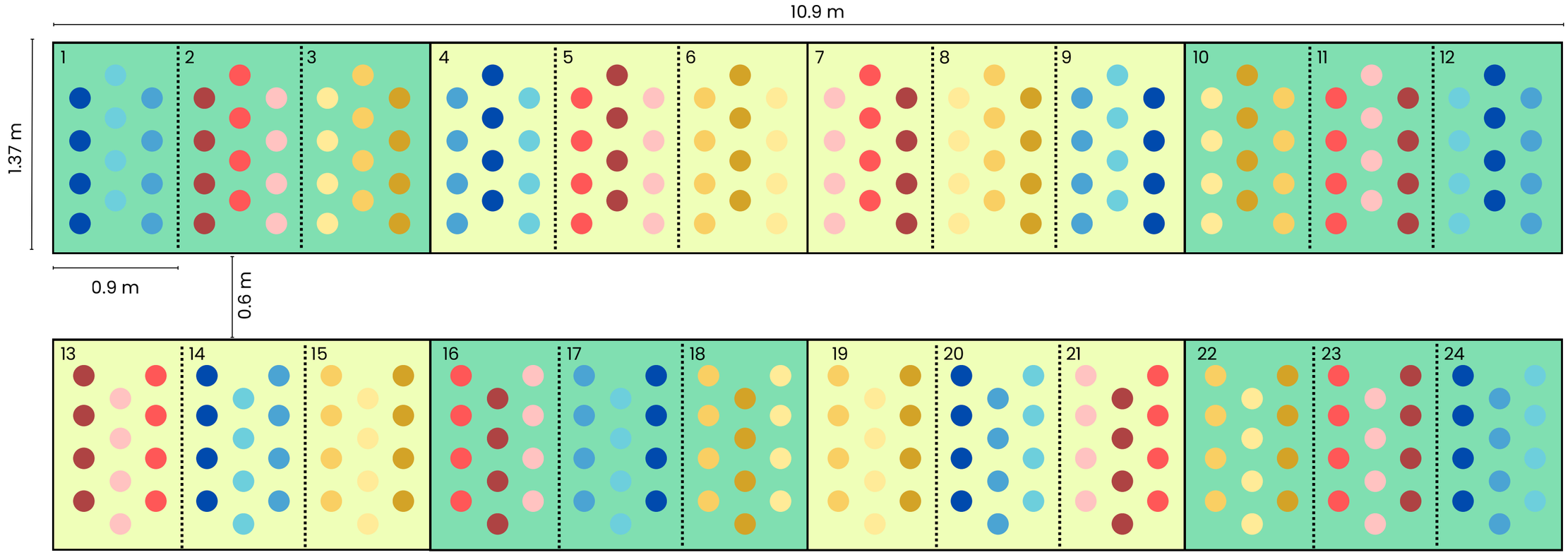
Casablanca

Blue Donna

RESEARCH LOCATION

- 2023 and 2024
- UAES - Greenville Farm (North Logan, UT)
  - Millville silt loam with 2% organic matter
  - 1,382 m elevation
  - USDA Hardiness Zone 6a
  - 135 freeze-free day (15 May to 25 Sep)
- HT (11 ft W × 34 ft L)
- Fields (52ft W × 40ft L + 14ft W × 60ft L)
- Analyses:
  - PROC GLIMMIX (SAS Studio), $\alpha = 0.05$
  - ANOVA-type mix model to compare interactions

DELPHINIUM EXPERIMENT DESIGN (HT)



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Planting Dates

- Late March
- Early April

Magic Fountain Series

- Dark Blue w/ Dark Bee
- Mid Blue w/ White Bee
- White w/ White Bee

Pacific Giant Series

- Blue Bird
- Summer Skies
- Galahad

Belladonna Series

- Blue Donna
- Cliveden Beauty
- Casablanca

DELPHINIUM EXPERIMENT DESIGN (F)

Planting Dates

- Early May
- Mid-May

Magic Fountain Series

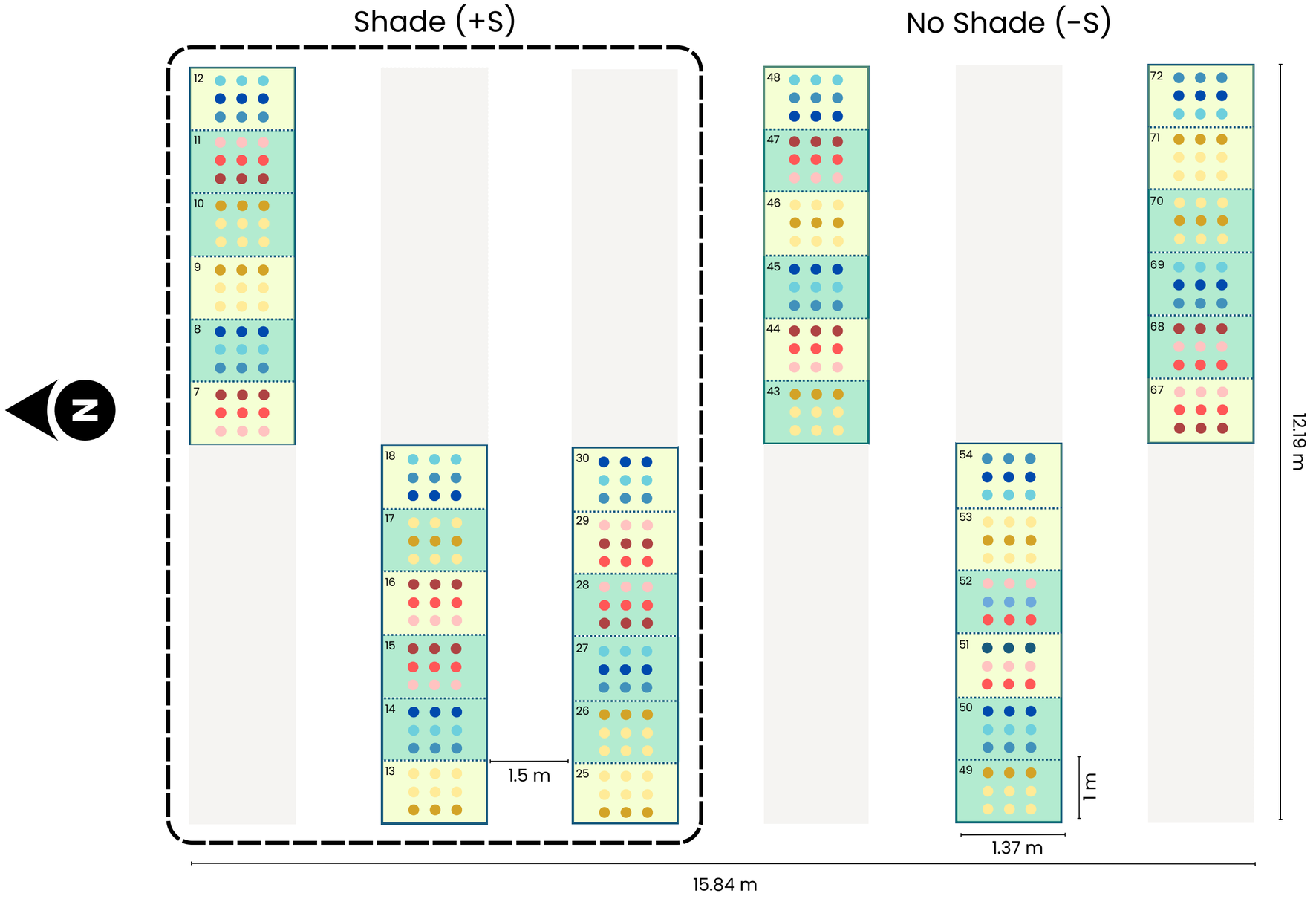
- Dark Blue w/ Dark Bee
- Mid Blue w/ White Bee
- White w/ White Bee

