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A contractor comparison of novel IPT tools and techniques for Brazilian peppertree (*Schinus terebinthifolia*) management

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Abstract

Brazilian peppertree (*Schinus terebinthifolia* Raddi) is a multistemmed shrub or small tree from South America that is invasive in Florida, Texas, Hawaii, and Australia. It forms multistemmed trunks with spreading branches that create dense thickets. State agencies in Florida manage it at annual costs of over $3 million, and individual plant treatment (IPT) techniques are widely used for control. Recent research testing novel hack and squirt approaches with aminopyralid and aminocyclopyrachlor and basal bark treatment with a new triclopyr formulation has shown these treatments are highly effective. However, they have not been evaluated at larger scales, which would be useful to land managers. Therefore, our objective was to compare the reduced hack and squirt technique using aminopyralid and aminocyclopyrachlor herbicides to basal bark treatment with triclopyr on a field scale. We used two contractor crews to apply treatments to twenty-four 0.2-ha plots. Treatments included aminocyclopyrachlor (120 g L^{-1}) or aminopyralid (120 g L^{-1}) applied with the reduced hack and squirt technique and triclopyr ester (108 g L^{-1}) and triclopyr acid (34 g L^{-1}) formulations applied with two basal bark treatment techniques. We confirmed that reduced hack and squirt significantly reduced the amount of herbicide and carrier applied compared with the basal bark treatments. By 540 d after treatment, aminocyclopyrachlor more effectively controlled *S. terebinthifolia* than aminopyralid with reduced hack and squirt and resulted in control comparable to that seen with either triclopyr basal bark treatment. These results verify reduced hack and squirt treatment with aminocyclopyrachlor and basal bark treatment with triclopyr acid as alternatives to basal bark treatment with triclopyr ester. Both resulted in significantly less herbicide use with comparable efficacy. This operational research approach has accelerated our understanding of novel IPT strategies and their implementation in the field.

Introduction

Brazilian peppertree (*Schinus terebinthifolia* Raddi) is an evergreen shrub or small tree in the Anacardiaceae family that is native to Brazil, Argentina, and Paraguay. Introduced into south Florida in the mid-1800s for the ornamental trade, it has escaped to natural areas and thrives in a wide variety of habitats (Morton 1978). *Schinus terebinthifolia* fruits are dispersed by birds and small mammals, as well as by water (Donnelly and Walters 2008; Ewel et al. 1982; Panetta and McKee 1997). The combination of numerous vectors and massive numbers of fruit produced annually have facilitated broad dispersal across the Florida peninsula.

Schinus terebinthifolia has invaded more than 280,000 ha across Florida, including fallow farmland, coastal scrub, upland pine (*Pinus* spp.) forests, hardwood hammocks, rights-of-way, and mangrove forests (red mangrove [*Rhizophora mangle* L.], black mangrove [*Avicennia germinans* (L.) L.], white mangrove [*Laguncularia racemosa* (L.) C.F. Gaertn.], and buttonbush [*Conocarpus erectus* L.]) (Ferriter et al. 2006). It is one of the top five most expensive weeds managed by the state of Florida; annual management costs are approximately US$3.5 million (Hiatt et al. 2019). It is regulated as a noxious weed by the Florida Department of Agriculture and Consumer Services and is also classified as a Florida Invasive Species Council Category 1 species. It negatively impacts ecosystems by shading out native plants, altering fire regimes, producing allelopathic compounds, and creating impenetrable thickets that reduce habitat for native fauna (Doren et al. 1991; Gordon 1998; Morton 1978).

