ETHOFUMESATE

Thomas J. Peters[1], Alexa L. Lystad[2], and David Mettler[3]

[1]Extension Sugarbeet Agronomist and Weed Control Specialist, [2]Research Specialist
North Dakota State University & University of Minnesota, Fargo, ND, and [3]Research Agronomist, Southern Minnesota Beet Sugar Cooperative, Renville, MN

Summary

1. Chemical properties of ethofumesate, including adsorptivity and water solubility, partially explain the inconsistent waterhemp control across environmental conditions.
2. Waterhemp control from ethofumesate is best following timely, adequate, and penetrating rainfall events.
3. Ethofumesate rate alone does not overcome sub-optimal environmental conditions.
4. The use of shallow tillage to incorporate ethofumesate in the top soil may improve the probability for waterhemp control.
5. Moisture in the soil solution is necessary for waterhemp control, even if ethofumesate moves into the soil during tillage.

Introduction

Ethofumesate or 'Nortron' was registered by Fisons Corporation in 1977 for control of small seeded broadleaves including common lambsquarters, waterhemp, and redroot pigweed control in sugarbeet (Edwards et al. 2005; Ekins and Cronin 1972). Ethofumesate is applied preplant incorporated (PPI) and preemergence (PRE) at use rates from 1.00 (2 pt/A) to 3.75 (7.5 pt/A) pound per acre (Kellogg 2011) and up to 0.38 (0.75 pt/A) pound per acre postemergence.

Weed control following PRE application requires timely and adequate precipitation to activate ethofumesate in the weed seedling layer due to low water solubility and strong adsorption to soil characteristics as compared to the chloroacetamide family of herbicides, dicamba, and trifluralin (Table 1; Shaner 2014; Schweitzer 1975). Ethofumesate rarely leaches in soil and provides up to 10 weeks of residual control to grass and broadleaf weed species (Ekins and Cronin 1972). Ethofumesate is absorbed through emerging roots and shoots when applied to soil (Eshel et al. 1978).

Table 1. Herbicides behavior in soil.

Common Name	Trade Name	Adsorptivity[a]	Water Solubility[b]
		K_{OC}	ppm[c]
acetochlor	Warrant	200	233
dimethenamid-p	Outlook	155	1,174
S-metolachlor	Dual Magnum	200	488
ethofumesate	Nortron	340	110
trifluralin	Treflan	7,000	0.3
dicamba	XtendiMax	2	4,500

[a]K value represents the ratio of herbicide bound to soil collides versus what is free in the water solution. The higher the K value, the greater the adsorption to soil colloids.
[b]Water solubility is a measure of the amount of chemical substance that can dissolve in water at a specific temperature. For example, milligrams per liter.
[c]ppm=Parts per million

Waterhemp control from ethofumesate has been an enigma (Merriam-Webster Dictionary definition: mysterious, puzzling, or difficult to understand) and it seems our interpretation of ethofumesate becomes more confusing with experiments in more environments. One of our first waterhemp experiments was near Herman, MN in 2014. We observed greater than 85% waterhemp control in July from ethofumesate alone or ethofumesate mixed with Dual Magnum PRE, but found ethofumesate did not provide season-long waterhemp control (Table 2). This outcome led to the development of a layered strategy in sugarbeet beginning with ethofumesate alone or ethofumesate mixtures with Dual Magnum PRE, followed by (fb) the split application of chloroacetamide herbicides at the V2 and V6 sugarbeet stage.

Table 2. Waterhemp control in response to herbicide treatment, Herman MN, 2014.

Treatment[a]	Application	Rate	Waterhemp Control			
			Jun 23	Jul 2	Jul 10	Aug 27
		---pt/A---	----------%----------			
Ethofumesate	PPI	6	78	90	86	74
Ethofumesate	PRE	6	88	88	86	70
Etho + Dual Magnum	PRE	3 + 0.5	99	99	97	94
Etho + Dual Magnum	PRE	4 + 0.5	98	97	97	94
Etho + Dual Magnum	PRE	3 + 1	98	100	100	98
Etho + Dual Magnum	PRE	4 + 1	100	100	100	98

[a]Treatments included repeat Roundup PowerMax applications POST at 28 fl oz/A followed by (fb) 28 fl oz/A fb 22 fl oz/A + Prefer 90 NIS at 0.25% v/v and N-Pak AMS at 2.5% v/v.

