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EVALUATION OF CONVENTIONAL and ORGANIC ALTERNATIVES to GLYPHOSATE

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Background on glyphosate

Glyphosate was found to control weeds by a Monsanto scientist in 1970. The herbicide was patented in 1971 and was introduced commercially as Roundup in 1974. It has since gone off patent and is sold under a variety of formulations and trade names.

Glyphosate is a nonselective postemergence herbicide, meaning that it controls essentially all weeds. Glyphosate is systemic, so it moves into and controls underground portions of weeds (roots, rhizomes, tubers, etc.), making it the preferred product for perennial weed control in many situations. This chemical binds to soil particles and has essentially no soil activity, so crops can be planted a week after application.

Glyphosate is used for preplant weed control/site preparation, lawn renovation, spot treatment of weeds in landscape beds, as a directed spray application in fruit and nursery production, and for noncrop weed management, such as guard rails, railroad lines, and parking lots, among other uses. It controls grasses, sedges, and broadleaf weeds, making it a broad-spectrum herbicide.

There have been several issues recently concerning the use of glyphosate for weed control. The recent development of glyphosate-resistant weeds has pushed researchers and growers to find alternative means to control these weed species. It has been suggested that glyphosate causes non-Hodgkin lymphoma (NHL), a type of cancer, and other diseases. For these reasons, along with an increasing interest in organic production methods, there is a need for research on alternatives to glyphosate use.

Alternatives to glyphosate

There are a variety of potential alternatives to glyphosate, including use of propane weeders (flame weeding), steam/hot water/foam steam, soil solarization, anaerobic soil disinfestation, and chemicals, among others. My work has focused on the use of both conventional and organic herbicides. We conducted several trials in 2020 to evaluate alternative chemicals for control of a range of annual and perennial weeds. Some of the chemicals evaluated have been approved for organic programs (Organic Materials Review Institute, abbreviated as OMRI).

Conventional and organic trials we conducted

Field trial 1. This study was conducted at our research station (HRAREC) in Virginia Beach in a field that had a native stand of southern crabgrass and yellow nutsedge. Treatments are listed in Table 1 and ingredients are listed in Table 2. A rate of 100% v/v means the product was not diluted prior to application. The surfactant Capsil was added to the Diquat treatment at 0.25% v/v. Products were applied on a spray to wet basis, approximately 100 gallons per acre. The site was treated 8/17/20 under 76 F Air temperature, 82% relative humidity, 95% cloud cover, wind 2-4 MPH N, and soil temperature 75 F. Southern crabgrass was 6" tall, and yellow nutsedge 14" tall.

Roundup Promax, Cheetah Pro, and Weed Slayer + Agro Gold gave complete control of southern crabgrass at 17 and 28 days after treatment (DAT) (Table 3). The other treatments caused significant burning of southern crabgrass foliage at 4 DAT but this weed outgrew that injury by 17 DAT. Roundup Promax and Cheetah Pro gave excellent control of yellow nutsedge at 17 and 28 DAT, with good control seen with Diquat and fair control with Weed Slayer + Agro Gold (Table 4). The other treatments did not provide acceptable control of yellow nutsedge. Cheetah Pro (glufosinate) is an effective conventional alternative to glyphosate while Weed Slayer + Agro Gold appears to be an acceptable organic alternative.

TABLE 1. Chemical trade name, classification as either a conventional (synthetic) or organic product, and mixing rate in the field trial at the HRAREC.

	Treatment	Conventional or Organic	Rate
1	Nontreated		
2	Roundup Promax	Conventional	2 fl oz/gal
3	Cheetah Pro	Conventional	3 fl oz/gal
4	Diquat	Conventional	0.75 fl oz/gal
5	Natural Armor RTU	Organic	100 % v/v [a]
6	Weed Zap	Organic (OMRI) [b]	6.4 fl oz/gal
7	Weed Slayer +	Organic	3 % v/v
	Agro Gold	Organic	3 % v/v
8	Avenger Weed Killer	Organic (OMRI)	12.5 % v/v
9	Scythe	Conventional	7 % v/v
10	WeedPharm	Organic (OMRI)	100 % v/v

[a] v/v means volume to volume

[b] OMRI = approved for organic programs by the Organic Materials Review Institute.

TABLE 2. Chemical trade name and active ingredient for each herbicide in the field trial at the HRAREC.

