Finding, Evaluating, and Fine-tuning Herbicide Alternatives to Glyphosate for the Florida Landscape Industry: Part II

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ABSTRACT

Many naturally derived or organic non-selective contact herbicide options are available for landscape maintenance but not much research is available on the efficacy of these products. The objective of this research was to evaluate the efficacy of 9 different non-selective contact herbicides in comparison with glyphosate on common landscape weeds including doveweed (*Murdannia nudiflora*), yellow nutsedge (*Cyperus esculentus*), and longstalk phyllanthus (*Phyllanthus tenellus*). Overall, results were similar to previous research where glufosinate was the most effective herbicide and provided results similar to glyphosate on the two annual species evaluated (longstalk phyllanthus and doveweed). A very high level of control ("burndown") was noted at early evaluation dates with products including acetic acid, capric caprylic acid, pelargonic acid, ammoninum nonanoate and others, but plants recovered by the conclusion of the trial at 6 weeks after treatment. This indicates that many of these options may be effective but that sequential applications would be needed, and should most likely be targeted towards weeds at a younger growth stage than the mature plants that were evaluated in this trial.

OBJECTIVES AND METHODS

Due to negative publicity, many homeowners no longer want glyphosate to be used on their property and many municipalities in Florida have placed bans on glyphosate application on public property. As many landscape contractors rely on glyphosate to control troublesome and invasive weed species in landscapes, alternatives are needed in cases where glyphosate can no longer be used. In addition, regardless of bans or consumer preferences, alternative herbicides are needed for sound integrated weed management programs, to prevent/delay resistance development, and in many cases there are weeds for which glyphosate is not an effective option. While many non-selective alternatives exist, information is lacking on the efficacy of these herbicides against common weed species in Florida. Therefore, the objective of this research was to continue upon previous years' research and determine the efficacy of 9 different non-selective herbicides compared with glyphosate. In 2022, the weed species evaluated included longstalk Phyllanthus (*Phyllanthus tenellus*), doveweed (*Murdannia nudiflora*) and yellow nutsedge (*Cyperus esculentus*) (**Figure 1**).

Experiments were conducted at the Mid-Florida Research and Education Center in Apopka, FL in 2022. Nursery pots (1.9 liter) were filled with a pinebark:sand:peat potting soil that had been amended with a controlled release fertilizer [Osmocote Blend (8 to 9 month) 17-5-11] at a rate of 16 lbs. per cubic yard based on the manufacturer rate for incorporation. After filling, pots were moved to a full sun container pad and received 0.5 inches of overhead irrigation daily. On May 3, pots were seeded with approximately 30 seeds of either longstalk phyllanthus or doveweed while yellow nutsedge tubers were planted 1 inch deep at 5 tubers per pot. Weeds were allowed to grow until June 22 (~7 weeks after sowing, (**Figure 2**) when herbicide treatments (**Table 1**) were applied. Herbicides were applied using a CO_2 backpack sprayer calibrated to deliver 40 to 100 gallon per acre application volume (0.9 to 2.3 gal./1000 ft^2) based on herbicide label instructions (**Table 1**). Non-ionic

surfactants were added to each product if recommended on the manufacturer's label. Following treatment, pots were grouped by weed species in a completely randomized design with 8 single pot replications per treatment in each species. Data collected including visual control ratings at 1, 2, 4, and 6 weeks after treatment (WAT) on a 0 to 100 basis where 0 = no control or no difference with the non-treated pots (used for comparison) and 100 = 100% or no visible living plant tissues. At 6 weeks after treatment, shoot weight was assessed by clipping plants at the soil line and weighing on a portable field balance.

All data were subjected to analysis of variance using JMP statistical software (SAS) and arcsine transformed as needed to meet model assumptions. Each weed species was analyzed separately. For comparison purposes, all species and weed stages were also combined in order to compare the efficacy of each herbicide treatment over a range of species and growth stages. In all cases, treatment means were compared using Tukey's Honest Significant Difference Test and differences were considered significant at $P = 0.05$.