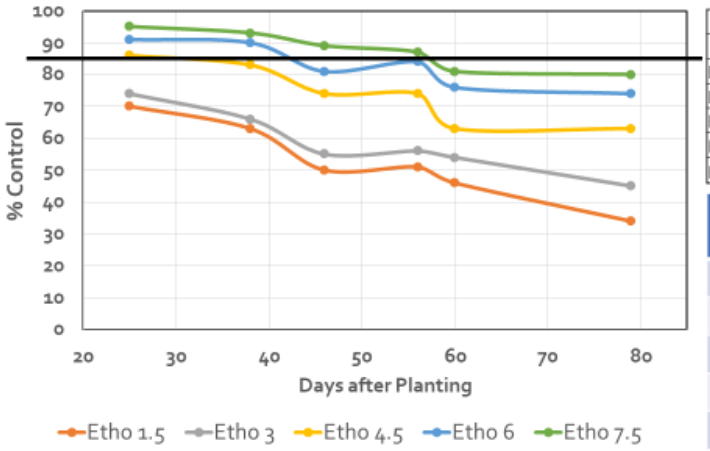
Ethofumesate alone or mixed with Dual Magnum PRE layered with chloroacetamide herbicides consistently controlled waterhemp in field experiments from 2015 to 2019. In general, sugarbeet were planted in May and received sufficient rainfall for activation of soil residual herbicides. However, our promising results did not reflect our historical knowledge, especially Dr. Dexter's research, which found incorporating ethofumesate improved the consistency of pigweed control from ethofumesate. Moreover, Dr. Dexter conducted several experiments over the years comparing preplant ethofumesate with preemergence ethofumesate (Table 3). Dr. Dexter's data suggests the importance of timely rainfall for activating ethofumesate. Finally, he conducted research on the appropriate depth to incorporate ethofumesate as well as comparing tillage equipment for optimal ethofumesate incorporation (Dexter et al., 1982).

Table 3. Comparing preplant incorporated and preemergence ethofumesate at 3.75 to 4.0 lb/A; 1973 to 1986.[a]

Nortron application	Redroot pigweed control at 4 of 7 locations	Redroot pigweed control at 3 of 7 locations
	----------%	----------%
PPI	97	91
PRE	79	93
LSD (0.05)	**11**	**NS**

[a]Data taken from NDSU PLSC 350 class notes.

Growers frequently inquired about the maximum ethofumesate rate one can apply without injury to nurse crops. An experiment, first established in 2020, considered waterhemp control in response to ethofumesate rate (Figure 1 and Table 4). The experiment was established near Blomkest and at the ACS Technical Center, Moorhead, MN in 2020. Spring barley was drilled perpendicular to plots sprayed with ethofumesate at 1.5 to 7.5 pt/A. The primary objective was to find the threshold between spring barley safety and waterhemp control. Our second objective was to determine waterhemp control from ethofumesate at various application rates.



	Days after planting					
	25	38	46	56	60	79
Etho 1.5	70	63	50	51	46	34
Etho 3	74	66	55	56	54	45
Etho 4.5	86	83	74	74	63	63
Etho 6	91	90	81	84	76	74
Etho 7.5	95	93	89	87	81	80

Calendar date	Rainfall (inch)	Total Rainfall (inch)
May 9	0.7	0.7
May 26	1.7	2.4
June 10	0.3	2.7
June 25	1.3	4.0
July 10	3.8	7.8

Figure 1. Waterhemp control in response to ethofumesate PRE at 1.5 to 7.5 pt/A, Blomkest MN, 2020.