Pacific Giant Series

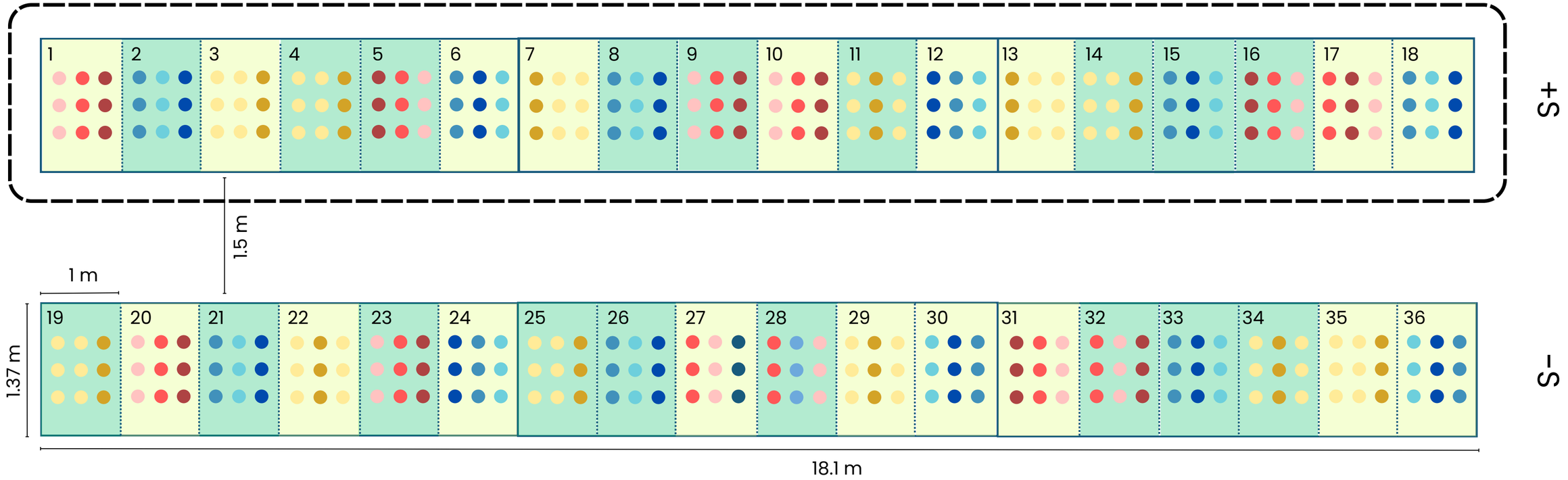
- Blue Bird
- Summer Skies
- Galahad

Belladonna Types

- Blue Donna
- Cliveden Beauty
- Casablanca



DELPHINIUM EXPERIMENT DESIGN (F)



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Planting Dates

- Early May
- Mid-May

Magic Fountain Series

- Dark Blue w/ Dark Bee
- Mid Blue w/ White Bee
- White w/ White Bee

Pacific Giant Series

- Blue Bird
- Summer Skies
- Galahad

Belladonna Series

- Blue Donna
- Cliveden Beauty
- Casablanca

GREENHOUSE PLUG PRODUCTION

- Seeds chilled for 3 wks at 36°F[1]
- Greenhouse sown, peat-based media
- Transplanted from 128- to 32-cell trays at ~21 DAS (2–4 sets of true leaves)
- Temperature maintained at 64 to 72°F with no day/night differential[2-6]
- Watered daily
- Fertilizer (12-5-20) applied at 100 ppm N
- Supplemental light: 6 hrs per day (16 hours total light)
- Hardened off at 7–10 wks after sowing

SOURCES

1. CARPENTER AND BOUCHER 1992
2. NAU 1993
3. KOLAR ET AL 2017
4. SYNGENTA 2023
5. SAKATA SEED 2003
6. JOHNNY'S SELECT SEEDS 2023

CROP MANAGEMENT

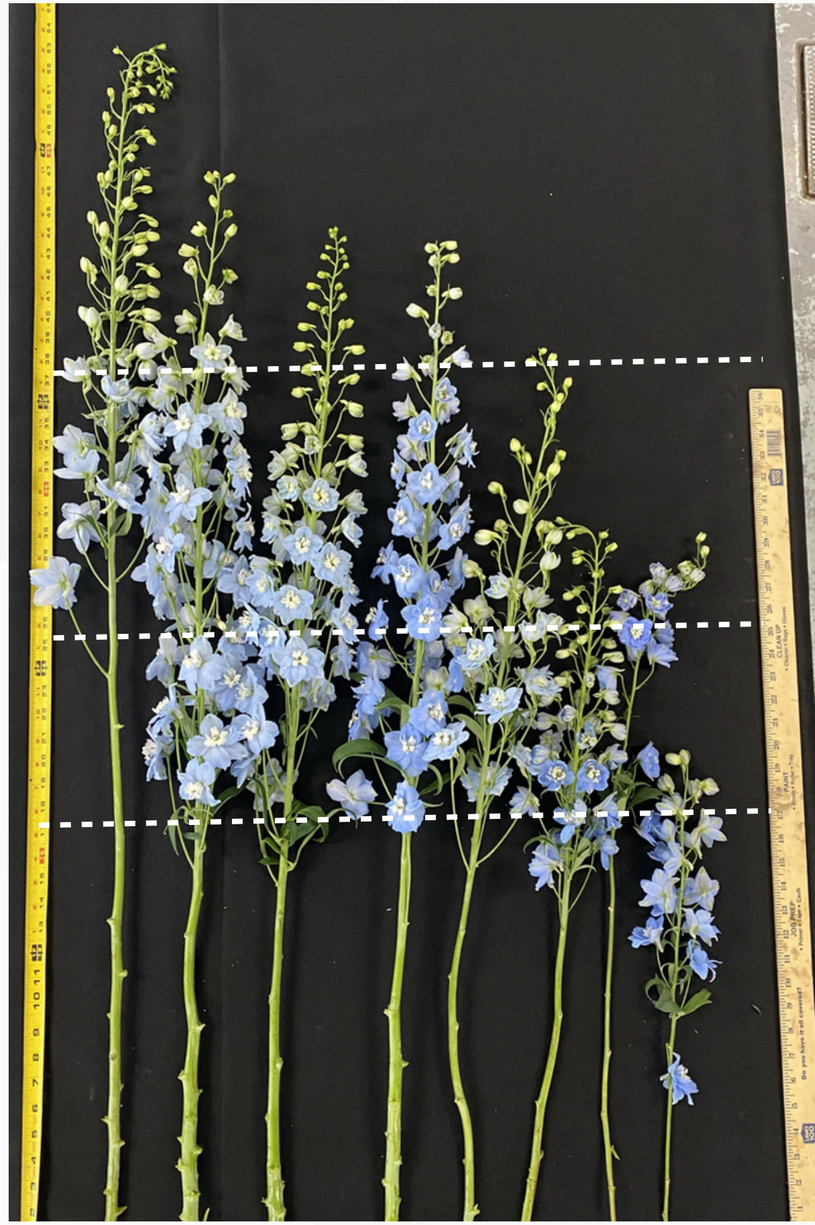
- Transplants spaced 1 ft apart[3]
- Horizontal trellis applied at crop height
- Irrigated up to 3× week (4 lines of drip tape were laid per bed (1.5 ft apart))[4 5]
- HT venting; windows: >400 W m^2 + >40 °F; doors when >60 °F sides when >75 °F[1 2]
- N applied at 150 lbs N $acre^{-1}$ in 3 apps[6 7]
  - HT: late Mar, mid-May, and mid-Aug
  - F: mid-May, mid-Jun, and late Jul
- P, K, and Fe applied based on soil and tissue tests

SOURCES

1. LEWIS ET AL 2021
2. UTAH CLIMATE CENTER 2024
3. ARMITAGE AND LAUSHMAN 2003
4. SURYAVANSHI ET AL 2015
5. COLLAGUAZO-LITA ET AL. 2022
6. BALA ET AL. 2005
7. WEGULO AND VILCHEZ 2008

DATA COLLECTION

- Air temp (T_a) and precip. from Greenville Weather station
- Canopy (T^c_{ht} + T^{cf}) and soil ($T_{s\ ht}$ +T_s^f) temps logged hourly (Mar–Oct) in HT and F (-S/+S)
- Stand counts: 2 wks pre-1st and 2nd flush
- Harvested 3×/wk at ⅓–½ raceme open, then graded[1] [2]
- Marketable stems defoliated, stored at 2°C w/ preservative
- Sold via local co-ops/farmers at Wasatch Front markets ($12 to $16 per bunch)[1] [2] [3]



