Post-emergence Weed Control Options in Tree Nut Orchards

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Herbicides are the primary means of vegetation management in tree nut orchards in California. Among registered herbicides, post-emergence (POST) materials, like glyphosate, are the most widely used in tree crops because of low cost and broad weed control spectrum. However, herbicide resistance has compromised the efficacy of POST only herbicide programs in many parts of the state. Most cases of resistance in orchards are glyphosate-resistant hairy fleabane, horseweed, ryegrass, and junglerice. To manage resistant weed species, pre-emergence (PRE) herbicides can be applied during winter before weeds emerge; however, PRE herbicide use can be limited by cost and the need for rainfall to incorporate them. Even when PRE herbicides are used, most orchards will need a POST treatment to control weed escapes and to prepare the orchard for harvest operations.

One approach to optimize control of late emerging or glyphosate-resistant weeds is to use alternate herbicides, mixtures, rates, or more appropriate application timing. The objective of this project was to evaluate POST control of hairy fleabane and yellow nutsedge with different herbicides combinations.

Methods

Field experiments were conducted in a three year-old almond orchard infested with hairy fleabane and yellow nutsedge. The orchard was located in a sandy soil area in Merced County, and irrigated with solid set sprinklers. The area is known to be infested with glyphosate-resistant hairy fleabane. Hairy fleabane had been mowed for 3 to 4 times during season and allowed to regrow to six inches in height (bolting) before the treatments were applied. Nutsedge was still at vegetative stage with 8 to 12 leaves. Other species also found sparsely distributed at the site were three-spike goosegrass, large crabgrass, spotted spurge, and cut-leaf evening primrose.

Hairy fleabane treatments were applied to 20 by 7.5 ft plots between the tree rows on July 23 and August 21, 2012 for the first and second hairy fleabane trials, respectively (table 1). Spray equipment was a CO2-pressurized back pack sprayer using TT11002 (Teejet) nozzles and calibrated to deliver 25 gallons per acre. Percent visual control (%), weed density (plants per square meter), and plant biomass (g m^{-2}) were recorded 28 days after treatment (DAT). ANOVA analysis indicated no differences between experimental runs therefore data were combined.

The yellow nutsedge trial was conducted within the tree rows, and percent visual control (%) was recorded 35 DAT. Treatments were applied on August 21, 2012 using the previously described equipment. Treatments included herbicides known to have activity on nutsedge as

standard comparison; however, not all tested treatments are registered for use in almonds (table 2).

Results – hairy fleabane trials

Hairy fleabane was not controlled with glyphosate (trt-2), carfentrazone (trt-3), or the tank mix of both herbicides (trt-4) 28 DAT. These treatments were not significantly different than untreated control in percent control or biomass (table 1, figure 1). Glyphosate and glyphosate + carfentrazone treatment reduced biomass of other species present at the site, but not biomass of hairy fleabane supporting the reports of glyphosate resistance in this population.
Good (>85%) to excellent (>95%) control of hairy fleabane was provided by treatments that included glufosinate (trt 5, 6 & 9), saflufenacil (trt 7, 8, 9 & 17), 2,4-D (10, 11, & 12), or paraquat (13, 14, & 19). The majority of these treatments completely eliminated hairy fleabane plants by 28 DAT (figure 1). These treatments could be used during pre-harvest weed control, when bare ground is desired, provided that their use follows label recommendations for pre-harvest interval.

Effective treatments for hairy fleabane control are also needed for other weed species, but not all tested treatments succeeded in both duties. Saflufenacil (trt 7) and 2,4-D (trt 10) treatments provided no control of other species, mainly grasses, present in the site. These herbicides are not active in grass species, and for this reason are recommended with burndown partners herbicides like glyphosate. Tank mixes of glyphosate + saflufenacil (trt 7) and glyphosate + 2,4-D (trt 11) provided excellent control of all species as indicated by biomass accumulation (figure 1). Mixtures of herbicides with different mode of actions, as the case of these treatments, are a good strategy to delay the onset of herbicide resistance and manage existing resistant species. Another approach for managing glyphosate-resistant weeds is the sequential herbicide application, as the case of glyphosate followed by paraquat (trt 14). In this treatment, the initial glyphosate application was followed 14 days later with a paraquat treatment. Excellent control of all species was provided by this treatment, but not statistically different than the paraquat treatment (trt 13). The sequential application has the disadvantage of additional application costs.