Due to *S. terebinthifolia*'s sprawling growth form, management with individual plant treatment (IPT) techniques is very challenging, and applicators must often cut access paths to the base of each tree. The standard treatment technique is basal bark application, in which a triclopyr and oil mixture is applied as a spray-to-wet treatment to the entire circumference of the

Management Implications

Schinus terebinthifolia (Brazilian peppertree) is an aggressive, multistemmed shrub or small tree that invades natural areas across the entire peninsula of Florida. The plant's low branching architecture makes management challenging for backpack sprayers used for basal bark application. Employing two professional applicator crews, we compared two reduced hack and squirt treatments including aminocyclopyrachlor at 120 g L^{-1} (Method® herbicide, 50% v/v) and aminopyralid at 120 g L^{-1} (Milestone® herbicide, 50% v/v) with two basal bark treatments including triclopyr ester at 108 g L^{-1} (Garlon® 4 Ultra, 22.5% v/v) and triclopyr acid at 34 g L^{-1} (Trycera® herbicide, 10% v/v). The herbicides for reduced hack and squirt treatment were mixed with water, and the herbicides for basal bark treatment were mixed with an oil carrier. The reduced hack and squirt approach tested one hack per 10 cm (4 in.) of stem diameter for each major stem with 1 ml of herbicide solution applied into each hack. The triclopyr ester basal bark treatment was applied to the lower 30 cm of each trunk, while the triclopyr acid treatment was applied to the lower 60 cm of each trunk. We found that aminocyclopyrachlor applied as a reduced hack and squirt treatment significantly reduced the volume of herbicide and carrier applied and provided similar control at 540 d after treatment when compared with the triclopyr ester basal bark approach. In addition, basal bark application of triclopyr acid provided control comparable to that of triclopyr ester. These results provide alternative options for *Schinus terebinthifolia* management that can reduce herbicide use while maintaining efficacy. The scale of this research provides insight into the practicality of these application types for contractors engaged in *Schinus terebinthifolia* control.

lower 30 to 38 cm (12 to 15 in.) of each stem (Enloe et al. 2015). This can be challenging to applicators, as navigating through thickets of lateral branches to access the base of trees while wearing a 15-L backpack sprayer can be extremely difficult. Additionally, basal bark application to high-density multistem shrubs can result in excessive rates of triclopyr on a per hectare basis (Holmes and Berry 2009).

Recent advances in hack and squirt technology have attempted to address these issues. In IPT studies, Enloe et al. (2023) demonstrated that both aminocyclopyrachlor and aminopyralid controlled large-statured shrubs, including *S. terebinthifolia*, when applied as a reduced hack and squirt treatment. The technique involves making a single hack per stem and applying 0.5 ml of a 100% solution of either herbicide. This resulted in 95% to 100% *S. terebinthifolia* mortality for each herbicide, and these results were not different from those seen with basal bark or cut stump efficacy with triclopyr. Additionally, the reduced hack and squirt and basal bark application treatment times did not differ, but were significantly shorter than the cut stump treatment time. Furthermore, the reduced hack and squirt treatments resulted in 95% and 76% reductions in total herbicide mix and herbicide active ingredient applied, respectively, compared with basal bark application with triclopyr. In addition to the hack and squirt studies, Bell (2019) found that a novel triclopyr acid formulation applied as a basal bark treatment at 34 or 68 g L^{-1} controlled *S. terebinthifolia* as effectively as the triclopyr ester formulation at 96 g L^{-1}.

The results from those IPT small-plot studies support both the reduced hack and squirt technique with aminocyclopyrachlor and aminopyralid and basal bark treatment with the triclopyr acid formulation. However, it is important to scale up small-plot IPT research to verify treatment efficacy on a larger scale. Contractor studies with an operational context are useful for this purpose and can result in meaningful feedback and land manager acceptance (Glueckert et al. 2023). For a hack and squirt treatment, this is especially important, as the technique has been utilized for silvicultural weed control for single-stemmed trees (Helgerson 1990; Sterrett 1969) but has been limited for multistemmed invasive shrub control (Enloe et al. 2023).

Given the current knowledge gap surrounding novel application types and herbicide chemistries available for *S. terebinthifolia* management, our objective was to compare the reduced hack and squirt technique using aminopyralid and aminocyclopyrachlor herbicides with the basal bark treatment with triclopyr on a field scale. We hypothesized that compared with the triclopyr ester and acid basal bark approaches, reduced hack and squirt would (1) take a similar amount of time to apply, (2) provide a significant reduction in herbicide applied, and (3) deliver similar control of *S. terebinthifolia*. Results from this study would be beneficial to land managers in selecting appropriate herbicide treatments and techniques for *S. terebinthifolia* management.

