A COMPENDIUM OF OUR ETHOFUMESATE KNOWLEDGE

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Summary

1. Ethofumesate might be our most important sugarbeet herbicide; however, it is our least understood sugarbeet herbicide.
2. Ethofumesate applied at greater than 2 pt/A will reduce stands of nurse crops including spring barley.
3. Early season waterhemp control from ethofumesate is dependent on rainfall or mechanical tillage for activation. Rainfall provides the best quality activation but has been unreliable, especially in years with late sugarbeet planting.
4. Our research supports ethofumesate alone applied either at 4 or 6 pt/A or tank mixed with Dual Magnum for early season waterhemp control.

Introduction

We have designed and conducted many ethofumesate experiments. Our experiments consider many facets of ethofumesate including reduced rates combined with Dual Magnum for waterhemp control, potential to injure nurse crops, and amount of rainfall required for activation. More recently we have compared ethofumesate preplant and preemergence, especially since spring rainfall for activation has been inconsistent. This compilation completes a series of five experiments conducted from 2020 to 2023 comparing waterhemp control and spring barley injury from ethofumeste applied up to 12 pt/A preplant or preemergence.

Nurse crop safety. Growers frequently ask if ethofumesate can be used safely with a nurse crop. Nurse crops are used as companion crops to reduce effect of blowing soil on sugarbeet. Stated another way, growers want to know the trade-off between using a soil residual herbicide for waterhemp control versus a successful establishment of nurse crops. We learned nurse crops respond differently to ethofumesate and Dual Magnum, that spring wheat and barley are more sensitive than oat (Peters et al. 2015). Second, nurse crops tolerate Dual Magnum better than ethofumesate, although both Dual Magnum and ethofumesate inhibit the root and apical meristem in susceptible species. The difference is Dual Magnum is metabolized faster than ethofumesate by cereals. However, there are situations where Dual Magnum and ethofumesate cause minimal stand loss to cover crops; situations where rainfall fails to incorporate herbicides into the soil for uptake by emerging shoots or developing roots. We have received questions regarding winter rye as a cover crop (fall seeded) and winter rye as a nurse crop (spring seeded). To be clear, we have not evaluated rye tolerance to ethofumesate; however, I anticipate no injury from fall-seeded rye and less injury from spring-seeded rye as compared with oat, spring wheat, or barley.

Activation. Challenges with activating soil residual herbicides have been commonplace since 2021. Conditions were so poor that the experiment at Moorhead was abandoned due to erratic emergence of spring barley and we observed very poor overall control of waterhemp at the Fargo location in 2021. Waterhemp escapes were either small or big plants, depending on treatment, suggesting control of either early or late emerging waterhemp. Ethofumesate preplant provided no control of early emerging waterhemp, but 56% control of late emerging waterhemp. Conversely, ethofumesate preemergence provided 55% control of early emerging waterhemp, but only 28% control of late emerging waterhemp. 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 1). Ethofumesate moved into the soil solution following rain events in early June and was partially effective at controlling later emerging waterhemp. Ethofumesate PRE likely was bound to the soil surface and may have moved into the soil following these rainfall events in late May and early June, providing some early season control. However, degradation likely reduced control of late emerging waterhemp.

