Tan Section: Adjuvant and Application Technology Page

Adjuvant effect on Atrazine and Glyphosate. Dr. Howatt and Mettler. DKC40-77RIB corn was seeded near Fargo on May 29, 2019. Preemergence treatments were applied May 30 with 65.6°F, 65.1% relative humidity, 100% cloud-cover, 20 mph wind velocity at 160°, and dry soil surface at 58°F. Four inch treatments were applied to V3 corn, 10 inch tall redroot pigweed and common mallow, 4 inch tall common lambsquarters and Venice mallow, 8 inch tall wild buckwheat, and 5 leaf green foxtail on June 29 with 71.8°F, 65.6% relative humidity, 10% cloud-cover, 7 to 8 mph wind velocity at 250°, and moist soil at 64°F. All treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles. The experiment was a randomized complete block design with four replicates.

Treatment	Rate (oz ai/A)		7/3 Wibw	7/3 Coma	7/3 Vema	7/12 Colq	7/12 Wibw	7/12 Coma
Untreated	0		0	0	0	0	0	0
Acet&Mest&Clpy/ Handweeded Check	39.5/0	PRE	98	98	97	99	98	98
Mest+Atra 4L+Glyt-ipa	1.5+8+12	4"	86	82	88	91	96	94
Mest+Atra 4L+Glyt-ipa+TLD+AMS	1.5+8+12+0.5%+11	4"	84	80	86	92	97	97
Mest+Atra 4L+Glyt-ipa+TLD+AMS+MOL	1.5+8+12+0.5%+11+4	4"	83	79	84	89	97	98
Mest+Atra 4L+Glyt-ipa+TLD+AMS+KEY	1.5+8+12+0.5%+11+57 g/A	4"	85	81	88	91	96	97
Mest+Atra 4L+Glyt-ipa+TLD+AMS+BAG	1.5+8+12+0.5%+11+3	4"	81	79	87	89	97	97
Mest+Atra 4L+Glyt-ipa+TLD+AMS+SAL	1.5+8+12+0.5%+11+18	4"	84	83	89	92	96	96
Mest+Atra 4L+Glyt-ipa+TLD+AMS+MOL+KEY	1.5+8+12+0.5%+11+4+57g/A	4”	81	80	85	87	97	96
CV			3.74	3.7	3.67	2.52	1.41	1.62
LSD			4.14	3.98	4.20	2.99	1.78	2.04

Treatment	Rate (oz ai/A)		7/12 Vema	7/12 Colq	7/20 Wibw	7/20 Coma	7/20 Vema	7/20 Colq
Untreated	0		0	0	0	0	0	0
Acet&Mest&Clpy/ Handweeded Check	39.5/0	PRE	94	98	99	99	95	99
Mest+Atra 4L+Glyt-ipa	1.5+8+12	4"	93	97	95	99	96	99
Mest+Atra 4L+Glyt-ipa+TLD+AMS	1.5+8+12+0.5%+11	4"	93	95	98	99	97	99
Mest+Atra 4L+Glyt-ipa+TLD+AMS+MOL	1.5+8+12+0.5%+11+4	4"	96	98	98	99	94	98
Mest+Atra 4L+Glyt-ipa+TLD+AMS+KEY	1.5+8+12+0.5%+11+57 g/A	4"	95	97	96	99	97	98
Mest+Atra 4L+Glyt-ipa+TLD+AMS+BAG	1.5+8+12+0.5%+11+3	4"	93	97	92	99	96	97
Mest+Atra 4L+Glyt-ipa+TLD+AMS+SAL	1.5+8+12+0.5%+11+18	4"	92	97	95	99	96	95
Mest+Atra 4L+Glyt-ipa+TLD+AMS+MOL+KEY	1.5+8+12+0.5%+11+4+57g/A	4”	95	97	96	99	96	95
CV			2.64	1.32	1.51	0.0	1.78	1.23
LSD			3.22	1.67	1.89	.	2.23	1.56

Adjuvant effects on Dicamba and glyphosate. Dr. Howatt and Mettler. DKC40-77RIB corn was seeded near Fargo on May 29, 2019. Preemergence treatments were applied May 30 with 64.5°F, 65% relative humidity, 100% cloud-cover, 20 mph wind velocity at 160°, and dry soil at 58°F. Post treatments were applied to V3 corn, 5 to 16 inch redroot pigweed, 5 to 13 inch common lambsquarters, 12 inch common mallow and 8 inch wild buckwheat on June 29 with 72°F, 65% relative humidity, 10% cloud-cover, 8 to 9 mph wind velocity at 270°, and moist soil at 64°F. All treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 40 foot plots. The experiment was a randomized complete block design with four replicates.

Treatment	Rate (oz ai/A)	7/3 Wibw	7/3 Coma	7/3 Vema	7/3 Colq	7/3 Rrpw	7/12 Wibw	7/12 Coma
Untreated	0	0	0	0	0	0	0	0
Acet&Mest&Clpy/ Handweeded	39.5	99	98	99	99	99	99	97
Dica&Difl+Glyt-ipa	3+12	74	74	80	77	71	95	96
Dica&Difl+Glyt-ipa+SXP+AMS	3+12+10+11	80	83	86	86	76	98	99
Dica&Difl+Glyt-ipa+SXP+AMS+MOL	3+12+10+11+4	80	80	84	86	77	97	98
Dica&Difl+Glyt-ipa+SXP+AMS+KEY	3+12+10+11+57 g/A	80	79	80	80	75	97	98
Dica&Difl+Glyt-ipa+SXP+AMS+BAG	3+12+10+11+3	76	77	77	84	79	97	96
Dica&Difl+Glyt-ipa+SXP+AMS+SAL	3+12+10+11+4+18	79	79	82	82	81	97	97
Dica&Difl+Glyt-ipa+SXP+AMS+MOL+KEY	3+12+10+11+4+57 g/A	80	81	84	85	75	96	98
CV		3.58	4.16	4.09	4.65	5.71	1.15	1.38
LSD		3.76	4.39	4.46	5.12	5.87	1.45	1.75

