



UNIVERSITY OF
GEORGIA

College of Agricultural &
Environmental Sciences

Managing Herbicide-Resistant Palmer Amaranth In Field Corn, Grain Sorghum, Peanut, and Soybean - 2017

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The occurrence of herbicide resistance in Palmer amaranth and other weeds in Georgia is cause for significant concern for the agricultural industry. Changes in cropping practices, specifically the reliance on a limited number of herbicides, have streamlined weed management. However, the consequence has been the development of herbicide resistance. An effective herbicide-resistant weed management plan will require the integration of multiple herbicide chemistries in an effort to minimize selection pressure and delay the occurrence of herbicide resistance in a field. Other control strategies, such as tillage, extreme cover crops, narrow row spacing, hand-weeding, crop rotation, and mechanical cultivation must also be included in an herbicide resistant weed management plan (Table 1). The herbicide recommendations in Tables 2-6 are aimed at preserving the herbicide tools that are available for weed management. For additional information about herbicide resistant weeds, contact your local county extension agent and visit the UGA Weed Science Web-Page at the following web address: <http://www.gaweed.com/resistance.html>

Updated: January 5, 2017

This version supersedes all previous versions.

Table 1. Non-Chemical Control Strategies for the Management of Herbicide-Resistant Palmer Amaranth*.

Strategy	Effect
Tillage (moldboard plow)	Burying Palmer amaranth seed at least 4" deep in the soil will provide approximately 50% control of Palmer amaranth.
Extreme Rye Cover Crops	A well-managed rye cover crop, planted in the fall, terminated at its maximum height, and rolled will form a dense mat of residue which will provide approximately 60-90% control of Palmer amaranth.
Decreased row widths	Decreasing row widths results in faster canopy closure and shade formation. Palmer amaranth seed requires light for germination.
Hand-Weeding	Hand-removal of escaped female Palmer amaranth plants before seed production will prevent further seed-rain into a field.
Crop Rotation	Crop rotations that include field corn provide growers with an opportunity to use alternative herbicide modes of action and also provide for additional time in the fall for seed-bank management.
Mechanical Cultivation	No weeds are steel-resistant.

*An aggressive combination of non-chemical and chemical control tactics will be required to manage herbicide-resistant Palmer amaranth.

Table 2. Herbicide Programs for Managing Glyphosate and ALS-Resistant Palmer Amaranth in Field Corn.¹

Corn Hybrid	Preemergence	Postemergence	Layby/Directed if needed
Conventional	Atrazine**	Prowl ² + Atrazine + Crop Oil	2,4-D ⁵ or Banvel/Clarity ^{4,5} or Status ¹⁰
	Atrazine**	Atrazine + 1 of the following: Callisto, Laudis, Capreno ¹⁴ , Steadfast Q ¹⁵ , Revulin Q ¹⁶	2,4-D ⁵ or Banvel/Clarity ^{4,5} or Status ¹⁰
	Dual II Magnum ⁶ or Warrant or Zidua or Anthem ¹²	Atrazine + 1 of the following: Callisto, Laudis, Capreno ¹⁴ , Steadfast Q ¹⁵ , Revulin Q ¹⁶	2,4-D ⁵ or Evik or Banvel/Clarity ^{4,5} or Status ¹⁰
Liberty-Link	Atrazine**	Liberty ¹³ + atrazine ⁷	2,4-D ⁵ or Banvel/Clarity ^{4,5} or Status ¹⁰
	Dual II Magnum ⁶ or Warrant or Zidua or Anthem ¹²	Liberty ¹³ + atrazine ⁷	2,4-D ⁵ or Evik or Banvel/Clarity ^{4,5} or Status ¹⁰
Roundup Ready	Atrazine**	1) glyphosate + 1 of the following: atrazine or Dual Magnum ⁶ or Warrant or Status ¹⁰ or Laudis or Capreno ¹⁴ or Revulin Q ¹⁶ 2) Expert ⁸ 3) Sequence ⁹ 4) Halex GT ¹¹	2,4-D ⁵ or Banvel/Clarity ^{4,5} or Status ¹⁰
	Dual II Magnum ⁶ or Warrant or Zidua or Anthem ¹²	1) glyphosate + 1 of the following: atrazine or Status ¹⁰ or Laudis or Capreno ¹⁴ or Revulin Q ¹⁶ 2) Expert ⁸ 3) Halex GT ¹¹	2,4-D ⁵ or Evik or Banvel/Clarity ^{4,5} or Status ¹⁰