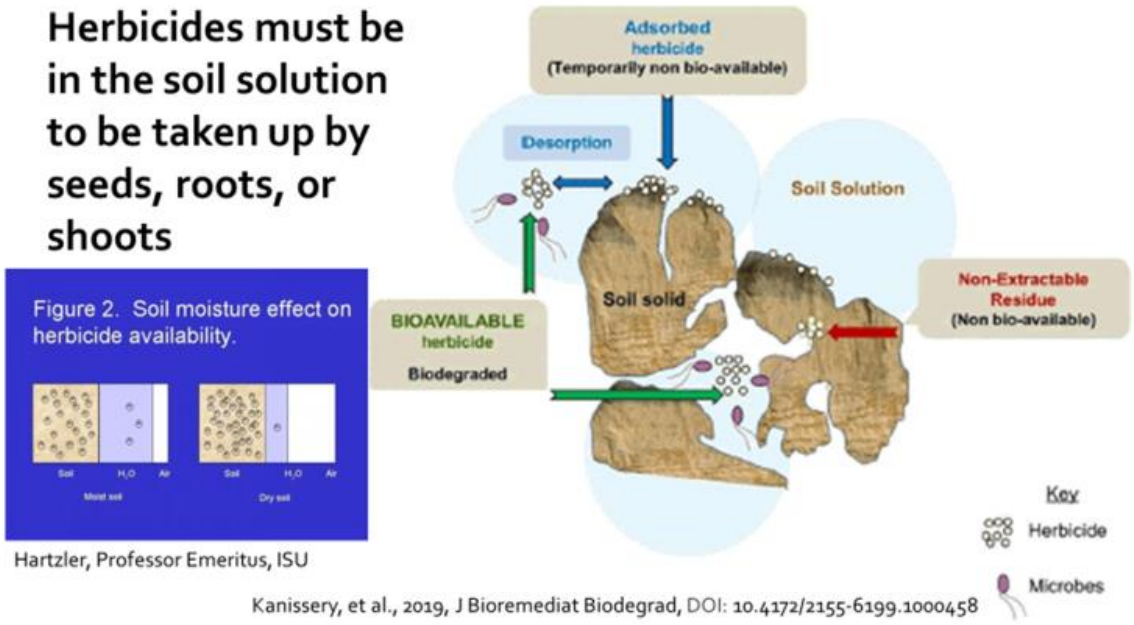

Figure 1. Illustration depicting ethofumesate bound to soil colloids when soil water content is low and in the soil solution when the soil water content is greater.

Our hypothesis is supported by the physical properties of ethofumesate compared with other herbicides (Table 1). KOC value of 350 for ethofumesate means that it has a high affinity for soil colloids and would rather be bound to soil than be in the soil solution as compared with other chloroacetamide herbicides. Second, water solubility value of 110 means ethofumesate is less water soluble than other chloroacetamide herbicides and requires more rainfall (quantity and intensity) to be incorporated into the soil. Further, we believe rainfall and soil moisture (above and below) are a predictor of waterhemp control from ethofumesate and at least partially explains the inconsistent results growers have experienced when ethofumesate has been applied preemergence in some fields in previous years. Finally, 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.

Table 1. Herbicide absorptivity (KOC) and water solubility (ppm).

Herbicide	Absorptivity	Water Solubility
	---K_{OC}[a]---	---ppm---
Treflan	7,000	0.3
Dicamba	2	4,500
Acetochlor	200	233
Outlook	155	1,174
S-metolachlor	200	488
Ethofumesate	340	110

[a]The K value represents the ratio of herbicide bound to soil collides versus what is free in the water. Thus, the higher the K value, the greater the adsorption to soil colloids.

Waterhemp control. Ethofumesate has not provided season-long waterhemp control in our, or previous NDSU, sugarbeet research. Further, growers are reluctant to use full rates preplant or preemergence due to price, specter of carryover to grass crops planted in sequence with sugarbeet, and injury potential to nurse crops. Rather, growers have adopted an integrated strategy whereby chloroacetamide herbicides applied POST to sugarbeet and PRE to

waterhemp in a single or split application at the V2 and/or V6 sugarbeet stage precede application PRE. Ethofumesate alone or ethofumesate mixed with Dual Magnum are applied PRE at less than full rates. We teach that PRE is not providing season long control, but rather is a layer to protect sugarbeet against early germinating waterhemp until the chloroacetamides are applied. However, we have wondered about waterhemp control from less than labeled rates. That is, are less than labeled rates providing full control for a short duration or are less than labeled rates providing substandard control for short duration?