	Treatment	Active Ingredients
1	Nontreated	glyphosate
2	Roundup Promax	glufosinate
3	Cheetah Pro	diquat
4	Diquat	Citric acid, clover oil, acetic acid, NaCl, lemon juice
5	Natural Armor RTU	Clove oil, cinnamon oil
6	Weed Zap	Eugenol (clove oil), molasses
7	Weed Slayer +	Streptomyces rimosus, Bacillus megaterium
	Agro Gold	d-Limonene (citrus oil)
8	Avenger Weed Killer	pelargonic acid
9	Scythe	Acetic acid
10	WeedPharm	

TABLE 3. Southern crabgrass control in the field trial at the HRAREC.

				% Control Southern Crabgrass			
	Treatment			Aug1820 1 DAT	Aug2120 4 DAT	Sep0320 17 DAT	Sep1420 28 DAT
1	Nontreated			3	8	0	0
2	Roundup Promax	2	fl oz/gal	0	83	100	100
3	Cheetah Pro	3	fl oz/gal	0	70	100	100
4	Diquat +	0.75	fl oz/gal	100	50	13	5
	Capsil	0.25	% v/v				
5	Natural Arrmor RTU	100	% v/v	15	23	0	0
6	Weed Zap	6.4	fl oz/gal	3	43	0	0
7	Weed Slayer +	3	% v/v	18	65	100	100
	Agro Gold	3	% v/v				
8	Avenger Weed Killer	12.5	% v/v	0	45	0	0
9	Scythe	7	% v/v	13	50	15	15
10	WeedPharm	100	% v/v	35	28	8	8
LSD P=.05				8	19	11	11

TABLE 4. Yellow nutsedge control in the field trial at the HRAREC.

				% Control Yellow Nutsedge			
	Treatment			Aug1820 1 DAT	Aug2120 4 DAT	Sep0320 17 DAT	Sep1420 28 DAT
1	Nontreated			13	5	0	0
2	Roundup Promax	2	fl oz/gal	28	30	100	98
3	Cheetah Pro	3	fl oz/gal	33	40	99	98
4	Diquat +	0.75	fl oz/gal	81	99	98	89
	Capsil	0.25	% v/v				
5	Natural Arrmor RTU	100	% v/v/a	58	45	30	23
6	Weed Zap	6.4	fl oz/gal	50	15	15	8
7	Weed Slayer +	3	% v/v	28	45	75	69
	Agro Gold	3	% v/v				
8	Avenger Weed Killer	12.5	% v/v	55	13	0	0
9	Scythe	7	% v/v	80	40	23	15
10	WeedPharm	100	% v/v	55	40	38	58
LSD P=.05				16	18	23	28

Field trial 2. Treatments are listed in Table 5 and percent control is listed in Table 6. Most treatments, except Fiesta and Roundup, caused significant injury to weeds at 4 days after treatment (4 DAT). However, none of these five treatments gave acceptable weed control at 32 DAT due to regrowth from these contact herbicides. Roundup gave good weed control at 32 DAT. Fiesta did not provide acceptable weed control at any rating date. Fiesta is only effective on broadleaf weeds and this site had primarily grassy weeds.

Container trial. Six weed species were grown in one-gallon containers to determine effectiveness of the treatments on an annual grass (southern crabgrass), a perennial grass (bermudagrass), an annual sedge (compressed sedge), a perennial sedge (yellow nutsedge), an annual broadleaf weed (longstalk Phyllanthus), and a perennial broadleaf weed (Virginia buttonweed). The study was treated 8/12/20 using a single nozzle on a spray to wet basis (approximately 120 gallons per acre) under 84 F Air temperature, 79% relative humidity sunny, 25% cloud cover, and wind 0–3 MPH W and the study was irrigated 5 hours after application.

In this trial. Virginia buttonweed was 12" wide, southern crabgrass was 14" tall, yellow nutsedge was 13" tall, longstalk Phyllanthus was 5" tall, compressed sedge was 4" wide, bermudagrass was 2" tall and 7' wide. In addition, pots were seeded at treatment with southern crabgrass for the nontreated control and the Weed Slayer + Agro Gold treatment.

Roundup Promax (glyphosate) and Cheetah Pro (glufosinate) gave excellent control of all six weed species at 19 DAT. Weed Slayer plus Agro Gold provided excellent control of longstalk phyllanthus, good control of southern crabgrass, Virginia buttonweed and compressed sedge, and fair control of bermudagrass and yellow nutsedge. This combination provided good preemergence control of southern crabgrass at 19 DAT. Diquat gave excellent control of longstalk phyllanthus, yellow nutsedge, and compressed sedge but poor control/regrowth of the other weed species. Scythe gave fair control of longstalk phyllanthus but poor control of the other weeds. The other treatments caused injury soon after application but the weed species were able to outgrow the damage. Repeat applications would be needed for these treatments.