Our working hypothesis was ethofumesate provides greater than 85% waterhemp control for less than 30 days at 1.5, 3.0 and 4.5 pt/A and greater than 85% waterhemp control for more than 30 days at 6.0 and 7.5 pt/A. That is, complete waterhemp control but for short duration at rates less than 4.5 pt/A. To our surprise, the 1.5 and 3.0 pt/A rates did not accomplish 85% control at either Moorhead or Blomkest. The Moorhead experiment was completely overgrown with waterhemp by July 4, 2020 (Table 4). We attributed the Moorhead results to less than optimal results from ethofumesate in a season where ethofumesate activation by rainfall was compromised by below normal rainfall after planting.

Table 4. Waterhemp control in response to ethofumesate rate, Moorhead MN, 2020

		Waterhemp Control		
Herbicide	**Rate**	**May 26**	**June 15**	**June 28**
	--pt/A--	----------%----------		
Ethofumesate	0	8 e	0 d	3 d
Ethofumesate	1.5	38 d	35 c	13 cd
Ethofumesate	3	50 c	51 b	18 c
Ethofumesate	4.5	73 a	68 a	33 b
Ethofumesate	6.0	63 b	70 a	58 a
Ethofumesate	7.5	65 ab	76 a	53 a
LSD (0.20)		**9**	**9**	**14**

This experiment was repeated at two locations in 2021, a location near Hector International Airport, Fargo, ND and a second location at the ACS Technical Center, Moorhead, MN. We elected to include both preplant incorporation and preemergence application in the experimental design in 2021 in response to previous year results with below normal rainfall. We also elected to conduct the experiment at 2, 4, 6, 8, 10 and 12 pt/A ethofumesate. Unfortunately, 2021 was equally as dry as 2020. Conditions were so poor that the experiment at Moorhead was abandoned due to erratic emergence of spring barley. We observed very poor overall control of waterhemp at Fargo location. However, we observed that waterhemp escapes were either small or large plant, depending on treatment, suggesting control of either early or late emerging waterhemp. Ethofumesate PPI, averaged across treatments, provided no control of early emerging waterhemp, but 56% control of late emerging waterhemp (Figure 2). Conversely, ethofumesate PRE, averaged across treatments, provided 55% control of early emerging waterhemp, but only 28% control of late emerging waterhemp.

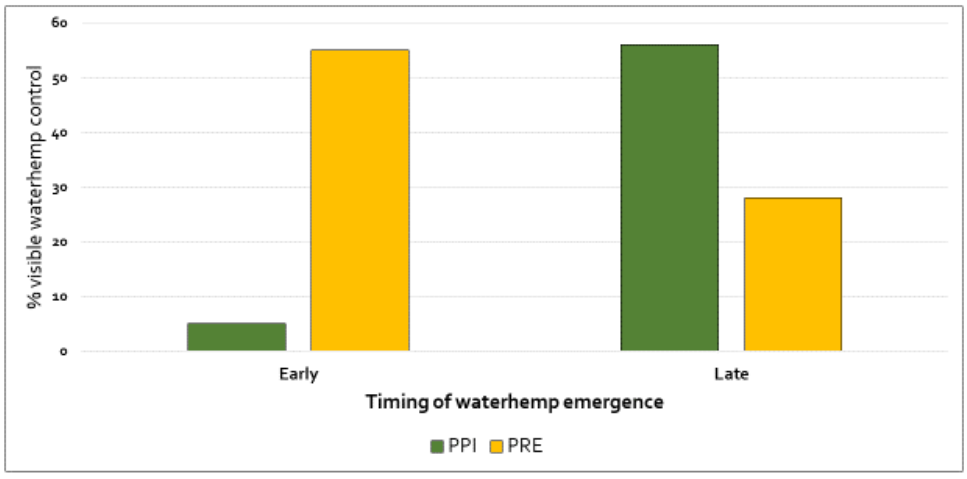


Figure 2. Early and late emerging waterhemp control in response to ethofumesate PPI or PRE, Fargo ND, 2021.

