PUTTING OUT THE WEED CONTROL FIRES

R. Gordon Harvey[1]

This is the 87th presentation that I or one of my graduate students and technicians have given at this meeting over the last thirty years. And it is the hardest because I can't use my own voice. I joined the faculty of the Department of Agronomy, University of Wisconsin -Madison as an Assistant Professor on July 1, 1970. I had one personal goal. That was to help Wisconsin farmers optimize their weed management. I was 24 years old and knew I could conquer any challenge. Although my Ph.D. research had been a laboratory project, I knew from start that I would have a big field program. I just didn't dream of how big it would become. At that time I also made a commitment to always obtain crop yield data from every field study (most other weed scientists were only rating weed control). I had arrived at the right time, at the early stages of the herbicide revolution. After my arrival, every experimental herbicide being developed for alfalfa, corn, dry beans, lupines, peas, soybeans and sweet corn came through my program. I wrote the first section 18 label for the state, and worked with IR-4 to register herbicides for minor crops. I don't know how many herbicides that came through my program? There were hundreds! But looking back now, much of that research was a wasted effort. About four or five years after each new herbicide was registered, a species shift would occur or herbicide-resistant weeds would develop minimizing the benefit. These are fires mentioned in the title of this presentation. I have spent much of my career identifying the most serious weed management fires confronting Wisconsin farmers, and then I tried to put them out.

Just look at the projects with which I was involved. I started out trying to find solutions for fall panicum and crabgrass problems in corn. Wisconsin farmers were using too much atrazine and those weeds were tolerant. We solved that problem with Lasso and Dual. But, then we developed severe velvetleaf, wild-proso millet, woolly cupgrass, triazine-resistant lambsquarters and triazine-resistant pigweed problems. We solved the velvetleaf, lambsquarters and pigweed problems with dicamba (Banvel, Clarity and a component of Distinct, Marksman and Northstar) which happily is still

[1]Professor, Department of Agronomy, University of Wisconsin-Madison, Madison, WI 53706.

working. But we solved the cupgrass and millet problems with Accent. Now we have trouble with crabgrass, yellow foxtail and ALS-inhibitor resistant giant foxtail. In soybeans, we started with Treflan and developed eastern black nightshade, common ragweed and velvetleaf problems. When Sencor came along, we could better control velvetleaf but not the eastern black nightshade, and we often had injured soybeans. Basagran then came along, but now we could not control lambsquarters and pigweed. Blazer then came along (and subsequently Galaxy, Cobra and Reflex) but we again encountered injured soybeans. The ACCase-inhibitors like Assure, Fusion, Poast Plus and Select came along but now there are ACCase-inhibitor resistant crabgrass and giant foxtail. Command did not control pigweed, and Pursuit is being overrun by common ragweed, waterhemp and ALS-inhibitor resistant weeds.

So what is the answer? Until we can grow prostrate, medium height

and tall crops together and utilize all of the sunlight intercepted by a field, mother nature will be sending us new weeds. When farmers use the same herbicides repeatedly, they run the risk of losing the effectiveness of those products. That might not have been a problem in 1970, but it is today. There are not as many new products in development now.

Let me describe the results of two long-term studies I recently completed. The first was a four-year study of species shifts when twelve herbicide treatments were repeatedly applied to corn in a field infested with a diversity of weeds on my own farm. Included were Roundup treatments to Roundup Ready corn, Liberty treatments to Liberty Link corn, Lightning treatments to Clearfield corn, and Balance (this herbicide is not registered for use in Wisconsin), Accent plus Clarity, Harness plus atrazine and Harness followed by Marksman treatments to SR corn (Table 1). Every treatment experienced species shifts, and corn grain yields of only three of the twelve treatments did not decline over four years of repeated treatment use. That leads me to think it is never desirable to use the herbicide repeatedly in the same field.