Materials and Methods

A field site was established northwest of Opa-Locka, FL (25.960°N, 80.422°W) on a South Florida Water Management District property adjacent to the C-9 canal. Historically, the site was a wet sawgrass prairie but was drained for agriculture and ranching in the early 1900s (Doren et al. 1991). Farming in the area ceased in the late 1990s and the area is now covered in a dense stand of *S. terebinthifolia*. Soils are a Dania muck (euic, hyperthermic, shallow Lithic Haplosaprists) (USDA-NRCS 2023), and the site is subject to frequent inundation during the summer wet season. Annual precipitation in 2018 and 2019 was 142 and 169 cm, respectively. Annual temperatures in 2018 and 2019 were 26.1 and 25.8 C, respectively. These amounts bracketed mean annual precipitation (166 cm) and were slightly above the mean annual temperature (24.8 C) (Southern Regional Climate Center 2023).

In May 2018, 24 plots, each 0.2 ha (0.5 acre) in size, were established in a four-by-six grid. Plot borders were cleared with a mulching machine that created a 3-m-wide buffer around each plot. Plots consisted of an overstory composed of nearly 100% cover of *S. terebinthifolia* with Javanese bishopwood (*Bischofia javanica* Blume), day jessamine (*Cestrum diurnum* L.), and some ruderal species scattered throughout the site. The 24 plots were divided into two blocks with 12 plots each. Four treatments were each assigned to three plots in each block in a completely randomized design (CRD).

Treatments included a nontreated control (reduced hack and squirt with water only), aminocyclopyrachlor at 120 g ae L^{-1} (50% v/v, Method® 240SL, Bayer, Alexander Drive, Research Triangle Park, NC 27709) applied with the reduced hack and squirt technique, aminopyralid at 120 g ae L^{-1} (50% v/v, Milestone®, Dow AgroSciences, 9330 Zionsville Road, Indianapolis, IN 46268), also applied as the reduced hack and squirt technique, the acid formulation of triclopyr at 34 g ae L^{-1} (10% v/v, Trycera®, Helena AgriEnterprises, 225 Schilling Boulevard, Suite 300 Collierville, TN 38017) applied with the basal bark technique, and the ester formulation of triclopyr at 108 g ae L^{-1} (22.5% v/v, Garlon® 4 Ultra, Dow AgroSciences) applied with the basal bark technique. Water was the carrier for both hack and squirt treatments and a basal oil

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(Impel™ Red Oil, Helena AgriEnterprises) was the carrier for both basal bark treatments.

Two independent applicator crews from private companies were chosen based on contractual obligations with the South Florida Water Management District. Each crew consisted of six applicators with several years of experience treating woody invasive plants with IPT techniques including basal bark application and hack and squirt. Crews were randomly assigned to each block of 12 plots. Across all treatments, Crew 1 elected to use machetes to cut access trails to the base of each target tree in each plot before applying treatments. Crew 2 elected to use lightweight chainsaws to cut access trails to the base of each target tree before applying treatments. This contributed to clear differences in time required to complete each plot, which was accounted for in the statistical analyses.

Each crew was initially trained with a standardized reduced hack and squirt protocol. Each crew used new spray bottles (Ace Hand Sprayer, Ace Hardware, 2200 Kensington Court, Oak Brook, IL 60523) that had a known volume output of 1.0 ± 0.1 ml stroke^{-1}. To demonstrate the appropriate number of hacks to perform on the specific diameter of stems, we used 2-L soda bottles as a training aid. A 2-L soda bottle provided a visual cue for stems with 2.5-cm (1-in.) and 10-cm (4-in.) diameters, given that the bottle cap is 2.5 cm in diameter and the bottle diameter is 10 cm. Applicators were instructed to make one 45° hack at a height of 60 cm (24 in.) and apply one 1 ml of herbicide solution into the hack with no runoff from the cut on each primary stem sized 2.5 to 10 cm. Stems 10 to 20 cm in diameter received two evenly spaced hacks, and stems 20 to 30 cm in diameter received three evenly spaced hacks. Stems less than 2.5 cm arising as sprouts from the bases of all treated individuals were ignored. We excluded these because it was not possible to deliver a 1-ml dose of the herbicide solution to the cambium of such small-diameter stems.