We hypothesize that ethofumesate incorporated into the soil was bound to soil colloids and unavailable for waterhemp uptake early in the season due to sub-optimal soil moisture conditions (Figure 3). However, ethofumesate moved into the soil solution following rain events in June and was partially effective at controlling later emerging waterhemp. Ethofumesate PRE, which likely was bound to the soil surface, may have moved into the soil following rainfall events on May 20 and June 7, providing some early season control. However, degradation likely reduced control of late emerging waterhemp.

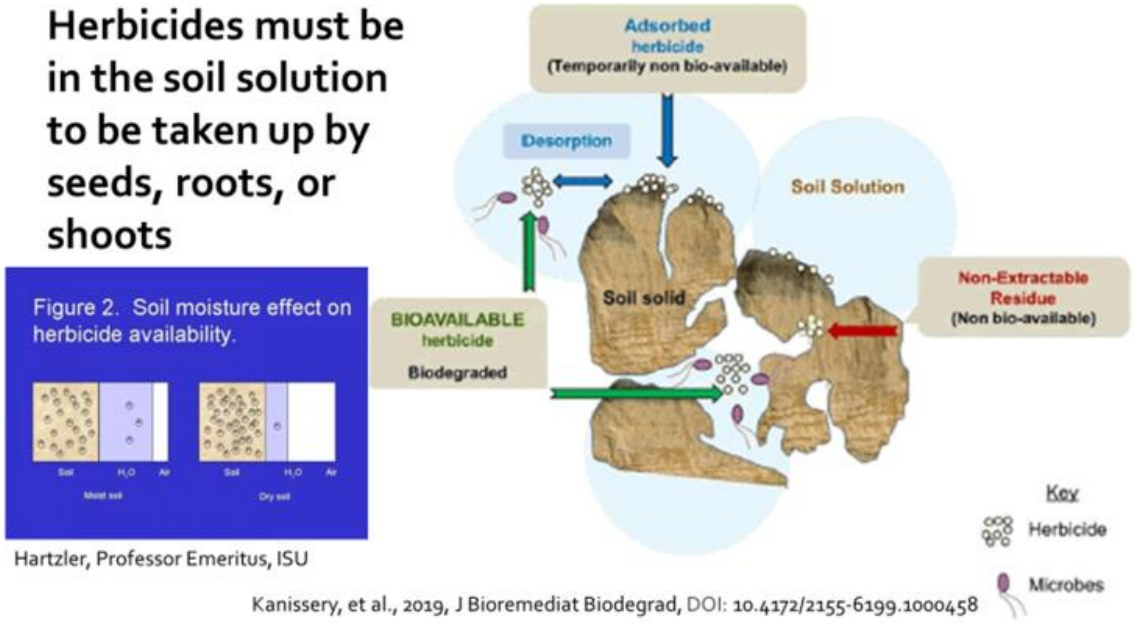


Figure 3. Illustration depicting ethofumesate bound to soil colloids when soil water content is low and in the soil solution when the soil water content is greater.

We believe soil moisture is a predictor of ethofumesate performance and at least partially explains the inconsistent results growers have experienced when ethofumesate has been applied preemergence in some fields in 2021 (and 2022). Likewise, waterhemp control from ethofumesate has been inconsistent even with effective incorporation, when soil moisture levels were sub-optimal such as conditions in some geographies in 2021.

Our working hypothesis is that ethofumesate controls waterhemp best following timely, adequate, and penetrating rainfall events to move ethofumesate off the soil surface and into the water solution and/or spaces between colloids. Ethofumesate rate does not overcome challenges caused by a dry spring. Finally, incorporating ethofumesate might be an effective way for improving waterhemp control, provided ethofumesate is not incorporated too deep, thereby diluting concentration.

The objective of this 2022 experiment was to 1) demonstrate crop safety to nurse crop barley and 2) determine the duration of waterhemp control from ethofumesate.

Materials and Methods

An experiment was conducted near Moorhead, MN in 2022. The experimental area was prepared for planting by fertilizing and conducting tillage across the experimental area. Sugarbeet was planted on May 25 at Moorhead, MN in 2022. Sugarbeet was seeded in 22-inch rows at approximately 62,000 seeds per acre with 4.6 inch spacing between seeds. Herbicide treatments are found in Table 5.

Treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 40 psi to the center four rows of six row plots 40 feet in length in 2022. Ethofumesate

applied preplant was incorporated into soil using a Kongskilde s-tine field cultivator with rolling baskets set approximately 2-inch deep and operated at approximately 5 mph.

Table 5. Herbicide treatment, application timing, and rate, Moorhead, MN, 2022.

Herbicide Treatment	Application timing	Rate (pt/A)
Ethofumesate	Preplant	2
Ethofumesate	Preplant	4
Ethofumesate	Preplant	6
Ethofumesate	Preplant	8
Ethofumesate	Preplant	10
Ethofumesate	Preplant	12
Ethofumesate	Preemergence	2
Ethofumesate	Preemergence	4
Ethofumesate	Preemergence	6
Ethofumesate	Preemergence	8
Ethofumesate	Preemergence	10
Ethofumesate	Preemergence	12

Visible waterhemp control (0 to 100% control, 0% indicating no control, and 100% indicating complete control) was collected approximately 10 days after treatment (DAT). Experimental design was randomized complete block design with four replications in a factorial arrangement, with factors being herbicide rate and application timing. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

Results and Discussion

Waterhemp control was evaluated on approximately ten-day intervals from June 16 to August 3, 2022. Figure 4 demonstrates waterhemp control × ethofumesate rate, averaged across application type, since waterhemp control from ethofumesate PPI (preplant incorporated) did not interact with ethofumesate PRE (P-Value = 0.8926, 0.7840, 0.6326, 0.4246, 0.2129 and 0.3762, approximately 20, 30, 40, 50, 60, and 70 DAP (days after planting) evaluation, respectively). Cumulative rainfall was 0.9, 2.6, and 4.5 inches, 14, 30 and 45 DAP and ethofumesate application, in 2022, which was enough to activate the herbicide, regardless of application method, and explains the lack of interaction. However, waterhemp control from ethofumesate at labeled rates failed to reach 85% control.

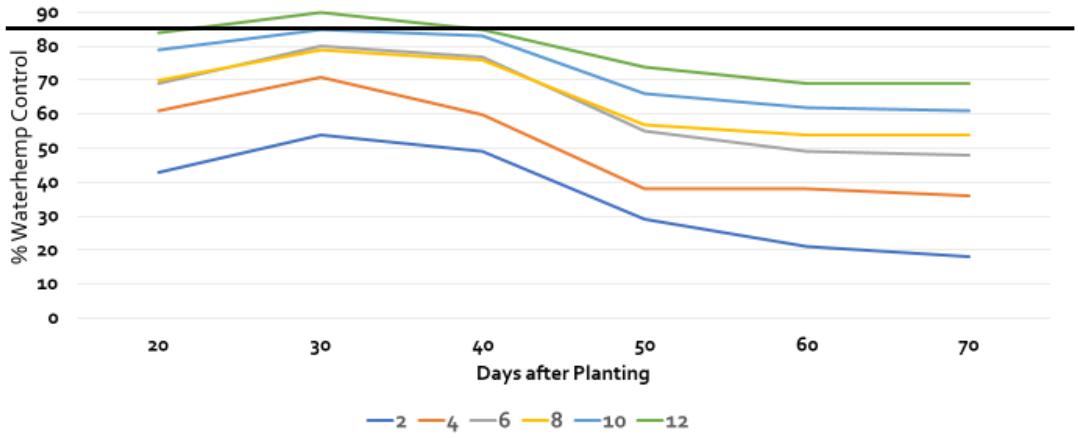


Figure 4. Waterhemp control in response to ethofumesate, averaged across PPI and PRE, Moorhead MN, 2022.

