Use of 2,4-D and Other Phenoxy Herbicides in Flax, Millet, Rice, Wildrice, Seed Crops, Sugarcane, Pea, and Fallow in the United States

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- 2,4-D and MCPA provide effective and economical control of a very wide range of broadleaf weeds.
- 2,4-D serves an important role in control of resistant weeds and development of resistance management programs.
- Some crops have very few alternative herbicide options for postemergence broadleaf weed control.

INTRODUCTION

Phenoxy herbicides are used in flax, millet, rice/wild rice, seed crops, sugarcane, and pea to control weeds and maintain optimum yield potential and economic return. These crops tend to have limited options of registered herbicides. Some rely heavily on phenoxy herbicides to control weeds, while others benefit from the broad weed control spectrum of 2,4-D and other phenoxy herbicides to supplement other herbicide choices.

Red potato grown for fresh market must meet physical preferences of the consumer. Retention of deep red color is a key characteristic for price determination and can be improved with use of 2,4-D.

Controlling weeds in fallow, especially through non-tillage means, conserves moisture for the subsequent crop. This allows greater profit over the duration of the rotation cycle even though economic return is not realized during the fallow season. Because crop is not produced in the fallow season, managers seek low cost weed control options such as phenoxy herbicides. Use of 2,4-D in potato is not primarily for the purpose of weed control. Red potato grown for fresh market must meet physical preferences of the consumer. Retention of deep red color is a key characteristic for price determination and can be improved with use of 2,4-D (Rosen et al. 2009).

Data on crop area in production and herbicide use were obtained from the National Agricultural Statistics Service (NASS) where available. To supplement limited herbicide use information in these crops, confirm amounts reported by NASS, and provide local insight to practices and impact of the loss of phenoxy herbicides, researchers with responsibility in these crops were surveyed through e-mail and phone correspondence. These responses were solicited from production areas indicated by NASS.

Assessment was conducted for current use of 2,4-D and phenoxy herbicides. This information was then compared with the 1996 assessment of phenoxy herbicide use (Nalewaja 1996).

Table 7.1 *Loss of production income with removal of phenoxy herbicides in various crops*

Crop	Herbicide removed	Production income lost ($)
Flax	MCPA	793 000
Millet	2,4-D	1 600 000
	MCPA	200 000
Rice	2,4-D	4 810 000
Wild Rice	2,4-D	270 000
Potato	2,4-D	4 830 000

Table 7.2 *Additional costs from use of alternative herbicides (caused by removal of phenoxy herbicides) in various crops*

Crop	Herbicide removed	Additional costs ($)
Flax	MCPA	802 000
Millet	2,4-D	909 000
	MCPA	100 000
Rice	2,4-D	1 630 000
Wild Rice	2,4-D	14 000
Seed Crops	2,4-D	620 000
	MCPA	425 000
Sugarcane	2,4-D	6 200 000
Dry Pea	MCPB	214 000
Green Pea	MCPA + MCBP	1 130 000
Fallow	2,4-D	13 000

Crop Production

Weeds compete with crops for several resources. Lack of weed control can eliminate harvestable grain yield in many crops because of competition, as well as rendering mechanical harvest impossible because of vegetation overgrowth. Ability to control weeds is one factor in the selection of crop under integrated pest management practices. Cool versus warm season crop, crop competitive ability, seeding in rows versus solid seeding, direct seeding versus tillage systems, and commodity price and profitability are other factors that influence the choice of crop to plant.

Flax is seeded relatively early in the growing season. Early establishment can increase the crop's competitive ability against later emerging weeds, but the crop is not an aggressive competitor. Early emerging broadleaf weeds, such as wild mustard and kochia, are especially troublesome in flax production. Flaxseed yield loss in several studies averaged 35% (Dunham 1964). Flushes of early weeds can be removed with tillage or non-selective herbicides if seeding is delayed, but potential flaxseed yield decreased 0.28 bu/A per day after May 1 in North Dakota (Hammond 1973). Flax production area varies widely from year to year, as commodity price does as well. Production area for the years considered in Table 7.1 was relatively similar. However, production per unit area increased 50%.

Table 7.3. Annual production and price for selected crops and fallow in the United States.