g/A=gram/Acre

Treatment	Rate (oz ai/A)	7/12 Vema	7/12 Colq	7/12 Rrpw	7/20 Wibw	7/20 Coma	7/20 Vema	7/20 Colq	7/20 Rrpw
Untreated	0	0	0	0	0	0	0	0	0
Acet&Mest&Clpy/ Handweeded	39.5	97	99	97	98	99	95	99	97
Dica&Difl+Glyt-ipa	3+12	97	91	84	97	99	97	96	89
Dica&Difl+Glyt-ipa+SXP+AMS	3+12+10+11	98	95	87	99	99	96	97	92
Dica&Difl+Glyt-ipa+SXP+AMS+MOL	3+12+10+11+4	97	96	94	97	99	97	93	92
Dica&Difl+Glyt-ipa+SXP+AMS+KEY	3+12+10+11+57 g/A	97	95	87	99	99	97	89	85
Dica&Difl+Glyt-ipa+SXP+AMS+BAG	3+12+10+11+3	97	95	87	99	99	98	92	82
Dica&Difl+Glyt-ipa+SXP+AMS+SAL	3+12+10+11+4+18	96	93	81	98	99	95	87	80
Dica&Difl+Glyt-ipa+SXP+AMS+MOL+KEY	3+12+10+11+4+57 g/A	97	90	83	98	99	96	85	81
CV		1.62	1.91	3.39	1.15	0.0	1.19	2.9	3.12
LSD		2.04	2.33	3.85	1.47	.	1.50	3.47	3.54

g/A=gram/Acre

Volunteer corn control with herbicide+ Dicamba. Dr. Howatt and Mettler. DKC40-77RIB corn was seeded May 17, 2019 to simulate volunteer corn infestation. Treatments were applied to V5 corn and 6 to 8 inch redroot pigweed on July 16 with 74°F, 79% relative humidity, 100% cloud-cover, 0.9 mph wind velocity at 270°, and moist soil surface at 74°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with four replicates.

Treatment	Rate	Jul-31-2019 Vcorn	Aug-14-2019 Vcorn
	oz ai/A	%	%
Quiz+HSOC	0.4+20	85	93
Quiz+Dica-X+HSOC	0.4+8+20	74	81
Quiz+Dica-X+HSOC	0.5+8+20	79	88
Quiz+Dica-X+HSOC	0.9+8+20	86	95
Flzp+HSOC	0.75+20	82	92
Flzp+Dica-X+HSOC	0.75+8+20	64	80
Flzp+Dica-X+HSOC	1+8+20	71	85
Flzp+Dica-X+HSOC	1.5+8+20	74	88
Cleth+HSOC	0.75+20	80	89
Cleth+Dica-X+HSOC	0.75+8+20	71	76
Cleth+Dica-X+HSOC	1+8+20	79	85
Cleth+Dica-X+HSOC	1.5+8+20	80	89
CV		3.18	2.99
LSD P=.05		3.53	3.73

Volunteer corn control with herbicide+2,4-D. Dr. Howatt and Mettler. DKC40-77RIB corn was seeded May 17 as a simulated corn infestation. Treatments were applied to V5 corn and 6 to 8 inch redroot pigweed on July 16 with 76°F, 78% relative humidity, 100% cloud-cover, 2 mph wind velocity at 325°, and moist soil surface at 74°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with four replicates.

Treatment	Rate	corn July 31	corn August 14
	oz ai/A	%	%
Quiz+HSOC	0.4+20	85	93
Quiz+2,4-D-CH+HSOC	0.4+16+20	27	0
Quiz+2,4-D-CH+HSOC	0.5+16+20	32	0
Quiz+2,4-D-CH+HSOC	0.9+16+20	76	84
Flzp+HSOC	0.75+20	82	90
Flzp+2,4-D-CH+HSOC	0.75+16+20	61	75
Flzp+2,4-D-CH+HSOC	1+16+20	67	80
Flzp+2,4-D-CH+HSOC	1.5+16+20	72	86
Cleth+HSOC	0.75+20	82	91
Cleth+2,4-D-CH+HSOC	0.75+16+20	74	76
Cleth+2,4-D-CH+HSOC	1+16+20	80	88
Cleth+2,4-D-CH+HSOC	1.5+16+20	86	94

Influence of adjuvant type and nitrogen on quizalofop. Dr. Howatt and Mettler. Barley, Corn, foxtail millet, and wheat were seeded near Casselton, North Dakota June 3, 2019. Treatments were applied to 10 to 12 inch barley, 2- to 14 inch corn, 8 to 10 inch foxtail millet, and 12 inch wheat on July 8 with 83°F, 63% relative humidity, 20% cloud-cover, 7 mph wind velocity at 165°, and moist soil surface at 77°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with four replicates