The three nontreated control plots in each experimental run served as training plots to familiarize each applicator crew with the reduced hack and squirt technique. Crew supervisors and the researchers closely followed each crew member through these plots to ensure they performed the technique appropriately. Water and a 1% v/v blue spray indicator were applied to all hacks in these plots as part of the training process. These applications resulted in no foliar injury to any *S. terebinthifolia* at any subsequent evaluation date.

As a commercial standard comparison to the hack and squirt treatments, basal bark treatment with two formulations of triclopyr was also tested. However, Crew 1 only applied triclopyr as the acid formulation at 34 g ae L^{-1}. For this crew, the basal bark treatment was applied from the ground level to approximately 60 cm. This high band height was used due to previous contractor experience and consultation with the manufacturer (J Boggs, personal communication). Crew 2 only applied 108 g ae L^{-1} triclopyr ester. For this crew, the basal bark treatment was applied from the ground level to approximately 30 cm. Both basal bark applications were made using the same basal oil carrier (Impel™ Red Oil, Helena AgriEnterprises). This resulted in differing triclopyr concentrations being applied between the two crews. However, an important finding in the operational use of the two triclopyr formulations arose from this protocol change (see "Results and Discussion" for details). Additionally, contrary to the hack and squirt treatments, epicormic stems less than 2.5 cm in diameter were treated as part of both basal bark treatments.

Crew 1 applied treatments on June 6 to 8, 2018, and Crew 2 applied treatments on June 18 to 20, 2018. Treatments were applied over a 3-d period for each experimental run to prevent applicator fatigue. Additionally, for each applicator crew, all herbicide-treated plots were treated in a randomly assigned order to prevent daily applicator fatigue from potentially biasing treatment outcomes.

Application data included total herbicide mix applied, herbicide acid equivalent applied, and time required to apply treatments per plot. Application time was measured as the time each crew spent within a plot. This included both the time required to cut access trails to the base of each target and the time required to make the herbicide applications. The number of trees per plot was also counted in addition to the number of stems based on a random subsample of 10 trees per plot to capture the relationship between amount of product applied and *S. terebinthifolia* density (Doren and Whiteaker 1990). The 10 trees were marked with a metal tag attached to a 1.5-m PVC pole that was placed at the southeast corner of each tree. These trees were measured with metal calipers to obtain individual stem sizes and stem count. They were also evaluated at 60, 360, and 540 d after treatment (DAT) to determine percent canopy defoliation. Percent defoliation was evaluated visually to assess treatment effects based on the individual architecture of each tree. Additionally, mortality was assessed by counting the number of trees per plot that were 100% defoliated with no epicormic sprouting and the presence of dead cambium to the ground level.

Statistical Analyses

The ANOVA considered crew and treatment as fixed effects, as described in the multilocation fixed-effect analysis presented by Littell et al. (2006). Crews did not represent a probability distribution but were selected to determine how properly trained crews might differ. The complication was that the basal treatments differed by crew. This was addressed by specifying crew-treatment levels as treatments and using tests of linear combinations of crew by treatment means to test orthogonal main effects and interactions, as is typical of an ANOVA (Milliken and Johnson 1992).

The analysis was modified to make the important comparisons for (1) pretreatment description of vegetation, (2) treatment application metrics (only related to methods), and (3) efficacy of application methods and herbicides. The test of crew by treatment interaction was only conducted for the hack and squirt treatments, because the two basal spray treatments were confounded with crew. While differences between the basal spray treatments may have been due to crew, this was addressed through the quantified application metrics to determine whether basal treatments were applied as prescribed. There were no crew by hack and squirt treatment interactions, which allowed pretreatment and application metric analyses to compare the four averages of crew (1 or 2) combined with application method (basal or hack and squirt) for the plot-level variables of stem density (stems ha^{-1}), application volume (L ha^{-1}), plot-level application times (min ha^{-1}), and tree sample average sum of stem diameters (cm tree^{-1}). Efficacy was compared for the four herbicide treatments and the nontreated control, as there were no significant interactions for the variables of percent defoliation at 90, 360, or 540 DAT; percent of trees with epicormic sprouts at 540 DAT; and percent tree mortality at 540 DAT.