TABLE 5. Chemical trade name, classification as either a conventional (synthetic) or organic product, and mixing rate in the field trial in Blacksburg.

Herbicide	Category	Active Ingredient	Fl oz/ Gallon
Scythe	synthetic	pelargonic acid	7
Suppress	organic	caprylic acid + capric acid	8
Fiesta	organic	iron HEDTA	5
Avenger	organic	D-limonene (citrus oil)	42
Burnout	organic	citric acid + clove oil	42
Natures Wisdom	organic	acetic acid	128
Weed Zap	organic	clove oil + cinnamon oil	6
Roundup	synthetic	glyphosate	2
Rely 280	synthetic	glufosinate	4

	Percent Weed Control				
Treatment	4 DAT	8 DAT	16 DAT	32 DAT	64 DAT
Nontreated	0	0	0	0	0
Scythe	75	70	67	51	22
Suppress	95	93	79	34	7
Fiesta	6	5	0	0	0
Avenger	45	33	40	14	11
Burnout	96	91	77	45	19
Natures Wisdom	85	88	72	15	5
Roundup	5	75	99	87	73
LSD	26	19	11	19	12

TABLE 6. Percent control of southern crabgrass in the container trial at the HRAREC.

				Southern Crabgrass					
				% Postemergence Control					Pre #/Plot
	Treatment			Aug1220 15 min	Aug1320 1 DAT	Aug1720 5 DAT	Aug2520 13 DAT	Aug3120 19 DAT	Aug3120 19 DAT
1	Nontreated			1	0	0	3	0	36.3
2	Roundup Promax	2	fl oz/gal	0	0	55	98	100	
3	Cheetah Pro	3	fl oz/gal	1	8	63	96	99	
4	Diquat +	0.75	fl oz/gal	10	55	65	48	35	
	Capsil	0.25	% v/v						
5	Natural Arrmor RTU	100	% v/v	4	60	35	8	20	
6	Weed Zap	6.4	fl oz/gal	3	10	6	0	0	
7	Weed Slayer +	3	% v/v	1	10	40	73	86	7.8
	Agro Gold	3	% v/v						
8	Avenger Weed Killer	12.5	% v/v	8	25	28	10	23	
9	Scythe	7	% v/v	15	55	45	11	18	
10	WeedPharm	100	% v/v	3	45	28	5	23	
LSD P=.05				5	23	11	12	11	13.0

TABLE 7. Percent control of bermudagrass in the container trial at the HRAREC.

				Percent Control Bermudagrass			
	Treatment			**Aug1320 1 DAT**	**Aug1720 5 DAT**	**Aug2520 13 DAT**	**Aug3120 19 DAT**
1	Nontreated			0	0	0	0
2	Roundup Promax	2	fl oz/gal	0	15	100	100
3	Cheetah Pro	3	fl oz/gal	5	84	100	99
4	Diquat +	0.75	fl oz/gal	63	45	28	13
	Capsil	0.25	% v/v				
5	Natural Arrmor RTU	100	% v/v	73	50	20	0
6	Weed Zap	6.4	fl oz/gal	23	5	3	0
7	Weed Slayer +	3	% v/v	18	38	85	74
	Argo Gold	3	% v/v				
8	Avenger Weed Killer	12.5	% v/v	25	15	5	0
9	Scythe	7	% v/v	83	40	25	15
10	WeedPharm	100	% v/v	65	33	8	0
LSD P=.05				16	21	21	13

TABLE 8. Percent control of compressed sedge in the container trial at the HRAREC.

				Percent Control Compressed Sedge			
	Treatment			**Aug1320 1 DAT**	**Aug1720 5 DAT**	**Aug2520 13 DAT**	**Aug3120 19 DAT**
1	Nontreated			0	3	8	15
2	Roundup Promax	2	fl oz/gal	0	23	100	100
3	Cheetah Pro	3	fl oz/gal	0	20	88	100
4	Diquat +	0.75	fl oz/gal	90	100	100	100
	Capsil	0.25	% v/v				
5	Natural Arrmor RTU	100	% v/v	20	35	30	23
6	Weed Zap	6.4	fl oz/gal	0	5	4	0
7	Weed Slayer +	3	% v/v	3	20	78	85
	Agro Gold	3	% v/v				
8	Avenger Weed Killer	12.5	% v/v	8	23	30	38
9	Scythe	7	% v/v	25	48	25	18
10	WeedPharm	100	% v/v	18	25	28	23
LSD P=.05				7	16	16	20

TABLE 9. Percent control of yellow nutsedge in the container trial at the HRAREC.