¹Glyphosate- and ALS-resistant Palmer amaranth are very serious concerns. An aggressive management program is necessary to slow spread of resistant biotypes and to reduce selection pressure in areas currently not infested with resistant biotypes.

²Generic brands of Prowl (pendimethalin) are available and perform similarly.

³Bicep II Magnum is a pre-mixture of S-metolachlor and atrazine. Less expensive, generic brands containing metolachlor and atrazine are available (Parallel Plus, Stalwart Xtra). These generic brands may not provide the same length of residual control as Bicep II Magnum (which contains S-metolachlor).

⁴Generic brands of Banvel (dicamba-DMA) are available and perform similarly.

⁵Use extreme caution to avoid drift to sensitive crops, such as cotton, tobacco, soybeans, and vegetables. Use only amine formulations of 2,4-D. Follow all label directions for drift management.

⁶Generic brands containing metolachlor are available (Me-Too-Lachlor-II, Parallel, Stalwart-C). However, these generic brands may not provide the same length of residual control as Dual II Magnum (S-metolachlor).

⁷Also available in a pre-mixture sold under the trade name of Liberty ATZ.

⁸Expert is a pre-mixture of glyphosate + S-metolachlor (Dual Magnum) + atrazine.

⁹Sequence is a pre-mixture of glyphosate + S-metolachlor (Dual Magnum).

¹⁰Status is a pre-mixture of dicamba-Na + diflufenzoxypr + isoxadifen (safener).

¹¹Halex GT is a pre-mixture of glyphosate + S-metolachlor (Dual Magnum) + mesotrione (Callisto).

¹²Anthem is a pre-mixture of pyroxasulfone (Zidua) + fluthiacet (Cadet).

¹³Generic formulations of glufosinate are also available including Kong and Interline. Generic formulations of glufosinate should be used with caution because limited data has been collected by UGA.

¹⁴Capreno is a pre-mixture of tembotrione (Laudis) + thiencarbazone + isoxadifen (safener).

¹⁵Steadfast Q is a pre-mixture of nicosulfuron (Accent) + rimsulfuron (Matrix) + isoxadifen (safener).

¹⁶Revulin Q is a pre-mixture of mesotrione (Callisto) + nicosulfuron (Accent) + isoxadifen (safener).

**** When atrazine is applied PRE + POST, a total of 2.5 lb ai/A can be applied per year (2.5 qt/A of 4L or 44 oz/A of 90DF). When atrazine is applied only POST, then a total of 2.0 lb ai/A can be applied per year (2 qt/A of 4L or 36 oz/A of 90DF).**

SPECIAL NOTE: Anthem, Dual Magnum, Warrant, and Zidua have the same mode of action (inhibit very long chain fatty acids). Multiple applications (> 2) of these herbicides in a single year should be avoided to prevent or delay the evolution of resistance. These herbicides have no postemergence activity.

Table 3. Herbicides Programs for Managing Glyphosate, ALS, and Atrazine Resistant Palmer Amaranth in Field Corn.

Hybrid	Preemergence	Postemergence ¹
Any	Dual II Magnum or Warrant or Zidua or Anthem	Callisto ² , Capreno, Impact, Armezon, Laudis, Revulin Q, or Status
Liberty-Link	Dual II Magnum or Warrant or Zidua or Anthem	Liberty ³

¹Atrazine can be tank-mixed with these herbicides if other weeds are a concern such as sicklepod and morningglory. ²Callisto Xtra is a pre-mixed formulation of Callisto + Atrazine. ³Generic formulations of glufosinate are also available including Kong and Interline. Generic formulations of glufosinate should be used with caution because limited data has been collected by UGA.