Treatment	Rate	Growth	7/20 foxtail millet	7/20 Spring wheat	7/20 Barley*	7/20 Corn	8/6 foxtail millet	8/6 Spring wheat	8/6 Barley	8/6 Corn
Name	fl oz/A	Stage	%	%	%	%	%	%	%	%
Assure II+R-11 (NIS)	4+0.25%	12-14" corn	75	67	60	67	86	99	99	90
Assure II+R-11 (NIS)+AMS	4+0.25%+48	12-14" corn	74	70	75	75	78	99	99	89
Assure II+Prime Oil (COC)	4+1%	12-14" corn	85	72	75	79	95	99	99	96
Assure II+Prime Oil (COC)+AMS	4+1%+48	12-14" corn	85	79	85	85	87	99	99	96
Assure II+Premium MSO (MSO)	4+1%	12-14" corn	74	65	70	70	87	99	99	92
Assure II+Premium MSO (MSO)+AMS	4+1%+48	12-14" corn	66	65	70	66	71	99	99	87
Assure II+Glacier EA (HSMOC)	4+0.75%	12-14" corn	80	70	75	75	90	99	99	94
Assure II+Glacier EA (HSMOC)+AMS	4+0.75%+48	12-14" corn	79	74	80	75	84	99	99	94
Assure II+Hybrid (HSMOC)	4+0.75%	12-14" corn	86	75	75	74	94	99	99	96
Assure II+Hybrid (HSMOC)+AMS	4+0.75%+48	12-14" corn	79	74	80	75	82	99	99	92
CV			5.53	6.17	.	5.53	5.28	0.0	0.0	2.82
LSD P=.05			6.27	6.36	.	5.95	6.56	.	.	3.8

*One rep

HPPD herbicide mixtures with quizalofop. Dr. Howatt and Mettler. Barley, Corn, foxtail millet, and wheat were seeded in bioassay strips near Casselton, North Dakota on June 3, 2019. Treatments were applied to 12 to 14 inch corn on July 8 with 85°F, 63% relative humidity, 60% cloud-cover, 7 mph wind velocity at 180°, and moist soil surface at 77°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with four replicates.

Treatment	Rate	Growth Stage	7/20 foxtail millet	7/20 Spring wheat	7/20 Barley	7/20 Corn	8/6 foxtail millet	8/6 Spring wheat	8/6 Barley	8/6 Corn
	fl oz/A		%	%	%	%	%	%	%	%
Assure II+Premium MSO	6+1%	12-14" corn	89	78.8	85	82	93	98	98.6	96
Callisto+Premium MSO	3+1%	12-14" corn	10	17	14	14	2	5	0.6	5
Assure II+Callisto+Premium MSO+AMS	6+3+1%+48	12-14" corn	91	81	86	88	88	99	99	97
Impact+Premium MSO	0.75+1%	12-14" corn	32	22	35	27	17	7	19	17
Assure II+Impact+Premium MSO+AMS	6+0.75+1%+48	12-14" corn	84	66	76	80	92	96	99	96
Liberty+AMS	22+48	12-14" corn	99	91	90	22	93	81	80	15
Assure II+Liberty+Premium MSO+AMS	6+22+1%+48	12-14" corn	99	95	91	85	99	98	99	97
2,4-D Amine+Premium MSO	1.5+1%	12-14" corn	25	21	27	17	0	0	0	2
2,4-D Amine+Assure II+Premium MSO+AMS	1.5+6+1%+48	12-14" corn	86	81	84	60	92	92	93	70
Clarity+Premium MSO	16+1%	12-14" corn	27	22	30	20	2	2	0.6	2
Clarity+Assure II+Premium MSO (MSO)+AMS	16+6+1%+48	12-14" corn	96	82	89	67	94	96	99	84
CV			8.55	8.3	8.34	10.94	6.78	7.82	9.55t	10.97
LSD P=.05			8.30	7.19	7.74	8.12	6.01	6.96	3.69	8.39

Glyphosate adjuvants. Dr. Howatt and Mettler. Flax, Amaranth, Quinoa, and tame buckwheat were seeded near Hillsboro on June 6. Treatments were applied to 8 to 12 inch flax, 2 to 6 inch Amaranth, 4 to 10 inch quinoa, and 20 to 24 inch buckwheat on July 12 with 77°F, 74% relative humidity, 5% cloud-cover, 2 to 7 mph wind velocity at 0°, and moist soil surface at 72°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with four replicates.

Treatment	Rate	7/23 Flax	7/23 Pgwd	7/23 Copu	7/23 Quinoa	7/23 Tabw	8/7 Flax	8/7 Pgwd	8/7 Quinoa	8/7 Tabw
	oz ai/A	%	%	%	%	%	%	%	%	%
Glyphosate4.5+WC240	6+2.5%	97	99	92	93	83	99	99	99	96
Glyphosate4.5+WC112+WC240	6+0.25%+2.5%	99	99	96	96	86	99	99	99	96
Glyphosate4.5+WC109	6+2.5%	98	99	93	94	77	99	99	99	92
Glyphosate4.5+WC024	6+2.5%	98	99	95	93	87	99	99	99	96
Glyphosate4.5+WC459	6+2.5%	97	99	93	93	82	99	99	99	96
Glyphosate4.5+WC443	6+0.5%	97	99	94	91	75	99	99	99	90
Glyphosate4.5+WC498	6+2.5%	98	99	94	95	75	99	99	99	92
Glyphosate4.5+WC232	6+0.5%	97	99	94	95	70	99	99	99	87
Glyphosate4.5+WC239	6+0.5%	96	99	88	87	73	97	99	99	92
Glyphosate4.5+WC221	6+0.5%	99	99	91	88	73	99	99	99	93
Glyphosate4.5+WC221+WC240	6+0.25%+2.5%	98	99	90	95	82	99	99	99	95
Glyphosate4.5+WC450+WC240	6+3fl oz+2.5%	98	99	93	88	65	99	99	99	93
Glyphosate4.5+WC460+WC240	6+3fl oz+2.5%	97	99	85	94	67	99	99	99	94
Glyphosate4.5+WC124	6+2.5%	98	99	95	95	77	99	99	99	95
CV		1.41	0.0	3.5	2.76	7.9	0.94	0.0	0.0	3.11
LSD P=.05		2.31	.	5.41	4.29	10.14	1.55	.	.	4.88

Smaller glyphosate adjuvant trial. Dr. Howatt and Mettler. Flax, amaranth, quinoa, and tame buckwheat were seeded near Hillsboro, North Dakota on June 6, 2019. Treatments were applied to 8 to 10 inch flax, 4 to 6 inch amaranth, 12 to 14 inch quinoa, and 18 to 24 inch buckwheat on July 12 with 75°F, 77% relative humidity, 5% cloud-cover, 4 to 6 mph wind velocity at 325°, and moist soil surface at 72°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with four replicates.

