Texas A&M AgriLife 2019
Bushland Corn and Sorghum Herbicide Trials
and
Herbicide Management for the Texas High Plains

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Introduction

Weeds rob essential water and nutrients from the primary crop necessary to optimize yields. In the Texas High Plains, more than 50% of the yearly water requirement for corn and sorghum is supplemented by irrigation from the declining Ogallala Aquifer. Consequently, timely weed control is essential to enhance crop water use efficiencies and crop yields. Herbicides are recognized as a method to enhance crop water use by eliminating weeds and competition for resources. Resistant and herbicide tolerant weed species have become a problem in the Texas High Plains. Hard to control weeds require critical evaluation of herbicide programs that include preplant burndown and residual herbicides as well as in-season herbicide applications.

Management decisions are magnified by the expense of herbicide applications, so university trials are conducted to evaluate commercially available herbicides and provide producers information about weed control under regional conditions. This publication includes herbicide tank-mixes evaluated in corn and sorghum herbicide trials at the Texas A&M AgriLife James Bush Research Farm at Bushland, Texas, and corn and sorghum herbicides marketed for Texas High Plains production. The listed herbicides are registered with the Environmental Protection Agency (EPA) and approved for use on corn and sorghum in Texas.

Section 1: Texas A&M AgriLife Bushland Corn and Sorghum Herbicide Trials

Corn Trials

Herbicide treatments evaluated in the 2019 corn herbicide trials were provided by industry partners AmVac, Bayer, Corteva, FMC, Summit, and Syngenta. All treatments were replicated using the same corn hybrid P0157AM(LLRR2AQ) at the Texas A&M AgriLife James Bush Research Farm at Bushland, Texas to evaluate crop injury and weed control. Plots were fertilized for a predetermined yield goal based on soil test results performed prior to planting, and plots were irrigated at a deficit rate throughout the growing season. Plots were sprayed at a total spray volume of 15 gallon/acre (GAC), with a Lee Agra Spider broadcast sprayer using flat-fan nozzles at 40 PSI. All treatments were assessed against an untreated check to evaluate herbicide efficacy. Crop injury was assessed as a percent average of all replicated plots. Reported weed control ratings are an average of ratings for all plots at a specified number of days after application.

Sorghum Trials

Sorghum pre and post emergent herbicide treatments were also evaluated in the 2019 trials adjacent to the corn trials. Funding was provided by the United Sorghum Checkoff Program. All treatments were replicated using the same grain sorghum hybrid DKS3707, to evaluate crop injury and weed control. Plots were fertilized, irrigated at a deficit rate, and sprayed using the same volume and sprayer as the corn herbicide plots. Treatments were assessed against an untreated check, crop injury was assessed as a percent average of all replicated plots and reported weed control ratings are an average of ratings for all plots at a specified number of days after application, just as the corn plots.

Weed Species Targeted

Primary weeds targeted in the Bushland herbicide trials included broadleaf weeds: redroot pigweed (*Amaranthus retroflexus*), Palmer Amaranth (*Amaranthus palmeri*), tumble pigweed (*Amaranthus albus*), kochia (*Kochia scoparia*), Russian thistle (*Salsola ibercia*), and grassy weeds: barnyardgrass (*Echinochloa crus-galli*), windmill grass (*Chloris verticillata*),

and witchgrass (Panicum capillare).

In 2019, corn herbicide plots were established in April and the primary weed pressure was Amaranthus species, while in 2018, weed pressure was mainly kochia, thereby providing an opportunity to evaluate pre and post emergent herbicide control on both weed species across different years. Sorghum herbicide plots were established in late June and weed pressure was mainly the Amaranthus species.

Acknowledgements
We gratefully acknowledge and appreciate the assistance of students Layney Miller-Reynolds, Mattie Brooks, and Shelby Lain with herbicide applications and plot maintenance.

Table 1. 2019 Corn Herbicide Trials

Primary Company Protocol	Treatment	Rate in ai/a	Application Timing	Crop Injury Days After First/Last Application	% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application		
					Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds
					28 Days			50 Days		
AmVac	ImpactZ	8 fl oz/a	1 shot post crop/post weeds 2"- 4"	0 @ 7, 28, 50 Days	100	100	100	100	100	100
	Roundup PowerMax	28 fl oz/a								
	Atrazine	1 qt/a								
	MSO	0.25% v/v								
	N-Pak AMS Liquid	2.5% v/v								
					28 Days			50 Days		
AmVac	ImpactZ	8 fl oz/a	1 shot post crop/post weeds 2"- 4"	0 @ 7, 28, 50 Days	100	98	100	100	98	100
	Roundup PowerMax	28 fl oz/a								
	Chinch	21 fl oz/a								
	Atrazine	1 qt/a								
	MSO	0.25% v/v								
	N-Pak AMS Liquid	2.5% v/v								
					28 Days			50 Days		
AmVac	ImpactZ	8 fl oz/a	1 shot post crop/post weeds 2"- 4"	0 @ 7, 28, 50 Days	100	98	100	100	98	100
	Roundup PowerMax	28 fl oz/a								
	DiFlexx	6 fl oz/a								
	Atrazine	1 qt/a								
	MSO	0.25% v/v								
	N-Pak AMS Liquid	2.5% v/v								
					28 Days			50 Days		
AmVac	Laudis	3 fl oz/a	1 shot post crop/post weeds 2"- 4"	0 @ 7, 28, 50 Days	100	100	100	100	100	100
	DiFlexx	6 fl oz/a								
	Roundup PowerMax	28 fl oz/a								
	Atrazine	1 qt/a								
	MSO	0.25% v/v								
	N-Pak AMS Liquid	2.5% v/v								
					28 Days			50 Days		
AmVac	Acuron	1.5 qt/a	1 shot post crop/post weeds 2"- 4"	0 @ 7, 28, 50 Days	100	99	100	100	99	100
	N-Pak AMS Liquid	2.5% v/v								
	Roundup PowerMax	28 fl oz/a								
					28 Days			50 Days		
Corteva	Resicore	2.5 qt/a	Pre at planting	0 @ 7, 28, 50 Days	100	100	100	100	100	100
	Atrazine	1 qt/a								
	Durango DMA	32 fl oz/a								
	AMS	2.5% v/v								
					28 Days			50 Days		
Corteva	Resicore	1.25 qt/a	Pre at planting	0 @ 7, 28, 50 Days	100	100	100	100	100	100
	Atrazine	1 pt/a								
	Resicore	1.25 pt/a	Early post weeds 2"-4" Corn V2-V4							
	Atrazine	1 pt/a								
	Durango DMA	32 fl oz/a								
	AMS	2.5% v/v								

Table 1. 2019 Corn Herbicide Trials Continued

Primary Company Protocol	Treatment	Rate in ai/a	Application Timing	% Crop Injury Days After First/Last Application	% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application		
					Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds
Bayer	Balance Flexx	3 fl oz/a	Pre at planting	0 @ 7, 28, 50 Days	28 Days			50 Days		
	Aatrex	1 qt/a			100	100	100	100	100	100
	Warrant	64 fl oz/a	Early post weeds 2"- 4" Corn V2-V4							
	Aatrex	1 pt/a								
	Roundup PowerMax	32 fl oz/a								
	SuperB HC	0.5% v/v								
	AMS	1% v/v								
Bayer	Balance Flexx	3 fl oz/a	Pre at planting	0 @ 7, 28, 50 Days	28 Days			50 Days		
	Aatrex	1 qt/a			100	100	100	100	100	100
	Laudis	3 fl oz/a	Early post weeds 2"- 4" Corn V2-V4							
	Aatrex	1 pt/a								
	Warrant	48 fl oz/a								
	Roundup PowerMax	32 fl oz/a								
	Diflexx	8 fl oz/a								
	SuperB HC	0.5% v/v								
	AMS	1% v/v								
Bayer	Balance Flexx	3 fl oz/a	Pre at planting	0 @ 7, 28, 50 Days	28 Days			50 Days		
	Aatrex	1 qt/a			100	100	100	100	100	99
	Warrant	48 fl oz/a								
	Laudis	3 fl oz/a	Early post weeds 2"- 4" Corn V2-V4							
	Aatrex	1 pt/a								
	Roundup PowerMax	32 fl oz/a								
	SuperB HC	0.5% v/v								
	AMS	1% v/v								
Bayer	Balance Flexx	3 fl oz/a	Pre at planting	0 @ 7, 28, 50 Days	28 Days			50 Days		
	Warrant	40 fl oz/a			100	100	100	100	100	100
	Laudis	3 fl oz/a	Early post weeds 2"- 4" Corn V2-V4							
	Warrant	40 fl oz/a								
	Roundup PowerMax	32 fl oz/a								
	SuperB HC	0.5% v/v								
	AMS	1% v/v								
Bayer	Balance Flexx	3 fl oz/a	Pre at planting	0 @ 7, 28, 50 Days	28 Days			50 Days		
	Aatrex	1 qt/a			100	100	100	100	100	100
	Laudis	3 fl oz/a	Early post weeds 2"- 4" Corn V2-V4							
	Aatrex	1 pt/a								
	Roundup PowerMax	32 fl oz/a								
	SuperB HC	0.5% v/v								
	AMS	1% v/v								
Bayer	Resicore	40 fl oz/a	Pre at planting	0 @ 7, 28, 50 Days	28 Days			50 Days		
	Aatrex	1 pt/a			100	100	100	100	100	100
	Resicore	40 fl oz/a	Early post weeds 2"- 4" Corn V2-V4							
	Aatrex	1 pt/a								