Waterhemp control was dependent on ethofumesate PRE rate and evaluation timing (Figure 2). We believe our target must be 85% to 90% waterhemp control for 30 to 40 days or until chloroactamide herbicides can be applied and are activated by rainfall. The 85% waterhemp control threshold was accomplished when ethofumesate was applied at 4.5, 6.0, or 7.5 pt/A. The 90% waterhemp control threshold was accomplished when ethofumesate was applied at 6.0 or 7.5 pt/A. Ethofumsate PRE at 7.5 pt/A provided 85% waterhemp control, 54 days after application, indicating ethofumesate at the full rate does not provide season long waterhemp control. Sub-lethal rates or ethofumesate at 1.5 or 3.0 pt/A did not meet our 85% to 90% waterhemp control threshold. These data suggest sub-lethal rates are providing insufficient waterhemp control, even for a short duration.

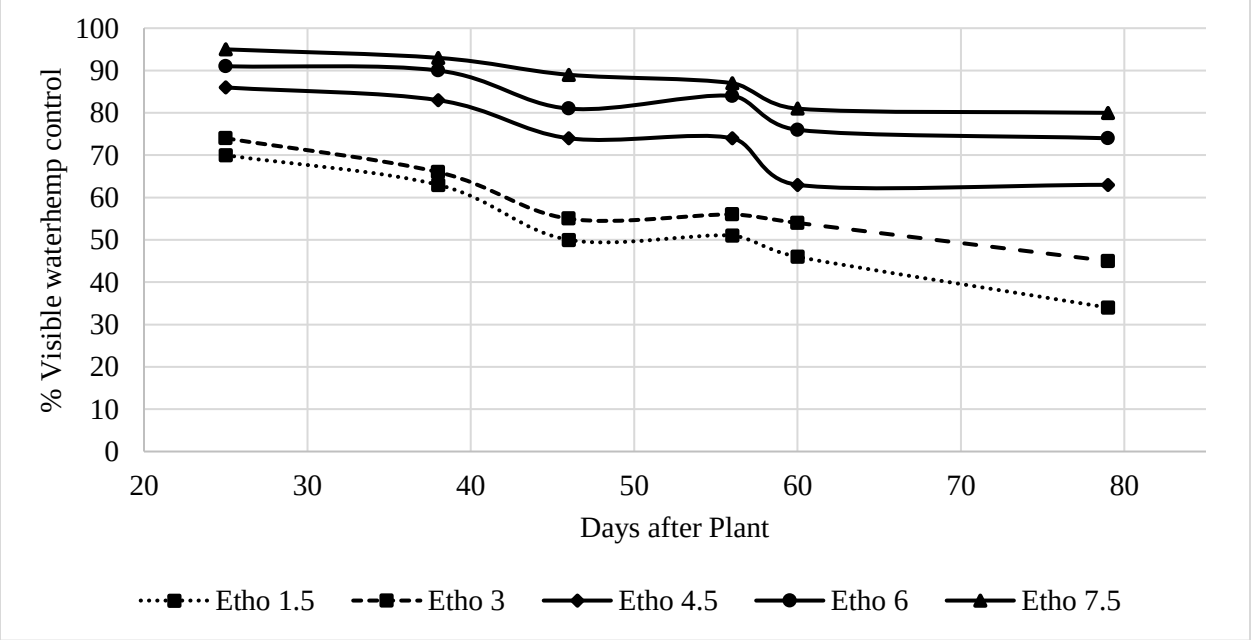

Figure 2. Waterhemp control from ethofumesate PRE across rates, Blomkest, MN, 2020.

We continued to evaluate the fate of ethofumesate on both nurse crops and waterhemp control (Peters et al. 2022). 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, 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.

The objective of this 2023 experiment was to 1) demonstrate crop safety to nurse crop spring barley and 2) determine the duration of waterhemp control from ethofumesate.

Materials and Methods

An experiment was conducted near Moorhead, MN in 2023. The experimental area was prepared for planting by fertilizing and conducting tillage across the experimental area. Sugarbeet was planted on May 24 at Moorhead, MN in 2023. Sugarbeet was seeded in 22-inch rows at approximately 62,000 seeds per acre with 4.5 inch spacing between seeds. Herbicide treatments are found in Table 2.

Treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 35 psi to the center four rows of six row plots 40 feet in length. Spring barley was seeded perpendicular to sugarbeet rows using a Land Pride grain drill (Great Plains Manufacturing, Salina, KS). Ethofumesate applied preplant and spring barley was incorporated into soil parallel to sugarbeet rows using a Kongskilde s-tine field cultivator with rolling baskets set approximately 2-inch deep and operated at approximately 5 mph.

Table 2. Herbicide treatment, application timing, and rate, Moorhead, MN, 2023.

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

Spring barley nurse crop ground coverage was evaluated using a numeric scale of 1 to 9 (1-3=poor ground coverage, 4-6=good ground coverage, and 7-9=excellent ground coverage). Visible waterhemp control (0 to 100% control, 0% indicating no control, and 100% indicating complete control) was collected 34, 42, 49, 54, and 67 days after treatment (DAT). Experimental design was randomized complete block design with four replications in a factorial arrangement, with factors being herbicide application method and herbicide rate. Data were analyzed with the ANOVA procedure of ARM, version 2023.6 software package.

Results and Discussion

Herbicide activation technique did not interact with ethofumesate rate (P-value=0.3202, 0.6570, 0.8676; 13, 19, 26 days after planting (DAP), respectively) so assessment of ground coverage was averaged across activation technique. However, we observed improved spring barley ground coverage across rates when ethofumesate was applied PRE as compared with ethofumesate machine incorporated into soil (data not shown). The site received 0.8-inch rainfall, 5 and 7 DAP, which should have been plenty of rainfall to both activate ethofumesate PRE into the soil and further distribute ethofumesate incorporated with tillage.

Spring barley stands decreased as ethofumesate rate increased (Figure 3). We observed what was considered ‘poor nurse crop ground cover’ following ethofumesate at 12 pt/A. We observed ‘good nurse crop ground coverage’ following ethofumesate rates of 4 to10 pt/A and ‘excellent nurse crop ground coverage’ following ethofumesate at 2 pt/A. These evaluations were consistent between 12 and 25 DAP; however, we observed numerically improved

spring barley ground coverage over time. This could be due to continued growth and tillering as the spring barley established.

Ultimately, what is considered acceptable nurse crop ground cover is up to the producer. Our experiment indicates ethofumesate applied for waterhemp control at greater than 2 pt/A significantly reduced nurse crop ground coverage.