The residual herbicides penoxsulam/oxyfluorfen (trt 15), rimsulfuron (trt 16), and flumioxazin (trt 18) with glyphosate did not provide acceptable POST control of established hairy fleabane. These herbicides are effective for pre-emergence and early post-emergence control of hairy fleabane and many other weed species. When mature weeds are present, it is necessary to tank mix these herbicides with post-emergence herbicides such as glyphosate. However, the addition of glyphosate did not improve control of the glyphosate-resistant hairy fleabane in advanced stage of development. Tank mixes of glyphosate + rimsulfuron + saflufenacil (trt 17) or paraquat + flumioxazin (trt 19) provided excellent control of all species. These results indicate the importance of post-emergence herbicides to complement pre-emergence herbicide programs. Likewise it reiterates the importance of preserving the post-emergence herbicides for the long term to avoid onset of new resistance. Populations of hairy fleabane resistant to both glyphosate and paraquat are present in the state. The management of multiple-resistant populations would be greatly limited by the loss of paraquat susceptibility.

Yellow nutsedge trial

Best activity on nutsedge was provided by treatments including flumioxazin (trt 4), halosulfuron (trt 13), rimsulfuron (trt 12), and penoxsulam/oxyfluorfen (trt 9) (table 2, figure 2). Best POST activity (greater than 95% control) was observed up to three weeks after application (data not shown), and control started to decline at 35 DAT. Flumioxazin, rimsulfuron, and penoxsulam/oxyfluorfen are registered for almonds. These treatments did not provide acceptable post-emergence control of hairy fleabane, but did control yellow nutsedge up to 35 DAT thus may be a promising alternative for suppressing nutsedge.

Glyphosate, glyphosate + saflufenacil, glyphosate followed by paraquat, or glyphosate + glufosinate provided only initial suppression of nutsedge. The burndown activity of these treatments were only visible for the first three weeks (data not shown), and would require multiple application during the season in order to continue suppressing nutsedge growth.

Conclusion

There are herbicides to control hairy fleabane and yellow nutsedge. Mixtures of herbicides with different mode of action were, in some instances, superior to single herbicide application due to greater spectrum of weed control.

The success of post-emergence activity is dependent on the species present at the time. Some pre-emergence herbicides tested also provided good burndown activity in selected species, but the long-term activity was not evaluated in this trial. Additional research is required to evaluate timing of application for the pre-emergence material in order to explore its maximum potential of burndown and residual activity. However, because post-emergence herbicides will still be required to complement pre-emergence program, it is important to preserve post-emergence active ingredients for effective, season-long weed control in orchards.

Table 1. Hairy fleabane visual control (%) with herbicide combinations 28 days after treatment.