Table 1. 2019 Corn Herbicide Trials Continued

Primary Company Protocol	Treatment	Rate in ai/a	Application Timing	Crop Injury Days After First/Last Application	% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application		
					Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28 & 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Anthem Maxx	4 fl oz/a	Pre at planting							
	Balance Flexx	3 fl oz/a								
	Atrazine	1 qt/a								
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28 & 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Anthem Maxx	4 fl oz/a	Pre at planting							
	Mesotrione	3 fl oz/a								
	Atrazine	1 qt/a								
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28 & 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Anthem Flex	4.5 fl oz/a	Pre at planting							
	Mesotrione	3 fl oz/a								
	Atrazine	1 qt /a								
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28 & 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Resicore	2.5 pt/a	Pre at planting							
	Atrazine	1 qt/a								
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28 & 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Anthem Maxx	4 fl oz/a	Pre at planting							
	Mesotrione	3 fl oz/a								
	Atrazine	1 qt/a								
	Status	4 fl oz/a	Early post weeds 2"-4" Corn V2-V4							
	Herbimax COC	1 % v/v								
	AMS	2.5% v/v								
	Roundup PowerMax	40 fl oz/a								
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28 & 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Anthem Flex	4.5 fl oz/a	Pre at planting							
	Mesotrione	3 fl oz/a								
	Atrazine	1 qt/a								
	Status	4 fl oz/a	Early post weeds 2"-4" Corn V2-V4							
	Herbimax COC	1 % v/v								
	AMS	2.5% v/v								
	Roundup PowerMax	40 fl oz/a								
FMC	Crusher	2 fl oz/a	10 Day Pre plant	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Herbimax COC	1 % v/v			100	100	100	100	100	100
	Resicore	1.25 pt/a	Pre at planting							
	Atrazine	1 qt/a								
	Resicore	1.25 pt/a	Early post weeds 2"-4" Corn V2-V4							
	Atrazine	1 qt/a								
	Roundup PowerMax	40 fl oz/a								

Table 1. 2019 Corn Herbicide Trials Continued

Primary Company Protocol	Treatment	Rate in ai/a	Application Timing	Crop Injury Days After First/Last Application	% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application		
					Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds
Summit	Bicep Lite II Magnum	10 fl oz/a	Pre At planting	0 @ 14, 28 & 50	28 Days			50 Days		
					80	100	100	77	100	100
Summit	Bicep Lite II Magnum	10 fl oz/a	Early post weeds 2"-4" Corn V2-V4	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Shieldex	1 fl oz/a			100	100	100	100	100	100
	AMS	1 % v/v								
	Atrazine	1 pt/a								
Summit	Bicep Lite II Magnum	10 fl oz/a	Pre At planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Shieldex	1.3 fl oz/a	Early post weeds 2"-4" Corn V2-V4		100	100	100	100	100	100
	AMS	1 % v/v								
	MSO	1 % v/v								
	Atrazine	1 pt/a								
Summit	Bicep Lite II Magnum	10 fl oz/a	Pre at planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Impact	1 fl oz/a	Early post weeds 2"-4" Corn V2-V4		100	100	100	100	100	100
	AMS	1 % v/v								
	MSO	1 % v/v								
	Atrazine	1 pt/a								
Summit	Bicep Lite II Magnum	10 fl oz/a	Pre at planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Laudis	3 fl oz/a	Early post weeds 2"-4" Corn V2-V4		100	100	100	100	100	100
	AMS	1 % v/v								
	MSO	1 % v/v								
	Atrazine	1 pt/a								
Summit	Bicep Lite II Magnum	4 fl oz/a	Pre at planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Calisto	3 fl oz/a	Early post weeds 2"-4" Corn V2-V4		100	100	100	100	100	100
	AMS	1 % v/v								
	NIS 100%	0.25 % v/v								
	Atrazine	1 pt/a								
Syngenta	Acuron	1.5 qt/a	Pre at planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Acuron	1.5 qt/a	Post Corn V2-V4 Weeds 2-4"							
	N-Pac AMS	2.5% v/v								
	Roundup PowerMax	32 fl oz/a			100	100	100	100	100	100
Syngenta	Acuron	1.25 pt/a	Pre at planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Halex GT	4 pt/a	Post Corn V2-V4 Weeds 2-4"		100	100	100	100	100	100
	Aatrex 4L	1 pt/a								
	Induce	0.25 % v/v								
	N-Pac AMS	2.5 %v/v								
Syngenta	Balance Flexx 2 SC	3 oz/a (1/2 rate)	Pre at planting	0 @ 14, 28, 50 Days	28 Days			50 Days		
	Aatrex 4L	1 pt/a			93	100	100	90	100	100
	Roundup Powermax	32 oz/a	Post Corn V2-V4 Weeds 2-4"							
	N-Pac AMS	2.5 % v/v								

Table 2. 2019 Bushland Sorghum Preemergence at Plant Herbicide Trials

Treatment	Rate in ai/a	Crop Injury Days After First/Last Application	% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application		
			Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds
			15 Days			29 Days			57 Days		
Atrazine	1 pt/a	0 @ 15, 29 & 57	100	100	100	100	100	100	100	100	100
Bicep II Magnum	1.6 qt/a	0 @ 15, 29 & 57	100	100	100	100	97	100	100	98	100
Bicep Lite II Magnum	1.5 qt/a	0 @ 15, 29 & 57	100	100	100	100	100	100	100	98	100
Degree Xtra	2.25 qt/a	0 @ 15, 29 & 57	100	100	100	100	100	100	100	98	100
Dual Magnum	1.5 pt/a	0 @ 15, 29 & 57	100	100	100	100	97	100	98	95	100
Dual Magnum	1 pt/a	0 @ 15, 29 & 57	100	100	100	100	93	100	93	92	83
Me-Too- Lachlor	1.43 pt/a	0 @ 15, 29 & 57	100	100	100	100	83	100	83	73	100
Me-Too- Lachlor	0.95pt /a	0 @ 15, 29 & 57	100	80	100	100	88	100	100	57	100
Warrant	2 qt/a	0 @ 15, 29 & 57	100	100	100	100	98	100	90	93	100
Verdict	10 oz/a	0 @ 15, 29 & 57									
Outlook	10 oz/a		100	100	100	100	93	100	97	88	100
Callisto	6 oz/a	0 @ 15, 29 & 57									
Atrazine	1.5 pt/a		100	100	100	100	100	100	100	99	100
Dual Magnum	1.5 pt/a										
Valor (14 day prepl)	2 fl oz/a	0 @ 15, 29 & 57	100	100	100	100	98	97	100	98	83