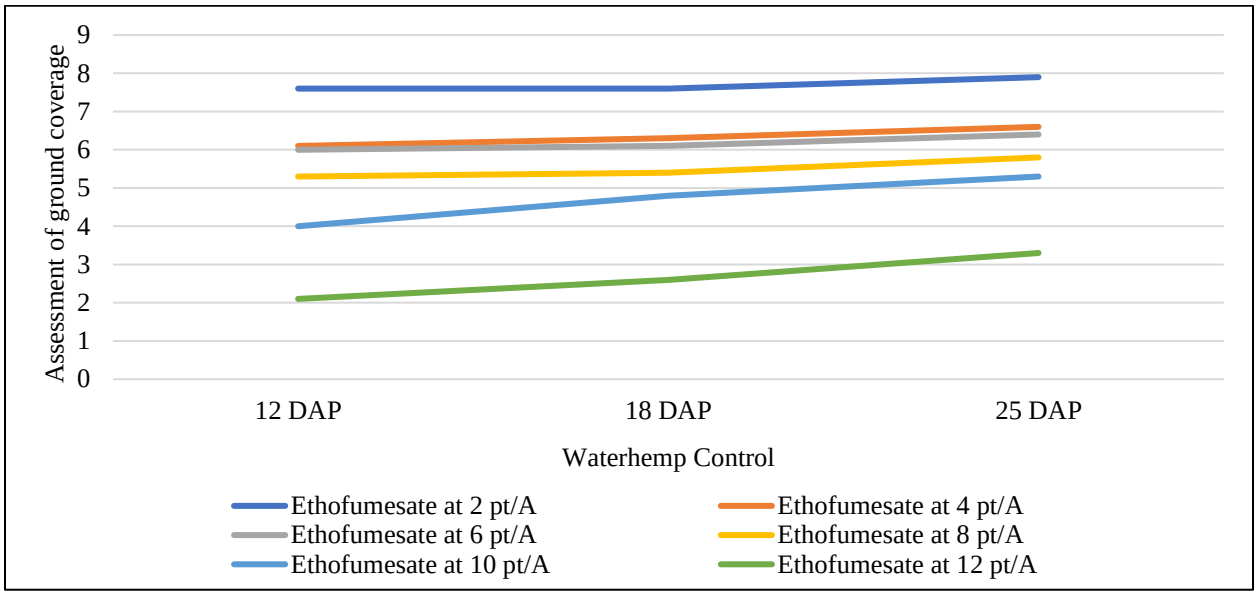

Figure 3. Spring barley ground coverage 12, 18, and 25 days after planting (DAP) in response to ethofumesate rate, Moorhead, MN, 2023.

Herbicide activation technique did not interact with ethofumesate rate (P-value >0.10) 34 to 67 DAP so assessment of waterhemp control was averaged across herbicide application method. Overall, waterhemp control was slightly greater when ethofumesate was rainfall activated as compared with tillage incorporation (Table 3). Improved waterhemp control PRE ranged from 14% to 20% across evaluation timing. Depth of incorporation for preplant incorporated (PPI) treatments may have contributed to decreased waterhemp control as compared with PRE treatments. We have often cautioned producers on pushing ethofumesate too deep into the soil with tillage since waterhemp germinates from the surface to 1-inch deep in soil. Ethofumesate PRE provided greater and longer lasting control as compared with ethofumesate PPI, which is likely due to the uniformity and consistency from rainfall activation.

Table 3. Waterhemp control in response to herbicide application method, averaged across ethofumesate rate, Moorhead, MN, 2023.[a]

Herbicide Application Method	Waterhemp Control				
	34 DAP[b]	42 DAP	49 DAP	54 DAP	67 DAP
	----------%----------				
Preplant Incorporated	63 b	54 b	47 b	47 b	31 b
Preemergence	77 a	74 a	61 a	64 a	54 a
LSD (0.10)	6	6	7	6	8

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.

[b] DAP=days after planting.

Waterhemp control and length of waterhemp control was dependent on rate (Table 4). Ethofumesate at 10 and 12 pt/A provided the greatest waterhemp control across all evaluation timings. However, ethofumesate at 10 and 12 pt/A are not labeled rates in sugarbeet. Ethofumesate at 4 to 8 pt/A provided similar waterhemp control up to 34 days after planting. Waterhemp control from ethofumesate at 6 and 8 pt/A was the same up to 67 days after application (DAA). Ethofumesate at 4 pt/A provided greater waterhemp control across evaluation timings in this experiment.

Table 4. Waterhemp control in response to ethofumesate rate, averaged across activation technique, Moorhead, MN, 2023.[a]

		Waterhemp Control				
Herbicide Treatment	Rate	34 DAP[b]	42 DAP	49 DAP	54 DAP	67 DAP
	---pt/A---	----------%----------				
Ethofumesate	2	45 c	32 d	15 e	19 d	10 e
Ethofumesate	4	66 b	54 c	34 d	38 c	29 d
Ethofumesate	6	70 b	72 ab	64 bc	61 b	49 bc
Ethofumesate	8	74 ab	66 bc	58 c	62 b	41 cd
Ethofumesate	10	82 a	77 ab	75 ab	74 a	59 ab
Ethofumesate	12	84 a	83 a	78 a	77 a	66 a
LSD (0.10)		10	11	11	11	13

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.

[b] DAP=days after planting.