POST-HARVEST (FIELD CORN) MANAGEMENT OF PALMER AMARANTH

After field corn harvest, Palmer amaranth plants that emerge up until 35 days before first frost will have the potential to produce viable seed. Consequently, these post-harvest populations should be managed up until this time using 1 or more of the following strategies:

a) For plants larger than 6" in height:

- 1) Mowing
- 2) Tillage

b) For plants less than 6" in height:

- 1) Tillage or
- 2) Gramoxone SL @ 48 oz/A or Firestorm/Parazone/Helmquat 3SL @ 32 oz/A + 2,4-D **amine** 3.8SC @ 16-24 oz/A + COC (1.0% v/v). If cotton is nearby and drift is a concern, consider using Clarity 4SL @ 8 oz/A instead of 2,4-D. Delay planting of small grains for at least 10 days for each 16 oz/A of 2,4-D applied or 15 days for each 8 oz/A of Clarity applied.
- 3) If residual control is desired and a small grain will **not** be planted in the fall, Dual Magnum/ Stalwart, etc. @ 1 pt/A can be included with the burndown treatment.
- 4) In dairy situations (*i.e. no rotations with peanuts, soybeans, and cotton: no overuse of PPO herbicides*), Valor 51WG (2 oz/A) can be used for the residual control of Palmer amaranth after field corn harvest. Wheat can be planted 30 days after application (*need 1" rainfall/irrigation after application*), cereal rye and barley can be planted 3 months after application, and ryegrass can be planted 4 months after application (with tillage). Valor can be tank-mixed with paraquat.

It is important to remember that viable Palmer amaranth seed can be produced within 2 weeks after pollen shed. Thus, control strategies need to be implemented before this time to be effective in reducing weed-seed rain back into a field.

Table 4. Herbicide Programs for Managing Palmer Amaranth in Grain Sorghum.

Preemergence ¹	Postemergence ² (over the top)	Postemergence ³ (Directed Spray)	Hooded Sprayer
Dual Magnum or Warrant	1) Atrazine 2) Huskie + Atrazine	2,4-D or Clarity	Gramoxone SL or Firestorm or Parazone or Helmquat

¹Must use Concep treated seed. ²3-leaf sorghum up until 12" in height. ³8-15" tall sorghum.

Table 5. Herbicide Programs for Managing ALS-Resistant Palmer Amaranth in Peanut.¹

Preplant Incorporated	Preemergence ²	Cracking or early postemergence ³ (Palmer < 3 in.)	Postemergence ⁴ (Palmer < 3 in.)
Prowl ⁵ or Sonalan	Valor ⁹ or Spartan Charge ^{6,7}		Cobra ⁷ or Ultra Blazer ⁷ + Dual Magnum ⁸ or Warrant ⁸ + 2,4-DB
Prowl ⁵ or Sonalan		Gramoxone SL or Firestorm or Parazone or Helmquat + Storm + Warrant or Dual Magnum ⁸	Cobra ⁷ or Ultra Blazer ⁷ + Dual Magnum ⁸ or Warrant ⁸ + 2,4-DB

¹ALS-resistant Palmer amaranth is a very serious concern. An aggressive management program is necessary to slow spread of the resistant biotypes and to reduce selection pressure in areas currently not infested with resistant biotypes. A combination of soil residual and postemergence herbicides will be required for optimum control.

²Strongarm is not included in this table because it is an ALS-inhibiting herbicide. However, it can be used for the control of other broadleaf weeds.

³Apply cracking or early postemergence treatment only if weeds have emerged.

⁴Cadre may be tank-mixed with Cobra or Ultra Blazer if needed for control of other weed species. Cadre is an ALS- inhibitors. Because of concerns with weed resistance to ALS-inhibitors, a mixture of Cobra or Ultra Blazer with Cadre would be preferred over Cadre alone. When using Cadre , follow all labeled crop rotation restrictions.

⁵Generic brands of Prowl (pendimethalin) are available and perform similarly. Prowl or Sonalan can be used preemergence if 0.5-0.75" of water can be applied within 48 hours of application. They can be tank-mixed with Valor or Spartan Charge in this situation.