Table 3. 2019 Bushland Sorghum Postemergence Herbicide Trials

Treatment	Rate in ai/a	Application Timing	Crop Injury Days After First/Last Application	% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application			% Weed Control Days After First/Last Application		
				Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds	Kochia	Amaranth	Grass Weeds
Dual Magnum	1.5 pt/a	Pre at plant	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Dual Magnum	1 pt/a	Late post weeds 6"-10"		100	100	100	100	28	75	100	3	75
Atrazine	1 qt/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
COC	1.7 % v/v			100	85	88	100	60	88	100	58	38
Clarity	2 fl oz/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Atrazine	1 qt/a			100	80	63	100	77	50	100	77	17
COC	1.7 % v/v											
Clarity	4 fl oz/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Atrazine	1 qt/a			100	76	75	100	77	100	100	80	67
COC	1.7 % v/v											
Clarity	8 fl oz/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
NIS	1 % v/v			100	65	100	100	58	25	100	78	25
Huskie	13 fl oz/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
NIS	0.25 %			100	50	100	100	45	25	100	63	38
AMS	1 % v/v											
Huskie	13 fl oz/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Clarity	4 fl oz/a			100	80	75	100	68	75	100	81	63
NIS	0.25 %											
AMS	1 % v/v											
Huskie	13 fl oz/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Atrazine	1 pt/a			100	100	93	100	84	25	100	90	30
NIS	0.25 %											
AMS	1 % v/v											
Prowl H2O	2 pt/a	Early post weeds 2"-4" Corn V2-V4	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
				100	0	100	100	5	100	100	10	100
Moccasin II Plus	1.5 pt/a	Early post weeds 2"-4" Corn V2-V4	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
				100	0	100	100	0	100	100	0	100
Coyote	1.5 qt/a	Early post weeds 2"-4"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
COC	1% v/v			100	33	100	100	15	100	100	20	100
AMS	1% v/v											
Huskie	13 fl oz/a	Late post weeds 6"-10"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Atarazine	1 pt/a			100	0	100	100	58	50	100	68	50
NIS	0.25 %											
AMS	1 % v/v											
Moxy	1 pt/a	Late post weeds 6"-10"	0 @ 15, 30 & 56		15 Days			30 Days			56 Days	
Atrazine	1 pt/a			100	10	100	100	38	88	100	43	88
Clarity	2 fl oz/a											

Table 4. Rotational Intervals of Herbicides Evaluated in the Bushland Herbicide Trials

Active Ingredient	Manufacturer	Corn	Cotton	Sorghum	Wheat
		months unless interval noted differently*			
2,4-D amine	Alligare	7 days	1	7 days	7 days
Aatrex	Syngenta	0	12	0	12
Acuron	Syngenta	0	10	10	4
Afforia	Corteva	2 wks-4 mos.	1 to 2	1	1 to 2
Anthem Max	FMC	0	4	11 to 18	4 to 6
Armezon Pro	BASF	0	9	9	18
Atrazine	Syngenta	0	12	0	12
Authority MTZ	FMC	4 to 18	12 to 18	12 to 18	4
Balance Flexx	Bayer	0	10	6	4
Basis Blend	Corteva	0	1	10	3
Bicep II	Syngenta	0	12	0	12
Callisto	Syngenta	0	10	0	4
Caprino	Bayer	0	10	10	4
Cinch ATZ	Corteva	0	12	0	4.5
Clarity	BASF	0 to 4	1 to 4	0.5 to 4	1
Diflexx Duo	Bayer	0	10	0	4
Dual II Magnum	Syngenta	0	0	0	4.5
Durango	Corteva	0	0	0	0
Facet L	BASF	10	10	0	0
Gramoxine Inteon	Syngenta	0	0	0	0
Halex GT	Syngenta	0	10	0	4.5
Harness Xtra 5.6	Bayer	0	12	12	4
Huskie	Bayer	4	12	7 days	7 days
Impact	AmVac	0	9	9	3
ImpactZ	AmVac	0	12	9	12
Laudis	Bayer	0	10	10	4
Liberty 280SL	Bayer	0	0	6	2
Lumax	Syngenta	0	18	0	4.5
Keystone NTX	Corteva	0	12	0	4
Peak	Syngenta	1	10	0	0
Prequel	Corteva	1 to 10	18	10	4
Prowl	BASF	0	12	12	4
Realm Q	Corteva	0	10	10	4
Resicore	Corteva	0	12	10.5	4
Round-up Powermax	Bayer	0	0	0	0
Sequence	Syngenta	0	0	0	4.5
Sharpen	BASF	0	1.5 to 9	0 to 1	0 to 3
Solstice	FMC	0	10	0	4
Status	FMC	7 days	1	1	1
Sure Start II	Corteva	0	26	12	4
Verdict	BASF	0	1.5 to 12	0	4
Warrant	Bayer	0	0	0	4
Zemax	Syngenta	0	12	0	4.5
Zidua	BASF	0	1 to 4	6 to 12	0 to 6

***Ranges vary due to application rate, cummulative irrigation and/or precipitation, soil texture, and soil organic matter. Always check the label and follow label instructions. Brand names and companies are subject to change.**

Section 2: Herbicides and Management for the Texas High Plains

Safety Precautions

Precautions must be taken to ensure safe handling of herbicides. Applications of all herbicides must follow federal and state pesticide laws. Always apply according to the current label and check regularly for any changes or updates with supplemental labels. Use approved personal protective equipment, clothing, and the appropriate respirator if required, during mixing and application. Mix herbicides away from water sources to prevent water contamination. If chemigation is used, ensure that irrigation systems have anti-backflow devices, especially if broadcasting through center pivot systems. Triple rinse all equipment in accordance with label instructions. Many herbicides require additives including bleach, ammonia, or tank neutralizers as a component of the second rinse. Store and dispose of herbicides in accordance with EPA requirements and follow all label guidelines for storage of herbicides.

Herbicide Activity

The **site of absorption** is the location where the plant takes up the herbicide. The plant absorbs the herbicide through the root, shoot, or leaves. Preplant and preemergent herbicides are soil applied herbicides, which prevent germination of seeds as the seed imbibes in addition to absorption of the herbicide via the root and shoots. Absorption through the leaves is the common site of most post emergence herbicides. Herbicides can have more than one site of absorption. Labels list the primary site of absorption first followed by subsequent sites of absorption. Some herbicides are used for both pre-and post-emergence and are classified as R/L (roots/leaves), but the primary site of absorption, and generally most effective for weed kill, is the roots.

The **mode of action** describes how herbicides affect plant development. Damage to the plant occurs by absorption through the tissues and translocation through the plant parts. Classification of modes of action are numbered and correspond to the plant process effected.

Group 1 - Lipid Biosynthesis
Inhibitors Group 2 - Amino Acid
Biosynthesis Inhibitors Group 3 -
Cell Division Inhibitors
Group 4 - Synthetic Auxins (Growth
Regulators) Groups 5, 6, 7 -
Photosynthesis Inhibitors D1 Protein
Group 9 - EPSP Synthase Inhibitors

Group 13 – Pigment
Inhibitor Group 14 -
Pigment Inhibitors
Group 22 - Cell Membrane
Disruptors Groups 16, 17,
26 - Unknown

The **site of action** is the targeted location where the herbicide works or the biochemical pathway within the plant where the herbicide acts. For example, Groups 5, 6, and 7 have the same mode of action and are all photosynthesis inhibitors, but they differ at the site where they bind with a different amino acid to disrupt the synthesis of the D1 protein. Herbicides work by binding to proteins at specific sites. There are thirty sites of action recognized by the Weed Science Society of America (WSSA) and twenty-four letters denoting sites of action by the Herbicide Resistance Action Committee (HRAC). The HRAC established a group letter to classify herbicides by site of action, thereby using herbicides while minimizing weed resistance. If different herbicides share the same mode of action only one letter is used, and numbers are added as sub- scripts. The letters O, J, and Q are omitted to avoid confusion. The WSSA group number along with HRAC classification letter is usually found on the label or product information guide and should be consulted before applying any herbicide.

Managing Herbicides to Enhance Weed Control and Prevent Resistance

For proper weed management, several suggestions are listed below for long term sustainability of crops in well-managed fields.

1. Continually scout your fields and the fields around you. Misidentification of weed species can lead to improper treatments. Scout adjacent fields and roadsides for weeds which may end up in your fields, and especially after cultivation or herbicide applications. Control weeds on fallow ground, CRP grass pastures, and in bar ditches because resistance can develop, if weeds are not completely controlled. Control weeds you suspect of being resistant with an alternative herbicide or cultural practice before they go to seed.
2. Rotate crops and cropping systems.
3. Use cultural practices such as tillage, in conjunction with herbicide applications.
4. Burn down and control all weeds between rotations and at each application, thereby lowering the possibility for resistant weeds to populate.
5. Select and apply herbicides with different modes of actions. Applying the same herbicides repeatedly in the same year, or year after year applications of single mode of action herbicides, promotes resistance. Follow label recommendations to mix herbicides in the same tank to ensure compatibility.