Treatment	Rate	7/23 Flax	7/23 Pgwd	7/23 Copu	7/23 Quinoa	7/23 Tabw	8/7 Flax	8/7 Pgwd	8/7 Quinoa	8/7 Tabw
	oz ai/A	%	%	%	%	%	%	%	%	%
Glyphosate	6	96	98	88	95	85	99	99	99	97
Glyphosate+WC459	6+2.5%	98	99	96	98	88	99	99	99	97
Glyphosate+WC109E	6+2.5%	99	98	94	96	88	99	99	99	97
Glyphosate+WC109W	6+2.5%	99	99	96	96	86	99	99	99	97
Glyphosate+WC508	6+2.5%	98	99	93	97	91	99	99	99	97
Glyphosate+WC509	6+2.5%	98	98	95	96	89	99	99	99	97
Glyphosate+WC529	6+2.5%	97	99	96	94	87	99	99	99	91
Glyphosate+WC530	6+2.5%	98	99	97	96	89	99	99	99	97
Glyphosate+WC221	6+0.25%	99	99	96	97	88	99	99	99	97
Glyphosate+WC221	6+0.5%	99	98	95	96	88	99	99	99	97
CV		1.09	1.01	2.9	1.25	2.2	0.0	0.0	0.0	1.33
LSD P=.05		1.83	1.71	4.71	2.06	3.32	.	.	.	2.19

HPPD tank-mix adjuvants. Dr. Howatt and Mettler. . Flax, amaranth, quinoa, and tame buckwheat were seeded near Hillsboro, North Dakota on June 6, 2019. Treatments were applied to 6 to 10 inch flax, 4 to 6 inch amaranth, 10 to 14 inch quinoa, 18 to 24 inch buckwheat and 1 to 2 inch carpet of common purslane on July 12 with 76°F, 78% relative humidity, 5% cloud-cover, 6.6 mph wind velocity at 325°, and moist soil surface at 97°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with three replicates.

Treatment	Rate	7/23 Flax	7/23 Pgwd	7/23 Copu	7/23 Quinoa	7/23 Tabw	8/7 Flax	8/7 Pgwd	8/7 Quinoa	8/7 Tabw
	oz ai/A	%	%	%	%	%	%	%	%	%
Mest+Glyt4.5+WC240	1+6+2.5%	99	99	96	95	92	99	99	99	98
Mest+Glyt4.5+WC079+WC240	1+6+0.5%+2.5%	98	99	95	92	91	99	99	99	99
Mest+Glyt4.5+WC161+WC240	1+6+0.5%+2.5%	97	99	89	91	85	99	99	99	98
Mest+Glyt4.5+WC446+WC240	1+6+0.5%+2.5%	98	99	95	91	89	99	99	99	98
Mest+Glyt4.5+WC448+WC240	1+6+0.5%+2.5%	98	99	91	89	84	99	99	99	98
Mest+Glyt4.5+WC082+WC240	1+6+0.5%+2.5%	99	99	96	96	87	99	99	99	97
Mest+Glyt4.5+WC342+WC240	1+6+0.5%+2.5%	98	99	91	95	90	99	99	99	98
Mest+Glyt4.5+WC442+WC431+WC240	1+6+0.25%+0.25%+2.5%	98	99	96	90	88	99	99	99	99
Mest+Glyt4.5+WC450+WC240	1+6+0.5%+2.5%	98	99	92	94	85	99	99	99	98
Mest+Glyt4.5+WC250+WC240	1+6+0.25%+2.5%	97	99	94	93	85	99	99	99	98
Mest+Glyt4.5+WC221	1+6+0.5%	98	99	92	94	87	99	99	99	98
Mest+Glyt4.5+WC221+WC240	1+6+0.25%+0.5%	99	99	96	90	85	99	99	99	98
Mest+Glyt4.5+WC538+WC240	1+6+0.5%+0.25%	99	99	89	93	89	99	99	99	99
Mest+Glyt4.5+WC257+WC240	1+6+0.5%+2.5%	98	99	94	89	94	99	99	99	99
Mest+Glyt4.5+WC472+WC240	*1+6+0.5%+2.5%*	96	99	90	91	92	99	99	99	98
Mest+Glyt4.5+WC513+WC240	1+6+0.5%+2.5%	98	99	97	92	93	99	99	99	98
CV		1.39	0.0	2.9	4.0	3.85	0.0	0.0	0.0	1.44
LSD P=.05		2.28	.	4.52	6.16	5.67	.	.	.	2.35

Liberty Adjuvants. Dr. Howatt and Mettler. Flax, amaranth, quinoa, and tame buckwheat were seeded near Hillsboro, North Dakota on June 6, 2019. Treatments were applied to 8 to 10 inch flax, 4 to 6 inch amaranth, 12 to 14 inch quinoa, 18 to 24 inch buckwheat and 1 to 2 inch carpet of common purslane on July 12 with 74°F, 78% relative humidity, 5% cloud-cover, 5.5 mph wind velocity at 325°, and moist soil surface at 70°F. Treatments were applied with a backpack sprayer delivering 8.5 gpa at 40 psi through 11001 TT nozzles to a 7 foot wide area the length of 10 by 30 foot plots. The experiment was a randomized complete block design with three replicates.