	1989 to 1991[a]			2014[b]		
Crop	Area	Production	Price	Area	Production	Price
	A x 1000	unit/A	$/unit	A x 1000	unit/A	$/unit
Flax	273	14 bu	4.52	311	21 bu	13.20
Millet	292	15 cwt	7.00	505	31 bu	3.19
Rice	2,859	60 cwt	6.47	2,900	76 cwt	15.60
Rice, wild	28	585 lb	1.68	47	580 lb[c]	1.65[c]
Seed crops	1,730	274 lb	0.87	550[c]	varies	varies
Sugarcane	855	34 ton	29.74	829	35 ton	33.33
Pea, dry	233	1,670 lb	0.07	921	1,910 lb	0.11
Pea, green	330	1.4 ton	259.00	195	1.9 ton	358.00
Potato	1,370[b]	290	6.13	1,061	426 cwt	8.60
Fallow	72,000	--[d]	--	22,000[e]	--	--
Total	78,600		--	28,731	--	--

[a] Nalewaja 1996.
[b] NASS 2015.
[c] Researcher survey.
[d] Not applicable.
[e] Estimated from figure.

Millet typically is seeded later in the season to allow for warmer soil temperatures that encourage rapid growth. This also allows for control of early emerging weeds. In addition, high seeding rates and close plant proximity contribute to the excellent competitive ability of millet. However, mustard and pigweed species are major production concerns in millet.

The area seeded to millet increased by 73% since the early 1990s (Table 7.1).An increase in the interest of feeding wild birds might be driving an increased commodity need. Production per acre has increased by approximately 10%, while the commodity price has dropped about $0.59/bu (based on 54 lb/bu).

Rice production includes water management as a physical weed control option. Weeds can still establish in the high moisture environment and cause substantial yield loss depending on weed architecture and emergence time. Even a rather short-statured weed such as ducksalad can reduce grain yield of rice by 21% (Smith 1970). Rice and wild rice also have the disadvantage of high harvest losses when large amounts of weed biomass travel with the crop through harvest machinery. Yield of rice has increased 16 cwt/A during the two decades of this comparison (Table 7.1).

Wild rice production area has increased an estimated 19,000 acres (Table 7.1). This is a small absolute area considering total farmland in production but a large relative increase based on the limited initial area. Wild rice production includes flooding for weed control, and the crop plants are quite large in size, which provides competition against weeds later in the season.

Seed crops could include many broadleaf species that would be susceptible to 2,4-D and other phenoxy herbicides. The previous 2,4-D use report appeared to include all seed crops in the production area estimate (Nalewaja 1996). The current report focused on only those seed crops where phenoxy use would be reasonable, i.e., species with tolerance to phenoxy herbicides. In addition to losses due to weed competition and harvest inefficiency, weed presence can increase seed cleaning costs and occasionally has been associated with reduced crop seed germination and vigor by survey respondents.

Sugarcane is a very competitive crop once established. During crop establishment, broadleaf weeds are devastating to growth of sugarcane seedlings. Sugarcane establishment is very costly and labor intensive. These costs need to be averaged across several years of production for the system to be profitable. Competition from weeds can reduce the initial stand of sugarcane, thereby reducing the viable years of production. Reduced crop establishment also can allow broadleaf weeds to compete at the beginning of each season before crop shading occurs.

Green pea production area was reported as 195,000 acres in 2014 (Table 7.1). This represents 41% less production area than in 1989 through 1991. This decrease in acreage was partly offset by increased production per acre of 36%, but overall production was substantially less, 20%, in 2014 than in the previous report.

Dry pea is susceptible to weed competition early in the season and responds favorably to more aggressive weed management programs (Young et al. 1994). Dry pea often is grown in arid environments. Control of weeds early in the season is important to conserve moisture for the crop. By mid-season, canopy closure provides shade to minimize growth of late-emerging weeds.

Potato is susceptible to competition from weeds and physical interference by weed roots that may cause deformed tubers, such as quackgrass rhizomes which penetrate the potato tuber. While weed control is important for maximum yield, acceptance in the fresh market is highly dependent on physical appearance. For red potato, this is partly dependent on depth of red color and retention of red color during storage. Depending on season and market demand, red potatoes for fresh market have been heavily discounted for having poor red color and can be rejected.

Fallow acreage was considerably less than in decades past. Management of crop choice, increase in local precipitation, and increased area of irrigated land have influenced the choice to keep land in continuous production. Control of weeds during fallow with tillage or herbicide conserves moisture for the subsequent crop and limits weed seed rain.

Phenoxy Herbicide Use

Registration of 2,4-D and other phenoxy herbicides introduced valuable selective weed control in many crops. Even though these herbicides have been available for 60 to 70 years and many other herbicides have been discovered and registered for weed control, phenoxy herbicides remain important tools for weed control in several crops. This is especially true for crops grown on limited acreage, because alternative herbicides are limited. Small acreage means less return on investment for development and registration funds. The IR-4 program has provided support and infrastructure to obtain alternative herbicide registrations for these crops, but choices are often limited.

Even though these herbicides have been available for 60 to 70 years and many other herbicides have been discovered and registered for weed control, phenoxy herbicides remain important tools for weed control in several crops. This is especially true for crops grown on limited acreage because alternative herbicides are limited.