6. Always use the recommended labeled rate, spray volume, nozzle and pressure at the correct stage to ensure good spray coverage. Poor spray coverage and subsequent control leads to escapes and/or partial "kill" that increases the risk of herbicide resistance.
7. Consult your local Extension Agent or Texas A&M AgriLife Research and Extension Center for advice if needed.

Application Timing

Preplant incorporated: applied to soil and mechanically incorporated into the top 2 to 3 inches of soil before the crop is planted
Preplant: applied to soil before the crop is planted
Preemergence: applied after the crop is planted but before it emerges
Postemergence: applied after crop emergence

Corn Growth Stages and Post Emergent Herbicide Timing

Post emergent herbicide applications are necessary for season long weed control. Post emergent corn herbicide labels define the latest growth stage for which herbicide applications can be made without causing crop injury. Herbicide applications past the recommended application stages can result in significant crop injury. For some herbicides, later applications can be made according to the label, but drop nozzles are recommended to prevent herbicides being sprayed in the whorl. Some herbicide labels provide a recommended height for the last herbicide application as plant height often corresponds with a particular vegetative stage. However, in high input environments with abundant irrigation and/or precipitation and fertility, internode distances can expand at a greater rate than new leaves. Consequently, plant height does not always correspond to the correct vegetative stage so, it is important to accurately stage the corn crop prior to making post emergent herbicide applications. In stressful production environments with limited water or cool temperatures, corn growth is slowed, which results in magnified crop injury because the plant does not metabolize the herbicide quickly enough to avoid injury. For labels that provide both plant height and growth stage, the applicator should follow the more conservative recommendation. Non-labeled spray adjuvants can enhance herbicide injury from a post emergent application. In addition to the crop stage and condition, knowledge of the weed species and weed size are also important for effective post emergent herbicide applications. The vegetative stages are described using the leaf collar method (Table 5). Leaves are counted from the lowermost first (rounded-tip) leaf to the uppermost leaf with a leaf collar, which is the connection between the leaf blade and the leaf sheath. The leaves in the whorl that are not fully expanded are not counted. Leaf stages are labeled as a "V" stage. (See images below)

Image reflecting first leaf with round tip. (image from Kay Ledbetter)

Image identifying the leaf collar. (image from Kay Ledbetter)

Table 5. Corn vegetative growth stages noted as "V" stages important for herbicide application timing.

Emergence(VE)	Coleoptile leaf (1st leaf) visible. This leaf will be shorter than later emerging leaves and has a rounded tip. Also referred to as spike.
	Growing point of the plant should be 1 to 1.75 inches below the soil surface. Seminal roots begin growing from the seed. Permanent (nodal) root system will begin developing at this point. If seed is planted too shallow the root system will have a difficult time becoming established.
2-Leaf (V2)	Collar of the 2nd true leaf is visible. Plant is still relying primarily on seed reserves for survival.
3-Leaf (V3)	Collar of 3rd leaf visible. Occurs approximately 10 to 14 days after emergence.
	Growing point below the soil surface. The plants total leaf number and ear shoot are developing in the stalk.
	Photosynthesis now very active and supporting the plant.
	May apply 2,4-D or dicamba from emergence through the 5th leaf stage without drop nozzles.
	Begin checking roots for Western corn rootworm larvae (white). Watch corn that is next to wheat or grass for Banks grass mites infesting lower surface of leaves.
4-Leaf (V4)	Collar of 4th leaf visible.
	Growing point below the soil surface.
	Roots are elongating. The roots system is nor primarily nodal roots.
	Weed competition will begin to significantly reduce yield potential.
5-Leaf (V5)	Collar of 5th leaf visible. May have lost the coleoptile leaf by this time.
	Leaf number and ear shoot formation is now complete.
	Plant is approximately 8 inches tall. Growing point is just below the ground surface. A hail or light freeze will cause little long-term damage to the plant. However, flooding while the growing point is below ground can kill the plant, especially if temperatures are high.
	The first internode to elongate is approximately 0.5 inch long and is located just below the node to which leaf 5 is connected. This is an important reference for crop growth staging.
	Tassel formation has been initiated.
6-Leaf (V6)	Collar of 6th leaf visible. Occurs approximately 3-weeks after emergence.
	Growing point and tassel above soil surface making the plant more vulnerable to a hail or freeze.
	Permanent root system rather than the seminal roots is now the primary root system supporting the plant. Root system extends approximately 18 inches.
7-Leaf (V7)	Collar of 7th leaf visible. Plant beginning to grow rapidly.
	The number of kernel rows being determined from V7 to V8. Maximum row set by V8.
8-Leaf (V8)	Collar of 8th leaf visible. Occurs approximately 45 days after emergence. Plants may have lost lower two leaves.
9-Leaf (V9)	Collar of 9th leaf visible. Ear shoots are visible in the leaf collar regions. May have up to 8 ear shoots.
	Tassel is rapidly developing.
10-Leaf (V10)	Collar of 10th leaf visible. New leaf stage occurring every 3 to 4 days.
	Water and nutrient demands are high.
11-Leaf (V11)	Collar of 11th leaf visible. May have lost lower three leaves.
12-Leaf (V12)	Collar of 12th leaf visible.
	Approximately 6 weeks after planting.
13-17 Leaves (V13-V17)	V17 is approximately 8 weeks after emergence.
	Leaf stages 13 to 17 will develop very rapidly. At some point the tip of the tassel will be visible.
	Early maturing hybrids progress from the 13-leaf stage through the 17-leaf stage faster than later maturing hybrids and have smaller ears.
	Brace roots developing from the 6th node.
Tassel (VT)	Tassel is fully emerged 2 to 3 days prior to silking.
	Plant is at full height and all leaves have emerged.

WSSA Number	Site of Action
1	ACCase = Acetyl-CoA Carboxylase Inhibitor
2	AHAS = Acetolactate Synthase Inhibitor
3	MT = Microtubule Assembly Inhibitor
4	GR = Growth Regulator (Synthetic Auxin)
5	PSII(A) = Inhibitor of photosynthesis at photosystem II site A
6	PSII(B) = Inhibitor of photosynthesis at photosystem II site B
7	PSII(B) = Inhibitor of photosynthesis at photosystem II site A; different behavior from group
8	SHT = Shoot Inhibitor (Inhibitor of lipid synthesis; not ACCase inhibition)
9	EPSPS = 5-enolypyruvyl-shikimate-3-phosphate synthase Inhibitor
10	GS = Glutamine Synthetase Inhibitor
11	CB = Inhibitor of carotenoid biosynthesis (unknown target)
12	PDS = Phytoene Desaturase Synthesis Inhibitor
13	DOXP = 1-deoxy-D-xyulose 5-phosphate sunthatase Inhibitor
14	PPO = Protoporphyrinogen oxidase Inhibitor
15	SHT/RT = Shoot and Root Inhibitor (Mitosis inhibitor)
16	Unknown
17	Unknown
18	DHP = 7,8-dihydro-preroate Synthesis Inhibitor
19	IA = Indoleacetic Acid Transport Inhibitor
20	CWA = Cell Wall Synthesis Inhibitor at site A
21	CWB = Cell Wall Synthesis Inhibitor at site B
22	ED = Photosystem 1 Electron Diverter
23	M = Mitosis Inhibitor
24	MD = Membrane Disruptor (uncouplers)
25	Unknown
26	Unknown
27	4-HPPD = 4-hydroxyhenyl-pyruvatedioxygenase Inhibitors
28	HPPD = hydroxyphenylpyruvate dioxygenase synthesis Inhibitor
29	CWC = Cell Wall Synthesis Inhibitor at site C
30	TA = Tyrosine Aminotransferase
	NC are several herbicides that are Not Classified

Herbicide Application Calculations

Proper mixing is the most important step in herbicide application and understanding how to calculate rates is critical. Use equations with fractions to make the appropriate proportions, ratios, or percentages, following the calculations in the 19th Edition of the Private Pesticide Applicator Training Manual and the Pesticide Environmental Stewardship recommendations for calculating herbicide mixes available at https://pesticidestewardship.org/calibration/doing-the-math/ .

To calculate the rate in question, express your rate question as a proportion. When using proportions to determine pesticide application rates, the units on the top and bottom of one ratio must match the units on top and bottom of the other ratio. The two examples below will illustrate:

How much herbicide do you need to apply to an area that is 270 acres, if the label indicates that 3 lbs. of granular herbicide are to be applied per acre?