SOURCES

1. A. HARRISON, PERSONAL COMM.
2. H. GRIFFITHS, PERSONAL COMM.
3. PICKLING 2024

ENVIRONMENTAL CONDITIONS

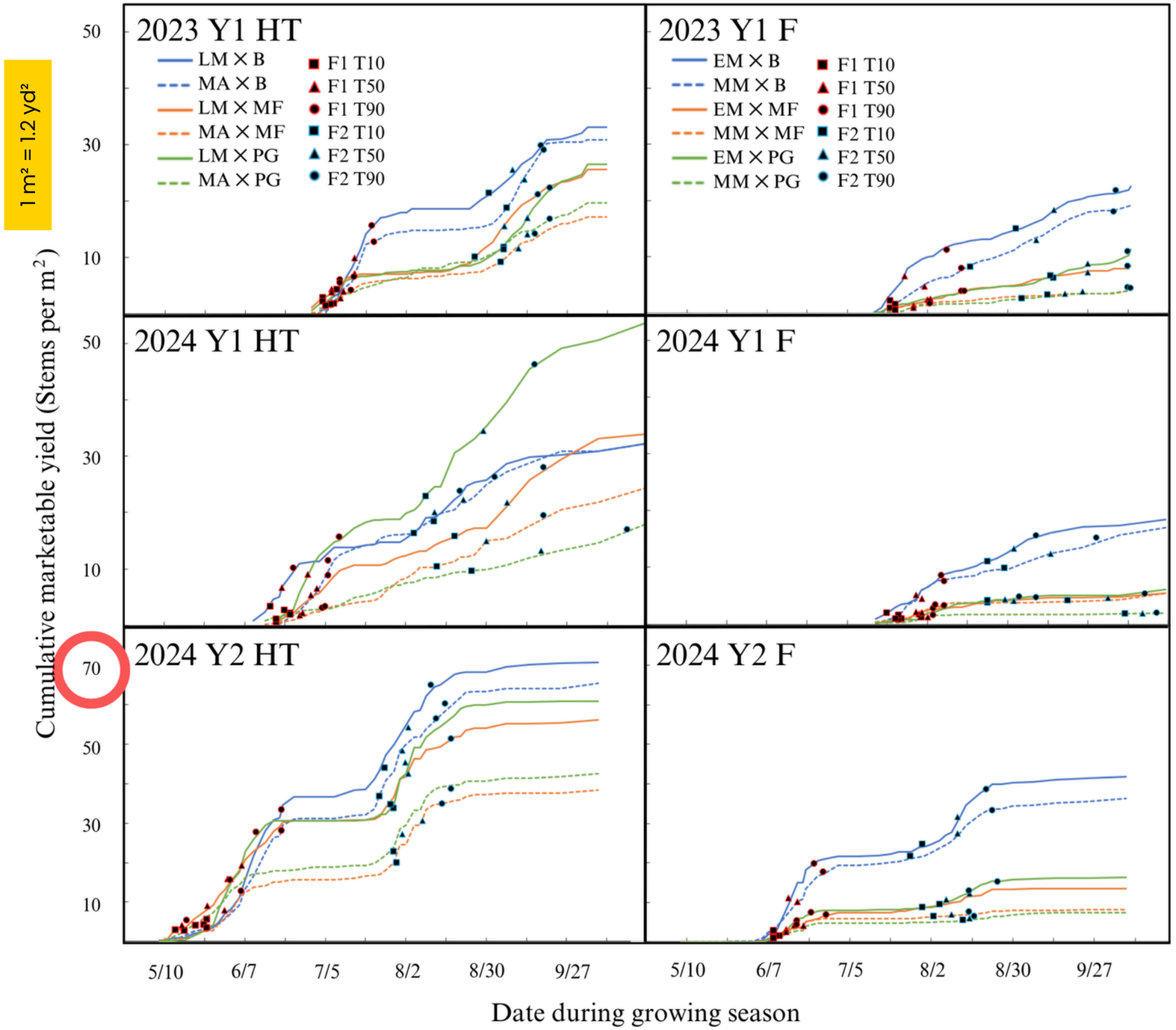
Table is in °C not °F

	Month		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
T_a[x] (°C)	30-yr Normal[y]		4.2	8.4	13	17.7	22.8	21.7	16.1	9
	2023	Avg	-1.9	4.5	15	16.6	24.2	21.7	16.2	9.3
		Min	-6.2	-1	8.1	9.8	15.7	14.9	9.2	3.6
		Max	2.2	10.5	22	23.6	32.2	28.7	24.1	16.3
	2024	Avg	3.9	8.9	11.3	20.5	23.8	21.8	18	12.6
		Min	-1.3	2.8	4.1	12.1	15.1	13.6	9.9	4.9
		Max	9.4	15.1	18	28.3	32	30.3	26.3	21.5
$T_{c,HT}$ (°C)	2023	Avg	-[z]	15.3	19.4	18.5	26.6	23.2	17.3	15.6
		Min	-[z]	5.74	16.2	13.5	22.5	16.7	9.2	6.2
		Max	-[z]	25.9	26.2	23	31.1	27.4	22.8	19.3
	2024	Avg	8.9	13	13.7	21	24	21.7	18	-[z]
		Min	1.4	7.3	7.1	11.2	18.8	15.3	12	-[z]
		Max	15.6	20.2	18.4	25.7	29.5	26.2	23.8	-[z]
$T_{c,F}$ (°C)	2023	Avg	-[z]	-[z]	-[z]	17.7	24.2	22	16.1	10.5
		Min	-[z]	-[z]	-[z]	12	20.6	16.9	9.1	3.3
		Max	-[z]	-[z]	-[z]	20.6	28.4	26.2	22.7	13.6
	2024	Avg	-[z]	9.7	12.1	21.2	24.1	21.8	17.6	-[z]
		Min	-[z]	1.6	4.6	10.5	18.7	14.9	12.2	-[z]
		Max	-[z]	17.4	18.8	26.5	29.7	26.9	24.3	-[z]
P (mm)	30-yr Normal[x]		42	50	53	29	8	18	31	38
	2023		87	47	41	58	5	64	57	65
	2024		60	63	29	7	21	14	8	11

(Optimum Temp Range: 58 to 75 °F)

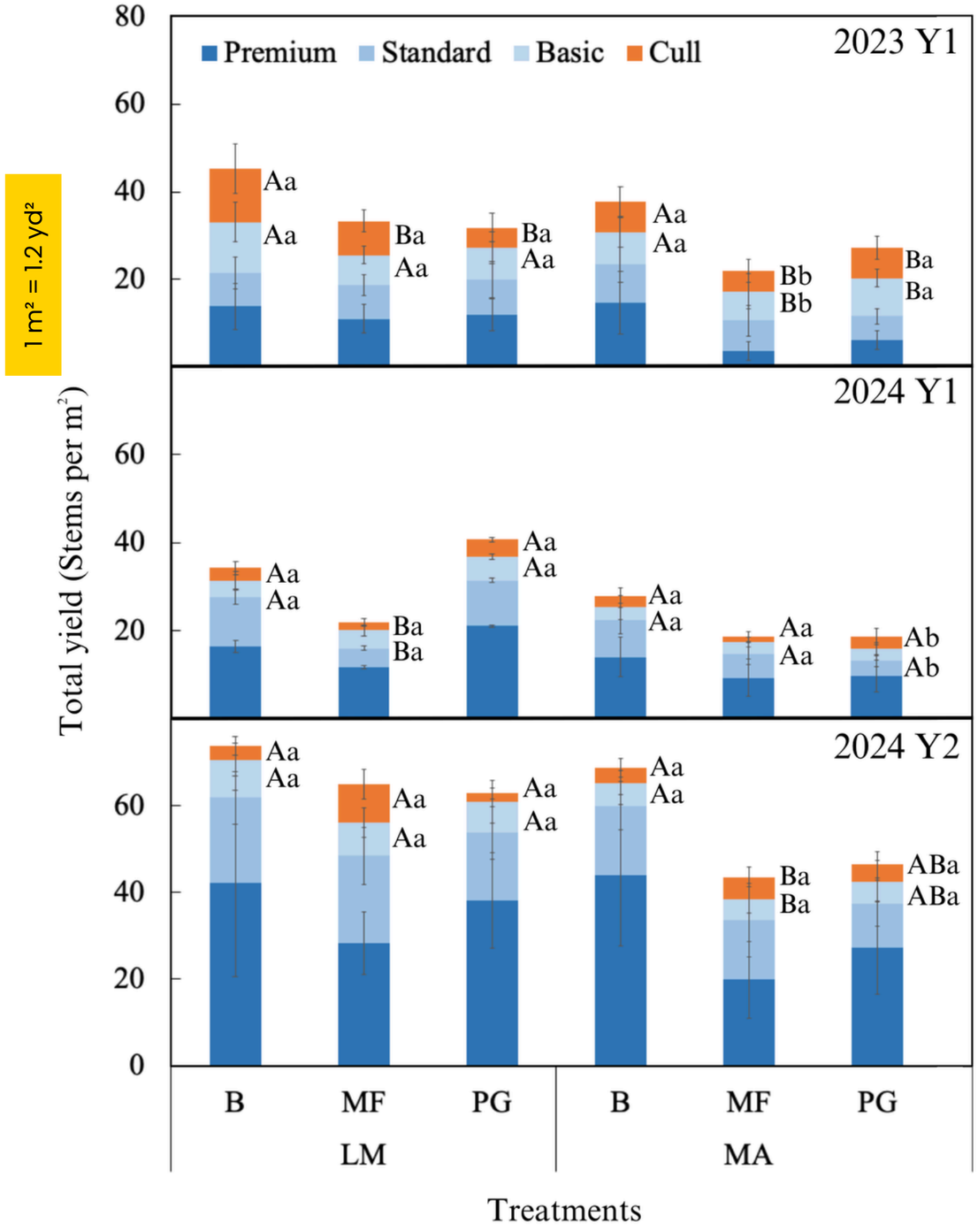
- HT in April–May:
  - Optimum temps: 269 hrs (2023) vs 445 hrs (2024)
- F in June, avg. monthly temps:
  - 17.0 (2023) vs 17.2 °C (2024)
  - optimum temp hours:
  - 228 hrs (2023) vs 304 hrs (2024)