Trt #	Treatment	Rate per acre		Control %	(SE)
1	untreated control			0	(0.0)
2	Roundup Powermax (glyphosate) + NIS + AMS	27.6	fl oz	3	(1.6)
3	Shark EW (carfentrazone) + NIS + AMS	2	fl oz	1	(1.3)
4	Roundup Powermax (glyphosate) + NIS + AMS	27.6	fl oz	14	(5.3)
	Shark EW (carfentrazone)	2	fl oz		
5	Rely 280 (glufosinate) +AMS	69	fl oz	88	(4.1)
6	Roundup Powermax (glyphosate) + AMS	27.6	fl oz	82	(12.6)
	Rely 280 (glufosinate)	69	fl oz		
7	Treevix (saflufenacil) + AMS + MSO	1	oz	96	(2.6)
8	Roundup Powermax (glyphosate) + AMS + MSO	27.6	fl oz	92	(3.4)
	Treevix (saflufenacil)	1	oz		
9	Rely 280 (glufosinate) + AMS + MSO	69	fl oz	95	(2.5)
	Treevix	1	oz		
10	Dri-Clean (2,4-D)	27	oz	85	(9.6)
11	Roundup Powermax (glyphosate)	27.6	fl oz	99	(0.7)
	Dri-Clean (2,4-D)	27	oz		
12	Rely 280 (glufosinate) + AMS	69	fl oz	100	(0.3)
	Dri-Clean (2,4-D)	27	oz		
13	Gramoxone SL (paraquat) + NIS	4	pt	99	(0.6)
14	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	98	(1.2)
	[1]Gramoxone SL (paraquat) + NIS	2	pt		
15	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	54	(5.0)
	Pindar GT (penoxsulam/oxyfluorfen)	1.5	pt		
16	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	43	(5.0)
	Matrix (rimsulfuron)	2	oz		
17	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	94	(2.5)
	Matrix (rimsulfuron)	2	oz		
	Treevix (saflufenacil)	1	oz		
18	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	11	(2.3)
	Chateau (flumioxazin)	6	oz		
19	Gramoxone SL (paraquat) + NIS	4	pt	100	(0.1)
	Chateau (flumioxazin)	6	oz		
		Tukey's critical value		30	

[1]paraquat applied 14 days after glyphosate treatment

abbreviations: NIS – non-ionic surfactant R-11 at 0.25% v/v; SE – standard error; AMS – ammonium sulfate Pro AMS plus at 10 lb/100 gal; MSO – methylated seed oil Monterey MSO at 1 % v/v