Set up the equation and cross multiply

$$\frac{3 \text{ lbs}}{1 \text{ acre}} = \frac{n}{270 \text{ acres}}$$

1 x *n* = 3 x 270

1 *n* = 810

$$n = \frac{810}{1}$$

n = 810 lbs/270 acres

Proportions can be used when converting between square feet and acres.

How much herbicide is needed to treat 3 acres if the label rate is 2 oz per 1,000 sq.ft.

First convert area to square feet:

$$3 \text{ acres x } \frac{43{,}560 \text{ sq.ft.}}{\text{acre}} = 130{,}680 \text{ sq.ft.}$$

Then cross multiply to find out how many ounces:

$$\frac{2 \text{ oz}}{1000 \text{sq.ft.}} = \frac{n \text{ oz}}{130{,}680 \text{ sq.ft.}}$$

1,000 x *n* = 2 x 130,680 sq.ft.

1,000*n* = 261,360

$$n = \frac{261{,}360}{1000} = 261.4 \text{ oz}$$

Then convert ounces to quarts and gallons:

$$\frac{261.4 \text{ oz}}{\text{x qts}} = \frac{1 \text{ qt}}{32 \text{ ozs.}} = 8.2 \text{ qts}$$

Since there are 4 qt. in a gallon:

$\frac{8.2 \text{ qts}}{\text{x gal.}} = \frac{1 \text{ gal}}{4 \text{ qts}}$ = 2.04 gallons or 2 gal. and 5 oz.

Proportions can be used to convert from acres to square feet.

How much is herbicide is needed to treat 4,000 sq. ft. if the label rate is 3 quarts herbicide per acre?

As a first step, convert the label rate to match the square feet units

$\frac{3 \text{ qts.}}{43{,}560 \text{ sq.ft.}} = \frac{n \text{ qts.}}{4000 \text{ sq.ft.}}$

43,560 x *n* = 3 x 4,000

43,560*n* = 12,000

$n = \frac{12{,}000}{43{,}560} = 0.275$ qt.

Then convert quarts to ounces:

0.28 qt. x $\frac{32 \text{ oz.}}{\text{qt.}} = 9.28$ oz.

Multiplying Fractions

Calculations involving conversions from one unit of measure to another, can be done by multiplying fractions or setting up ratios. To solve, you need to target the units of measure desired in your answer, then use ratios to cancel out the units that are the same on top and bottom.

What is the flow rate in gallons per minute if 52 ounces of water were collected from a nozzle in one minute? (The units of measurement in your answer are gallons/minute.)

$\frac{52 \text{ oz.}}{\text{min}}$ x $\frac{1 \text{ gal}}{128 \text{ oz.}}$

Ounces are cancelled out:

$\frac{52}{128}$

resulting in gallons per minute in the final answer:

$\frac{0.41 \text{ gal}}{\text{min}}$

How many acres can be treated from a spray tank with a capacity of 300 gallons for an application rate of 25 gallons per acre?

The target units of measure in the answer are acres/tank

$$\frac{300 \text{ gal.}}{\text{tank}} \text{ X } \frac{1 \text{ acre}}{25 \text{ gal.}}$$

Gallons are cancelled, and the answer is in acres per tank:

$$\frac{300}{25} = 12 \text{ acres/tank}$$

To spray 50 acres with an herbicide labeled at 5 pints/acre in a spray application volume of 20 gallons per acre (GPA) how much herbicide is needed to apply the labeled spray volume on 50 acres?

Multiply the GPA by the number of acres that will be sprayed to find the total herbicide. Use the formula:

20 X 50 acres = 1000 gallons of herbicide mix or spray mix solution are needed.

At 5 pints per acre multiply 5 X 50 acres = 250 pints or 31.25 gallons of herbicide a.i. are needed.

1000 gallons total of spray mix solution – 31.25 gallons of herbicide a.i. = 968.75 gallons of water.

For percentages

To create a solution that is mixed with water at a specific percent solution, convert the percentage of concentrate in the final solution to a decimal before calculating the amount of concentrate to mix with water.

How to mix 5 gallons of a 3% pesticide solution in water?

1. Convert 3% to its decimal equivalent:
   $\frac{3}{100} = 0.03$

2. To determine the number of ounces of herbicide needed per gallon:
   Multiply the rate per gallon (0.03) by 128 (ounces in 1 gallon):

   $0.03 \times 128 = 3.84$ oz.

3. To determine the amount of herbicide needed: Multiply the amount of herbicide per gallon by the total spray mix:

   $\frac{3.84\text{oz.}}{\text{gal.}}$ x 5 gal. = 19.2 oz.

Adjuvants are typically added to herbicide mixtures based on a percentage of the final solution.

How much adjuvant should be added to 500 gallons of herbicide mixture if the adjuvant is used at 0.5 percent concentration by volume?

Convert to decimal: 0.5% = 0.005

500 gal. × 0.005 = 2.5 gal. adjuvant

* Herbicides and other ingredients of a liquid mixture should be considered a part of the total solution. For example, if you want to make 100 gallons of a 10% solution of an herbicide solution in water, you would add 10 gallons of herbicide concentrate to 90 gallons of water (10% of 100=10).

Calculating Commercial Products

Many recommendations state the application rate in amount of active ingredient (a.i.) per acre or 1,000 sq. ft. The active ingredient must then be converted to the actual product.

For dry formulations (wettable powders, granules and dusts) the amount of a.i. is expressed as a percentage of the weight.

$$\frac{\text{Amount a.i.}}{\%\ \text{a.i.(decimal)}} = \text{amount product}$$

How many lbs. of a.i. are in a 50-lb. bag of herbicide with the label stating 23WP where 23% is a.i.?

50 x 0.23 = 11.5 lbs.

A 50-pound bag of will have 11.5 pounds of active ingredient.

How much product is needed per acre for an herbicide that is 75WP applied at a rate of 2 lbs. a.i./acre?

$\frac{2\text{lbs.a.i./acre}}{0.75}$ = 2.66 lbs. of the 75 WP/acre

How much is needed to treat 15 acres?

$\frac{2.66\ \text{lbs.of 75WP}}{\text{acre}}$ x 15 acres = 39.9 lbs.

For liquid formulations (emulsifiable concentrates, EC and flowables, DF or F are liquids where the amount of active ingredient, a.i. is expressed as the weight in pounds per gallon of product.) This information is provided as part of the label.

$$\frac{\text{lbs. a.i.}}{\text{lbs. a.i./gal}} = \text{gal. product}$$

How many lbs. of a.i. in a 3-gallon jug of a 4 EC herbicide? (A 4EC product has 4 pounds a.i. in each gal.)

3 gal. × 4 lbs. a.i./gallon = 12 lbs. a.i.)

A 3 gal. jug of 4EC has 12 lbs. a.i.

How much product is needed per acre for a 4EC herbicide applied at a rate of 2 lb a.i./acre.

$$\frac{2 \text{ lbs.a.i./acre}}{4 \text{ lbs.a.}\frac{\text{i}}{\text{gal.}}} = 0.5 \text{ gal./acre}$$

How much is needed to treat 15 acres?

$$\frac{0.5 \text{ gal.}}{\text{acre}} \text{ x } 15 \text{ acres} = 7.5 \text{ gal.}$$

The correct formula needs to be used to calculate the amount of product needed to treat an area at the rate specified on the label. Keep in mind that the package information on dry formulations and liquid formulations means different things, and that the formula you will use to figure the amount of product will be different. For further information on calibrations contact the pesticide Environmental Stewardship website at: **https://pesticidestewardship.org/**

Conversion Reference

1 gallon = 128 ounces
1 gallon = 4 quarts = 8 pints = 16 cups
1 quart = 32 ounces
1 quart = 2 pints = 4 cups
1 pint = 16 ounces
1 pint = 2 cups
1 cup = 8 ounces

Herbicide Mixing

Herbicides are usually sold as mixtures or formulations of one or more herbicides with various additives. Additives increase the effectiveness of herbicides. On certain labels, they are referred to as adjuvants, surfactants, emulsifiers, or wetting agents. The type of formulation determines the toxicity to plants, uniformity of plant coverage, and stability in storage. Herbicides are formulated to permit uniform and easy application is liquid sprays or dry granules if mixed with dry fertilizers.

Herbicide Types:

Emulsifiable concentrates (EC or E) are liquid formulations with an active ingredient that is dissolved in one or more petroleum-based solvents. An emulsifier is added to cause oil to form tiny globules that disperse in water. The formulation will then mix readily with water for proper application.