The second study was an evaluation of procedures recommended to prevent establishment of herbicide-resistant weeds. Triazine-resistant common lambsquarters (TR-CHEAL)and ACCase-inhibitor resistant giant foxtail (SR-SETFA) was seeded in every plot in an isolated field on my own farm and populations of the two herbicide resistant weeds were monitored from 1996 to 1999, and nonherbicide-resistant velvetleaf populations were monitored from 1997 to 1999. Poast-resistant (SR) field corn was planted each year. Standard herbicide treatments were atrazine plus Dual, and Clarity plus Poast Plus. Management systems included repeated annual applications of each standard herbicide treatment, alternate-year rotations of the respective herbicide treatments, and half- or full-rate sequential combinations of all four herbicides. All of the herbicide-based systems were compared with and without one annual row cultivation. Following continuous use of the atrazine plus Dual reatment, respective 1999 lambsquarters and velvetleaf populations were 503 and 132/m^2 uncultivated, and 242 and 12/m^2 cultivated. Following continuous use of the Poast Plus plus Clarity treatment, 1999 giant foxtail populations were 1483/m^2 uncultivated, and 615/m^2 cultivated. When herbicides were rotated annually, results varied depending on the order of herbicide treatments. But when the 1996 treatment was the one to which each respective weed was susceptible, respective 1999 lambsquarters, giant foxtail and velvetleaf populations were 103, 505 and 178/m^2 uncultivated and 28, 201 and 10/m^2 cultivated. When herbicides were applied annually in half-rate combinations, respective 1999 lambsquarters, foxtail and velvetleaf populations were 0, 42 and 15/m^2 uncultivated, and 2, 15 and 5/m^2 cultivated. When herbicides were applied annually in full-rate combinations, respective 1999 lambsquarters, foxtail and velvetleaf populations were 0, 1 and 6/m^2 uncultivated, and 0, 0 and 3/m^2 cultivated. Results suggest that alternate-year herbicide rotations combined with annual row cultivation reduced the rate but did not prevent population increases of herbicide-resistant or tolerant weeds. Seed dormancy appeared to responsible for the failure of alternate-year rotations. Four or five year herbicide rotations are possible for corn and probably would be more effective since there would a greater depletion of herbicide resistant or tolerant seeds in the soil seed

bank. Combinations of herbicides with different mechanisms of action plus annual row cultivation were most effective in preventing establishment of herbicide-resistant or tolerant weed populations. But herbicide combinations were also the most expensive alternatives and may lead to multiple resistance.

So what are my recommendations to keep herbicides effective longer? As we saw in the previous study, alternate year rotations were ineffective because of longer weed seed dormancy, and complex herbicide mixtures are too expensive. But you have to keep the weeds guessing! Thus, I recommend a four or five year herbicide rotation. I would be careful not to use a herbicide with the same mode of action more than once for the same weed over that period (a farmer could use Accent for wild-proso millet in corn and Pursuit for velvetleaf in soybeans). The only exception I would make is to use Roundup in Roundup Ready soybeans not more frequently than twice every four years. I would prefer that the Roundup Ready soybeans to be drilled or cultivated.

Years ago, I worked on another problem, enhanced soil biodegradation of thiocarbamate herbicides. We found that the enhanced biodegradation disappeared if we rotated herbicides. Some people speculate that whenever a herbicide is used repeatedly, there will be some level of enhanced biodegradation. If that was the case, it would be mitigated by a four- or five-year herbicide rotation. Some farmers like to cut herbicide rates. If a farmer has weeds that tolerate a herbicide, he may need to use a high rate to maintain weed control. With an extended herbicide rotation, a grower may be able to cut rates of all his herbicides!

With that, I will say good-bye. In my mind I still think I am 24 years old, able to conquer anything. If I could just wake up from this bad dream, I could get on with my life. I wish my career at the University could have been extended for another fifteen years. But the last thirty years have been fun and productive. I thank all of you in the audience for your friendship and support. When I was forced to take medical disability retirement, my program had a world-wide reputation for being responsive to needs of farmers. We had the technical staff, graduate students, equipment and financial support to continue to support Wisconsin and U.S. agriculture. But my colleagues at the university have decided to take weed science research in a different direction. They have pledged to try to fill the void, but they will be short one person and something will have to be dropped. So part of my program will die with me. If able, I will continue to work as an emeritus professor. I am planning to coordinate the pea and sweet corn research in 2001. But I must be realistic, I am already living on borrowed time.