Phenoxy herbicides provide very economical control of a broad spectrum of broadleaf weeds. They also offer an option for control of resistant weeds or for development of proactive resistance management programs. Current public concern regarding herbicide resistant weeds has focused on the use of glyphosate, which would be the staple herbicide in most chemical fallow programs. However, resistance to ALS-inhibiting herbicides, triazines, and PPO- inhibiting herbicides is also of concern for some crops in table 7.2. Include with these points the use of 2,4-D in red potato to improve quality, and the total volume of 2,4-D and other phenoxy herbicides applied to included crops was nearly 3.7 million pounds of acid equivalent (Table 7.2). Of this, almost 3.5 million pounds was 2,4-D, 166,000 lb was MCPA, and 50,000 lb was MCPB, with estimated product values of $18.2 million ($5.23/lb), $957,00 ($5.75/lb), and $1.49 million ($30.00/lb), respectively.

Annual phenoxy herbicide use in these crops in 1989 through 1991 was estimated to be 8.9 million pounds of 2,4-D and 171,000 lb of other phenoxy herbicides (Nalewaja 1996). Less use of 2,4-D in the current survey occurred in several crops, but was especially noted in fallow because of a decrease in fallow area(Table 7.2). Use of other phenoxy herbicides was slightly greater in current estimates because of increased use in flax, millet, seed crops, and dry pea. Since 2,4-D has been, and continues to be, the predominate phenoxy herbicide for these crops and fallow and the need in fallow was so much reduced, use of any phenoxy herbicide currently was estimated at 41% of usage in the early 1990s. However, the continued use of phenoxy herbicides, even after the introduction of many other herbicides, indicates that they remain an important tool in crop protection.

Flax was treated with MCPA more than any other broadleaf herbicide. The most commonly used product contained bromoxynil and MCPA. A product that contained MCPA was reported to have been used on 46% of flax acres. This estimate may be low, because the majority of flax acres were in North Dakota, where chemical use on about half the flax acreage was either unknown or withheld from the survey (Zollinger et al. 2014). The use rate of MCPA was similar to the previous report, but the increase in acres of flax resulted in 34,300 lb of MCPA being applied (Table 7.2).

Table 7.4. Phenoxy herbicide use in selected crops and fallow in the United States.

Crop	1989 to 1991[a]			2010 or 2011[b]		
	Area %	Use rate lb/A	Total used lb x 1000	Area %	Use rate lb/A	Total used lb x 1000
Flax						
MCPA	39.2	0.25	26.7	46[cd]	0.24[d]	34.3
Millet						
2,4-D	17.8	0.54	28	80[d]	0.45[d]	182
MCPA	NR[e]	NR	NR	10[d]	0.12[d]	6.1
Rice						
2,4-D	18.5	1	530	7	0.79	134
MCPA	0.5	1	14	NR	NR	NR
Rice, wild						
2,4-D	6.8	0.25	0.5	6[d]	0.25[d]	0.7
Seed crops						
2,4-D	15.3	0.73	193	30[d]	0.63[d]	104
MCPA	2	0.5	17	28[d]	0.75[d]	115
2,4-DB	1.7	0.72	21	NR[d]	NR	NR
Sugarcane						
2,4-D	40.6	2.7	922.9	75[d]	2.25[d]	1,400
Pea, dry	24.4	0.23	12.9	5cd	0.75d	36
MCPB						
Pea, green						
MCPA	NR	NR	NR	18	0.33	11
MCPB	31	0.77	79	12	0.74	13.7
Potato	NR	NR	NR	1	0.15	4
2,4-D						
Fallow	20.3	0.5	7,210	15[cd]	0.5[d]	1,650
2,4-D						
Total	--[f]	--	9,055	--	--	3,690

[a] Nalewaja 1996.
[b] NASS 2015, year of the most recent information varied.
[c] Zollinger et al. 2014.
[d] Researcher survey.
[e] Not reported.
[f] Not applicable.

Millet production area increased, but estimated millet acres treated with phenoxy herbicides also increased – by nearly 3.5 times – according to response estimates. In addition, MCPA was reportedly used on 10% of acres in the current survey responses, but was not reported in the previous survey (Table 7.2). Combined use of 2,4-D and MCPA totaled 188,100 lb of herbicide, a 570% increase over previous reported phenoxy use.

Rice acres treated with 2,4-D were reported as 7% of total area (Table 7.2). This was a 62% decrease compared with previous survey, and the 2,4-D use rate on those acres declined as well. In addition, MCPA use in rice was not reported in recent surveys. Total current phenoxy use in rice was estimated at 25% of use from 1989 to 1991.

