Biological control of arundo with the arundo wasp in the Central Valley

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Background

- The arundo wasp *Tetramesa romana* (Hymenoptera: Eurytomidae) makes galls in the shoot tips of arundo and no other plant[1,2]. Wasps from Mediterranean Europe, released in Texas in 2009-2012, have reduced arundo biomass by up to 44%, increasing diversity of other vegetation two-to three-fold[3,4,5].

- The arundo wasp lays eggs in shoot tips and completes its development in 2 to 3 months[6], with a quiescient period in winter and under drought conditions. The rate of wasp reproduction is reduced on drought-stressed plants[7].

- Mowing or 'topping' of arundo shoots at 1 m heightincreased colonization in Texas studies[8].

- An adventive (accidentally released at an unknown time) population of the arundo wasp occurs in southern California, including the area around Ventura[9].

- Arundo populations in the Sacramento Valley, Sacramento-San Joaquin Delta, and the San Joaquin Valley threaten water resources, obstruct flood control channels, increase fire hazards, and displace native species[10].

- **The objective of this study was to release and evaluate the arundo wasp as the first biocontrol agent targeting arundo in the Central Valley of northern California.**

Methods

Figure 1 (Left to right): Location of six arundo biological control sites in the Central Valley of northern California, including three in the northern Sacramento River watershed, along Stony Creek near Orland, CA (SAC1, 2, 3); three along and near the Sacramento River in the western Delta (DEL or DE1, 2, 3); and three in the southern San Joaquin watershed along Cottonwood Creek and Berenda Slough near Madera, CA (SJ1, 2, 3). Four center images of arundo infestations show how arundo occupies riparian habitats and impacts water resources. The two images on the right show topping of arundo plot in 2017 and vigorous regrowth.

- In 2017, nine 2 x 2 m plots were marked at each of the three Sacramento (SAC) and San Joaquin watershed sites. All plots were located within 50 m of the water channel and spaced at least 10 m apart. Three plots were cut to ground level, three were 'topped' at 1 m height, and three were left uncut. At the Delta (DE) sites, there were five plots, and all were topped.

- 150 arundo wasps from a south Texas population were released into each plot between May and October 2017.

- Wasp establishment after one year (June-October 2018) was assessed by cutting nine shoots from each plot, measuring length and counting exit holes made by wasps as they emerge from galls, as these holes are the key sign of wasp presence.

- Wasp establishment after two (July 2019) and three (August-September 2020) years was assessed by counting exit holes and un-emerged galls for 2 minutes in the 2017 plots, and in up to 10 haphazardly-selected survey points around each plot, between 10 and 350 m from the plot.

- To examine the effect of humidity on wasp progeny output and to compare wasps from TX and the adventive southern CA, wasps were caged in mesh cages either covered in plastic (enhanced humidity) or uncovered (ambient humidity) in a greenhouse. Productivity of TX and CA wasps was compared at the three SAC and three SJ sites in bagged arundo shoots. Data were pooled across all sites for analysis.

- Data were analyzed as appropriate with analyses of variance using a Poisson distribution assumption, appropriate for count data.

Thanks To:

Dr. Scott L. Portman, USDA-ARS; Dr. Michael Pitcairn-CDFA
Ed Vonasek-City of Orland
Sean Smith (formerly Madera Irrigation District)
Private landowners (Orland-Valley Rock and J. Larkin;
Madera-D. Loquaci, J. Sunia, E. Martinezzi)