Ethofumesate PPI or PRE is a component in the waterhemp control strategy which includes PRE fb EPOST fb POST application of soil residual herbicides. Sugarbeet reach the 2-lf stage between 14 and 28 DAP, depending on planting date. Ekins and Cronin (1972) reported ethofumesate provides up to 10 weeks of residual broadleaf control. However, Ekins and Cronin did not research waterhemp control. Our 2022 result suggests no more than 6-weeks of waterhemp control (Figure 5) which seems to align with results from previous years.

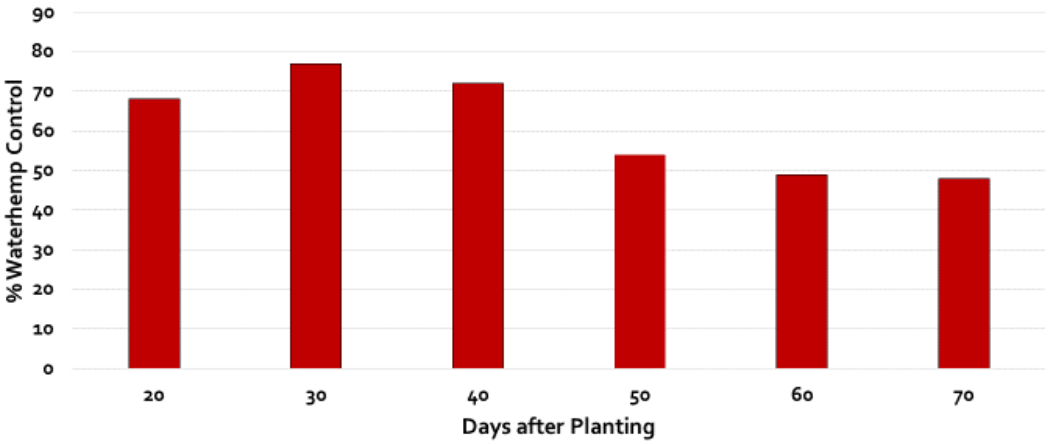


Figure 5. Waterhemp control in response to ethofumesate, averaged across ethofumesate rate and application type, Moorhead MN, 2022

Conclusion

Implementing the layered soil residual strategy is our best opportunity for season-long waterhemp control in sugarbeet. Our best opportunity for a clean start has been an early spring planting date along with an application of ethofumesate alone PRE or ethofumesate mixed with Dual Magnum PRE fb ample rainfall for activation. Our results suggest ethofumesate rate alone does not overcome environmental challenges when timely, adequate, and penetrating rainfall fails to occur. Thus, mixing Dual Magnum with ethofumesate is a strategy to reduce risk, as Dual Magnum adsorbs less to soil and is more water soluble, thus providing short duration control until sufficient rainfall occurs for ethofumesate activation. Incorporating ethofumesate is a risk-aversion strategy, provided ethofumesate is incorporated 0.5- or 1-inch (tillage at 1-inch or 2-inch) with tillage equipment that enables movement of ethofumesate into the soil, thereby maximizing pigweed control.

References

Dexter AG et al. (1981) Comparison of herbicide incorporation tools. Sugarbeet Res Ext Rep 12:49-56.

Edwards D et al. (2005) Reregistration eligibility decision for ethofumesate. Environmental Protection Agency. 738-R-05-010 https://www3.epa.gov/pesticides/chem_search/reg_actions/ reregistration/red_ PC-110601_1-Sep-05.pdf. Accessed: January 28, 2020

Ekins WL, Cronin CH (1972) NC 8438, a promising new broad spectrum herbicide for sugar beet. J Amer Soc Sugar Beet Technol 17:134–143

Entz MH (1982) Ethofumesate (Norton) layering—a comparison of different application times. Sugarbeet Res Ext Rep 13:76–79

Kellogg M (2011) Willowood ethofumesate 4SC. EPA. https://www3.epa.gov/pesticides/chem_search/ppls/087290-00001-20110411.pdf. Accessed: January 28, 2020

Schweizer EE (1975) Crop response to soil application of ethofumesate. Weed Sci 23:409–413

Shaner DL (2014) Herbicide Handbook. 10th edn. Lawrence, KS: Weed Science Society of America. 513 p