TIMING OF MARKETABLE YIELD



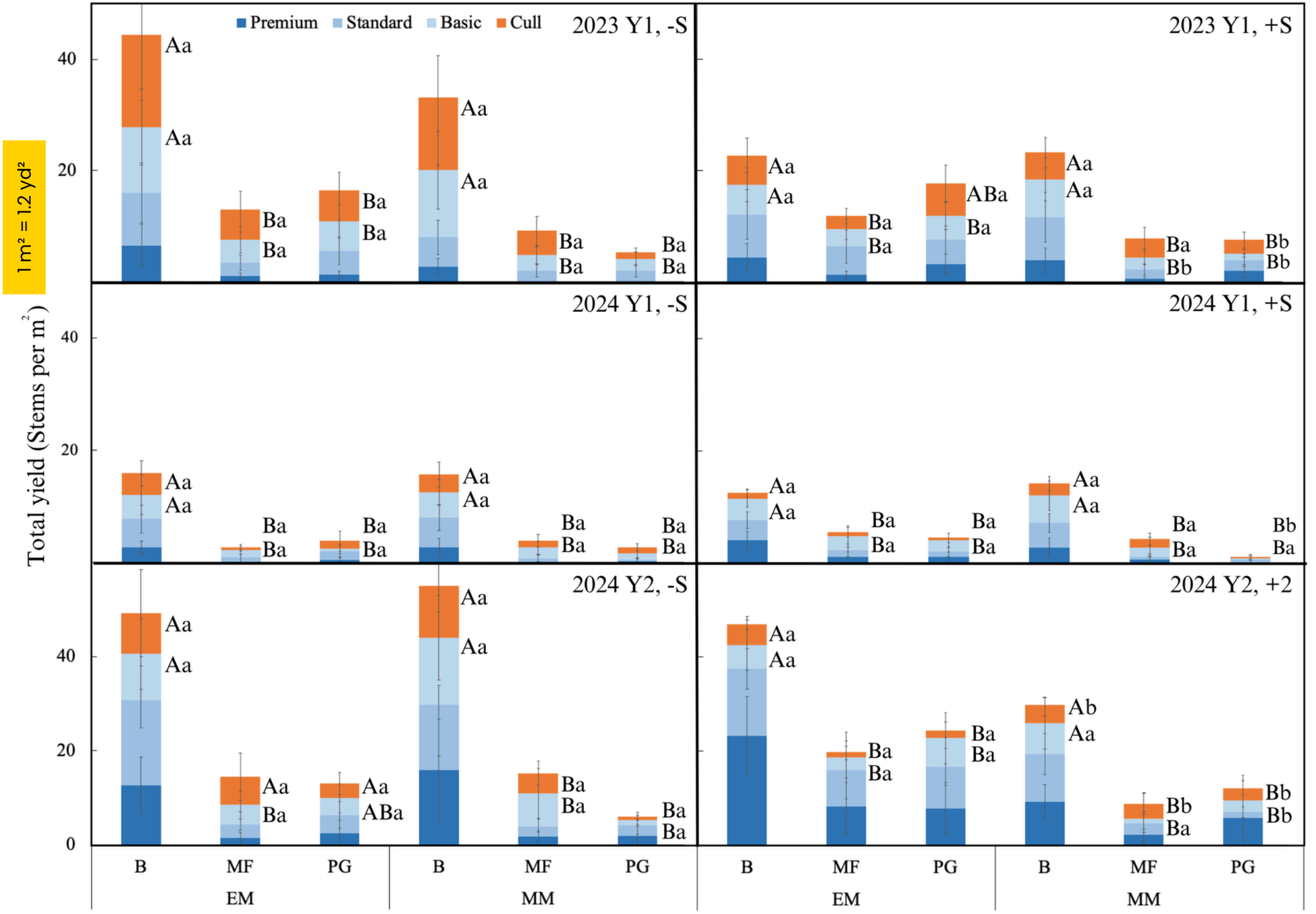
- 2nd flush: longer duration and higher yield than 1st flush
  - 1 - 4 wks longer
  - ~3× greater yield
- 2024 HT harvest up to 3 weeks earlier than 2023; no change in F
- 2nd-year vs 1st-year plant observations:
  - 2× marketable yield
  - F harvest 6 weeks earlier

HIGH TUNNEL TOTAL YIELD



- B had greater yields than MF and PG, which were not significantly different
- 2nd-year plants produced ~2-3X (premium) stems than 1st-year
- No significant difference between transplanting dates in 2nd year

FIELD TOTAL YIELD



- F had lower yields and more culls than HT
- Same series and transplanting date trends in both systems

CONCLUSION, RECOMMENDATIONS, AND FUTURE WORK

- HTs advanced early-season harvest by 2-5 weeks, increased yield (HT: 25.1 and F: 8.8 stems per m^2), and improved stem quality (HT 31% premium and F 13%)
- Combined 1st- and 2nd- year plants enabled a consistent stem supply from early May to mid-Oct (22 wks)
- Transplanting late Mar = greatest yields and stem quality, and projected gross returns
- Further evaluate earlier transplant date, determine lower temp thresholds

LARKSPUR

OVERVIEW

- Cool-season annuals[1] [3]
- Most cultivated cut flowers is *Consolida ajacis*[3]
- Optimal temperatures: 60 to 70 °F [1-4]
- Florists use for focal vertical line in arrangements, popular blue-grey colors
- Primary stems along with some secondary
  - 10 primary-stem bunches, $0.90 - $1.30[5] [6]
  - 15-20 secondary, $0.75 - $1.00[5] [6]
- No current regional production guidelines.

SOURCES

1. BERGMANN ET AL. 2016
2. NAU 1993B
3. ARMITAGE AND LAUSHMAN 2003
4. KARAGUZEL AND TASCIOGLU 2007
5. H. GRIFFITHS, PERSONAL COMM.
6. S. WORKMAN, PERSONAL COMM.