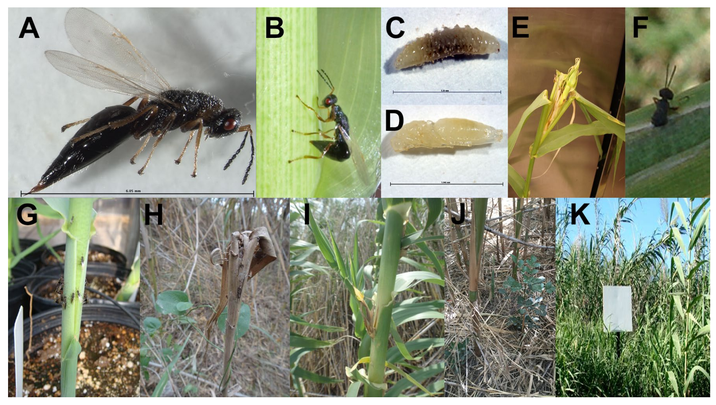


Figure 2: The arundo wasp *Tetramesa romana*. **A**, Adult. **B**, Adult ovipositing (laying egg) into arundo shoot tip. **C**, Larva dissected from gall. **D**, Pupa. **E**, Galled shoot tip in greenhouse. **F**, Adult emerging from gall. **G**, Adults in mass-rearing facility. **H**, Dead galled main shoot in field. **I**, Galled side shoot. **J**, Growth of native plants at Texas release site. **K,** Demonstration of increased visibility through galled arundo stands in Texas.

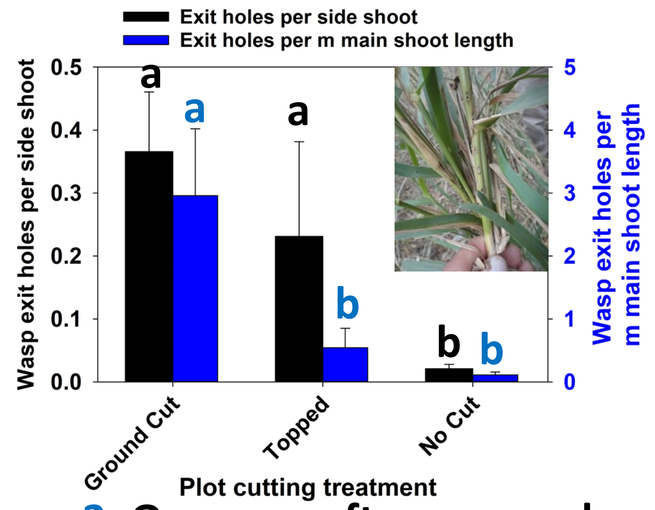


Figure 3: One year after wasp release (2018), topping or ground-cutting of arundo increased wasp exit hole density 26-fold.

ANOVA: F=11.4; df=2,12; p=0.002). Blue bars indicate exit hole density per m main shoot length (F=16.8; df=2,12; p=0.0003).

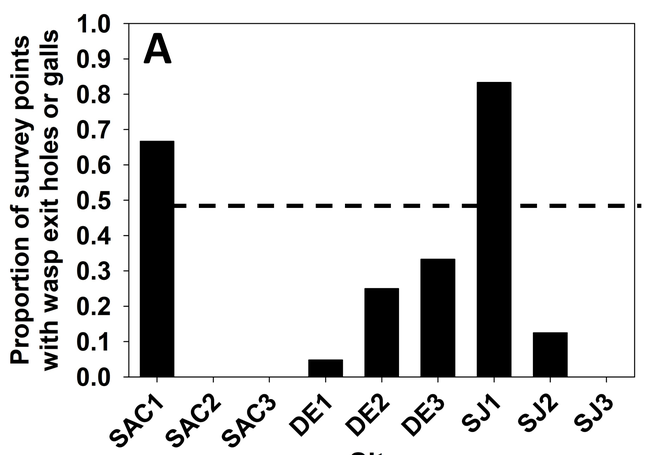
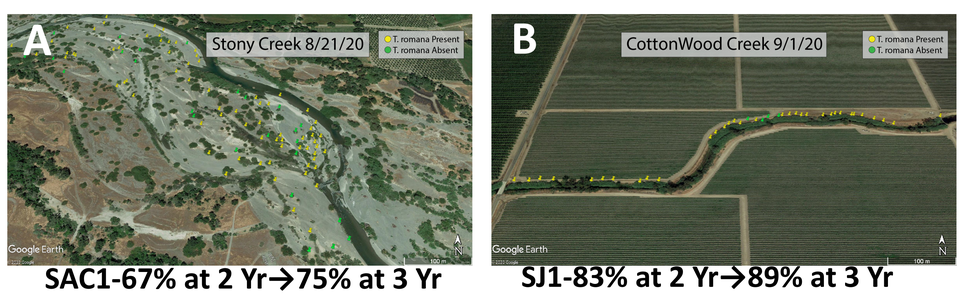


