ADUVANT KOCHIA CONTROL

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Summary
1. Ideal adjuvant selection based on active ingredients, tank mixtures, and weed-resistance history.
2. Kochia control is greatest when glyphosate is mixed with Spin-Aid and tallow amine adjuvants.

Introduction
Glyphosate resistant (GR) kochia has established in sugarbeet fields across the Red River Valley, adding to the complexity of weed control in sugarbeet. Many growers have responded by using maximum labeled rates of Roundup PowerMax3 in combination with adjuvant systems containing ethoxylated tallow amine (ETA). ETA-based adjuvants were integral to early glyphosate formulations and were widely regarded for superior herbicide uptake and performance. Results from 2024 greenhouse trials suggested that ETA–based adjuvants, such as Last Chance® Pro (CHS Inc., Inver Grove Heights, Minnesota) (5-15% tallow amine) improved kochia control compared with nonionic surfactants (NIS). However, field performance has been inconsistent, likely due to variability in tallow amine concentration, formulation differences, and interactions within tank mixtures. Products such as Full Load™ (AgraSyst, Inc. Spokane, WA) (40% tallow amine) and Fulltec (spraytec, Urbandale, IA) (carboxylic acid– and chelation-based conditioning system) provided informative comparisons of ETA vs. ETA, Fatty Alcohol Ethoxylate (FAE), NIS, and High Surfactant Methylated Oil Concentrate (HSMOC). This experiment was conducted to compare kochia control from Roundup PowerMax3 applied alone or in combination with Spin-Aid and several commercial adjuvants under field conditions. Our objective was to determine which adjuvant system provide the most consistent kochia control from glyphosate mixed with ethofumesate treatments.

Materials and Methods
A field experiment was conducted near Felton, MN in a sugarbeet field in 2025. Sugarbeet was seeded in 22-inch rows at approximately 63,500 seeds per acre and 4.5 inch spacing between seeds. Treatments were applied with a bicycle sprayer in 17 gallons per acre (GPA) spray solution through 8002 XR flat fan nozzles pressurized with CO2 at 35 psi to the center four rows of six row plots 40 feet in length when kochia was approximately 2-inch. (Table 1). Experiment was a randomized complete block design and 4 replications. Visible kochia control (0% to 99%, 0% indicating no control and 99 indicating complete control) were evaluated approximately 4, 7, and 14 days after application B (second POST application). Data were analyzed with the ANOVA procedure of ARM software package.

Table 1. Adjuvant treatments for kochia control field trial, Felton, MN, 2025.

Num	Treatment[a]	Rate
		(fl oz/A or %v/v)
1	Roundup PowerMax3 (RUPM3) + Prefer 90 / RUPM3 + Prefer 90	25 + 0.5% / 25 + 0.5%
2	RUPM3 + Level Best Pro (LBP) / RUPM3 + LBP	25 + 0.5% / 25 + 0.5%
3	RUPM3 + Full Load /RUPM3 + Full Load	25 + 0.5% / 25 + 0.5%
4	RUPM3 + Fulltec / RUPM3 + Fulltec	25 + 0.5% / 25 + 0.5%
5	RUPM3 + Spin-Aid (SA) + Prefer 90 / RUPM3 + SA + Prefer 90	25 + 28 + 0.5% / 25 + 32 + 0.5%
6	RUPM3 + SA + LBP / RUPM3 + SA + LBP	25 + 28 + 0.5% / 25 + 32 + 0.5%
7	RUPM3 + SA + Full Load / RUPM3 + SA + Full Load	25 + 28 + 0.5% / 25 + 32 + 0.5%
8	RUPM3 + SA + Fulltec / RUPM3 + SA + Fulltec	25 + 28 + 0.5% / 25 + 32 + 0.5%

[a]Ethofumesate at 6 fl oz/A and Amsol liquid AMS at 2.5% v/v with all treatments.