Table 1. **Weed populations and corn grain yield in herbicide treatments repeatedly applied to the same plots from 1997 to 2000.**

Treatment	Weed:	ABUTH	ACCVI	AMBEL	CAGSE	DIGIS	MELAL	SETFA	Yield
		$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Lightning +		----------	----------	----------	(Plants/7m^2)	----------	----------	----------	(T/ha)
AMS + Sun-it II	1997	1 (1)	0	2 (2)	1 (1)	0	12 (5)	15 (9)	10.8 (0.6)
(EP) at 0.056 +	1998	0	0	3 (3)	0	15 (20)	38 (20)	1 (1)	9.0 (0.8)
+ 2.5 lb ai/A +	1999	0	0	4 (4)	0	0	39 (25)	1 (1)	6.1 (1.4)
0.94% v/v	2000	0	48 (21)	33 (39)	0	0	49 (14)	37 (48)	5.4 (1.0)

Treatment	Weed: Year	ABUTH	ACCVI	AMBEL	CAGSE	CYPES	MELAL	SETFA	Yield
		$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Prowl/		----------	----------	----------	(Plants/7m^2)	----------	----------	----------	(T/ha)
Lightning +	1997	2 (3)	0	2 (2)	1 (1)	0	3 (3)	12 (18)	11.4 (0.6)
AMS + Sun-it II	1998	0	0	2 (1)	0	0	2 (1)	1 (1)	9.2 (0.7)
(PRE/EP) at 1.5 lb	1999	1 (1)	0	3 (1)	1 (1)	6 (10)	3 (1)	0	7.3 (1.0)
ai/A fb 0.056 + 2.5 lb ai/A + 0.94% v/v	2000	0	42 (23)	22 (18)	3 (5)	0	3 (1)	21 (28)	6.6 (0.8)

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	Weed:	ABUTH	ACCVI	AMBEL	CAGSE	CYPES	MELAL	SETFA	Yield
Treatment	Year	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Surpass/		---------- (Plants/7m^2) ----------							(T/ha)
Lightning +	1997	1 (1)	0	1 (1)	1 (2)	0	2 (1)	3 (1)	10.0 (1.2)
AMS + Sun-it II	1998	0	0	1 (1)	0	2 (2)	7 (5)	1 (1)	10.9 (1.0)
(PRE/EP) at 1.8 lb	1999	0	0	0	3 (5)	0	1 (2)	0	6.8 (1.8)
ai/A fb 0.056 + 2.5 lb ai/A + 0.94% v/v	2000	12 (11)	15 (7)	17 (25)	3 (5)	0	16 (10)	0	10.0 (1.3)

	Weed:	ABUTH	CAGSE	CYPES	DIGIS	SETFA			Yield
Treatment	Year	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Harness/		---------- (Plants/7m^2) ----------							(T/ha)
Marksman	1997	1 (1)	1 (1)	0	1 (1)	3 (2)			11.0 (0.5)
(PRE/EP) at 1.8 lb	1998	0	0	1 (1)	0	2 (1)			10.6 (0.7)
ai/A fb 1.4 lb ai/A	1999	63 (35)	2 (2)	1 (2)	0	1 (1)			8.5 (1.1)
	2000	99 (87)	3 (5)	19 (33)	0	171 (127)			9.0 (1.9)

Table 1. **Continued**.

	Weed:	**ABUTH**	**AMBEL**	**CAGSE**	**CHEAL**	**DIGIS**	**MELAL**	**SETFA**	**Yield**
Treatment	**Year**	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Harness +		--------------------	--------------------	--------------------	(Plants/7m^2)	--------------------	--------------------	--------------------	(T/ha)
atrazine (PRE) at	1997	2 (3)	1 (1)	2 (3)	1 (1)	0	1 (1)	16 (15)	6.6 (1.8)
1.8 + 1.0 lb ai/A	1998	36 (15)	0	0	0	1 (1)	2 (2)	8 (5)	9.7 (1.4)
	1999	224 (176)	1 (1)	8 (8)	0	0	0	0	5.1 (1.5)
	2000	53 (26)	4 (5)	37 (18)	9 (7)	0	0	24 (13)	2.7 (1.2)