RESULTS

Yellow Nutsedge. At 1 WAT, the highest control was achieved with diquat followed by ammonium nonanoate with many other actives providing similar control such as acetic acid, caprylic + capric acid, and d-limonene (**Table 1**). Recovery was noted in almost all treatments by 2 WAT as expressed by decreasing control ratings. Exceptions included diquat, glyphosate, and glufosinate which either had similar or increased control ratings. This trend continued through 6 WAT with recovery noted in all treatments with the exception of glyphosate and diquat (**Figure 3**). Biomass data showed that while all treatments caused a reduction in yellow nutsedge growth, the best control was achieved with glyphosate and diquat which both provided a 100% reduction (or 100% control) in yellow nutsedge shoot biomass. It is important to note that this high level of control would not typically be expected with diquat. Diquat is a well-studied herbicide and has been researched much more thoroughly than other herbicides evaluated in these experiments. Diquat is a strictly contact herbicide and multiple applications are typically needed to control perennial weeds such as yellow nutsedge (see https://doi:10.1017/wet.2019.6 as an example). In this experiment however, 100% control was observed on all evaluation dates. It is unclear why such a high level of control was achieved which is in contrast to previous research. Additionally, when considering that all three weed species were grouped and treated together, it is unclear why diquat would provide complete control of nutsedge while providing only marginal control of phyllanthus and doveweed, both annual species. More research is needed but based on these results, most of the herbicides evaluated provided minimal to marginal suppression of nutsedge with one application.

Doveweed. At 1 WAT, the highest level of control was observed in plants treated with diquat or ammonium nonanoate, with both treatments providing approximately 80 to 90% control (**Table 2**). By 2 WAT, the highest control was achieved with glufosinate and diquat. Similar to results with yellow nutsedge, recovery was noted in most treatments throughout the remainder of the trial with the exception of plants treated with glyphosate or glufosinate which provided 66% control based on a visual control rating and a 72 to 73% reduction in doveweed shoot weight (**Figure 4**). Few other differences were observed among herbicides.

Longstalk Phyllanthus. Most herbicides evaluated provided a very high level of Phyllanthus control initially, with all herbicides with the exception of glyphosate and eugenol providing 60% control or higher (**Table 3**). This would be expected as Phyllanthus is typically an easier weed to control compared with doveweed and yellow nutsedge as it is an annual broadleaf weed which are typically more susceptible to non-selective contact herbicides. By 2 WAT recovery was noted in all treatments with the exception of plants treated with glyphosate (91% control). Ratings continued to decrease in all treatments throughout the remainder of the experiment (**Figure 5**). Based on biomass reduction, the highest level of control was achieved with glyphosate (87% reduction) and glufosinate (62% reduction) but herbicides including ammonium nonanoate, and pelargonic acid provided results similar to those observed with glufosinate.

CONCLUSIONS

When averaged across all three species, similar to 2020-2021 experiments, the best overall control was achieved with glyphosate (86%) followed by glufosinate (53%) and diquat which was similar to glufosinate (44%) (**Figure 6**). In almost all cases, significant recovery was noted at later weeks during the evaluation process, and was most notable from 2 WAT to 4 WAT. This could indicate that this 2 to 4 period would be the best ideal to make a sequential application to achieve satisfactory control. Determining the ideal re-application time with these treatments is currently our next and ongoing objective with this research. While formal control ratings were first conducted at 1 WAT, a very high level of visual control was noted with many of the contact products such as acetic acid, diquat, pelargonic acid, ammonium nonanoaate, and d-limonene, especially from 1 through 3 days after treatment. Further, many of these products provided very high levels of control at early evaluation dates (**Figure 7**). This indicates that these herbicides had significant but transient activity on these weeds as recovery was observed, at least on large weeds as were evaluated here. With the exception of glufosinate and in some cases diquat, few differences were noted among the other non-selective contact herbicides evaluated. For users wishing to utilize these herbicides, decisions could be based for the most part on worker safety (i.e. comparing PPE requirements, Danger vs. Caution labels, etc.), availability, price, and if other characteristics such as organic or OMRI (Organic Materials Review Institute) certification was important for them or their clients.

