Manipulation of release conditions improves establishment of the wasp *Tetremesa romana* for biological control of arundo in northern California

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Biological control agent against arundo:
Shoot tip-galling wasp, *Tetramesa romana* (Hymenoptera: Eurytomidae)

- Widespread in Mediterranean Europe (native range of arundo or ancient introduced).
- Adventive (released accidentally at unknown point in time) in southern California.
- Females reproduce parthenogenetically; 90% of population is female.
- Larvae develop inside arundo shoot tip in 30-35 days.
- The wasp can develop only on the genus *Arundo*.
- Water deficit (drought) slows down development.
Impact of the wasp *T. romana*-Rio Grande Basin of the U.S. and Mexico

Original releases in the Lower Rio Grande Basin of Texas and Mexico (2009-2012):
- Over 1.2M wasps released, 25 sites.
- Reduced live biomass by 22% by 2014.
- Further reduction to total of 44% of pre-biocontrol by 2016.
- Increased mortality of side shoots.
- Two to three-fold increase in diversity of other plants.

- Released in northern California starting in 2010.

Arundo biological control release sites in California (2017-2020)

- Sacramento River Valley
  - Wasps sourced from Texas.
  - 11 total sites.
  - 5 to 9 plots per site.
  - 150 wasps per plot.
  - Total of 20,660 wasps.

- Sacramento-San Joaquin Delta

- San Joaquin River Valley
  - Wasps sourced from Texas.
  - 11 total sites.
  - 5 to 9 plots per site.
  - 150 wasps per plot.
  - Total of 20,660 wasps.
After one year (2018):
Manipulation of host plant influenced local establishment in plots

- Exit hole density per main shoot length was 26-fold higher in ground-cut than in uncut plots.
- Topped plot exit hole densities were 2 to 4-fold higher but not statistically different from uncut plots.
Arundo wasp establishment survey techniques

- **2019-2022 survey technique:** Two-minute counts of exit holes and galls (without holes).

- **2022 survey technique:** Dissection of shoots (At seven well-established sites started in 2017).

- **2023 survey technique:** Yellow sticky traps (to capture adult wasps).

- **Multi-year evidence of arundo wasp establishment:** 10 of 11 sites.
2019-2021 two-minute surveys - arundo wasp established in the northern Sacramento River watershed

- Over 120 points surveyed each year-2019-2021.
- Over 50% of points had at least one exit hole/ gall.
- Exit hole abundance decreased by 37% in 2021 compared to 2020.
- 6.4 km dispersal observed in 2021.
- The other two other sites downstream-no wasps in 2021.
2019-2021 two-minute surveys-arundo wasp established in the Southern San Joaquin River watershed
2019-2021 two-minute surveys: arundo wasp established in the Sacramento-San Joaquin Delta.

- Establishment of the wasp at all five sites by 2021-avg of 58% of survey points per site.
- Relatively small, isolated arundo populations.
- Two of the five sites sprayed with herbicides, except biocontrol plots.
## Results: establishment of arundo wasp in northern California at 10 of 11 sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Year of first arundo wasp release</th>
<th>2019: % of survey points with at least one exit hole or gall</th>
<th>2021: % of survey points with at least one exit hole or gall</th>
<th>2022: % of survey points with at least one exit hole or gall</th>
<th>2022-2023: Dissections - Density of exit holes per m main shoot length-2022-2023</th>
<th>2023: Sticky traps, number of wasps captured (over 3 months)</th>
<th>Wasp established?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sac-1</td>
<td>2017</td>
<td>67%</td>
<td>66%</td>
<td>0</td>
<td>$0.15 \pm 0.08$</td>
<td>1</td>
<td>YES</td>
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<tr>
<td>Sac-2</td>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>ND</td>
<td>0</td>
<td>NO</td>
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<tr>
<td>Sac-3</td>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>In process</td>
<td>6</td>
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<tr>
<td>SJ-1</td>
<td>2017</td>
<td>89%</td>
<td>78%</td>
<td>74%</td>
<td>$0.75 \pm 0.26$</td>
<td>8</td>
<td>YES</td>
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<tr>
<td>SJ-2</td>
<td>2017</td>
<td>13%</td>
<td>17%</td>
<td>27%</td>
<td>In process</td>
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<td>YES</td>
</tr>
<tr>
<td>SJ-3</td>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>13%</td>
<td>In process</td>
<td>7</td>
<td>YES</td>
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<tr>
<td>Delta-1</td>
<td>2017</td>
<td>33%</td>
<td>63%</td>
<td>100%</td>
<td>$0.74 \pm 0.46$</td>
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<td>Delta-2</td>
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<td>89%</td>
<td>$0.14 \pm 0.12$</td>
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<tr>
<td>Delta-3</td>
<td>2017</td>
<td>5%</td>
<td>0</td>
<td>50%</td>
<td>$0.05 \pm 0.02$</td>
<td>2</td>
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<tr>
<td>Delta-4</td>
<td>2019</td>
<td>-</td>
<td>30%</td>
<td>63%</td>
<td>$1.20 \pm 0.10$</td>
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<td>YES</td>
</tr>
<tr>
<td>Delta-5</td>
<td>2020</td>
<td>-</td>
<td>54%</td>
<td>33%</td>
<td>$0.25 \pm 0.10$</td>
<td>16</td>
<td>YES</td>
</tr>
</tbody>
</table>
Double-cutting of arundo plots to improve wasp establishment at two sites where establishment from prior released failed.

- **Double-cut**: Ground cut April 2020, then top regrowth to 1.5 m height June-July 2020.
- **Single cut**: Ground cut April 2020, regrowth, no subsequent topping.
- **Wasp release in all plots Sept-Nov 2020 (130 per plot). N=3 plots per treatment per site.**

- **Mark and examine 10 shoots per plot Nov. 2020-Sept. 2021; dissect Sept. 2021.**
Effect of cutting regime on arundo shoot tip-galling wasp exit hole abundance and density

- Wasp exit holes were 9-fold denser per main shoot and 11-fold denser per main shoot length in double-cut plots than in single-cut plots.
- Two-minute plot counts ignored marked shoots. These counts were 8.6-fold higher in double-cut than single-cut plots, but this difference was not statistically significant.
Integrated chemical-biological control of arundo in the Delta-2017-2022

• Examined wasp density in original, untreated biocontrol plots and in post-herbicide regrowth.

Ground application

Glyphosate+imazapyr applied in late summer or early autumn

Boom rig application

Before

After

After

Post-herbicide regrowth 2022

Some images provided by the Sonoma Ecology Center and Sacramento-San Joaquin Delta Conservancy.
Arundo wasp, established at low density on untreated arundo, established more dense populations on post-herbicide regrowth at three Delta sites

- Density of exit holes and immature wasps per side shoot was 12x higher in post-herbicide regrowth ($P=0.03$)
- 4.3x higher as density per main shoot ($P = 0.04$)
- 3.8x higher as density per main shoot length ($P = 0.05$)
- Up to 39-fold higher at one site.
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