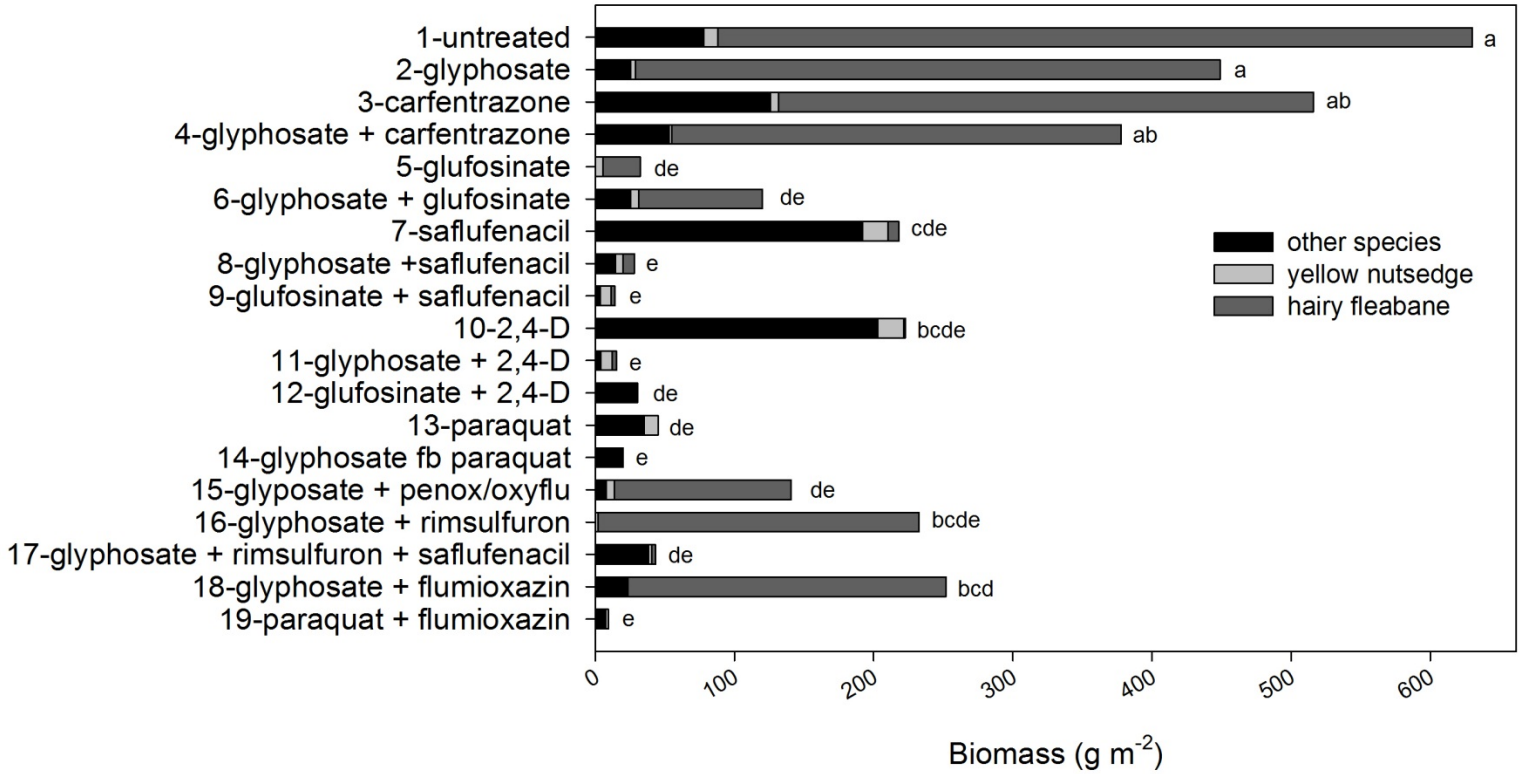

Figure 1. Weed dry biomass 28 day after herbicide treatment. Biomass of sparsely distributed species such as cut-leaf evening primrose, large crab-grass, three spiked goosegrass, and spotted spurge, were combined and are represented as black bars. Bars followed by the same letters are not statistically different according to Tukey's test ($p<0.05$).

Table 2. Yellow nutsedge visual control (%) with herbicide combinations 35 days after treatment.

Trt #	Treatment	Rate per acre		Control %	(SE)
1	Untreated			0	(0)
2	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(8.6)
3	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	20	(4)
	Treevix (saflufenacil)		oz		
4	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	89	(3.1)
	Chateau (flumioxazin)	12	oz		
5	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(8.6)
	Goal 2XL (oxyfluorfen)		oz		
6	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	50	(10.8)
	Goal 2XL (oxyfluorfen)		oz		
7	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	48	(7.5)
	Goal Tender (oxyfluorfen)		oz		
8	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	65	(8.6)
	Tangent (penoxsulam)	1.67	oz		
9	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	70	(7)
	Pindar GT (penoxsulam/oxyfluorfen)	2.5	pt		
10	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	55	(9.6)
	Zeus (sulfentrazone)	6	oz		
11	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	55	(8.7)
	Matrix (rimsulfuron)	2	oz		
12	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	70	(0)
	Matrix (rimsulfuron)	4	oz		
13	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	75	(6.5)
	Sandea (halosulfuron)	1	oz		
14	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	80	(0)
	Outrider (sulfosulfuron)	1.33	oz		
15	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(9.5)
	Rely 280 (glufosinate)	48	fl oz		
16	Roundup PowerMax (glyphosate) + MSO + AMS	28	fl oz	43	(8.5)
	[2]Gramoxone SL (paraquat)	48	fl oz		
	Tukey's critical value			39	

[1]glyphosate rate is expressed as acid equivalent (ae); [2]paraquat applied 14 days after glyphosate treatment

abbreviations: NIS – non-ionic surfactant R-11 at 0.25 % v/v; SE – standard error; AMS – ammonium sulfate Pro AMS plus at 10 lb/100 gal; MSO – methylated seed oil Monterey MSO at 1 % v/v