Treatment	Rate	7/18 Flax	7/18 Rrpw	7/18 Quinoa	7/18 Tabw	7/23 Flax	7/23 Pgwd	7/23 Copu	7/23 Quinoa	7/23 Tabw	8/07 Flax	8/07 Tabw
	oz ai/A	%	%	%	%	%	%	%	%	%	%	%
Glufosinate	4.7	95	63	93	87	95	58	53	90	92	90	92
Glufosinate+AMS-L	4.7+56	96	82	94	90	95	70	53	96	96	82	98
Glufosinate+AMS-L	4.7+112	96	90	89	91	92	63	50	89	96	89	98
Glufosinate+WC115	4.7+0.75%	96	93	95	87	94	70	62	92	92	77	93
Glufosinate+WC221	4.7+0.5%	94	77	94	86	94	62	50	92	90	75	85
Glufosinate+WC221+AMS-L	4.7+0.25%+56	96	93	95	91	96	75	77	95	96	83	98
Glufosinate+WC458+AMS-L	4.7+0.25%+56	96	80	90	88	93	72	63	93	93	74	92
Glufosinate+WC520	4.7+3%	95	88	95	87	91	72	77	95	96	60	97
CV		1.11	6.5	1.94	2.01	3.08	7.89	7.71	2.78	2.59	11.05	4.05
LSD P=.05		1.85	9.50	3.17	3.11	5.05	9.36	8.19	4.50	4.25	15.25	6.67

Is There Antagonism Between Glyphosate and Glufosinate?

Mike Ostlie, Joseph Ikley, Brian Jenks, and Greg Endres

In North Dakota we now have three crops where both glyphosate (ex RoundUp Powermax) and glufosinate (ex Liberty) can be applied in the same season. These crops are corn, soybeans, and canola. Since glyphosate is highly mobile in plants and glufosinate is a contact product, there is potential for antagonism on the plant surface. In 2018 we started to investigate the impact of adding glyphosate to glufosinate. In 2019 we tested combinations in three locations of ND with a variety of weed species. In each of these experiments we optimized the application for glufosinate (ex >15 GPA spray volume), which would be the recommendation. In 2019 we also tested combinations of glyphosate and glufosinate with Enlist One and Enlist Duo.

The weed species response varied. Shepard's purse, common ragweed and redroot pigweed were controlled by all treatment combinations. Green foxtail control was initially good with all treatment combinations, however, by 21 days after application the presence of glufosinate caused a mild reduction in control compared to glyphosate alone. Yellow foxtail control was not affected by the combination of products, it was simply less in treatments without glyphosate. Kochia control was negatively impacted by the combination of products (Table 1). This is the one case where both products applied alone performed better than the combination. In fact, when adding Enlist products, Enlist Duo was better without glufosinate than with. In all other cases Enlist Duo was a neutral or positive addition.

Common lambsquarters had a variable response. In 2019 at two locations (out of 2) all treatment combinations were equally effective achieving high levels of control. In 2018 there was notable antagonism (Table 2). RoundUp Powermax (28 oz) and Liberty (32 oz) alone provided similar levels of control. When combined, control dropped by 10%. Lowering the RoundUp Powermax rate (21 oz) and increasing the Liberty rate (43 oz) overcame this antagonism, but was less economical than either product alone. However, if trying to control glyphosate resistant weeds this may have been acceptable.

Wild buckwheat control was enhanced by the combination of the two products. When glufosinate was applied alone, it quickly burned the leaves of wild buckwheat, by the end of the trial the buckwheat had recovered. Glyphosate alone was very slow to control buckwheat, but by the end finished better than glufosinate. When the were added together it was the best of both worlds. The buckwheat was quickly burned back and by the end of the trial the combination performed better than either product alone. Glufosinate with Enlist Duo or Enlist One provided an even larger benefit to buckwheat control at 7 days after application, but was similar to glyphosate plus glufosinate by 21 days.

In short, there was less antagonism than expected when using these combinations, however, each weed species may have a unique response to the products. In fact, this may be a case where every application of this combination may respond in a unique way. When antagonism existed, it was often a reduction of 10-20% compared to glyphosate alone. These combinations may be highly effective when used to manage herbicide resistance, but scouting for escapes will be necessary. Generally these escapes were not detectable until 2 weeks following application.

To avoid potential antagonism and escapes, sequential applications will be most effective. Rarely did combining the products add to herbicide effectiveness (except with buckwheat). In our studies, the added cost of mixing the products rarely would gave an advantage. If using a sequential program,

glufosinate would be a good early POST product to target the weeds when they are small. A late POST application of glyphosate, with the lower water volume, would maximize the effectiveness of each product that is applied.

Table 1. Weed species of interest while testing combinations of glyphosate, glufosinate, and Enlist.

Treatment	Rate		W. buckwheat	W. buckwheat	G. foxtail	Kochia
			7 DAT	21 DAT	21 DAT	48 DAT
Check			0.0	0.0	0.0	0
Liberty	32	FL OZ/A	80.0	60.0	60.0	41.7
RoundUp Powermax	28	FL OZ/A	31.3	83.8	93.8	45.0
Liberty + RoundUp Powermax	32 + 28	FL OZ/A	85.0	86.3	75.0	32.7
Liberty + RoundUp Powermax	32 + 21	FL OZ/A	82.5	85.0	87.5	30.0
Liberty + RoundUp Powermax	43 + 21	FL OZ/A	87.5	88.8	72.5	30.0
Liberty + Enlist Duo	32 + 64	FL OZ/A	91.3	91.3	95.0	38.3
Liberty + Enlist One	32 + 32	FL OZ/A	90.0	90.0	37.5	38.3
Enlist Duo	4	PT/A	32.5	75.0	93.8	50.0
Enlist One	2	PT/A	25.0	27.5	0.0	10.0
LSD (0.05)			6.1	6.2	3.5	9.4

North Dakota State University

Effect of pH Modifiers on Engenia + Powermax Efficacy

Trial ID: 19S-HILLS-MS-09 Location: HILLSBORO
Protocol ID: 19S-HILLS-MS-09 Investigator (Creator): Dr. Joe Ikley
Project ID: Study Director: Joe Ikley
Sponsor Contact:

General Trial Information

Study Director: Joe Ikley
Investigator: Dr. Joe Ikley

Trial Status: E established
Trial Status Date: Jul-29-2019 **Last Changed By:** Dr. Joe Ikley
ARM Trial Created On: May-30-2019
Protocol Revision Date: May-22-2019

Conducted Under GLP: No
Conducted Under GEP: No

Contacts

Role: STYDIR study director
Study Director: Joe Ikley

Role: INVEST investigator
Investigator: Dr. Joe Ikley

Site and Design

Treated Plot Width: 6.67 FT
Treated Plot Length: 40 FT
Treated Plot Area: 266.8 FT2 **Treatments:** 9
Replications: 3 **Study Design:** RACOBL Randomized Complete Block (RCB)

Soil Description

Description Name: Hillsboro, ND
% Sand: 32 **% OM:** 4.6 **Texture:** CL clay loam
% Silt: 36 **pH:** 7.5 **Soil Name:** Gardena
% Clay: 32

Application Description

	A
Application Date	Jul-13-2019
Appl. Start Time	12:25 PM
Appl. Stop Time	12:50 PM
Application Method	SPRAY
Application Placement	BROFOL
Applied By	Haugrud, N.
Appl. Entry Date	Jul-29-2019
Air Temperature Start, Stop	82 81 F
% Relative Humidity Start, Stop	50 46
Wind Velocity+Dir. Start	6 MPH SSE
Wind Velocity+Dir. Stop	6 MPH SSE
Wind Velocity+Dir. Max	8 MPH SSE
Wet Leaves (Y/N)	N no
Soil Temperature	79 F
Soil Moisture	GOOD
Soil Surface Condition	SMOOTH
% Cloud Cover	30

North Dakota State University

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Sponsor Contact:

Application Equipment

	A
Appl. Equipment	Narsil
Equipment Type	BACCAI
Operation Pressure	28 PSI
Nozzle Type	TTI
Nozzle Size	11002
Nozzle Spacing	20 IN
Boom Length	6.67 FT
Boom Height	18 IN
Ground Speed	3 MPH
Carrier	WATER
Application Amount	15 GAL/AC
Mix Size	1119 mL
Propellant	COMCO2

Context	Date	By	Notes
STATUS	May-30-2019	Dr. Joe Ikley	Automatically added by ARM: Trial Status updated to 'S' during trial creation.
STATUS	Jul-29-2019	Dr. Joe Ikley	Automatically added by ARM: Trial Status updated to 'E' when Application Date entered.

Pest Type			W Weed	W Weed	W Weed	W Weed
Pest Code			LIUSS	CHEQU	FAGES	AMARE
Pest Scientific Name			Linum sp.	Chenopodium quinoa	Fagopyrum esculentum	Amaranthus retroflexus
Pest Name			Flax	Quinoa goosefoot	Common buckwheat	Redroot pigweed
Description						
Rating Date			Jul-27-2019	Jul-27-2019	Jul-27-2019	Jul-27-2019
Rating Type			CONTRO	CONTRO	CONTRO	CONTRO
Rating Unit			%	%	%	%
Number of Subsamples			1	1	1	1
Data Entry Date			Aug-14-2019	Aug-14-2019	Aug-14-2019	Aug-14-2019
Days After First/Last Applic.			14 14	14 14	14 14	14 14
Trt-Eval Interval			14 DA-A	14 DA-A	14 DA-A	14 DA-A
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1*	2*	3*	4*
1	Untreated Check				0.0 c	0.0 b	0.0 b	0.0 b
2	ENGENIA	12.8	fl oz/a	A	99.7 a	100.0 a	99.7 a	99.0 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
3	ENGENIA	12.8	fl oz/a	A	99.0 a	99.7 a	99.0 a	99.0 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
	NDEMAND 88	1	qt/a	A				
4	ENGENIA	12.8	fl oz/a	A	99.7 a	99.3 a	97.7 a	97.7 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
	NDEMAND ENTOURAGE K	1	qt/a	A				
5	ENGENIA	12.8	fl oz/a	A	99.7 a	100.0 a	97.0 a	99.0 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
	LINKAGE	1	% v/v	A				
6	ENGENIA	6.4	fl oz/a	A	97.0 a	99.7 a	86.7 a	97.0 a
	ROUNDUP POWERMAX	16	fl oz/a	A				
7	ENGENIA	6.4	fl oz/a	A	95.0 a	99.7 a	93.7 a	97.7 a
	ROUNDUP POWERMAX	16	fl oz/a	A				
	NDEMAND 88	0.5	qt/a	A				
8	ENGENIA	6.4	fl oz/a	A	73.3 b	99.7 a	88.0 a	94.7 a
	ROUNDUP POWERMAX	16	fl oz/a	A				
	NDEMAND ENTOURAGE K	0.5	qt/a	A				

North Dakota State University

Effect of pH Modifiers on Engenia + Powermax Efficacy

Trial ID: 19S-HILLS-MS-09 Location: HILLSBORO
Protocol ID: 19S-HILLS-MS-09 Investigator (Creator): Dr. Joe Ikley
Project ID: Study Director: Joe Ikley
Sponsor Contact:

Pest Type		W Weed	W Weed	W Weed	W Weed
Pest Code		LIUSS	CHEQU	FAGES	AMARE
Pest Scientific Name		Linum sp.	Chenopodium quinoa	Fagopyrum esculentum	Amaranthus retroflexus
Pest Name		Flax	Quinoa goosefoot	Common buckwheat	Redroot pigweed
Description					
Rating Date		Jul-27-2019	Jul-27-2019	Jul-27-2019	Jul-27-2019
Rating Type		CONTRO	CONTRO	CONTRO	CONTRO
Rating Unit		%	%	%	%
Number of Subsamples		1	1	1	1
Data Entry Date		Aug-14-2019	Aug-14-2019	Aug-14-2019	Aug-14-2019
Days After First/Last Applic.		14 14	14 14	14 14	14 14
Trt-Eval Interval		14 DA-A	14 DA-A	14 DA-A	14 DA-A
Trt No.	Treatment Name	Rate Rate Unit	Appl Code	1*	2*	3*	4*
9	ENGENIA	6.4 fl oz/a	A	95.7 a	99.7 a	93.3 a	96.3 a
	ROUNDUP POWERMAX	16 fl oz/a	A				
	LINKAGE	0.5 % v/v	A				
LSD P=.05				7.28	0.83	8.06	3.57
Standard Deviation				4.21	0.48	4.66	2.06
CV				4.99	0.54	5.55	2.38
Levene's F				3.142	0.375	1.18	1.164
Levene's Prob(F)				0.021*	0.92	0.363	0.371
Skewness				-2.3096*	-2.622*	-2.4555*	-2.5978*
Kurtosis				4.0318*	5.2619*	4.6948*	5.1809*
Replicate F				1.306	0.640	0.138	1.470
Replicate Prob(F)				0.2982	0.5403	0.8720	0.2595
Treatment F				181.333	14316.641	139.678	746.050
Treatment Prob(F)				0.0001	0.0001	0.0001	0.0001

North Dakota State University

Effect of pH Modifiers on Engenia + Powermax Efficacy

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Protocol ID: 19S-HILLS-MS-09 Investigator (Creator): Dr. Joe Ikley
Project ID: Study Director: Joe Ikley
Sponsor Contact:

Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	5*	6*	7*	8*
	Pest Type				W Weed	W Weed	W Weed	W Weed
	Pest Code				POROL	LIUSS	CHEQU	FAGES
	Pest Scientific Name				Portulaca oleracea	Linum sp.	Chenopodium quinoa	Fagopyrum esculentum
	Pest Name				Common purslane	Flax	Quinoa goosefoot	Common buckwheat
	Description							
	Rating Date				Jul-27-2019	Aug-9-2019	Aug-9-2019	Aug-9-2019
	Rating Type				CONTRO	CONTRO	CONTRO	CONTRO
	Rating Unit				%	%	%	%
	Number of Subsamples				1	1	1	1
	Data Entry Date				Aug-14-2019	Aug-14-2019	Aug-14-2019	Aug-14-2019
	Days After First/Last Applic.				14 14	27 27	27 27	27 27
	Trt-Eval Interval				14 DA-A	14 DA-A	14 DA-A	14 DA-A
1	Untreated Check				0.0 c	0.0 c	0.0 -	0.0 c
2	ENGENIA	12.8	fl oz/a	A	98.7 a	99.7 a	100.0 -	100.0 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
3	ENGENIA	12.8	fl oz/a	A	99.0 a	99.3 a	100.0 -	100.0 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
	NDEMAND 88	1	qt/a	A				
4	ENGENIA	12.8	fl oz/a	A	99.0 a	100.0 a	100.0 -	99.3 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
	NDEMAND ENTOURAGE K	1	qt/a	A				
5	ENGENIA	12.8	fl oz/a	A	97.0 a	100.0 a	100.0 -	98.7 a
	ROUNDUP POWERMAX	32	fl oz/a	A				
	LINKAGE	1	% v/v	A				
6	ENGENIA	6.4	fl oz/a	A	89.0 b	99.0 a	100.0 -	90.0 b
	ROUNDUP POWERMAX	16	fl oz/a	A				
7	ENGENIA	6.4	fl oz/a	A	90.0 b	96.3 a	100.0 -	97.7 a
	ROUNDUP POWERMAX	16	fl oz/a	A				
	NDEMAND 88	0.5	qt/a	A				
8	ENGENIA	6.4	fl oz/a	A	85.0 b	71.7 b	100.0 -	91.3 b
	ROUNDUP POWERMAX	16	fl oz/a	A				
	NDEMAND ENTOURAGE K	0.5	qt/a	A				

North Dakota State University

Effect of pH Modifiers on Engenia + Powermax Efficacy

Trial ID: 19S-HILLS-MS-09 Location: HILLSBORO
Protocol ID: 19S-HILLS-MS-09 Investigator (Creator): Dr. Joe Ikley
Project ID: Study Director: Joe Ikley
Sponsor Contact:

Pest Type		W Weed	W Weed	W Weed	W Weed
Pest Code		POROL	LIUSS	CHEQU	FAGES
Pest Scientific Name		Portulaca oleracea	Linum sp.	Chenopodium quinoa	Fagopyrum esculentum
Pest Name		Common purslane	Flax	Quinoa goosefoot	Common buckwheat
Description					
Rating Date		Jul-27-2019	Aug-9-2019	Aug-9-2019	Aug-9-2019
Rating Type		CONTRO	CONTRO	CONTRO	CONTRO
Rating Unit		%	%	%	%
Number of Subsamples		1	1	1	1
Data Entry Date		Aug-14-2019	Aug-14-2019	Aug-14-2019	Aug-14-2019
Days After First/Last Applic.		14 14	27 27	27 27	27 27
Trt-Eval Interval		14 DA-A	14 DA-A	14 DA-A	14 DA-A
Trt No.	Treatment Name	Rate Rate Unit	Appl Code				
9	ENGENIA	6.4 fl oz/a	A	91.7 ab	93.3 a	100.0 -	98.3 a
	ROUNDUP POWERMAX	16 fl oz/a	A				
	LINKAGE	0.5 % v/v	A				
LSD P=.05				5.60	9.42	.	5.38
Standard Deviation				3.24	5.44	0.00	3.11
CV				3.89	6.45	0.0	3.61
Levene's F				1.902	1.542	0.00	2.298
Levene's Prob(F)				0.123	0.212	.	0.068
Skewness				-2.4455*	-2.2461*	-2.6229*	-2.5315*
Kurtosis				4.6638*	3.7613*	5.265*	4.9478*
Replicate F				5.134	1.075	0.000	0.349
Replicate Prob(F)				0.0189	0.3648	1.0000	0.7107
Treatment F				286.432	109.735	0.000	328.296
Treatment Prob(F)				0.0001	0.0001	1.0000	0.0001