It should be noted that all three weed species were larger at the time of treatment than is typically recommended according to many of the product labels which recommend treating at a very young growth stage (e.g. 6 inches in height, 3 to 5 leaf, etc. or less). It would be expected that control ratings would be much higher if applications were made to weeds at an earlier timeframe relative to emergence than were evaluated here. Additionally, many of the products evaluated can be applied with a wide range of both concentrations and application volumes. Certain labels can be ambiguous with spot-spray rates and use verbiage such as "spray to wet" which can interpreted in different ways and lead to widely different application volumes (and consequently rates) being used in real-world situations. Therefore, we opted to choose broadcast rates (if provided), did not use the highest available application volume but chose 100 gallons/acre as the highest application volume (2.3 gal./1000 ft^2) evaluated, and we did not always choose the highest dose in all cases . Different results will likely be achieved with different rates, application volumes, and when applied to different weed species at different growth stages. This work is currently in the process of being replicated to validate results and further research is needed. Currently we are focusing our efforts on determining ideal reapplication timings and determining effective and realistic application volumes and rate concentrations to give Florida growers and landscape contractors the information they need to manage weeds in the most effective, economical, and environmentally friendly manner possible.

Table 1. Efficacy of glyphosate and alternative herbicides for control of yellow nutsedge (*Cyperus esculentus*) in Florida.

				7 Week Growth Stage[z]					
Treatment[y]				Visual Control Ratings (0 to 100)[x]				Biomass[w]	
Trade name	Herbicide (active)	Rate/acre	App. Vol.	1WAT	2WAT	4WAT	6WAT	F.W. (g)	% Control
Avenger Ag	d-limonene	20%	100	54 bcd	16 ef	6 de	11 b	40.0 ab	13 b
Axxe	Ammonium nonanoate	13%	100	70 b	29 cde	16 cde	11 b	39.7 ab	14 b
Terminator + Boost	Acetic acid	5%	100	61 bc	18 def	8 de	9 b	35.4 ab	23 b
Finale	Glufosinate	4 qt.	40	40 de	40 cd	25 cd	26 b	34.1 ab	26 b
FireWorxx	Caprylic + Capric acids	6% (v:v)	100	66 b	44 c	34 c	38 b	24.1 b	48 b
Ranger Pro	Glyphosate	2.66 qt.	40	30 e	68 b	74 b	98 a	0.2 c	100 a
Reward	Diquat	2 pts.	40	100 a	100 a	100 a	100 a	0.0 c	100 a
Scythe	Pelargonic acid	7% (v:v)	100	48 cde	23 cdef	10 de	33 b	29.7 ab	36 b
Green Gobbler	Acetic Acid	RTU	40	39 de	16 ef	6 de	9 b	37.4 ab	19 b
Weed Slayer	Eugenol	3 qt.	40	0 f	1 f	1 e	14 b	33.6 ab	28 b
Control	N.A.	N.A.	N.A.	---	---	---	---	46.2 a	---

[z]Growth stage shows the timing when herbicide applications were made relative to tuber planting.

[y]Rates are shown on a per acre basis. Application volume is shown in gallons per acre and was based on manufacturer label instructions.

[x]Visual control ratings were based on a 0 to 100 scale where 0 = 0% control or no difference from the non-treated control and 100 = 100% control or no visible green plant tissues present.

[w]Biomass shows shoot fresh weights collected at 6 weeks after treatment. % Control based on shoot weight reduction vs. control. Negative values indicate a percent increase relative to the non-treated control.

[v]Means followed by the same letter within each row and growth stage are not significantly different (Tukey's test, $P = 0.05$).

Table 2. Efficacy of glyphosate and alternative herbicides for control of doveweed (*Murdannia nudiflora*) in Florida.