Growing Conditions in the Field
Kochia emergence occurred from mid-April through June and was favored by intermittent cooling periods and timely rainfall (Figure 1). Early-emerging kochia remained between 0.5 and 3 inches tall until mid-May, consistent with below-normal temperatures and periodic cooling events reported by NDAWN during this period. Despite limited growth in April and May, successive emergence flushes resulted in high overall weed pressure at the Felton, MN site in 2025 (Figures 2 and 3). At application A (May 14), kochia averaged four side shoots and approximately

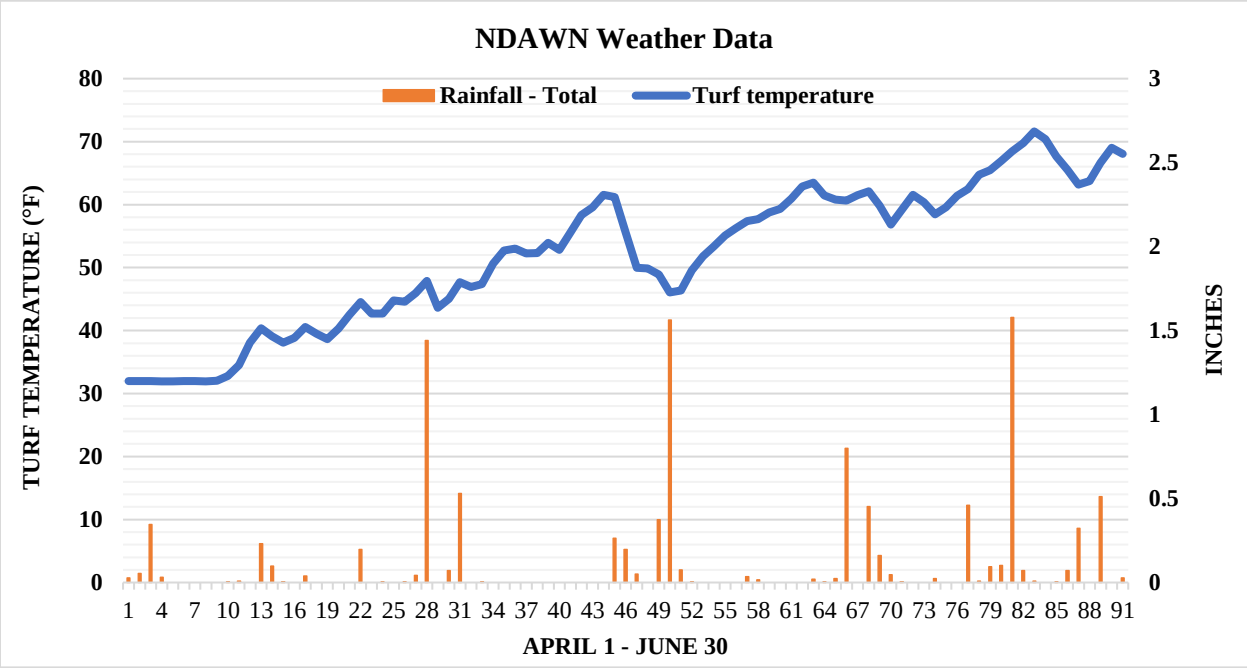

Figure 1. Soil covered with grasses temperature and rainfall at Felton, MN, 2025.

three inches in height. By application B (May 22), plants had increased to an average of six side shoots while remaining near three inches tall. Kochia measuring approximately three inches tall with multiple lateral shoots at both application timings represents a challenging growth stage for glyphosate control, as increased biomass with multiple growing points reduce translocation of active ingredients to meristematic tissues, thereby diminishing overall phytotoxic efficacy; moreover, kochia greater than 2 inches tall with multiple growing points readily metabolize and detoxify xenophobic compounds quickly compared to small kochia (Soltani et al. 2016).

Greenhouse

Greenhouse experiments were conducted using a glyphosate tolerant kochia seed source collected at North Dakota State University (NDSU) field research facilities. Kochia was grown in a flat filled with PROMIX general purpose greenhouse media (Premier Horticulture, Inc., Quakertown, PA) to 0.25-inch and transplanted in 4 × 4-inch pots and grown at 75F to 81F under natural light supplemented with a 16 h photoperiod of artificial light. Herbicide treatments were applied using a spray booth (Generation III, DeVries Manufacturing, Hollandale, MN) equipped with a TeeJet® 8001 even banding nozzle (TeeJet Technologies, Glendale Heights, IL) calibrated to deliver 15 GPA spray solution at 31 psi and 2 mph when kochia was approximately at the 5-lf or ‘dime’ size in diameter. Herbicide treatments follow (Table 2). Visible kochia control (0% to 99%, 0% indicating no control and 99 indicating complete control) were evaluated approximately 6 and 9 days after treatment (DAT). Experiment was a randomized