⁶If Valor or Spartan Charge is properly activated with 0.5-0.75" of rainfall or irrigation within 7 days of application, it is unlikely that an "at-cracking" treatment will be required. However, if control with Valor or Spartan Charge is unacceptable, an "at-cracking" treatment of Gramoxone Inteon or Firestorm or Parazone + Storm + Dual Magnum or Warrant should be applied.

⁷Valor, Cobra, Spartan Charge, Storm, and Ultra Blazer have the same mode of action (PPO inhibitor). Consequently, no more than 2 applications of these herbicides should be used in a season.

⁸Generic brands of metolachlor are available (Stalwart, Parallel PCS, Me-Too-Lachlor). However, these generic brands have not provided the same length of residual control as Dual Magnum (S-metolachlor) in some UGA field trials. When tank-mixing paraquat, Cobra or Ultra Blazer with Dual Magnum/generics, additional spray adjuvants (NIS, COC) are not recommended and will likely increase peanut injury. When using Warrant with POST application, add NIS.

⁹Generic formulations of Valor 51WG (flumioxazin) are also available including Outflank, Panther, Red Eagle-Flumioxazin, and Rowel. Panther SC and Valor EZ are liquid formulations of flumioxazin but these formulations have not yet been adequately tested by UGA weed scientists. The Red Eagle flumioxazin has also not been tested by UGA

SPECIAL NOTE: Dual Magnum and Warrant are in the same herbicide family and have the same mode of action (inhibit very long chain fatty acids). Multiple applications (> 2) of these herbicides in a single year should be avoided to prevent or delay the evolution of resistance. These herbicides have no postemergence activity.

Table 6. Herbicide Programs for Managing Glyphosate/ALS-Resistant Palmer Amaranth and Delaying PPO/VLCFA Resistance in Soybeans.¹

Soybean Variety	Program	Preemergence ²	Postemergence ^{3,4}
Roundup Ready	1	TriCor/Metribuzin; or Canopy/Cloak ⁵ ; or Authority MTZ ^{7,13}	glyphosate + Reflex ^{7,20} ; or glyphosate + Prefix ^{7,8} or Warrant Ultra ¹⁷ ; or Flexstar GT ^{7,10}
	2	Boundary ⁶	glyphosate + Reflex ^{7,20} ; or Flexstar GT ^{7,10}
	3	Prowl; or Dual Magnum ¹⁵ ; or Warrant ¹⁵ or Zidua ¹⁵ or Anthem ^{15,17}	glyphosate + Reflex ^{7,20} ; or Flexstar GT ^{7,10}
	4	Valor; or Envive ^{7,11} ; or Authority XL ^{7,14} ; or Fierce ^{7,16} or Survey ²²	glyphosate + Warrant ¹⁵ or Dual Magnum ¹⁵ or Zidua ¹⁵ ; or Sequence ⁹
Liberty-Link	1	Prowl; or Dual Magnum ¹⁵ ; or Warrant ¹⁵ ; or Zidua ¹⁵ or Anthem ^{15,17}	Liberty ¹⁹ + Reflex ^{7,20}
	2	Valor ; or Envive ^{7,11} ; or Authority XL ^{7,14} ;or Fierce ^{7,16} ; or Survey ²²	Liberty ¹⁹ + Dual Magnum ¹⁵ or Warrant ¹⁵ or Zidua ¹⁵ or Anthem ^{15,17}
Dicamba-Tolerant	1	Valor; or Fierce ^{7,16} ; or Envive ^{7,11} , or Authority XL ^{7,14} ; or Canopy ⁵ ; or Boundary ⁶ ; or Survey ²²	Xtendimax ²¹ or Engenia ²³ - repeat application in 7 days (pigweed) or follow with glyphosate (grasses). Dual or Warrant can be tank-mixed with glyphosate for increased residual pigweed control. For a current list of approved tank-mix partners for Xtendimax or Engenia, refer to the following: www.xtendimaxapplicationrequirements.com www.engeniatankmix.com
	2	Dual Magnum ¹⁵ or Warrant ¹⁵ or Zidua ¹⁵	Xtendimax ²¹ or Engenia ²³ – repeat application in 7 days (pigweed) or follow with glyphosate (grasses). Reflex can be tank-mixed with glyphosate for increased burndown/residual pigweed control. For a current list of approved tank-mix partners for Xtendimax or Engenia, refer to the following: www.xtendimaxapplicationrequirements.com www.engeniatankmix.com
Conventional	1	TriCor/Metribuzin; or Canopy ⁵ ; or Authority MTZ ^{7,13} (<i>include Prowl for grass control</i>)	Reflex ^{7,20} , or Ultra Blazer ⁷ + Dual Magnum ¹⁵ or Warrant ¹⁵ ; or Cobra ⁷ + Dual Magnum ¹⁵ or Warrant ¹⁵ ; or Prefix ^{7,8} or Warrant Ultra ¹⁷
	2	Boundary ⁶	Reflex ^{7,20}
	3	Prowl; or Dual Magnum ¹⁵ ; or Warrant ¹⁵ ; or Zidua ¹⁵ or Anthem ^{15,17}	Reflex ^{7,20}