Emulsifiable gels (EG or GL) are herbicides that traditionally are emulsifiable liquids formulated as gels. The gels typically are packaged in water-soluble bags (WSB) and are stable at temperatures ranging from –20 to 500°C.

Wettable powders (WP or W) are finely ground, dry particles that may be dispersed and suspended in water. They contain from 25 to 80 percent active ingredient. Suspensions of wettable powders appear cloudy and are nearly insoluble requiring agitation to remain in suspension.

Soluble liquid (S) and soluble powders (SP) dissolve in water to form a true solution. Once the soluble liquid or powder is dissolved, the spray mixture requires no additional mixing or agitation.

Dry flowables (DF), W*ater-dispersible granules (WDG or WG)* or *Dispersible Granules (DG)* are wettable powders formed into balls so they pour easily into the sprayer tank without clumping or producing a cloud of dust. Nearly insoluble, they require agitation to remain in suspension.

Flowables (F or FL), Suspension Concentrates (SC), and *aqueous suspension (AS)* are finely ground, wettable powders or solids already suspended in a liquid so they can be poured or pumped from one tank to another. They usually contain at least 4 pounds of active ingredient per gallon of formulation. Flowables are nearly insoluble in water and require agitation to remain in suspension.

Suspoemulsion (SE) is a combination formulation of an SC and an oil-based emulsion (E).

Microencapsulated (ME or MT) and *capsule suspension (CS)* are encased in extremely small capsules that can be suspended in a liquid carrier and pumped and applied with normal equipment. Microencapsulated formulations are nearly insoluble in water and require agitation to remain in suspension.

Granules (G) are formulated with a premixed carrier that contains a low percentage of active ingredient. The carrier may be fertilizer, clay, lime, vermiculite, or ground corn cobs. These herbicides are applied directly (dry) to the soil without further dilution. Granular forms generally require rainfall for activation.

Pellets (P) are like granules but are compressed into larger cylinders about ¼ inch long. Herbicides formulated as pellets usually contain from 5 to 20 percent active material and are hand-applied to control clumps of brush. They also may be applied with cyclone-type spinner spreaders mounted on helicopters or aircraft to control brush in forests or permanent pastures. Pellets gradually break down from rainfall and leach into the soil for root uptake.

Premixes are two or more herbicide active ingredients mixed into one product by the manufacturer. The actual formulation can be any of those discussed above and commonly combines two or more herbicides that are already used together. The primary reason for using premixes is convenience.

Adjuvants:

An adjuvant is a substance added to an herbicide tank mix that will modify or enhance the properties of the mixture and increase the effectiveness of the active ingredients in the herbicide. An adjuvant active ingredient is not the same as an herbicide active ingredient. There are two basic types of adjuvants, ones that modify the physical characteristics of the tank mix commonly referred to as utility adjuvants, and activators which enhance the efficacy of the chemical in the tank mix.

Utility adjuvants have specific uses in tank mixes such as pH adjustment or buffering, compatibility agents with fertilizers or other pesticides, spray drift reduction, deposition aids for drift control, and defoaming agents.
Activator adjuvants change the chemistry of the herbicide by acting as a modifier (changes the herbicide properties by a physiological mechanism, extender (extends the life of the herbicide in the soil), safener (reduces the herbicides toxicity to a plant), synergist (increases the toxicity of an herbicide), surfactants (improves the properties of an herbicide by modifying its surface characteristics). Common activator adjuvants are surfactants, crop oil concentrates, methylated seed oil, and nitrogen fertilizer. They can also be referred to as wetting agents, spreading agents, sticking agents, humectants, and penetration agents.

Surfactants are binding agents that act on the surface and are divided into categories depending on their ability to form ions in aqueous solutions:

nonionic - a binding agent made up of water and lipid segments, with no ions formed in water. (NIS)
anionic - a binding agent that forms a negative ion (anion) when placed in water.
cationic - a binding agent that forms a positive (cation) when placed in water.
amphoteric – a binding agent that can form either a surface-acting anion or cation depending on the pH of the solution. (rarely effective in tank mixes)

A complete listing of 779 adjuvants from 38 companies is available in the 13th Edition of the Compendium of Herbicide Adjuvants and can be downloaded from:
https://ppp.purdue.edu/wp-content/uploads/2016/11/PPP-115.pdf.
The booklet organizes adjuvants by type provided by the manufacturer. Most herbicide labels will also recommend which adjuvants to use and the mixing order. Many adjuvants contain a combination of products to enhance the effectiveness of the tank mix.

Mixing Order:
When mixing herbicides, one-third to one-half of the water needed for the mix should be added first along with any fertilizer, followed by the amount of herbicide denoted on the label, then add the remaining amount of water needed to reach the desired mix amount. Read the label for information on necessity and rates for additives, such as surfactants. When creating tank mixes, herbicides should be added following the order following the WALES acronym order:

- Add compatibility agents, ammonium sulfate, buffering agents, or other mixing adjuvants. For maximum benefit, they must be in the solution before herbicides are added.
- Add wettable powders and water dispensable granules.
- Agitate
- Liquid flowables and suspensions
- Emulsifiable concentrates formulations
- Surfactants

*A compatibility test should be performed by mixing herbicides in a jar before tank mixing occurs if any questions arise about the compatibility of combining herbicides, or herbicides and fertilizers.

Label Instructions:

Consult the label for all product information regarding:

- Mixing rate
- Maximum application rate for single spraying application
- Total application rate for yearly applications
- Soil texture information regarding rates
  (finer-textured soils or soils with high organic matter usually require higher application rates)
- Weeds controlled, and weeds partially controlled
- Rotational crops and re-plant intervals
- Number of nozzles, type, orientation and instructions
- Types of applications permitted (some herbicides are not approved for aerial application)
- Droplet size, volume and pressure
- Boom length
- Application height
- Swath adjustment
- Wind drift considerations
- Temperature and humidity recommendations
- Temperature inversions (characterized by increasing temperatures with altitude and are common on nights with limited cloud cover and light to no wind. They begin to form as the sun sets and often continue into the morning. During temperature inversions herbicide drift is more common.)
- Sensitive areas
- Cleaning and rinsing instructions- some herbicides require rinses with bleach, and some require rinses with ammonia, bleach, or tank neutralizers
- Storage instructions

Table 6. Single Mode of Action Herbicides Commonly Used in Texas on Corn and Sorghum and/or Evaluated in the Bushland Herbicide Trials.