North Dakota State University

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Protocol ID: 19S-HILLS-MS-09 Investigator (Creator): Dr. Joe Ikley
Project ID: Study Director: Joe Ikley
Sponsor Contact:

Trt No.	Treatment Name	Rate	Unit	Appl Code	9*	10*	11	12
	Pest Type				W Weed	W Weed		
	Pest Code				AMARE	POROL		
	Pest Scientific Name				Amaranthus retroflexus	Portulaca oleracea		
	Pest Name				Redroot pigweed	Common purslane		
	Description						Before spray	After spray
	Rating Date				Aug-9-2019	Aug-9-2019	Jul-13-2019	Jul-13-2019
	Rating Type				CONTRO	CONTRO	PH	PH
	Rating Unit				%	%	PH	PH
	Number of Subsamples				1	1	1	1
	Data Entry Date				Aug-14-2019	Aug-14-2019	Aug-20-2019	Aug-20-2019
	Days After First/Last Applic.				27 27	27 27	0 0	0 0
	Trt-Eval Interval				14 DA-A	14 DA-A	0 DA-A	0 DA-A
1	Untreated Check				0.0 b	0.0 d	.	.
2	ENGENIA	12.8	fl oz/a	A	96.3 a	95.0 a	4.520	4.530
	ROUNDUP POWERMAX	32	fl oz/a	A				
3	ENGENIA	12.8	fl oz/a	A	95.0 a	95.0 a	5.730	5.640
	ROUNDUP POWERMAX	32	fl oz/a	A				
	NDEMAND 88	1	qt/a	A				
4	ENGENIA	12.8	fl oz/a	A	95.3 a	94.0 a	7.000	6.690
	ROUNDUP POWERMAX	32	fl oz/a	A				
	NDEMAND ENTOURAGE K	1	qt/a	A				
5	ENGENIA	12.8	fl oz/a	A	95.0 a	93.3 a	4.910	4.890
	ROUNDUP POWERMAX	32	fl oz/a	A				
	LINKAGE	1	% v/v	A				
6	ENGENIA	6.4	fl oz/a	A	90.0 a	78.3 ab	4.650	4.610
	ROUNDUP POWERMAX	16	fl oz/a	A				
7	ENGENIA	6.4	fl oz/a	A	92.3 a	83.3 ab	5.850	5.620
	ROUNDUP POWERMAX	16	fl oz/a	A				
	NDEMAND 88	0.5	qt/a	A				
8	ENGENIA	6.4	fl oz/a	A	90.0 a	51.7 c	6.730	6.440
	ROUNDUP POWERMAX	16	fl oz/a	A				
	NDEMAND ENTOURAGE K	0.5	qt/a	A				

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Protocol ID: 19S-HILLS-MS-09 Investigator (Creator): Dr. Joe Ikley
Project ID: Study Director: Joe Ikley
Sponsor Contact:

Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	9*	10*	11	12
	Pest Type				W Weed	W Weed		
	Pest Code				AMARE	POROL		
	Pest Scientific Name				Amaranthus retroflexus	Portulaca oleracea		
	Pest Name				Redroot pigweed	Common purslane		
	Description						Before spray	After spray
	Rating Date				Aug-9-2019	Aug-9-2019	Jul-13-2019	Jul-13-2019
	Rating Type				CONTRO	CONTRO	PH	PH
	Rating Unit				%	%	PH	PH
	Number of Subsamples				1	1	1	1
	Data Entry Date				Aug-14-2019	Aug-14-2019	Aug-20-2019	Aug-20-2019
	Days After First/Last Applic.				27 27	27 27	0 0	0 0
	Trt-Eval Interval				14 DA-A	14 DA-A	0 DA-A	0 DA-A
9	ENGENIA	6.4	fl oz/a	A	91.7 a	71.7 b	4.950	4.980
	ROUNDUP POWERMAX	16	fl oz/a	A				
	LINKAGE	0.5	% v/v	A				
	LSD P=.05				5.79	13.72	.	.
	Standard Deviation				3.35	7.93	.	.
	CV				4.04	10.77	.	.
	Levene's F				0.937	1.79	.	.
	Levene's Prob(F)				0.511	0.145	.	.
	Skewness				-2.5492*	-1.6311*	0.5782	0.5561
	Kurtosis				5.0238*	1.7154	-1.2433	-1.1703
	Replicate F				1.592	0.824		
	Replicate Prob(F)				0.2341	0.4563		
	Treatment F				260.290	46.179		
	Treatment Prob(F)				0.0001	0.0001		

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Project ID:
Location: HILLSBORO
Investigator (Creator): Dr. Joe Ikley
Study Director: Joe Ikley
Sponsor Contact:

Pest Type
W, Weed = Weed or volunteer crop
Pest Code
LIUSS, Linum sp., Flax = US
CHEQU, Chenopodium quinoa, Quinoa goosefoot = US
FAGES, Fagopyrum esculentum, Common buckwheat = US
AMARE, Amaranthus retroflexus, Redroot pigweed = US
POROL, Portulaca oleracea, Common purslane = US
Rating Type
CONTRO = control / burndown or knockdown
PH = pH
Rating Unit
% = percent
PH = ph

Trial Comments

General comments: The grain amaranth seed did not germinate, but native redroot pigweed pressure came in place. A carpet of common purslane was present over the trial area.

pH data in column 11 is before spraying. pH data from column 12 is after spraying.