¹Glyphosate- and ALS-resistant Palmer amaranth are very serious concerns. An aggressive management program is necessary to slow spread of resistant biotypes and to reduce selection pressure in areas currently not infested with resistant biotypes.

²Generic brands of Prowl (pendimethalin) are available and perform similarly. When using Authority MTZ, Boundary, TriCor/Metribuzin or Canopy, follow label for appropriate rates, soil pH restrictions, and soybean variety tolerance. Dryland growers should consider mechanically incorporating Authority MTZ, Metribuzin, Canopy, Boundary, and Prowl. If mechanically incorporating herbicides, Treflan can be used instead of Prowl if preferred. If Envive or Authority XL are used, consider planting an STS/ST soybean variety to help minimize potential early-season Classic injury caused by cool, wet weather.

³**Postemergence applications MUST be made before the largest Palmer amaranth plant in the field exceeds 3" in height. If a preemergence herbicide is used but not moisture activated, this could occur as early as 10-14 days after planting depending upon the time of year. Palmer amaranth plants can grow from 1-3" per day.** When applied in combination with glyphosate, use either 16-24 oz/A of Reflex, 24 oz/A of Ultra Blazer, or 12.5 oz/A of Cobra.

⁴If residual herbicides are activated by a timely rainfall or irrigation event, a second postemergence application may not be needed. The total amounts of these herbicides that can be applied per acre per year are as follows: Cobra - 25 oz/A; Reflex – 24 oz/A; and Ultra Blazer – 32 oz/A. Reflex may be preferred because of residual control of Palmer amaranth. On Roundup Ready soybean, glyphosate can be included in the second application if needed for the control of other weeds.

⁵Canopy/Cloak is a pre-mixture of metribuzin + chlorimuron (Classic).

⁶Boundary is a pre-mixture of metribuzin and S-metolachlor (Dual Magnum).

⁷Authority MTZ, Authority XL, Cobra, Envive, Flexstar GT, Prefix, Reflex, Ultra Blazer, Valor, Valor XLT, and Fierce have the same mode of action (PPO inhibitor). More than 1 application of these herbicides in a single season should be avoided if at all possible to prevent/delay the development of PPO resistance.

⁸Prefix is a pre-mixture of fomesafen (Reflex) and S-metolachlor (Dual Magnum).

⁹Sequence is a pre-mixture of glyphosate and S-metolachlor (Dual Magnum). **Sequence will not control emerged glyphosate-resistant pigweed.**

¹⁰Flexstar GT is a pre-mixture of fomesafen (Reflex) and glyphosate (Touchdown).

¹¹Envive is a pre-mixture of chlorimuron (Classic), flumioxazin (Valor) and thifensulfuron (Harmony).

¹²Valor XLT is a pre-mixture of flumioxazin (Valor) and chlorimuron (Classic).

¹³Authority MTZ is a pre-mixture of sulfentrazone (Spartan) and metribuzin.