Table 2. Kochia control with adjuvants, NDSU Waldron Greenhouse, 2025.[a]

Treatments	Rates
	(fl oz/A and %v/v)
Roundup PowerMax3 + Nortron + Destiny HC[b]	25 + 4 + 0.5%
RUPM3 + Nortron + Last Chance Pro	25 + 4 + 0.5%
RUPM3 + Nortron + Full Load	25 + 4 + 0.25%
RUPM3 + Nortron + Fulltec	25 + 4 + 18
RUPM3 + Nortron + Spin-Aid + Destiny HC	25 + 4 + 24 + 0.5%
RUPM3 + Nortron + Spin-Aid + Last Chance Pro	25 + 4 + 24 + 0.5%
RUPM3 + Nortron + Spin-Aid + Full Load	25 + 4 + 24 + 0.25%
RUPM3 + Nortron + Spin-Aid + Fulltec	25 + 4 + 24 + 18
Untreated Check	

complete block design and 4 reps. Experiments were analyzed using Agricultural Research Manager (ARM) version 2025.5.

Field Results

Kochia control was influenced by adjuvant treatment at Felton (Table 3, Figures 1 and 2). At 4 DAAB (days after application B, treatments with Spin-Aid tended to increase kochia control as compared with Roundup PowerMax3 alone with adjuvants. Kochia control numerically was greatest when Spin-Aid and Roundup PowerMax3 were combined with Last Chance Pro (93%), Full Load (91%) or Fulltec (90%). Full Load mixed with Roundup PowerMax3 provided kochia control greater (81%) than Prefer 90 (63%) or Fulltec (58%). Kochia control from Spin-Aid mixed with Roundup PowerMax3 and adjuvants continued to provide greater control than Roundup PowerMax3 alone with adjuvants, 18 DAAB. Last Chance Pro, Full Load and Fulltec mixed with Roundup PowerMax3 and Spin-Aid tended to provide kochia control greater than Prefer 90 mixed with Roundup PowerMax3 and Spin-Aid. Roundup PowerMax3 mixed with Last Chance Pro, Full Load or Prefer 90 provided similar kochia control but control less than Spin-Aid mixed with RoundupPowerMax3 and adjuvants.

Table 3. Kochia control with adjuvants, Felton, MN 2025.[a]

Treatments	4 DAAB	11 DAAB	18 DAAB[c]
	----------%----------		
Roundup PowerMax3 + Nortron + Prefer 90[b]	63 c	78	79 c
Roundup PowerMax3 + Nortron + Last Chance Pro	70 bc	83	80 bc
Roundup PowerMax3 + Nortron + Full Load	81 ab	80	80 bc
Roundup PowerMax3 + Nortron + Fulltec	58 c	75	70 d
Roundup PowerMax3 + Nortron + Spin-Aid + Prefer 90	84 ab	88	85 abc
Roundup PowerMax3 + Nortron + Spin-Aid + Last Chance Pro	93 a	93	91 a
Roundup PowerMax3 + Nortron + Spin-Aid + Full Load	91 ab	89	90 a
Roundup PowerMax3 + Nortron + Spin-Aid + Fulltec	90 a	86	88 ab
LSD (0.05)	15	NS	6
P-Value	0.0001	0.1263	0.0001

[a]Means within evaluation columns not sharing a letter are significantly different according to Fisher's protected LSD at α=0.05.
[b]Treatments repeated 10 days after application A.
[c]Days after application B or application approximately at the 2-lf sugarbeet stage

Figure 2. Spin-Aid mixed with Roundup PowerMax3 and Prefer 90 NIS and Amsol liquid AMS, 18 DAAB, Felton, MN, June 9, 2025.

Figure 3. Roundup PowerMax3 mixed with Prefer 90 NIS and Amsol liquid AMS, 18 DAAB, Felton, MN, June 9, 2025.

Greenhouse Results. Spin-Aid mixed with Roundup PowerMax3 and adjuvants tended to improve kochia control from Roundup PowerMax3 with adjuvants (Table 4, Figures 4 and 5). Kochia control from Roundup PowerMax3 alone or Roundup PowerMax3 with Spin-Aid was influenced by adjuvants. Roundup PowerMax3 mixed with Last Chance Pro provided kochia control greater than all other adjuvant combinations, 6 and 9 days after treatment (DAT). Mixing Spin-Aid with Roundup PowerMax3 generally improved performance across adjuvant types. Fulltec consistently provided the least kochia control with or without Roundup PowerMax3.