Conclusions

Spring barley ground cover decreased as ethofumesate rate increased from 2 to 12 pt/A and loss of ground cover was greater from ethofumesate PPI than ethofumesate PRE. Ethofumesate at 2 pt/A caused negligible loss of ground cover; however, ethofumesate rates between 4 and 6 pt/A may cause up to 50% loss of nurse crop ground cover. Ground cover from nurse crops is a grower preference. Ultimately, the effect of ethofumesate rate and application method on cover crop will be dependent on conditions after application method and once herbicide rate is selected. Waterhemp control from ethofumesate was greatest PRE, indicating ethofumesate dilution occurs with mechanical tillage incorporation. Loss of control from mechanical activation as compared with rainfall activation averaged 18% across evaluation timings at Moorhead, MN in 2023. This outcome was in a season when there was timely rainfall for activation after application. Ultimately, the decision is about waterhemp control and a compromise between nurse crop ground cover and expectations for early season waterhemp control. Ethofumesate at 2 pt/A alone PRE

does not accomplish early season waterhemp control and is discouraged (Figure 4). We encourage ethofumesate alone at 4 to 6 pt/A PRE or ethofumesate at 2 to 3 pt/A tank mixed with Dual Magnum PRE at 0.5 to 0.75 pt/A, targeting a minimum of 85% waterhemp control for 30 to 40 days or until chloroacetamide POST application.

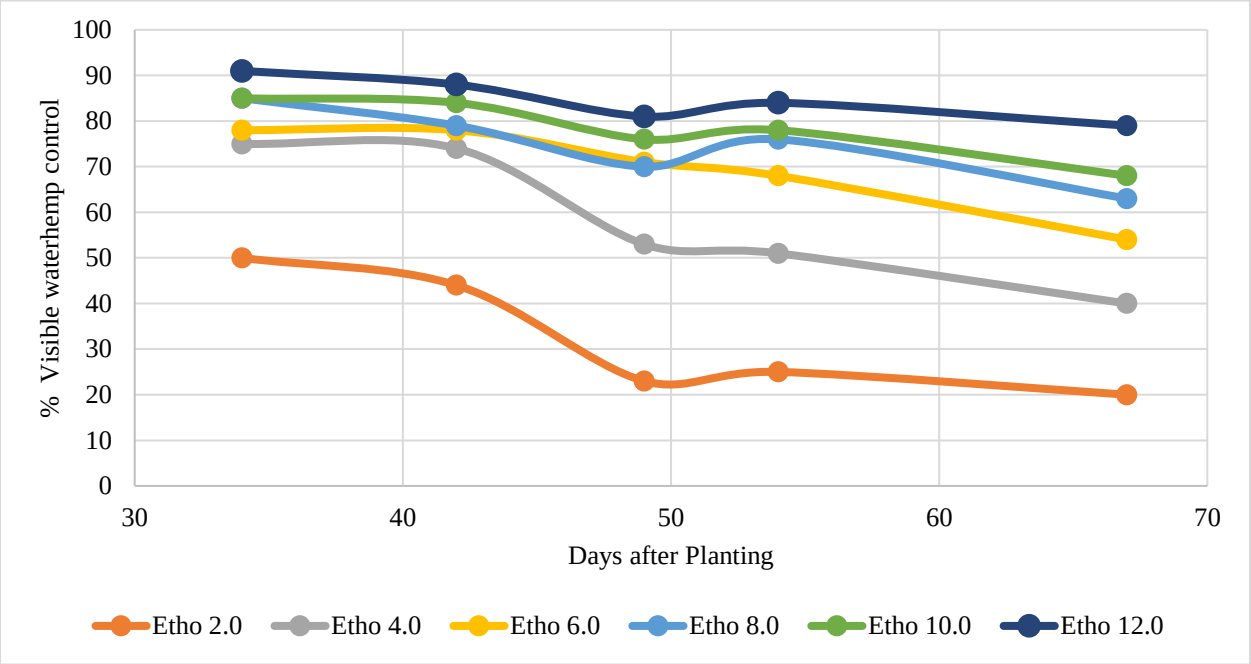

Figure 4. Waterhemp control from ethofumesate PRE across rates, Moorhead, MN, 2023.

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