The analysis depended on the variable and the need to address heterogeneity of variance. A generalized linear model approach was used for pre-application tree metrics and application time and volume metrics using a Poisson distribution with a log(unit) offset, so the results are in terms of a unit rate. Overdispersion was

Table 1. *Schinus terebinthifolia* plot characteristics in a field study conducted near Opa-Locka, FL. Plot characteristics collected included total stems treated and the time required for each crew to treat normalized to the hectare.[a]

Crew	Treatment[b]	Stems[c]	95% CL[d] (lower, upper)	Time to treat	95% CL (lower, upper)
		no. ha^{-1}		min ha^{-1}	
1	Basal bark	2,171 a	1,632, 2,887	585 a	525, 652
2	Basal bark	1,836 a	1,378, 2,446	205 c	171, 246
1	H&S average	1,590 a	1,345, 1,881	545 a	455, 653
2	H&S average	2,159 a	1,831, 2,546	343 b	277, 427

[a]Means within columns followed by the same letter are not different according to Holm's adjustment (P = 0.05).
[b]Hack and squirt (H&S) values presented are the means of the aminocyclopyrachlor and aminopyralid plots combined for each crew, as there was no crew by hack and squirt herbicide interaction for total stems per hectare (P = 0.44).
[c]Total number of stems was based on measurement of 10 randomly selected trees per plot.
[d]CL, confidence limit.

addressed through the addition of a residual error term or separate residual error terms for basal bark and reduced hack and squirt treatments (Littell et al. 2006). The arcsine square-root transformation of plot average percent defoliation was utilized to correct for heterogeneity of variance due to a significant Levene's test. Back-transformations of defoliation means are reported as described in Jørgensen and Pedersen (1997). Pretreatment sample tree plot averages of sum of stem diameter per tree were considered normally distributed. These analyses used the pooled experimental error of the CRD for each crew with a total of 16 degrees of freedom. The ANOVAs for tree mortality and proportion of trees with epicormic sprouting at 540 DAT were performed using a generalized linear model for a binomial variable with a logit link. All statistical analysis was performed using SAS/STAT® software v. 9.4 of the SAS System for Windows (SAS Institute, 100 SAS Campus Drive, Cary, NC 27513). The SAS GLIMMIX procedure was used to perform ANOVA (Littell et al. 2006; Schabenberger and Pierce 2002). Means were compared using Holm's adjustment for multiplicity (Holm 1979).

Results and Discussion

Schinus terebinthifolia stem number ranged from 1,590 to 2,171 stems ha^{-1} and there were no differences in total stem number per treatment for either crew among reduced hack and squirt– or basal bark–treated plots (Table 1). Additionally, the total sum of stem diameter per tree ranged from 46.4 to 54 cm and did not differ among treatments for either crew (data not shown). These indicate consistent conditions among treated plots between both crews.

The time required to treat on an area basis varied between crews for each application technique (Table 1). For the hack and squirt treatment, Crew 1 required 545 min ha^{-1}, while Crew 2 required 343 min ha^{-1}. For the basal bark treatment, Crew 1 required 585 min ha^{-1}, while Crew 2 only required 205 min ha^{-1}. For both the hack and squirt and basal bark treatments, the difference in time between crews is potentially confounded because of the different cutting techniques used to access individual trees in each plot. Crew 1 used machetes, while Crew 2 used lightweight chainsaws to cut access paths to each tree. Crew 1 treated a 60-cm band height with the triclopyr acid formulation, while Crew 2 treated a 30-cm which was not different from mortality produced by either hack and squirt treatment band height with the triclopyr ester formulation. While we cannot clearly partition the cause of the time differences, the overall outcome is highly logical, as the crew using chainsaws and applying a narrower basal bark band height should require less time than the crew using machetes and treating twice as wide a band height. The use of cutting tools and basal bark application techniques may depend on contractor preference, which is likely influenced by equipment costs, maintenance, applicator safety, labor, and site conditions.