				Percent Control Yellow Nutsedge			
	Treatment			**Aug1320 1 DAT**	**Aug1720 5 DAT**	**Aug2520 13 DAT**	**Aug3120 19 DAT**
1	Nontreated			0	0	0	0
2	Roundup Promax	2	fl oz/gal	0	9	63	96
3	Cheetah Pro	3	fl oz/gal	0	28	70	98
4	Diquat +	0.75	fl oz/gal	63	100	100	100
	Capsil	0.25	% v/v				
5	Natural Arrmor RTU	100	% v/v	38	48	35	35
6	Weed Zap	6.4	fl oz/gal	1	3	3	5
7	Weed Slayer +	3	% v/v	8	28	50	65
	Agro Gold	3	% v/v				
8	Avenger Weed Killer	12.5	% v/v	15	23	5	0
9	Scythe	7	% v/v	23	30	15	13
10	WeedPharm	100	% v/v	33	40	25	30
LSD P=.05				13	11	20	21

TABLE 10. Percent control of longstalk phyllanthus in the container trial at the HRAREC.

				Percent Control Longstalk Phyllanthus				
	Treatment			**Aug1220 15 min**	**Aug1320 1 DAT**	**Aug1720 5 DAT**	**Aug2520 13 DAT**	**Aug3120 19 DAT**
1	Nontreated			0	0	8	13	15
2	Roundup Promax	2	fl oz/gal	0	0	83	100	100
3	Cheetah Pro	3	fl oz/gal	0	5	91	100	100
4	Diquat +	0.75	fl oz/gal	1	80	100	100	100
	Capsil	0.25	% v/v					
5	Natural Arrmor RTU	100	% v/v	48	78	89	45	63
6	Weed Zap	6.4	fl oz/gal	8	25	45	8	0
7	Weed Slayer +	3	% v/v	0	3	35	85	93
	Agro Gold	3	% v/v					
8	Avenger Weed Killer	12.5	% v/v	3	28	60	33	20
9	Scythe	7	% v/v	58	68	89	79	75
10	WeedPharm	100	% v/v	20	55	75	49	50
LSD P=.05				11	24	25	43	46

TABLE 11. Percent control of Virginia buttonweed in the container trial at the HRAREC.

				Percent Control of Virginia Buttonweed				
	Treatment			**Aug1220 15 min**	**Aug1320 1 DAT**	**Aug1720 5 DAT**	**Aug2520 13 DAT**	**Aug3120 19 DAT**
1	Nontreated			1	0	0	0	3
2	Roundup Promax	2	fl oz/gal	1	0	23	100	100
3	Cheetah Pro	3	fl oz/gal	1	0	60	100	100
4	Diquat +	0.75	fl oz/gal	0	33	25	5	20
	Capsil	0.25	% v/v					
5	Natural Arrmor RTU	100	% v/v	19	78	68	53	58
6	Weed Zap	6.4	fl oz/gal	8	23	23	3	0
7	Weed Slayer +	3	% v/v	0	0	20	70	85
	Agro Gold	3	% v/v					
8	Avenger Weed Killer	12.5	% v/v	10	35	43	15	10
9	Scythe	7	% v/v	30	83	55	18	5
10	WeedPharm	100	% v/v	8	60	53	48	40
LSD P=.05				8	23	19	22	29

Summary

Of the conventional (synthetic) herbicides tested, glufosinate, sold under the names Cheetah Pro and Finale for nursery and landscape use and various non-agricultural uses, and Rely 280 (among others) for use in selected fruit crops, gave comparable weed control to glyphosate. Diquat gave good control of the annual sedges and broadleaf weeds evaluated, as well as control of yellow nutsedge, but it only provided short term control of the annual and perennial grasses tested. Scythe, as a contact herbicide, also provided only short-term control of the weed species tested.

Most of the organic herbicides also provided only short-term weed control. These products are contact in nature, like Scythe, and regrowth was noted for treated weed species. Multiple applications would be needed for acceptable control, especially for larger plants. The only exception was Weed Slayer + Agro Gold, which provided good control of the species tested.

However, news reports have noted that the synthetic herbicides glyphosate and diquat were found in some samples of Agro Gold (see https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=44341). The California Department of Food and Agriculture (CDFA) announced that a Stop Use notice and a statewide quarantine was issued for the organic product Agro Gold WS to all organic operations registered in California. The results we observed with Weed Slayer plus Agro Gold were consistent with contamination by glyphosate. So additional information and research will be needed to determine if Weed Slayer plus Agro Gold will be an acceptable treatment in the future for those desiring an organic alternative to glyphosate.

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