LARKSPUR TIMING AND YIELD

- Earlier Planting advances harvest, but risks yield loss from suboptimal temperatures

  Ithaca, NY (Zone 6a, 144 freeze-free days):
- HT larkspur transplanted early May: first harvest mid–late June[1] (avg. 0.7 m)
- ‘Cannes’ Deep Blue transplanted early April: 7–10 days earlier harvest vs late-Apr date, but lower yield (4.0 vs 4.4 stems/plant)[2]

SOURCES

1. WIEN 2007
2. WIEN 2009
3. WIEN 2013

OBJECTIVES

Assess both High Tunnel and Field systems for

- bloom timing, yield, and stem quality
- two spring direct-sow dates per system
  - Mid-Mar (MM) and Late Mar (LM) in HT
  - Late Apr (LA) and Early May (EA) in F
- three series with three color selections each
- 30% shade cloth use in field production and its effect on stem quality

Consolida ajacis
Cannes
Series


Lilac


White


Deep Blue

Consolida ajacis
QIS
Series


Light Pink


White


Dark Blue

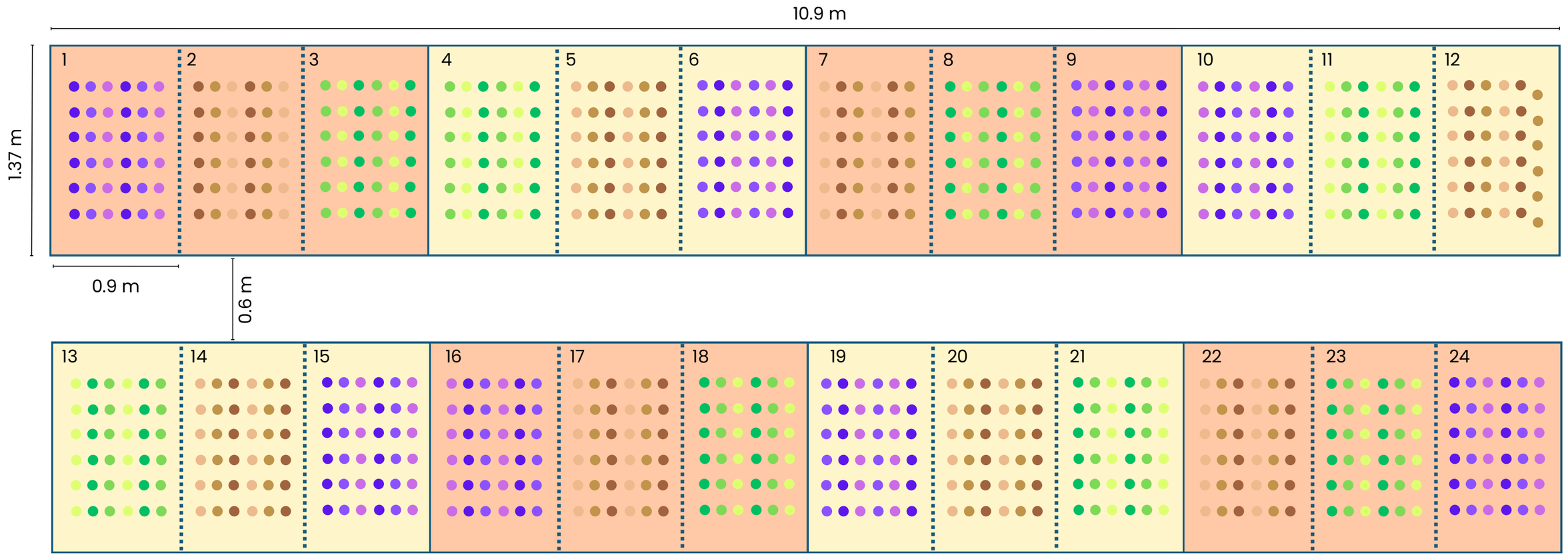
Consolida ajacis
Fancy
Series


Purple Picotee


Smokey Eyes


Belladonna

LARKSPUR EXPERIMENT DESIGN (HT)



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Planting Dates

- Mid-March
- Late March

Fancy Series

- Purple Picotee
- Belladonna
- Smokey Eyes

Cannes Series

- Deep Blue
- Lilac
- White

QIS Series

- Light Pink
- White
- Dark Blue

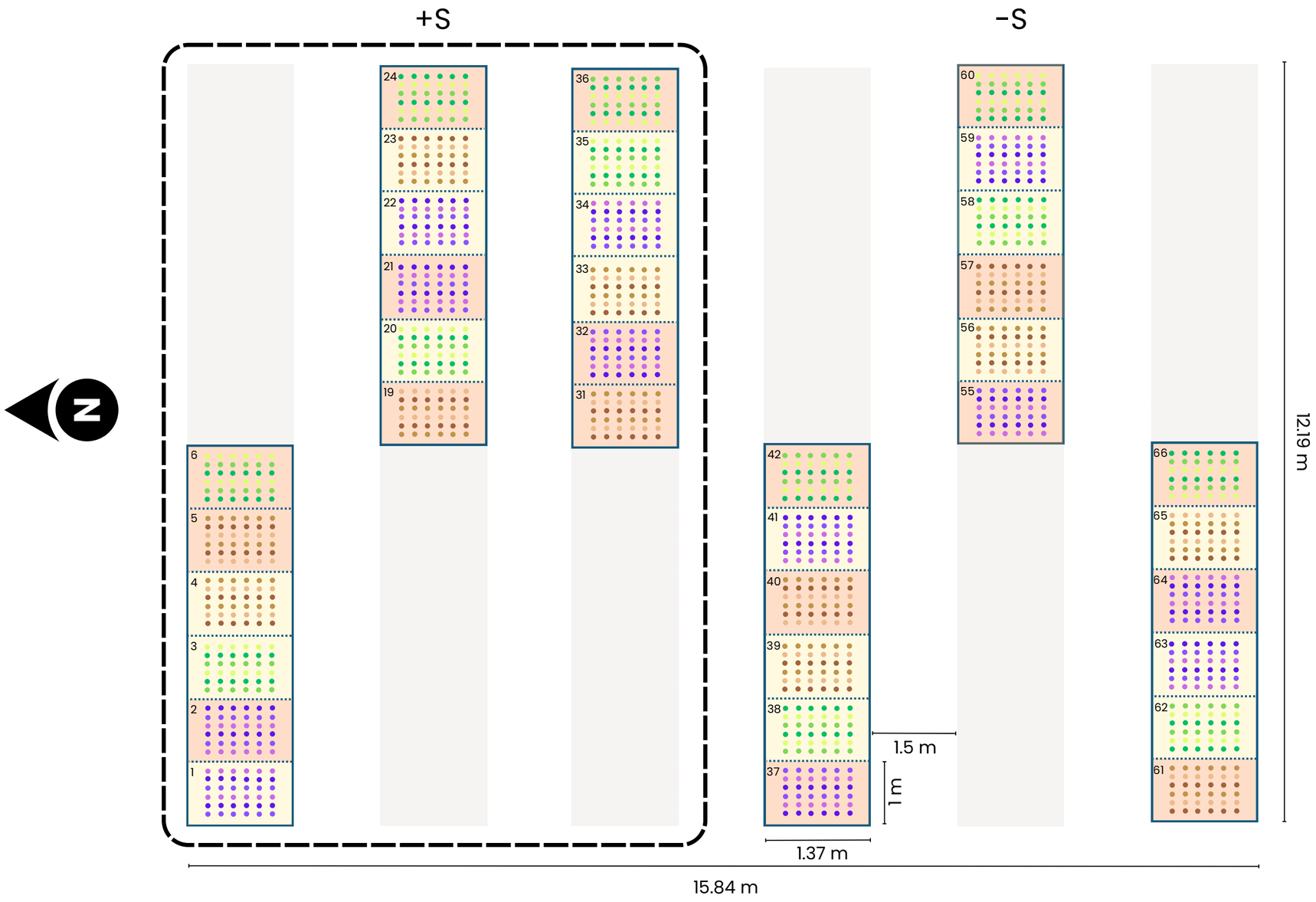
LARKSPUR EXPERIMENT DESIGN (F)