Figure 4: Two years after wasp release (2019), wasps were present at over 50% of survey sites at two sites-SAC1 and SJ1 (A, B), indicating that the wasp became established at those sites. The presence of young main shoots with galls (C) indicated widespread wasp attack. **New releases in 'double-cut' (ground cut followed by topping) plots were made at the SAC2,3 and SJ2,3 sites in 2020, to re-attempt to establish the wasp at those sites.**



SAC1-67% at 2 Yr→75% at 3 Yr

SJ1-83% at 2 Yr→89% at 3 Yr

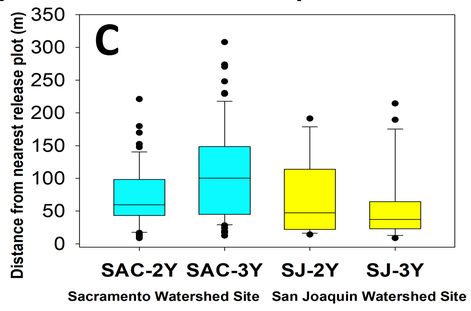
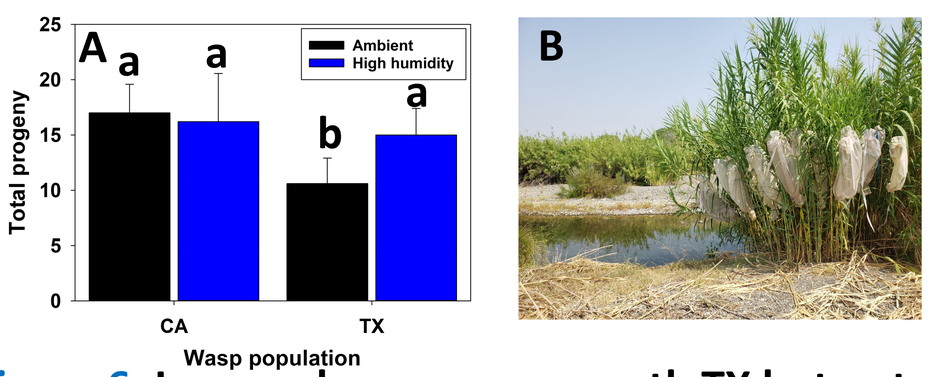


Figure 5: Three years after wasp release (2020), 75% of 98 survey points at the SAC1 site have wasp exit holes or galls (A), and 89% of 37 survey points at the smaller SJ1 site have evidence of the wasp (B). The average distance from 2017 release plots to survey points with wasps increased almost 2-fold from 2 Yr to 3 Yr surveys at SAC1 (C), indicating that wasps are dispersing.



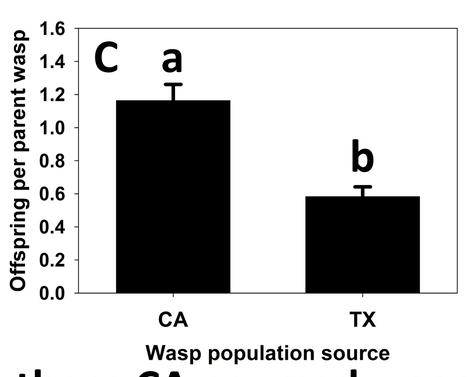


Figure 6: In greenhouse cages, south TX but not southern CA-sourced wasps benefited from enhanced humidity, producing 1.4-fold more offspring. On bagged field branches (B) placed at SAC1,2,3 and SJ1,2,3 sites, wasps sourced from southern CA produced 2-fold more offspring (C). The results suggest that CA-sourced wasps are more tolerant of dry Central Valley conditions.

Greenhouse test: For TX, $F_{1,42}$=15.9, P=0.0003, n=21 ambient, n=23 enhanced; for CA, $F_{1,20}$=0.21, P=0.65, n=12 ambient, n=10 enhanced.
Bagged branch test: $F_{1,156}$=14.47, P=0.0002, n=76 TX, n=82 CA

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