There are no previous comparable hack and squirt studies, and there are limited basal bark studies to serve as reference points for these results. Doren and Whiteaker (1990) assessed the average time to treat *S. terebinthifolia* using high-volume basal bark treatment and found an average treatment time of 24 h ha^{-1} for trees comparable in age to those in our study. However, they did not specify the number of applicators used, and the high-volume basal bark approach is inherently slower, as it pools the herbicide mix at the base of each shrub to increase soil activity.

Total application volume was different between crews for basal bark treatment but was not different between crews for hack and squirt treatment (Figure 1A). For the hack and squirt treatments, Crews 1 and 2 applied 2.4 to 2.7 L ha^{-1}, respectively, and these were not significantly different. Both were significantly lower than total volume applied for the basal bark treatments. For the basal bark treatments, Crew 1 treated a 60-cm band height and applied 147 L ha^{-1}. This was significantly more herbicide–oil mix than was used by Crew 2, who treated a 30-cm band height and applied 87 L ha^{-1}. These differences in total application volume are noteworthy for applicators, as the hack and squirt treatments used 97% less total volume than the basal bark treatments. For navigating through dense thickets, the hack and squirt approach would require substantially less energy than the basal bark approach, which was done with 15-L backpack sprayers.

Total herbicide applied was not different between the hack and squirt treatments and averaged 0.33 kg ha^{-1}. Again, this was a 94% to 96% reduction in herbicide applied compared with the basal bark treatments. Total herbicide applied in the basal bark treatment was significantly lower for Crew 1 than Crew 2 (Figure 1B). This is explained by two factors, herbicide concentration and formulation. Crew 1 used a 10% v/v concentration of the triclopyr acid product formulated at 344 g L^{-1}, while Crew 2 used a 22.5% concentration of the triclopyr ester product formulated at 480 g L^{-1}. Although inferences are limited due to the confounding issue of each crew using a different basal bark treatment, these data indicate significantly lower herbicide mix and active ingredient applied for the hack and squirt treatments compared with the basal bark treatments. Additionally, between the two crews that performed the work, the triclopyr acid basal bark approach required a much higher total application volume

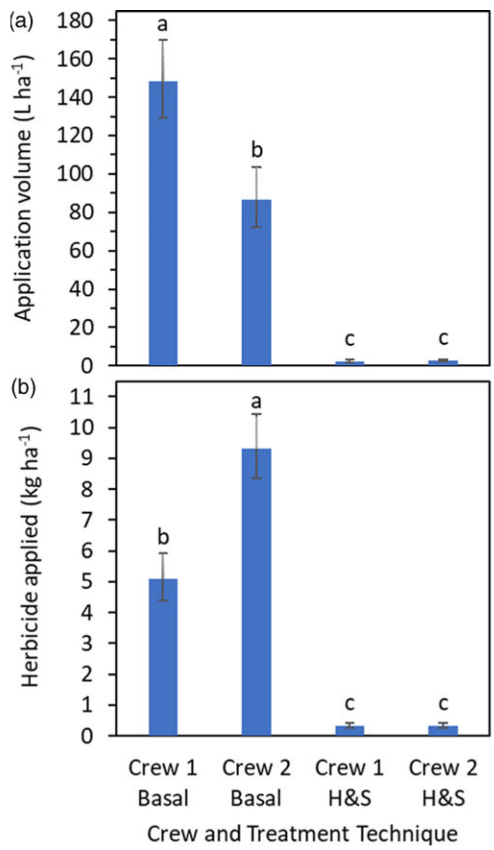

Figure 1. Total application volume (A) and total herbicide applied (B) by two applicator crews using basal bark and hack and squirt (H&S) treatments on *Schinus terebinthifolia* in a field study conducted near Opa-Locka, FL. For the basal bark treatments, Crew 1 applied triclopyr acid (34 g L^{-1}) in a 60-cm band, while Crew 2 applied triclopyr ester (108 g L^{-1}) in a 30-cm band. For the hack and squirt treatments, the aminocyclopyrachlor and aminopyralid treatments were the same (120 g L^{-1}) for each crew and were combined in this analysis. Bars with the same letter are not significantly different according to Holm's adjustment (P = 0.05)

Table 2. *Schinus terebinthifolia* response to basal bark and hack and squirt (H&S) treatment over time in a field study conducted near Opa-Locka, FL.