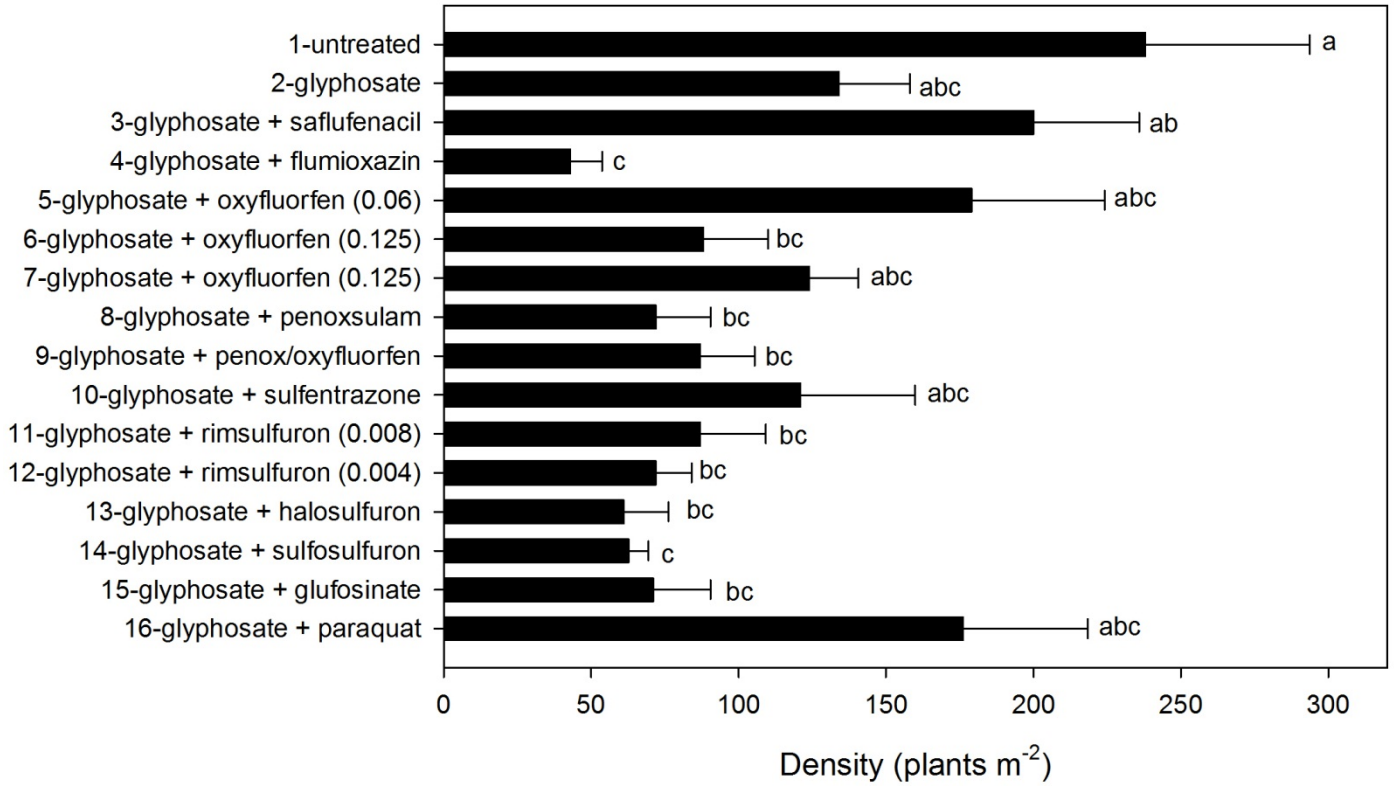

Figure 2. Yellow nutsedge plant density 35 days after herbicide treatment. Bars followed by the same letters are not significant different according to Tukey's test ($p<0.05$).