Trade Name	Active Ingredient	Chemical Family	Mode of Action*	WSSA Site of Action Group #	Manufacturer	Application Timing
2,4-D amine or ester	2,4-D	Synthetic Auxin	Growth Regulator/Auxin	4	various	Burndown
2,4-DB	2,4-DB	Synthetic Auxin	Growth Regulator/Auxin	4	various	Burndown
Aatrex	atrazine	Triazine	Photosynthesis Inhibitor	5	Syngenta	Pre/Post
Abundit	glyphosate	Glycine	EPSP Synthase	9	Corteva	Post
Accent Q	nicosulfuron	Sulfonylurea	ALS	2	Corteva	Post
Aim	carfentrazone	Triazolinone	PPO	14	FMC	Post
Armezon	topramezone	Triketone	HPPD	27	BASF	Post
Balance Flex	isoxaflutole	Pyrazole	HPPD	27	Bayer	Pre/Post
Banvel	dicamba	Benzoic Acid	Growth Regulator/Auxin	4	Arysta	Pre/Post
Banvel II	dicamba	Benzoic Acid	Growth Regulator/Auxin	4	BASF	Pre/Post
Barrage HF	2.4-D ester	Phenoxy-carboxylic-acid	Growth Regulator/Auxin	4	Helena	Pre/Post
Basagran	bentazon	Benzothiadiazinone	Photosynthesis Inhibitor	6	Arysta	Post
Basis	rimsulfuron + thifensulfuron	Sulfonylurea	ALS	2+2	Corteva	Pre/Post
Beacon	primisulfuron	Sulfonylurea	ALS	2	Syngenta	Post
Buctril	bromoxynil	Nitrile	Photosynthesis Inhibitor	6	BASF	Pre/Post
Cadet	fluthiacet methyl	Thiadiazole	PPO	14	FMC	Pre/Post
Callisto	mesotrione	Triketone	HPPD	27	Syngenta	Pre/Post
Cinch	S-metolachlor	Chloroacetamide	Mitosis Inhibitor	15	Corteva	Pre/Post
Clarity	dicamba	Benzoic Acid	Growth Regulator/Auxin	4	BASF	Pre/Post
Coyote	S-metolachlor	Chloroacetamide	Mitosis Inhibitor	15	United Phosphorus	Pre/Post
Crusher	rimsulfuron + thifensulfuron	Sulfonylurea	ALS	2	Cheminova	Post/Burndown
DiFlexx	dicamba	Benzoic Acid	Growth Regulator/Auxin	4	Bayer	Pre/Post
Direx	diuron	Urea	Photosynthesis Inhibitor	7	Adama	Pre/Post
Dual II Magnum	S-metolachlor	Chloroacetamide	Mitosis Inhibitor	15	Syngenta	Pre/Post
Dual Magnum	S-metolachlor	Chloroacetamide	Mitosis Inhibitor	15	Syngenta	Pre/Post
Durango DMA	glyphosate	Glycine	EPSP Synthase	9	various	Pre/Post
Exceed	primisulfuron + prosulfuron	Sulfonylurea	ALS	2 + 2	Syngenta	Post
FirstShot SG	thifensulfuron + tribenuron	Sulfonylurea	ALS	2 + 2	Corteva	Burndown
Gramoxone	paraquat	Bipyridylium	Cell Membrane Disrupter	22	Syngenta	Pre/Post
Halo Max 75	halosulfuron	Sulfonylurea	ALS	2	Aceto	Pre/Post
Harmony Extra SG	thifensulfuron + tribenuron	Sulfonylurea	ALS	2 + 2	Corteva	Burndown
Harmony GT	thifensulfuron	Sulfonylurea	ALS	2	Corteva	Post/Burndown
Harness	acetochlor	Chloroacetamide	Mitosis Inhibitor	15	Bayer	Pre/Post
Impact	topramezone	Triketone	HPPD	27	Amvac	Post
Incinerate	mesotrione	Triketone	HPPD	27	Winfield	Pre/Post
Karmex	diuron	Urea	Photosynthesis Inhibitor	7	Adama	Post
Laudis	tembotrione	Triketone	HPPD	27	Bayer	Post
LeadOff	rimsulfuron + thifensulfuron	Sulfonylurea	ALS	2 + 2	Corteva	Pre
Liberty, Interline	glufosinate	Phosphinic acid	Nitrogen Metabolism	10	Bayer, UPI	Pre/Post
Me-Too-Lachlor	metolachlor	Chloroacetamide	Mitosis Inhibitor	15	Drexel	Pre/Post
Moccasin II	S-metolachlor	Chloroacetamide	Mitosis Inhibitor	15	United Phosphorus	Pre/Post
Moxy	bromoxynil	Nitrile	Photosynthesis Inhibitor	6	Winfield	Pre/Post
Outlaw	2,4-D + dicamba	Phenoxy-carboxylic-acid + Benzoic Acid	Growth Regulator/Auxin	4 + 4	Helena	Burndown
Outlook	dimethenamid	Chloroacetamide	Mitosis Inhibitor	15	BASF	Pre/Post
Parazone	paraquat	Bipyridylium	Cell Membrane Disrupter	22	ADAMA	Pre/Post

Table 6. Single Mode of Action Herbicides Commonly Used in Texas on Corn and Sorghum and/or Evaluated in the Bushland Herbicide Trials continued.

Trade Name	Active Ingredient	Chemical Family	Mode of Action*	WSSA Site of Action Group #	Manufacturer	Application Timing
Peak	prosulfuron	Sulfonylurea	ALS	2	Syngenta	Post
Pendimax	pendimethalin	Dinitroaniline	Seedling Root Growth Inhib.	3	Corteva	Pre/Post
Permit	halosulfuron	Sulfonylurea	ALS	2	Gowan	Post
Princep	simazine	Triazine	Photosynthesis Inhibitor	5	Syngenta	Pre
Profine	halosulfuron	Sulfonylurea	ALS	2	Aceto	Pre/Post
Prowl	pendimethalin	Dinitroaniline	Seedling Root Growth Inhib.	3	BASF	Pre/Post
Prowl H2O	pendimethalin	Dinitroaniline	Seedling Root Growth Inhib.	3	BASF	Pre/Post
Python	flumetsulam	Triazolopyrimidine	ALS	2	Corteva	Post
Quik-Quat	paraquat	Bipyridylium	Cell Membrane Disrupter	22	Drexel	Pre/Post
Rely	glufosinate	Phosphinic acid	Nitrogen Metabolism	10	Bayer	Pre/Post
Resolve DF	rimsulfuron	Sulfonylurea	ALS	2	Corteva	Pre/Post
Resource	flumiclorac	N-phenylphthalimide	PPO	14	Valent	Pre/Post
Round-up	glyphosate	Glycine (isopropylamine)	EPSP Synthase	9	Bayer	Pre/Post
Sandea	halosulfuron	Sulfonylurea	ALS	2	Gowan	Post
Sharpen	saflufenacil	Pyrimidindione	PPO	14	BASF	Pre
Shieldex	tolpyralate	Pyrazole	HPPD	27	SummitAgro	Post
Status	dicamba + diflufenzopyr	Benzoic Acid + semicarbazone	Growth Regulator/Auxin	4 + 4	BASF	Post
Steadfast Q	nicosulfuron + rimsulfuron	Sulfonylurea	ALS	2 + 2	Corteva	Pre/Post
Touchdown, HiTech, Total	glyphosate	Glycine (diammonium)	EPSP Synthase	9	Syngenta	Pre/Post
Treflan HFP	trifluralin	Dinitroaniline	Seedling Root Growth Inhib.	3	Corteva	Post
Valor SX	flumioxazin	N-phenylphthalimide	PPO	14	Valent	Pre
Warrant	acetochlor	Chloroacetamide	Mitosis Inhibitor	15	Bayer	Pre
Zidua	pyroxasulfone	Isoxazoline	Mitosis Inhibitor	15	BASF	Pre/Post

*Mode of Action	Site of Action
ALS	Acetolactate Synthase Inhibitor
AHAS	Acetohydroxy Acid Synthase Inhibitor
EPSP Synthase	Amino Acid Synthesis Inhibitor: Inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase
Cell Membrane Disrupter	PPO, Inhibitor of protoporphyrinogen oxidase (Protox)
Cell Membrane Disrupter	Photosystem I electron diverter
HPPD	Inhibitor of 4-hydroxyhenyl-pyruvatedioxygenase
Nitrogen Metabolism	Inhibitor of glutamine synthetase
Seedling Root Growth Inhibitor	Inhibitor of microtubule assembly
Growth Regulator	Phenoxy-carboxylic-acid
Photosynthesis Inhibitor	Photosystem II Inhibitor

Herbicide group number according to primary site of action by Weed Science Society of America (WSSA) number designation.

Table 7. Multiple Mode of Action Herbicides Commonly Used in Texas on Corn and Sorghum and/or Evaluated in the Bushland Herbicide Trials.