Planting Date
- Late April
- Early May

Fancy Series
- Purple Picotee
- Belladonna
- Smokey Eyes

Cannes Series
- Deep Blue
- Lilac
- White

QIS Series
- Light Pink
- White
- Dark Blue



CROP MANAGEMENT

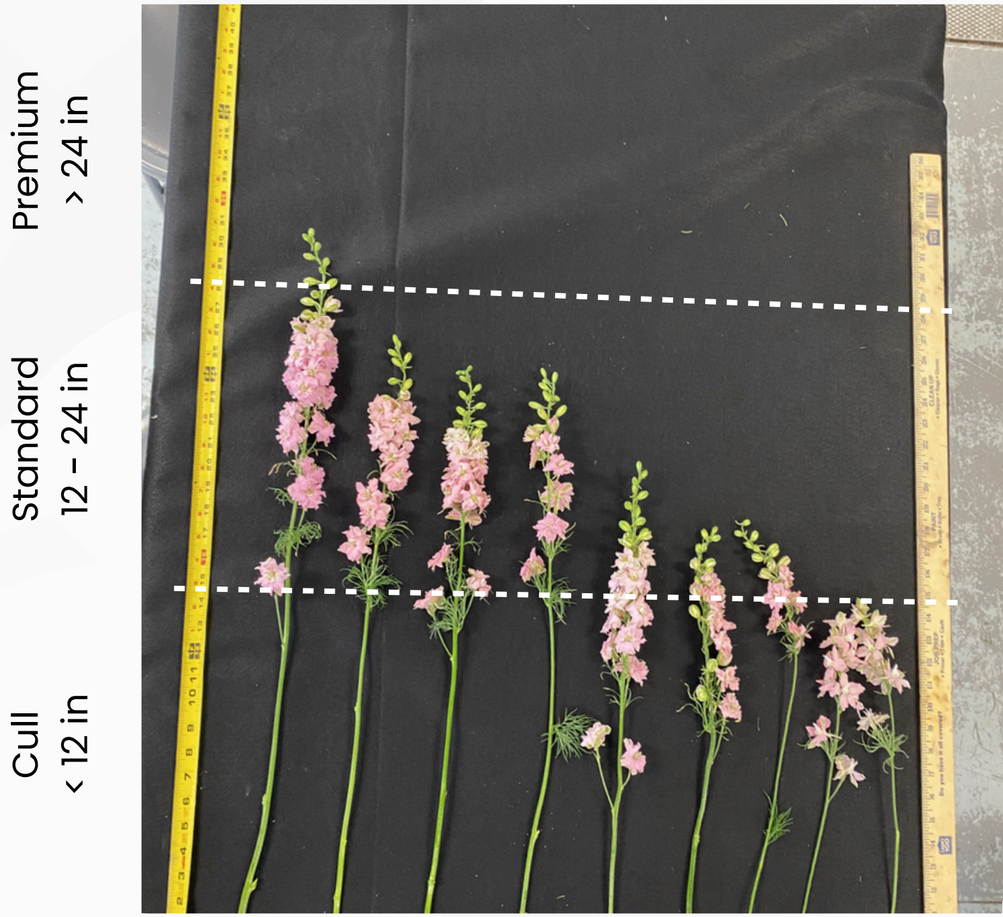
- Direct-sowed at 2-3× rate, later thinned for a target density = 36 plants per m^2 [2]
- Horizontal trellis applied (adjusted)
- Irrigated up to 3× week (4 lines of drip tape were laid per bed (0.5 m))[1]
- N applied at 130 lbs N $acre^{-1}$ in 3 apps[3]
  - HT: mid-Mar, mid-May, and late June
  - F: late May, mid-Jun, and mid-Jul
- P, K, and Fe applied based on soil and tissue tests

SOURCES

1. SURYAVANSHI ET AL. 2015
2. ARMITAGE AND LAUSHMAN 2003
3. BALA ET AL. 2005

DATA COLLECTION

- Air temp (T_a) and precip. from Greenville Weather station
- Canopy (T^c_{ht} + T^{cf}) and soil ($T_{s\ ht}$ +T_s^f) temps logged hourly (Mar–Aug) in HT and F (-S/+S)
- Stand counts: after thinning, before harvest
- Harvested 3×/wk at 1/4-1/3 raceme open and graded[1] [2]
- Marketable stems defoliated, stored at 36 °F w/ preservative
- Sold via local co-ops/farmers at Wasatch Front markets ($9 to $15 per bunch)[1] [2] [3]



SOURCES

1. A. HARRISON, PERSONAL COMM.
2. H. GRIFFITHS, PERSONAL COMM
3. S. WORKSMAN, PERSONAL COMM.

ENVIRONMENTAL CONDITIONS

Table is in °C not °F

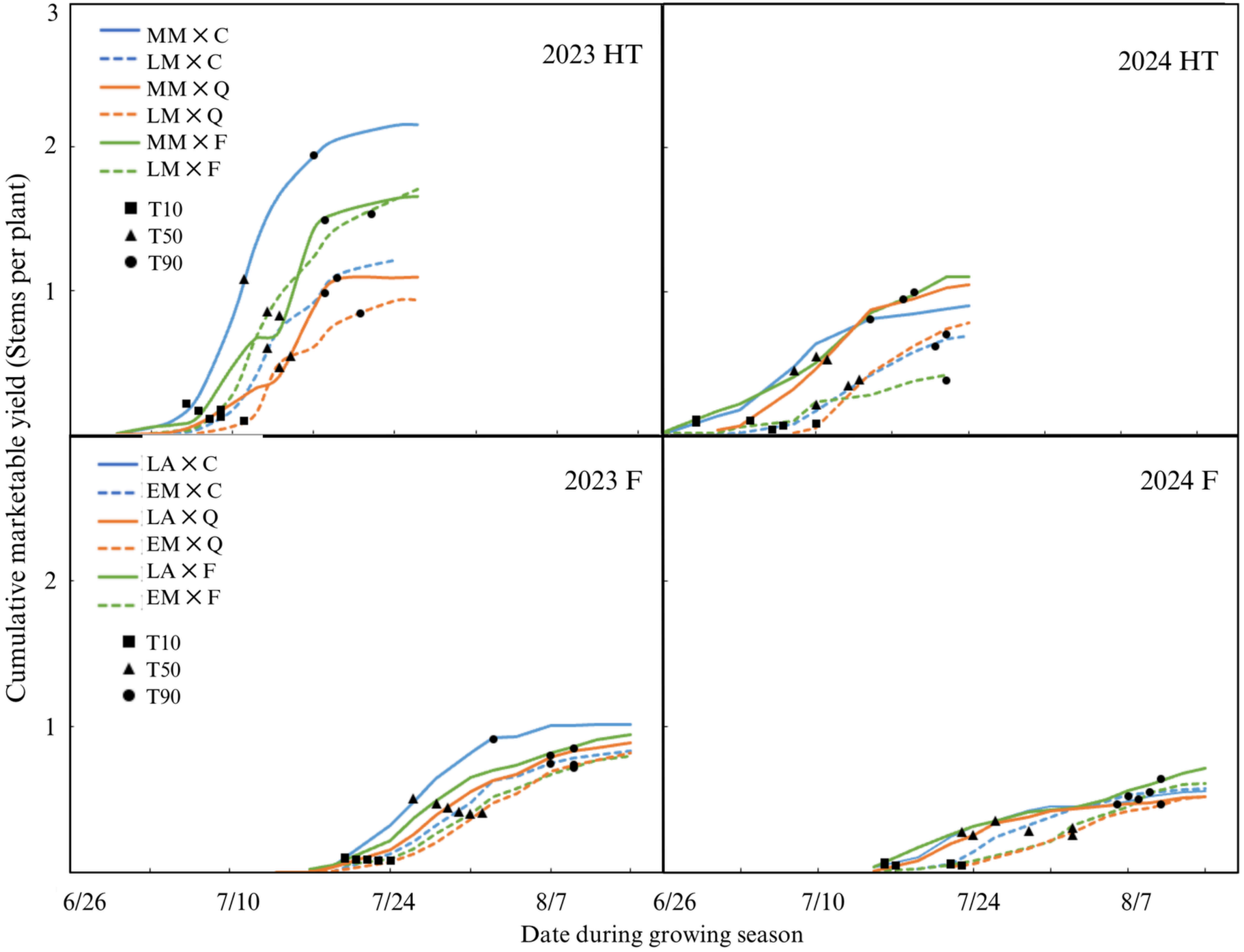
	Month		Mar	Apr	May	Jun	Jul
T_a^x (°C)	30-yr Normal[y]		4.2	8.4	13	17.7	22.8
	2023	Avg	-1.9	4.5	15	16.6	24.2
		Min	-6.2	-1	8.1	9.8	15.7
		Max	2.2	10.5	22	23.6	32.2
	2024	Avg	3.9	8.9	11.3	20.5	23.8
		Min	-1.3	2.8	4.1	12.1	15.1
		Max	9.4	15.1	18	28.3	32
$T_{c,HT}$ (°C)	2023	Avg	-[z]	15.2	19	18.3	25.4
		Min	-[z]	5	15.7	13.3	21.4
		Max	-[z]	25.5	26.4	21.4	30.3
	2024	Avg	8.6	12.8	13.2	20.3	23.3
		Min	1.5	7.2	6.8	10.7	18
		Max	13.1	18.3	19	25	28.3
$T_{c,P}$ (°C)	2023	Avg	-[z]	14.2	17.3	16.1	20.5
		Min	-[z]	7.7	15.4	13.8	17.7
		Max	-[z]	20.3	20.8	18.2	26.5
	2024	Avg	3.9	9.4	11.9	21.1	23.9
		Min	-4	1.3	4.3	10.4	18.5
		Max	9.4	17	17.9	26.2	29.4
P (mm)	30-yr Normal[x]		42	50	53	29	8
	2023		87	47	41	58	5
	2024		60	63	29	7	21