Table 4. Kochia control with adjuvants, NDSU Waldron Greenhouse, 2025.[a]

Num	Treatments	6 DAT	9 DAT[b]
		----------%----------	
1	Roundup PowerMax3 (RUPM3) + Nortron + Destiny HC	28 bc	53 c
2	RUPM3 + Nortron + Last Chance Pro	73 a	91 a
3	RUPM3 + Nortron + Full Load	34 bc	65 abc
4	RUPM3 + Nortron + Fulltec	5 c	10 d
5	RUPM3 + Nortron + Spin-Aid + Destiny HC	56 ab	81 ab
6	RUPM3 + Nortron + Spin-Aid + Last Chance Pro	61 ab	86 ab
7	RUPM3 + Nortron + Spin-Aid + Full Load	61 ab	85 ab
8	RUPM3 + Nortron + Spin-Aid + Fulltec	54 ab	65 abc
9	Untreated Check	0 c	0 d
	P-Value	0.0001	0.0001

[a]Means within evaluation columns not sharing a letter are significantly different according to Fisher's protected LSD at α=0.05.
[b]Days after treatment.

Figure 4. From left to right, kochia control from treatments 1, 2, 3, and 4, Roundup PowerMax3 with adjuvants, 14 days after treatment (14 DAT), Waldron greenhouse, 2025.

Figure 5. From left to right, kochia control from treatments 5, 6, 7, and 8, Roundup PowerMax3 mixed with Spin-Aid, 14 DAT, Waldron greenhouse, 2025.

Discussion.

Field and greenhouse experiments indicate ETA-based adjuvants with Roundup PowerMax3 improved kochia control as compared to Roundup PowerMax3 mixed with NIS, HSMOC, and FAE-based adjuvant systems. However, it is important to distinguish unique capabilities of each adjuvant system and how this influenced results. Differences in kochia control among adjuvant systems reflect fundamental differences in surfactant chemistry and formulation interactions. Ethoxylated tallow amines possess cationic, lipophilic properties that enhance cuticular penetration and plant mobility, increasing glyphosate uptake and translocation. Conversely, NIS and FAE primarily improve spray retention and spreading, resulting in less aggressive penetration and more variable efficacy. High surfactant methylated oil concentrates like Destiny HC enhance cuticle solubilization by "loosening" nonpolar cuticular waxes, thereby increasing cuticle permeability for polar herbicide molecules like glyphosate or glufosinate. In our experiments, Destiny HC with Roundup PowerMax3 (53%) provide less kochia control as compared to ETA product Last Chance Pro (91%) with PowerMax3 alone, but provided similar kochia control when Full Load was mixed with Spin-Aid and Roundup PowerMax3 suggesting these two adjuvant systems have effective carrier capabilities while Last Chance Pro increases glyphosate efficacy alone or in tank mixtures.

Fulltec contains 27.8% phosphoric acid, acting as a water conditioning agent like that of ammonium sulfate (AMS). However, poor kochia control from Fulltec treatments was evaluated. One possible explanation, Fulltec is not a cationic adjuvant, unlike products such as Full Load or Last Chance Pro. The absence of a cationic surfactant may have reduced glyphosate absorption and subsequent translocation to meristematic binding sites in a highly glyphosate-tolerant kochia population. Additionally, Fulltec has a viscous formulation that may have separated since May, 2025, and required further mixing before measuring Waldron Greenhouse treatments in November, 2025.

Fatty alcohol ethoxylate, Fulltec, is most important in complex tank mixtures since the nonionic reduces the potential for cation exchange and chelation among formulation types and active ingredients. Conditioning products like Fulltec are advantageous when hard water, multivalent ions, or multiple formulation chemistries are present, as chelation and pH buffering can preserve herbicide availability and spray solution stability. This effect was demonstrated when Roundup PowerMax3 was mixed with Spin-Aid, where improved compatibility and performance suggested enhanced glyphosate activity through cation chelation and pH stabilization (Table 4). In the absence of effective conditioning, these interactions may limit uptake of weak acid herbicides such as dicamba or 2,4-D.