	Weed:	**ABUTH**	**CAGSE**	**CHEAL**	**CYPES**	**MELAL**	**POLCO**	**SETFA**	**Yield**
Treatment	**Year**	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Harness +		--------------------	--------------------	--------------------	(Plants/7m^2)	--------------------	--------------------	--------------------	(T/ha)
Balance (PRE)	1997	1 (1)	1 (1)	3 (3)	0	2 (3)	0	17 (17)	6.0 (0.3)
at 0.9 + 0.094 lb ai/A	1998	8 (4)	1 (1)	11 (14)	23 (20)	5 (4)	0	8 (5)	7.6 (0.6)
	1999	0	28 (10)	0	4 (6)	1 (1)	6 (10)	0	3.9 (1.2)
	2000	6 (3)	53 (8)	10 (13)	52 (32)	5 (1)	18 (20)	27 (11)	2.6 (0.4)

	Weed:	**ABUTH**	**AMBEL**	**CHEAL**	**CYPES**	**DIGIS**	**SETFA**	**SOLPT**	**Yield**
Treatment	**Year**	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)
Accent + +Nicosulfuron +		--------------------	--------------------	--------------------	(Plants/7m^2)	--------------------	--------------------	--------------------	(T/ha)
Clarity + NIS +	1997	1 (2)	1 (1)	3 (1)	0	7 (6)	7 (9)	0	7.6 (0.7)
28%N (POST) at	1998	0	0	1 (1)	12 (10)	48 (29)	0	0	10.3 (0.7)

Table 1. **Continued**.

0.032 lb ai + 0.5 lb	**1999**	**19 (22)**	**0**	**17 (20)**	**9 (8)**	**28 (22)**	**0**	**0**	**7.3 (0.4)**
ae/ha +0.25% + 4 % v/v	**2000**	**23 (13)**	**0**	**1 (1)**	**0**	**263 (77)**	**0**	**14 (8)**	**6.1 (3.3)**

	Weed:	**ABUTH**	**AMBEL**	**CHEAL**	**CYPES**	**DIGIS**	**SETFA**	**SOLPT**	**Yield**
Treatment	**Year**	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)	$\bar{x}$ (***sd***)
Accent + Poast		**-------------------- (Plants/7m^2) --------------------**							**(T/ha)**
Plus + Clarity +	**1997**	**14 (23)**	**1 (1)**	**0**	**0**	**20 (5)**	**0**	**0**	**5.0 (0.3)**
NIS +28%N (POST)	**1998**	**2 (2)**	**2 (3)**	**2 (3)**	**1 (2)**	**59 (30)**	**8 (10)**	**0**	**10.3 (0.5)**
at 0.032 + 0.16 lb ai	**1999**	**12 (4)**	**0**	**7 (10)**	**34 (52)**	**15 (22)**	**0**	**0**	**7.7 (0.8)**
+ 0.5 lb ae/A + 0.25% + 4% v/v	**2000**	**21 (18)**	**0**	**1 (1)**	**151 (113)**	**0**	**0**	**8 (4)**	**5.4 (3.7)**

Table 1. **Continued**.

Treatment	**Weed:** / **Year**	**ABUTH** $\bar{x}$ (*sd*)	**CAGSE** $\bar{x}$ (*sd*)	**CYPES** $\bar{x}$ (*sd*)	**DIGIS** $\bar{x}$ (*sd*)	**MELAL** $\bar{x}$ (*sd*)	**SETFA** $\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	**Yield** $\bar{x}$ (*sd*)
Liberty +		---------- (Plants/$7m^2$) ----------							**(T/ha)**
atrazine + AMS	**1997**	**0**	**0**	**0**	**0**	**1 (1)**	**40 (29)**		**9.8 (0.6)**
(POST) at 0.27 +	**1998**	**1 (1)**	**0**	**45 (40)**	**7 (5)**	**0**	**33 (30)**		**8.5 (1.0)**
0.75 + 3.0 lb ai/A	**1999**	**3 (3)**	**0**	**70 (74)**	**6 (3)**	**0**	**3 (3)**		**7.1 (1.5)**
	2000	**0**	**11 (10)**	**185 (106)**	**0**	**6 (5)**	**0**		**6.0 (1.4)**