Trade Name	Active Ingredient	Chemical Families	Modes of Action*	WSSA Site of Action Group #s	Manufacturer	Application Timing
Acuron	S-metolachlor + bicyclopyrone + mesotrione + atrazine	Chloroacetamide + Triketone + Triazine	HPPD + Photosynthesis Inhibitor + Photosynthesis Inhibitor	15 + 27 + 27 +5	Syngenta	Pre/Post
Acuron Flexi	bicyclopyrone + mesotrione + S-metolachlor	Benzoylbicyclooctanedione + Triketone + Chloroacetamide	HPPD + HPPD + Photosynthesis Inhibitor	27 + 27 + 15	Syngenta	Pre/Post
Afforia	flumioxazin + thifensulfuron +	N-Phenylphthalimide + Sulfonyurea	PPO + ALS	14 + 2	Corteva	Pre
Anthem Maxx	pyroxasulfone + fluthiacet-methyl	isoxazoline + Thiadiazole	Mitosis Inhibitor + PPO	15 + 14	FMC	Pre/Post
Armezon PRO	isoxoflutole + thiencarbazone-methyl	Isoxazole + Sulfonly-amino-carbonyl-triazolinones (SACT)	HPPD + ALS	27 + 2	Bayer	Pre/Post
Authority MTZ	metribuzin + sulfentrazone	Triazolinone + Triazinone	PPO + Photosthesis Inhibitor	14 + 5	FMC	Pre
Axiom DF	flufenacet + metribuzin	Oxyacetamide + Triazolinone	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Bayer	Pre
Bicep II Magnum	S-metolachlor + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Syngenta	Pre/Post
Bicep Lite II Magnum	S-metolachlor + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Syngenta	Pre/Post
Capreno	tembotrione + thiencarbazone-methyl	Triketone + Sulfonly-amino-carbonyl-triazolinones (SACT)	HPPD + ALS	27 + 2	Bayer	Pre/Post
Cinch ATZ	S-metolachlor + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Corteva	Pre/Post
Corvus	isoxoflutole + thiencarbazone-methyl	Pyrazole + Sulfonly-amino-carbonyl-triazolinones (SACT)	HPPD + ALS	27 + 2	Bayer	Pre/Early Post
Costarr	glyphosate + dicamba	Glycine + Benzoic Acid	EPSP Synthase + Growth Regulator/Auxin	9 + 4	Albaugh	Pre/Post
Degree Xtra	acetochlor + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Bayer	Pre/Post
DiFlexx DUO	tembotrine + dicamba	Triketone + Benzoic Acid	HPPD + Growth Regulator/Auxin	27 + 4	Bayer	Pre/Post
Enlist Duo	glyphosate + 2,4-D	Glycine + Phenoxy-carboxylic-acid	EPSP Synthase + Growth Regulator/Auxin	9 + 4	Corteva	Pre/Post
Fierce	pyroxasulfone + flumioxazin	Pyrazole + N-Phenylphthalimide	Mitosis Inhibitor + PPO	15 + 14	FMC	Pre/Burndown
Guardsman Max	dimethenamid + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	BASF	Pre/Post
Halex GT	mesotrione + S-metolachlor + glyphosate	Triketone + Chloroacetamide + Glycine	HPPD + Photosynthesis Inhibitor + EPSP Synthase	27 + 15 + 9	Syngenta	Post
Harness Max	mesotrione + acetochlor	Triketone + Chloroacetamide	HPPD + Photosynthesis Inhibitor	27 + 15	Bayer	Pre/Post
Harness Xtra	acetochlor + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Bayer	Pre
Huskie	Pyrasulfotole + Bromoxynil	Pyrazole + Nitrile	HPPD + Photosynthesis Inhibitor	27 + 6	Bayer	Post
Impact Z	topramezone + atrazine	Triketone + Triazine	HPPD + Photosynthesis Inhibitor	27 + 5	AmVac	Post
Integrity	dimethenamid + saflufenacil	Chloroacetamide + Other	Mitosis Inhibitor + PPO	15 + 14	BASF	Pre
Keystone NXT	acetochlor + atrazine	Chloroacetamide + Triazine	Mitosis Inhibitor + Photosynthesis Inhibitor	15 + 5	Corteva	Pre/Post
Landmaster	glyphosate + 2,4-D	Glycine + Phenoxy-carboxylic-acid	EPSP Synthase + Growth Regulator/Auxin	9 + 4	Albaugh	Pre
Lariat	alachlor + atrazine	Chloroacetanilide + Triazine	Pigment Inhibitor + Photosynthesis Inhibitor	13 + 5	Bayer	Pre

Table 7. Multiple Mode of Action Herbicides Commonly Used in Texas on Corn and Sorghum and/or Evaluated in the Bushland Herbicide Trials continued.

Trade Name	Active Ingredient	Chemical Families	Modes of Action*	WSSA Site of Action Group #s	Manufacturer	Application Timing
Lexar EZ	mesotrione + S-metolachlor + atrazine	Triketone + Chloroacetamide + Triazine	HPPD + Photosynthesis Inhibitor + Photosynthesis Inhibitor	27 + 15 + 5	Syngenta	Pre
Lumax	mesotrione + S-metolachlor + atrazine	Triketone + Chloroacetamide + Triazine	HPPD + Photosynthesis Inhibitor + Photosynthesis Inhibitor	27 + 15 + 5	Syngenta	Pre
Prequel	isoxaflutole + rimsulfuron	Pyrazole + sulfonylurea	HPPD + ALS	27 + 2	Corteva	Pre
Realm Q	mesotrione + rimsulfuron	Triketone + sulfonylurea	HPPD + ALS	27 +2	Corteva	Burndown/Post
Resicore	mesotrione + acetochlor + clopyralid	Triketone + Chloroacetamide + Pyridine carboxylic acid	HPPD + Photosynthesis Inhibitor + Growth Regulator/Auxin	27 + 15 + 4	Corteva	Pre/Post
Resolve Q	rimsulfuron + thifensulfuron-methyl	Sulfonylurea	ALS	2 + 2	Corteva	Pre/Post
Revulin Q	mesotrione + nicosulfuron	Triketone + sulfonylurea	HPPD + ALS	27 +2	Corteva	Post
Sequence	glyphosate + S-metolachlor	Chloroacetamide + Glycine	Mitosis Inhibitor + EPSP Synthase	15 +9	Syngenta	Pre/Post
Solstice	mesotrione + fluthiacet methyl	Triketone + Thiadiazole	HPPD + PPO	27 + 14	FMC	Post
Starane NXT	bromoxynil + fluroxypyr	Nitrile + Synthetic Auxin	Photosynthesis Inhibitor + Growth Regulator/Auxin	6 + 4	Corteva	Post
Status	dicamba + diflufenzopyr	Benzoic Acid + semicarbazone	Growth Regulator/Auxin	4 + 19	BASF	Post
SureStart	acetochlor + clopyralid + flumetsulam	Chloroacetamide + Pyridine carboxylic acid + Triazolopyrimidine	Mitosis Inhibitor + Growth Regulator/Auxin + ALS	15 + 4 + 2	Corteva	Pre/Post
SureStart II	acetochlor + clopyralid + flumetsulam	Chloroacetamide + Pyridine carboxylic acid + Triazolopyrimidine	Mitosis Inhibitor + Growth Regulator/Auxin + ALS	15 + 4 + 2	Corteva	Pre/Post
TripleFLEX	acetochlor + clopyralid + flumetsulam	Chloroacetamide + Pyridine carboxylic acid + Triazolopyrimidine	Mitosis Inhibitor + Growth Regulator/Auxin + ALS	15 + 4 + 2	Bayer	Pre/Post
Verdict	dimethenamid + saflufenacil	Chloroacetamide + Other	Mitosis Inhibitor + PPO	15 + 14	BASF	Pre/Burndown
Yukon	halosulfuron + dicamba	Sulfonylurea + Benzoic Acid	ALS + Growth Regulator/Auxin	2 + 4	Gowan	Pre/Post
Zemax	mesotrione + S-metolachlor	Triketone + Chloroacetamide	HPPD + Photosynthesis Inhibitor	27 + 15	Syngenta	Pre/Post

*Mode of Action	Site of Action
ALS	Acetolactate Synthase Inhibitor
AHAS	Acetohydroxy Acid Synthase Inhibitor
EPSP Synthase	Amino Acid Synthesis Inhibitor: Inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase
Cell Membrane Disrupter	PPO, Inhibitor of protoporphyrinogen oxidase (Protox)
Cell Membrane Disrupter	Photosystem I electron diverter
HPPD	Inhibitor of 4-hydroxyhenyl-pyruvatedioxygenase
Nitrogen Metabolism	Inhibitor of glutamine synthetase
Seedling Root Growth Inhibitor	Inhibitor of microtubule assembly
Growth Regulator	Phenoxy-carboxylic-acid
Photosynthesis Inhibitor	Photosystem II Inhibitor
Pigment Inhibitor	deoDOxy-D-xyulose 5-phosphate sunthatase Inhibitor

Herbicide group number according to primary site of action by Weed Science Society of America (WSSA) number designation.

Liquid formulations include AC, applicator's concentration; CS, aqueous capsule suspension; E, EC or EW, emulsifiable concentrate; F, flowable; L, liquid; ME, micro-encapsulated; SL, soluble liquid; S, suspension. Dry formulations include DF, dry flowable; DG, dispersible granules; G, granules; SC, suspension concentrate; SP, soluble powder; W, WG or WDG, wettable dispersible granules; WP, wettable powder; WSG, wettable soluble granule. Herbicide group number according to primary site of action by Weed Science Society of America (WSSA) (number designation) and Herbicide Resistance Action Committee (HRAC) (letter designation). From Mallory-Smith and Retzinger 2003.