Treatment[a]	Herbicide	90 DAT[b,c]	360 DAT	540 DAT
		———% Defoliation———		
Basal bark	Triclopyr acid	99 ab	94 ab	94 ab
Basal bark	Triclopyr ester	100 a	99 a	99 a
H&S	Aminocyclopyrachlor	98 ab	98 ab	98 a
H&S	Aminopyralid	94 b	88 b	89 b
Non-treated	—	0.0 c	6 c	6 c

[a]Hack and squirt (H&S) values presented are the means of the aminocyclopyrachlor and aminopyralid plots combined for each crew as there was no crew by hack and squirt herbicide interaction at any sample date (P > 0.29 in all tests).
[b]DAT, days after treatment.
[c]Means within columns followed by the same letter are not different according to Holm's adjustment (P = 0.05).

but utilized substantially less herbicide compared with the triclopyr ester basal bark approach.

At 90 DAT, aminopyralid hack and squirt resulted in slightly lower defoliation (94%) compared with the triclopyr ester basal bark treatment (100%) but did not differ from the other herbicide treatments (Table 2). This pattern was similar to percent defoliation at 360 DAT. There were no differences between the aminocyclopyrachlor hack and squirt treatment and the two triclopyr basal bark treatments, as all resulted in at least 94% defoliation. Hack and squirt with aminopyralid resulted in 88% defoliation, which was again significantly lower than the triclopyr ester basal bark treatment defoliation. At 540 DAT, the aminopyralid hack and squirt treatment resulted in significantly lower defoliation than the aminocyclopyrachlor hack and squirt treatment and the triclopyr ester basal bark treatment (Table 2).

While all herbicide treatments resulted in very high canopy defoliation over the course of the study, the presence of epicormic sprouting varied among treatments at 540 DAT (Figure 2). Nontreated controls exhibited a high level of epicormic sprouting, which was greater than epicormic sprouting in all other treatments. The aminopyralid hack and squirt treatment resulted in new epicormic sprouts on approximately 40% of the trees. This was significantly greater than the epicormic sprouting on approximately 10% of the trees resulting from the aminocyclopyrachlor hack and squirt treatment. Both basal bark treatments resulted in epicormic sprouting that was intermediate and not different from results seen with either hack and squirt treatment.

When defoliation data and epicormic sprouting data were coupled with a visual examination of each tree for the presence of live cambium tissue at the root collar, tree mortality was higher for the aminocyclopyrachlor hack and squirt treatment (88%) than the aminopyralid hack and squirt treatment (55%). Both triclopyr basal bark treatments resulted in 77% to 83% mortality, which was not different from mortality produced by either hack and squirt treatment (Figure 2).

These data indicate that *S. terebinthifolia* is less sensitive to aminopyralid than aminocyclopyrachlor when each herbicide is applied at 120 g L^{-1} by two applicator crews with the reduced hack and squirt technique. These results are in contrast to Enloe et al. (2023). In that study, the researchers applied a comparable dose of undiluted aminopyralid with veterinary syringes in single hacks per *S. terebinthifolia* stem. They found efficacy comparable to that of aminocyclopyrachlor in terms of defoliation and mortality at 540 DAT. The difference between results may have been attributed to the applicators in the current study or season of application. The current study treatments were performed in June, while the previous work was conducted in December and January. Future studies should carefully examine the influence of seasonal timing on treatment efficacy.

This study also demonstrated that applicators tended to exceed maximum labeled rates per hectare for some plots in almost every treatment. This included two out of three plots in the triclopyr ester basal bark treatment, two out of six plots in the aminocyclopyrachlor hack and squirt treatment, and five out of six plots in the aminopyralid hack and squirt plots (data not shown). This was a result of high stem densities in the study (Table 1). The exception was the triclopyr acid basal bark treatment, which was under the maximum labeled rate for each plot and utilized only 43% to 58% of the maximum labeled rate. For the triclopyr ester basal bark treatment, the overapplication in two of three plots reflects the findings of Holmes and Berry (2009), who also exceeded triclopyr ester maximum labeled rates when treating multistemmed invasive fig (*Ficus carica* L.) trees. In general, these findings indicate applicators should be very cognizant of herbicide use in order to stay within labeled rates for both reduced hack and squirt herbicides and when using triclopyr ester as a basal bark treatment. Given this, the triclopyr acid formulation may be useful for applicators treating high stem numbers per hectare.