(Optimum Temp Range: 60 to 70 °F)

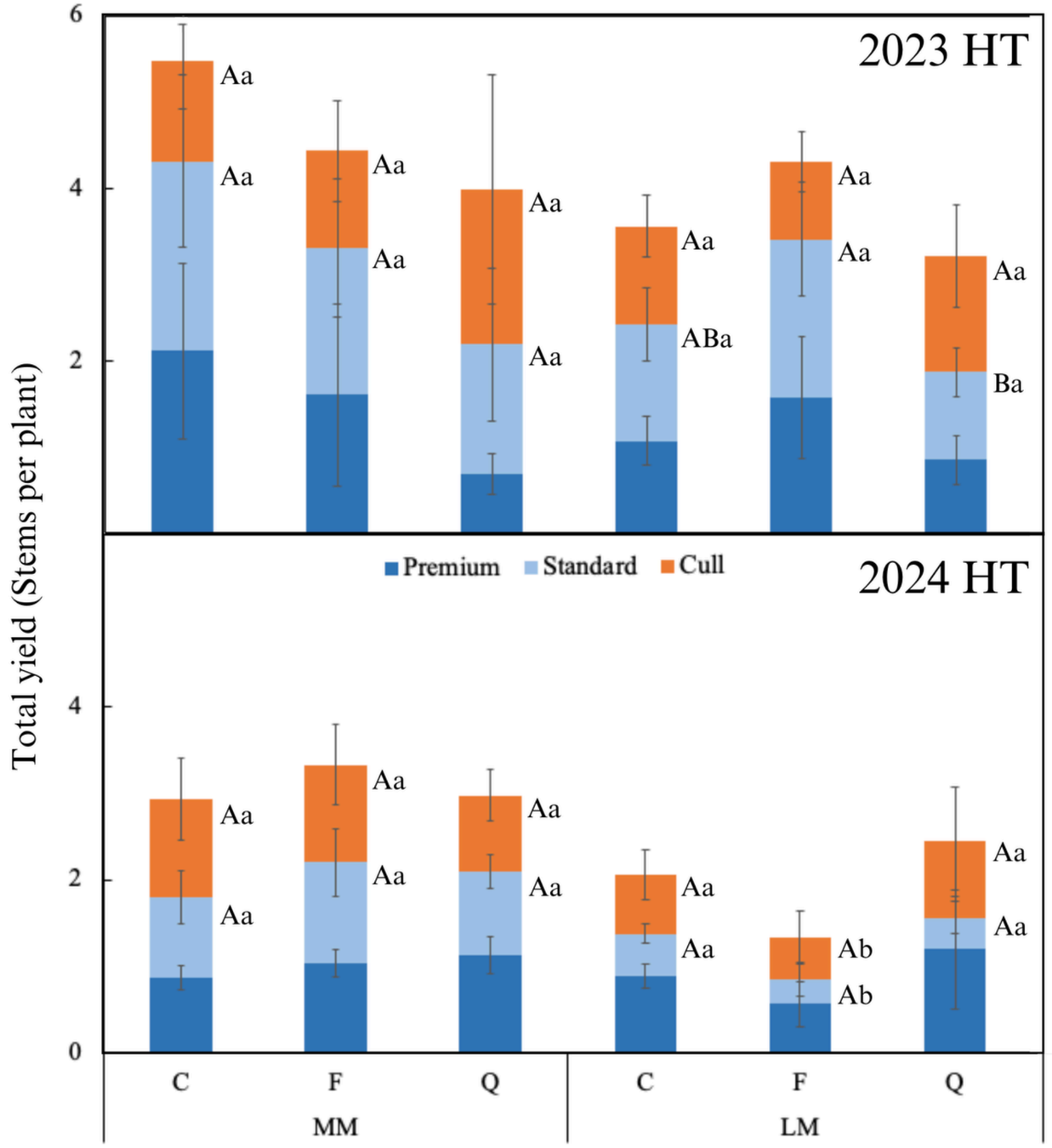
- 2024 had greater temperature extremes[1] :
  - Mar–Aug:
  - >22 °C[1] for 1,100 hrs (2023) vs 1,240 hrs (2024)
  - May–Aug:
  - <1.6 °C[1] for 0 hrs (2023) vs 45 hrs (2024)
- Overnight freeze on 24 May 2024 and radiative frost 18 Jun

SOURCES
1.LUBBE ET AL 2021.