				7 Week Growth Stage[z]					
Treatment[y]				Visual Control Ratings (0 to 100)[x]				Biomass[w]	
Trade name	Herbicide (active)	Rate/acre	App. Vol.	1WAT	2WAT	4WAT	6WAT	F.W. (g)	% Control
Avenger Ag	d-limonene	20%	100	68 bcd	21 c	9 bc	9 b	166.8 b	21 b
Axxe	Ammonium nonanoate	13%	100	79 ab	24 c	8 bc	8 b	169.0 ab	20 b
Terminator + Boost	Acetic acid	5%	100	54 e	23 c	3 c	4 b	221.0 a	-5 c
Finale	Glufosinate	4 qt.	40	60 cde	56 a	66 a	66 a	58.5 c	72 a
FireWorxx	Caprylic + Capric acids	6% (v:v)	100	58 de	30 c	0 c	1 b	197.0 ab	7 bc
Ranger Pro	Glyphosate	2.66 qt.	40	6 f	54 ab	55 a	66 a	56.2 c	73 a
Reward	Diquat	2 pts.	40	88 a	30 c	0 c	9 b	172.8 ab	18 bc
Scythe	Pelargonic acid	7% (v:v)	100	65 cde	34 bc	0 c	3 b	170.0 ab	19 bc
Green Gobbler	Acetic Acid	RTU	40	71 bc	14 c	0 c	0 b	220.9 a	-5 c
Weed Slayer	Eugenol	3 qt.	40	9 f	14 c	20 b	5 b	190.9 ab	9 bc
Control	N.A.	N.A.	N.A.	---	---	---	---	210.9 ab	---

[z]Growth stage shows the timing when herbicide applications were made relative to sowing seed.

[y]Rates are shown on a per acre basis. Application volume is shown in gallons per acre and was based on manufacturer label instructions.

[x]Visual control ratings were based on a 0 to 100 scale where 0 = 0% control or no difference from the non-treated control and 100 = 100% control or no visible green plant tissues present.

[w]Biomass shows shoot fresh weights collected at 6 weeks after treatment. % Control based on shoot weight reduction vs. control. Negative values indicate a percent increase relative to the non-treated control.

[v]Means followed by the same letter within each row and growth stage are not significantly different (Tukey's test, $P = 0.05$).

Table 3. Efficacy of glyphosate and alternative herbicides for control of longstalk phyllanthus (*Phyllanthus tenellus*) in Florida.

7 Week Growth Stage[z]									
Treatment[y]				Visual Control Ratings (0 to 100)[x]				Biomass[w]	
Trade name	Herbicide (active)	Rate/acre	App. Vol.	1WAT	2WAT	4WAT	6WAT	F.W. (g)	% Control
Avenger Ag	d-limonene	20%	100	93 a	45 cdef	11 cd	6 c	32.4 b	8 c
Axxe	Ammonium nonanoate	13%	100	99 a	55 bcde	25 bcd	25 c	25.8 bc	27 bc
Terminator + Boost	Acetic acid	5%	100	71 b	35 ef	0 d	5 c	35.1 ab	1 cd
Finale	Glufosinate	4 qt.	40	68 b	66 bc	61 ab	61 ab	13.5 cd	62 ab
FireWorxx	Caprylic + Capric acids	6% (v:v)	100	86 a	38 def	11 cd	14 c	31.1 b	12 c
Ranger Pro	Glyphosate	2.66 qt.	40	48 c	91 a	99 a	88 a	4.4 d	87 a
Reward	Diquat	2 pts.	40	89 a	60 bcd	20 cd	18 c	30.6 b	13 c
Scythe	Pelargonic acid	7% (v:v)	100	98 a	78 ab	40 bc	31 bc	25.3 bc	28 bc
Green Gobbler	Acetic Acid	RTU	40	60 bc	30 f	0 d	0 c	36.1 ab	-3 cd
Weed Slayer	Eugenol	3 qt.	40	4 d	0 g	0 d	0 c	46.2 a	-31 d
Control	N.A.	N.A.	N.A.	---	---	---	---	35.2 ab	---

[z]Growth stage shows the timing when herbicide applications were made relative to sowing seed.