Treatment	**Weed:** / **Year**	**ABUTH** $\bar{x}$ (*sd*)	**AMARE** $\bar{x}$ (*sd*)	**CAGSE** $\bar{x}$ (*sd*)	**CHEAL** $\bar{x}$ (*sd*)	**CYPES** $\bar{x}$ (*sd*)	**MELAL** $\bar{x}$ (*sd*)	**SETFA** $\bar{x}$ (*sd*)	**Yield** $\bar{x}$ (*sd*)
Liberty + AMS/		---------- (Plants/$7m^2$) ----------							**(T/ha)**
Liberty + AMS	**1997**	**0**	**0**	**0**	**0**	**0**	**1 (1)**	**2 (3)**	**10.2 (0.8)**
(POST/LPST) at	**1998**	**0**	**0**	**0**	**11 (12)**	**12 (11)**	**0**	**0**	**9.2 (0.6)**
0.27 + 3.0 lb ai/A/	**1999**	**1 (1)**	**3 (5)**	**0**	**7 (11)**	**52 (55)**	**0**	**0**	**7.5 (0.8)**
0.27 + 3.0 lb ai/A	**2000**	**0**	**8 (5)**	**1 (2)**	**8 (8)**	**138 (64)**	**2 (1)**	**5 (6)**	**6.0 (1.4)**

Table 1. **Continued**.

Treatment	**Weed:** / **Year**	**ABUTH** $\bar{x}$ (*sd*)	**AMARE** $\bar{x}$ (*sd*)	**CAGSE** $\bar{x}$ (*sd*)	**CYPES** $\bar{x}$ (*sd*)	**SETFA** $\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	**Yield** $\bar{x}$ (*sd*)
Roundup/ Glyphosate/		------------------------------	------------------------------	------------------------------	**(Plants/7m^2)**	------------------------------	------------------------------	------------------------------	**(T/ha)**
Roundup (POST/	**1997**	**2 (3)**	**0**	**1 (1)**	**0**	**2 (1)**			**8.6 (0.6)**
LPST) at 0.56 lb	**1998**	**1 (1)**	**0**	**0**	**0**	**3 (2)**			**9.8 (1.0)**
ae/ha/ 0.56 lb ae/A	**1999**	**7 (4)**	**0**	**0**	**9 (8)**	**0**			**8.1 (1.7)**
	2000	**49 (4)**	**8 (4)**	**2 (3)**	**24 (27)**	**14 (17)**			**8.5 (1.1)**

Treatment	**Weed:** / **Year**	**ABUTH** $\bar{x}$ (*sd*)	**CAGSE** $\bar{x}$ (*sd*)	**CHEAL** $\bar{x}$ (*sd*)	**CYPES** $\bar{x}$ (*sd*)	**MELAL** $\bar{x}$ (*sd*)	**SETFA** $\bar{x}$ (*sd*)	$\bar{x}$ (*sd*)	**Yield** $\bar{x}$ (*sd*)
Roundup +		------------------------------	------------------------------	------------------------------	**(Plants/7m^2)**	------------------------------	------------------------------	------------------------------	**(T/ha)**
Harness +	**1997**	**1 (1)**	**1 (2)**	**0**	**0**	**1 (1)**	**8 (11)**		**10.3 (0.3)**
atrazine (POST) at	**1998**	**1 (1)**	**0**	**0**	**9 (12)**	**1 (1)**	**0**		**10.8 (0.7)**
0.56 lb ae + 1.23	**1999**	**1 (1)**	**0**	**0**	**18 (32)**	**0**	**0**		**9.7 (0.8)**
+ 1.0 lb ai/A	**2000**	**178 (104)**	**5 (8)**	**57 (50)**	**75 (117)**	**0**	**4 (3)**		**7.0 (0.6)**

[2]**Common ragweed, AMBEL; velvetleaf, ABUTH; common lambsquarters, CHEAL; giant foxtail, SETFA; white campion or white cockle, MELAL; hedge bindweed, CAGSE; Virginia copperleaf or three-seeded mercury, ACCVI; yellow nutsedge, CYPES; smooth crabgrass, DIGIS; dandelion, TAROF; wild buckwheat, POLCO; eastern black nightshade, SOLPT.**

***Table 1*. Continued**.