TIMING OF MARKETABLE YIELD

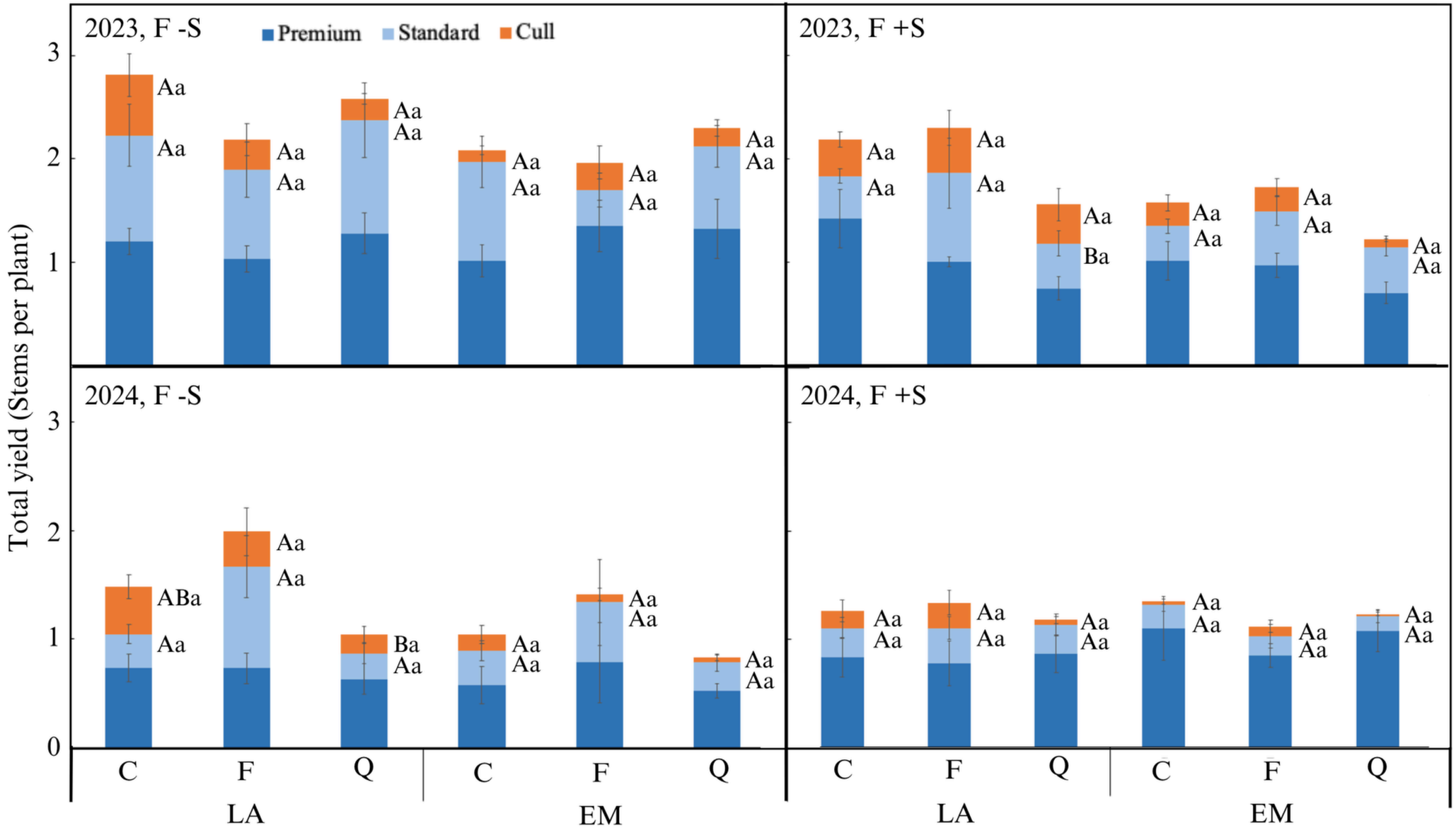


HIGH TUNNEL TOTAL YIELD



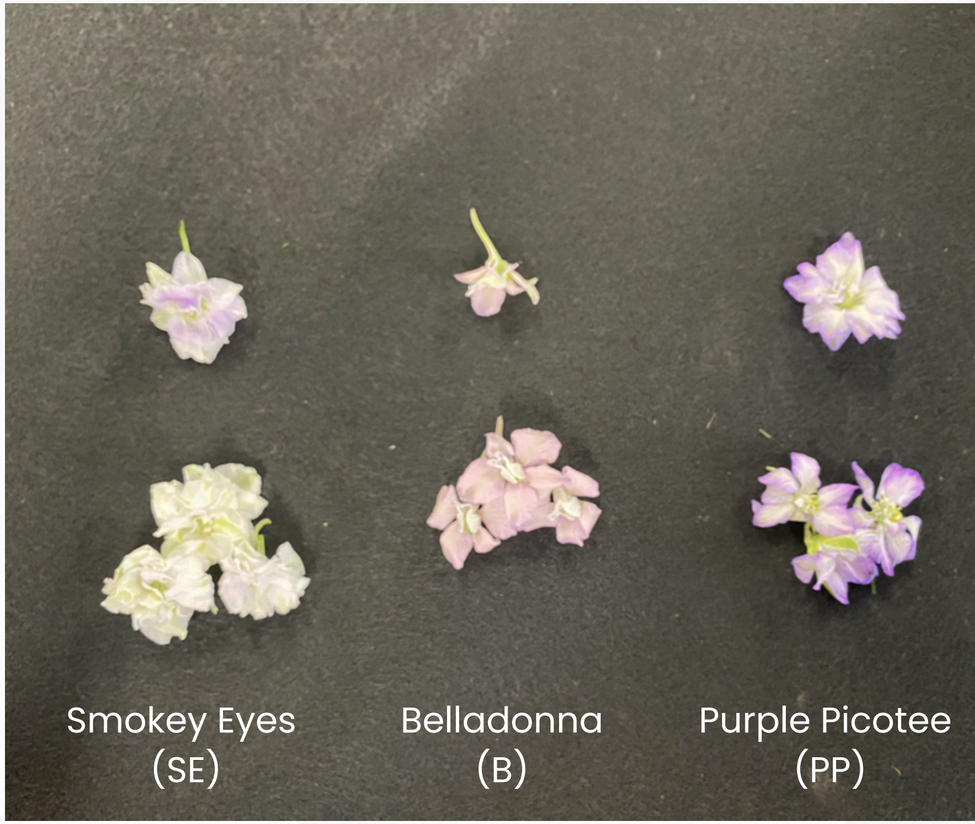
- Temperature extremes reduced 2024 yields
- No significant difference between direct sow dates, but earlier sow dates yielded more than the later
- Yields by series within direct sow dates were similar in total and marketable (no significant difference

FIELD TOTAL YIELD



SIGNIFICANCE IN COLOR

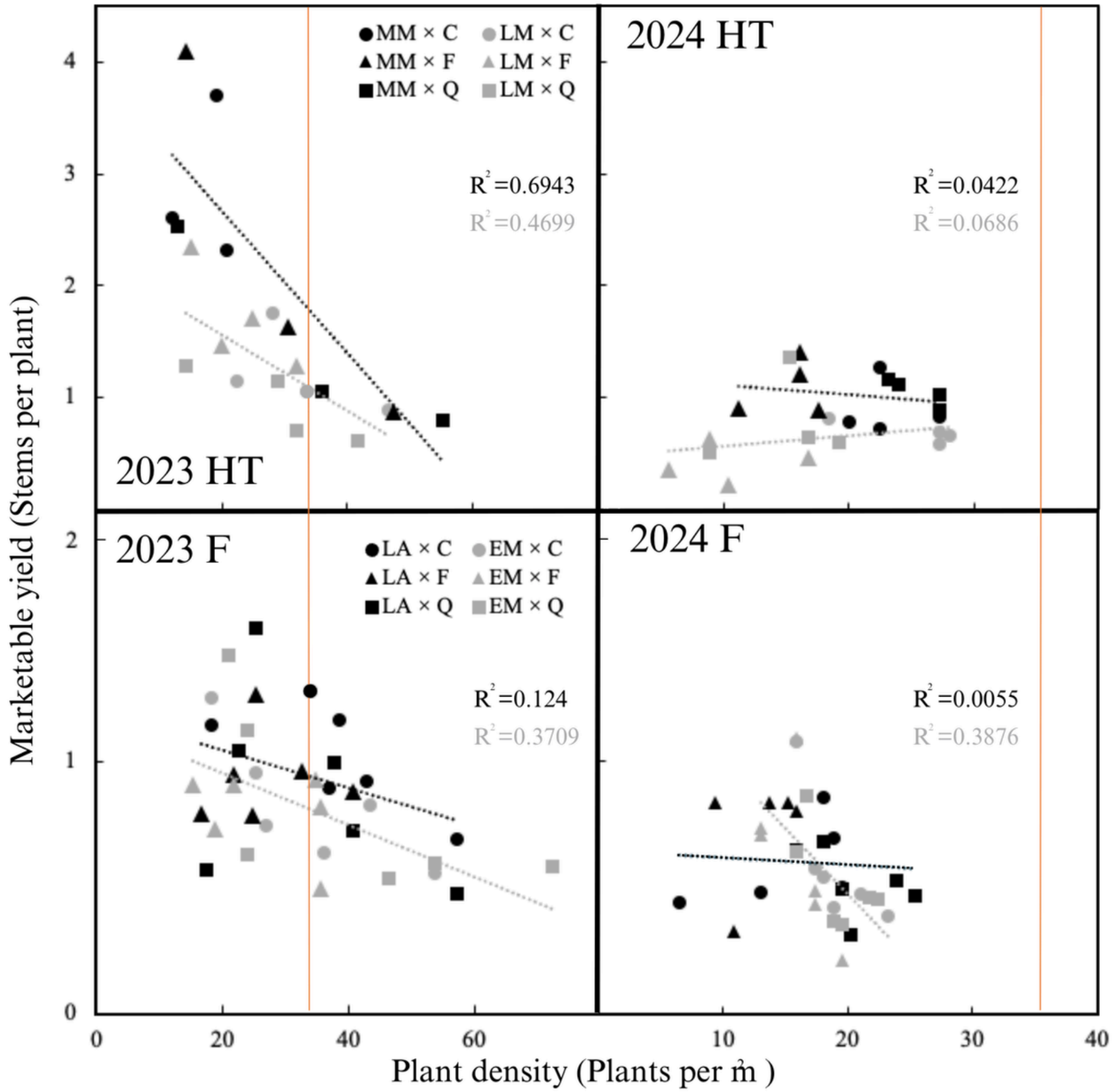
- Colors within C and Q series had similiar performance
- Within F series, B had consistently higher yields than SE and PP (2-3X more)
- *Consolida ajacis* varies in flower form (single vs double petals)[1] [2] [3]
- Commercial seed lots often mix single and double types
  - B: 100% single flowers
  - SE and PP: >80% double flowers



SOURCES

1. JABBOUR ET AL 2016
2. MA ET AL 2024
3. SHARMA ET AL 2024

LARKSPUR PLANTING DENSITY



- Yield was strongly influenced by sow timing and plant density
- Optimal and recommended density: 36 plants/m² [1]
- HT: Best performance at <36 plants/m²
- Field: Best performance up to 40 plants/m²

SOURCES
1. ARMITRAGE AND LAUSHMAN 2003

CONCLUSION, RECOMMENDATIONS, AND FUTURE WORK

- HTs advanced harvest by up to 2 wks and field prolonged harvest by 2 wks (7 wk total duration)
- Mid-Mar direct sow = highest yield, quality, and gross return
  - Up to 5.5 marketable stems/plant (>0.3 m)
  - Gross returns up to $77.87/m²
- Belladonna (Fancy) = greatest survivability & productivity
- Plant density:
  - F: up to 40 plants/m²
  - HT: <36 plants/m²

CONCLUSION

Delphinium:

- Early HT delphinium transplanting (late March) produced 37 stems/m² by mid-June
- Second-year delphinium yielded up to 70 stems/m², 2–3 weeks earlier
- Staggered planting dates extended overall harvest window (22 weeks)

Larkspur:

- Mid-March HT sowing of larkspur yielded 5.5 stems/plant by late July
- HT advanced harvest timing over field production

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