[y]Rates are shown on a per acre basis. Application volume is shown in gallons per acre and was based on manufacturer label instructions.

[x]Visual control ratings were based on a 0 to 100 scale where 0 = 0% control or no difference from the non-treated control and 100 = 100% control or no visible green plant tissues present.

[w]Biomass shows shoot fresh weights collected at 6 weeks after treatment. % Control based on shoot weight reduction vs. control. Negative values indicate a percent increase relative to the non-treated control.

[v]Means followed by the same letter within each row and growth stage are not significantly different (Tukey's test, $P = 0.05$).

Figure 1. Species evaluated (L to R) included doveweed (Murdania nudiflora), longstalk Phyllanthus (Phyllanthus tenellus) and yellow nutsedge (Cyperus esculentus).

Figure 2. Yellow nutsedge, doveweed, and longstalk phyllanthus at the time of herbicide application.

Figure 3. Yellow nutsedge treatments (derandomized for photos) at 7 days (left) and 28 days (right) after herbicide treatment. Plants were treated (from L to R) with glyphosate, glufosinate, diquat, pelargonic acid, capric + caprylic acid, eugenol, acetic acid (Green Gobbler), acetic acid (Terminator), d-limonene, ammonium nonanoate, and nontreated.

Figure 4. Doveweed treatments (derandomized for photos) at 7 days (left) and 28 days (right) after herbicide treatment. Plants were treated (from L to R) with glyphosate, glufosinate, diquat, pelargonic acid, capric + caprylic acid, eugenol, acetic acid (Green Gobbler), acetic acid (Terminator + Boost), d-limonene, ammonium nonanoate, and nontreated.

Figure 5. Longstalk Phyllanthus treatments (derandomized for photos) at 7 days (left) and 28 days (right) after herbicide treatment. Plants were treated (from L to R) with glyphosate, glufosinate, diquat, pelargonic acid, capric + caprylic acid, eugenol, acetic acid (Green Gobbler), acetic acid (Terminator), d-limonene, ammonium nonanoate, and nontreated.