Summary

Differences among adjuvant systems demonstrated relative strengths in controlling glyphosate tolerant kochia (Figure 6). Cationic ETA-based adjuvants consistently provided the most reliable control, particularly when tank-mixed with Spin-Aid, because their cationic and lipophilic properties enhance cuticle penetration, translocating movement, and spray retention. Nonionic systems like fatty alcohol ethoxylates improved spray coverage and spreading but generally provided less uptake and translocation. These results illustrate how adjuvant chemistry affects herbicide performance and highlight the potential of ETA and other adjuvant systems to improve control of non-target-site-resistant kochia. Finally, AMS was included in the 2025 field trial but not in the greenhouse trial. Adjuvant systems, ETA and FAE, contain sulfuric or phosphoric acid that acts like AMS by adjusting spray solution pH, further supporting herbicide activity.

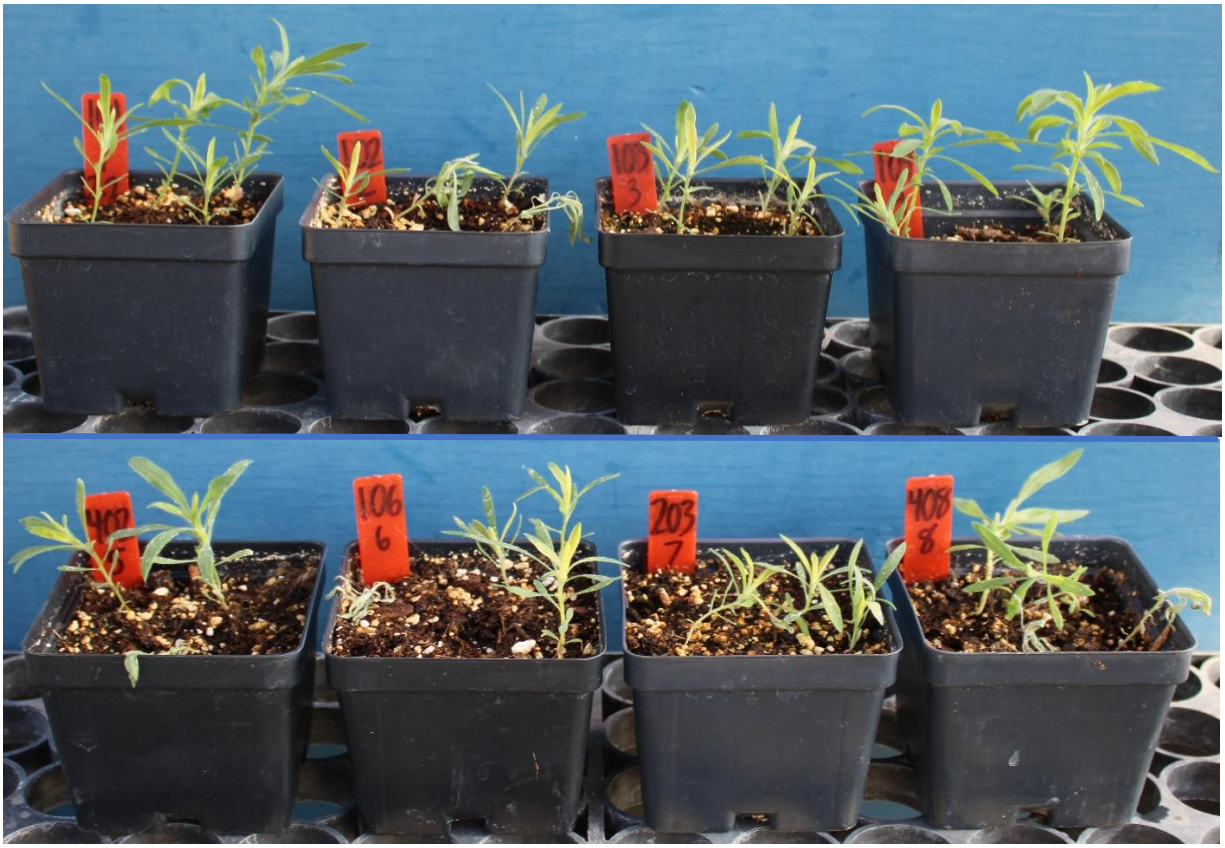

Figure 6. Kochia control 10 DAAA, Waldron Greenhouse, 2025.

Literature Cited

Soltani N, Nurse RE, Sikkema PH (2016). Biologically effective dose of glyphosate as influenced by weed size in corn. Canadian J of Plant Sci. 96:455–460.