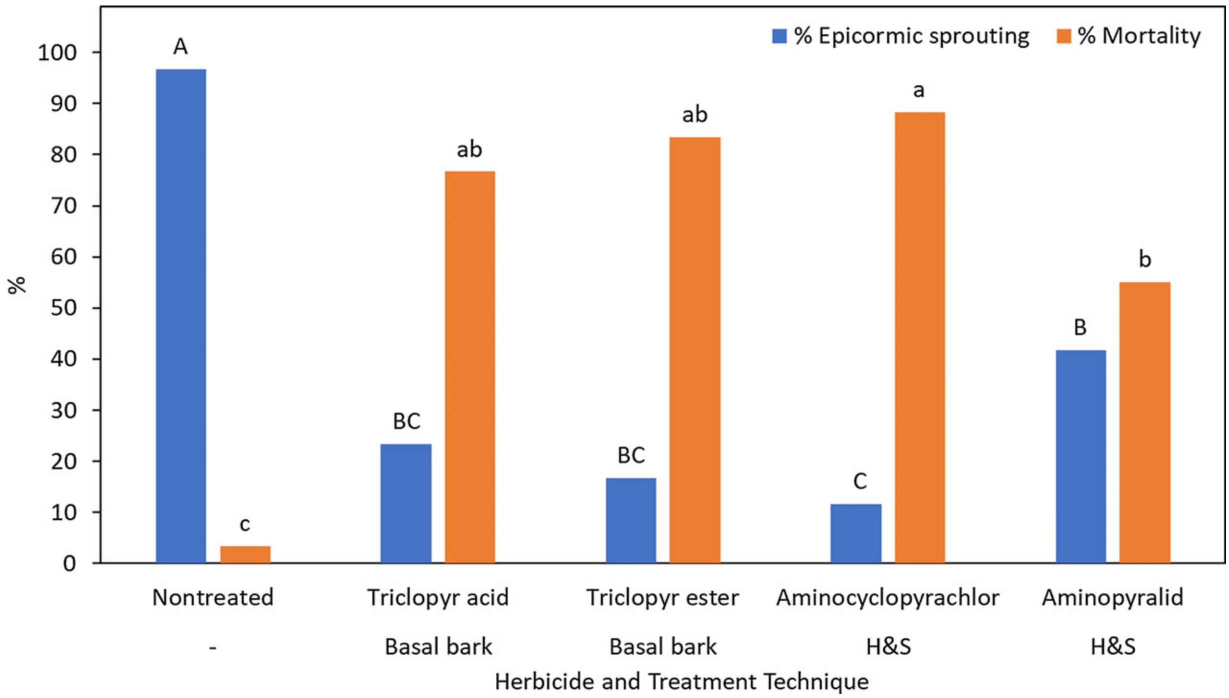

Figure 2. *Schinus terebinthifolia* percent epicormic sprouting and percent mortality response to basal bark and hack and squirt (H&S) treatments at 540 days after treatment in a field study conducted near Opa-Locka, FL. For the basal bark treatments, triclopyr acid was applied at 34 g L^{-1} in a 60-cm band, while triclopyr ester was applied at 108 g L^{-1} in a 30-cm band. For the hack and squirt treatments, both aminocyclopyrachlor and aminopyralid were applied at 120 g L^{-1}. Bars within each dependent variable with the same letter are not significantly different according to Holm's adjustment (P = 0.05)

The results of this study provide good insights into the operational application of the reduced hack and squirt technique and two contrasting basal bark application approaches. Future work should also seek to determine whether altering aminocyclopyrachlor and aminopyralid concentrations in relation to hack spacing could still provide efficacy without violating label restrictions.

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