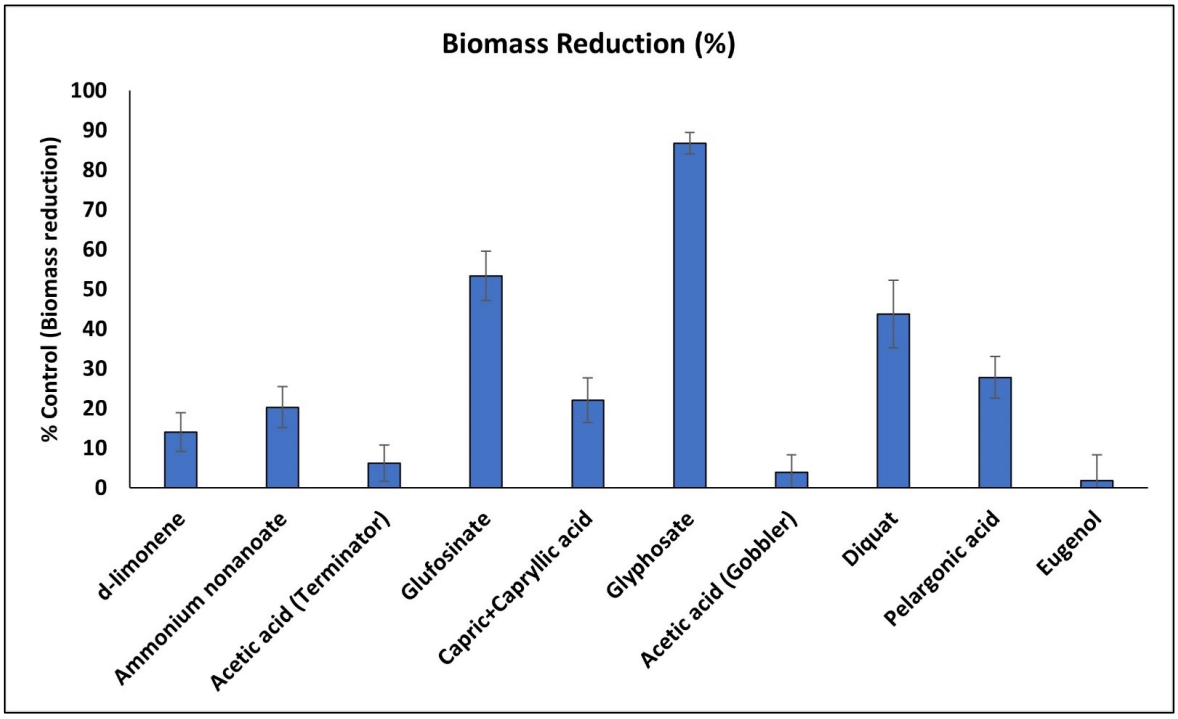

Figure 6. Mean % shoot weight (biomass) reduction (relative to non-treated) for 10 different herbicides averaged over results obtained from application to yellow nutsedge, longstalk Phyllanthus, and doveweed. Plants were harvested at 6 weeks after herbicides were applied.

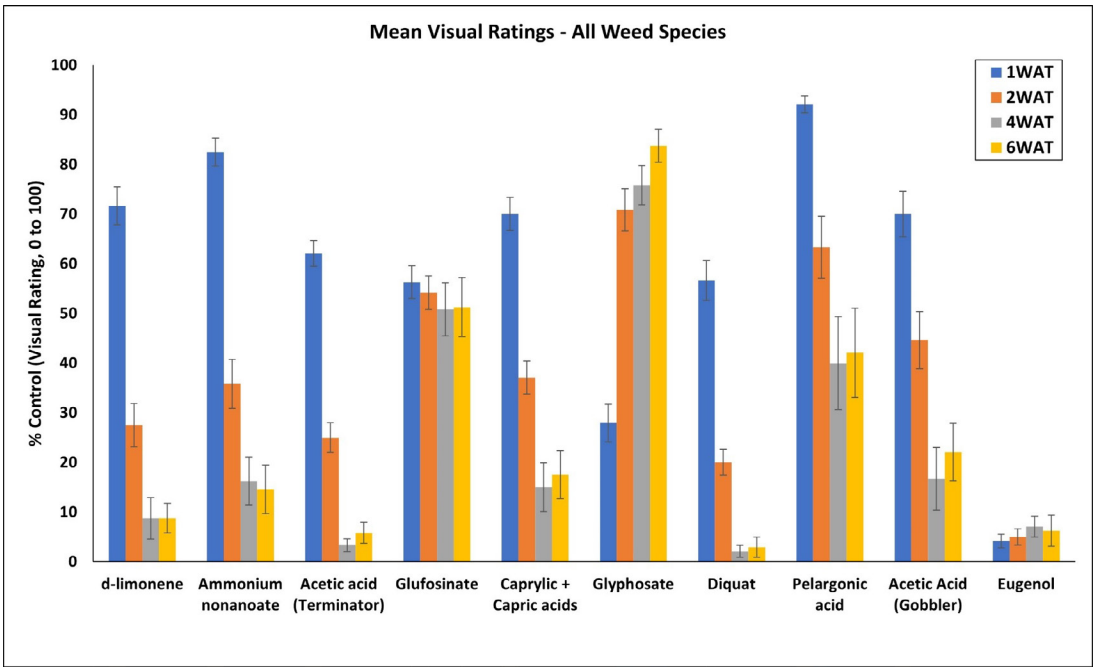

Figure 7. Visual control ratings taken on a 0 to 100% scale (0 = 0% control, 100 = 100% control/dead plant) at 1, 2, 4, and 6 weeks after herbicide treatment (WAT). Data shows means and standard errors for each herbicide over each rating period averaged over three different weed species including yellow nutsedge, longstalk phyllanthus, and doveweed.