¹⁴Authority XL is a pre-mixture of sulfentrazone (Spartan) and chlorimuron (Classic).

¹⁵Dual Magnum and Warrant are members of the same herbicide family (chloroacetamide) and have the same mode of action (inhibit very long chain fatty acids). Multiple applications (>2) of these herbicides in a single year should be avoided to prevent or delay the evolution of resistance. Anthem and Zidua are not in the same herbicide family as Dual or Warrant but do have the same mode of action. These herbicides have no postemergence activity except Anthem.

¹⁶Fierce is a pre-mixture of flumioxazin (Valor) and pyroxasulfone (Zidua)

¹⁷Anthem is a pre-mixture of pyroxasulfone (Zidua) + fluthiacet (Cadet).

¹⁸Warrant Ultra is a pre-mixture of fomesafen (Reflex) and acetochlor (Warrant)

¹⁹Generic formulations of glufosinate are also available including Cheetah, Kong, and Interline. Cheetah Max is a combination of glufosinate + fomesafen. Generic

formulations of glufosinate should be used with caution because limited data has been collected by UGA.

²⁰Generic formulations of Reflex 2SL (fomesafen) are also available including Dawn and TopGun. Sinister contains 2.87 lb ai/gal of fomesafen.

²¹Xtendimax with Vapor Grip Technology (dicamba-DGA).

²²Surveil is a pre-mixture of flumioxazin (Valor) + chloransulam (FirstRate).

²³Engenia (dicamba-BAPMA)

SOYBEAN VARIETY TOLERANCE TO METRIBUZIN HERBICIDES

Soybean varieties that have exhibited acceptable tolerance to metribuzin herbicides (i.e. Authority MTZ, Boundary, Canopy, TriCor, etc.) based on multiple sources include the following:

Group IV	Group V	Group VI	Group VII	Group VIII
Asgrow AG42X6	Asgrow AG53X6	Asgrow AG6931	AGS 758RR	
Asgrow AG4336	Asgrow AG5535	Asgrow AG69X6	Asgrow AG7231	
Asgrow AG44X6	Asgrow AG5732	Pioneer P67T90R2	Asgrow AG7535	
Asgrow AG45X6	Asgrow AG5831	Southern States 6810NR2	Benning	
Asgrow AG47X6	AGS 568RR	Vigoro V61N9	Northrup King NK-74M3	
Pioneer 94Y23	Hutcheson	Northrup King NKS-67R6	Northrup King NK-78G6	
Pioneer P42T71PR	Pioneer 95Y70		Pioneer P73T38X	
Pioneer P43T14L	Pioneer P50T15BR		Pioneer P76T54R2	
Pioneer P44T82SR	Pioneer P50T56X		Santee	
Pioneer P45T39L	Pioneer P50T92X		Stonewall	
Pioneer P45T48R	Pioneer P53T18X		Southern States 7215NSR2	
Pioneer 45T74X	Pioneer P53T62L		Vigoro V74N9	
Pioneer 46T01R	Pioneer P52T73SR		Woodruff	
Pioneer P46T30X	Pioneer P55T81R			
Pioneer P46T59R	Pioneer P56T03R2			
Pioneer P47T44X	Pioneer P56T12SR			
Pioneer P48T27X	Pioneer P56T29R2			
Pioneer 49T09BR	Southern States 5215NSR2			
Pioneer 49T31L	Southern States 5511NR2			
Southern States LL423N	Southern States 5615NR2			
Southern States 4514NR2				
Southern States LL473N				
Southern States 4714NSR2				

** Metribuzin herbicides are NOT recommended for use on sands or other coarse soils with less than 1% OM.

*****METRIBUZIN HERBICIDE SHOULD NOT BE USED ON THE FOLLOWING SOYBEAN VARIETIES: Asgrow AG4232, AG4835, AG49X6, AG5332, AG5935, AG6130, AG6730, AG75X6, AG7934; AGS LL5911; Pioneer P47T06X, P47T36R, P48T53R, P49T80R, P49T97R, P60T95X, P67T25R2; Southern States LL511N and LL595N.**