Wild rice benefits greatly from tall plant architecture and flooding for weed control. Current use of 2,4-D was consistent with previous estimates. California and Minnesota are states of major production, but 2,4-D is only used in Minnesota on this crop. This was reflected in the area treated according to state acreages.

Seed crops benefitted from the use of 2,4-D and MCPA, but in the current summary, use of 2,4-DB was not reported. Practices shifted to a more even distribution of treatment with 2,4-D or MCPA than previously reported. Correcting for differences in base acreage, acres treated with phenoxy herbicides (3% less) and total phenoxy use (5% less) in seed crops were relatively similar between the two reports.

Sugarcane had the highest 2,4-D use rate of crops in this comparison: 2.25 lb/A (Table 7.2). Individual treatment rate was at least 1 lb/A, and was identified as typically 1.5 lb/A. The high total use rate is because many fields were treated twice during the growing season. This seasonal use rate was less than previously reported, but acres treated were much greater, which resulted in an increase of more than 50% in use of 2,4-D, to 1.4 million pounds. This accounts for more than one-third of the phenoxy herbicide use for these categories.

Dry pea acreage and MCPB use rate per acre increased substantially, but percentage of acres treated with MCPB was dramatically reduced in the current survey. The increased factors of production area and application rate heavily influenced the overall herbicide use numbers. This resulted in 36,000 lb of MCPB being used in the current survey (Table 7.2).

Sugarcane… accounts for more than one-third of the phenoxy herbicide use for these categories."

Green pea was reported to have been treated with MCPA as well as MCPB in the current information. The previous survey did not include MCPA as an herbicide used in green pea production. Percentage of acres treated was similar to the earlier report, but the decline in production area reduced the amount of phenoxy herbicides used. In addition, MCPA, which was used on 60% of the acres, was only used at 0.33 lb/A as opposed to 0.74 lb/A for MCPB (Table 7.2). Therefore, total phenoxy herbicide use was much less than previously reported, respectively 24,700 and 79,000 lb.

Potato treatment with 2,4-D was not reported during the previous survey. This use is to improve red color for fresh market and is still gaining acceptance within the industry (Rosen et al. 2009; Thornton et al. 2013). The use also improves quality relative to potato size and flesh texture without adversely affecting yield and might suppress or control broadleaf weeds. Potato injury is possible with some cultivars, if not applied correctly or under adverse weather conditions.

Use pattern prescribes application of 0.075 lb/A at the pre-bud stage of potato growth with a second application 10 to 14 days later. Very few 2,4-D labels include this use. Documented use of 2,4- D in potato by NASS includes all potato classes, so the area percentage was very low. Local assessment in one fresh market region on 2,4-D use in red potato fields approached 100% of acres. Reporting could underestimate acres treated with 2,4-D because of the stigma of using 2,4-D in a perceived susceptible crop, especially one that is consumed as the commodity. However, the use is standard agronomic procedure under some contracts.

Fallow acres can be maintained with tillage or chemical. Chemical fallow reduces soil disturbance that can cause soil drying. Glyphosate is the most commonly used herbicide in chemical fallow, especially since the cost of glyphosate has declined substantially with post-patent market competition. Weed control in fallow was supplemented with 2,4-D on an estimated 15% of fallow acres (Table 7.2). Because of the large acreage of land in fallow, 1.65 million pounds of 2,4-D were used for weed control.

Without Phenoxy Herbicides

Loss of 2,4-D registrations with the retention of other phenoxy herbicide labels likely would lead to a substitution with MCPA in many situations, although labels would have to be modified to include some crops. The two herbicides are reasonably similar in weed spectrum and cost, which would allow this substitution without many issues. However, if this were to occur, cancellation of MCPA and other phenoxy herbicides could be quick to follow because of similarities between the herbicides. Therefore, information in this section for alternatives and impact of 2,4-D cancellation did not include other phenoxy herbicides as alternatives.

Several herbicide alternatives had substantially different costs per acre in the 1996 report. The current report shows that several of those herbicides now have costs more comparable to phenoxy herbicides. Cost per pound of 2,4-D and MCPA has increased to about $5.50/lb. Costs for some commonly identified alternatives have decreased even through inflation: dicamba at $16.25/lb and clopyralid as low as $50/lb. The typical use rates of the different herbicides bring the cost per acre even closer to, and in some instances less than, the cost of phenoxy herbicides. The amounts of alternatives included above were adjusted to acres potentially treated with each herbicide if they were to replace phenoxy herbicides. Each herbicide would be used on a portion of previous phenoxy herbicide acreage such that the total amount of all herbicides included would be needed to control weeds.

The availability of herbicide alternatives that provide good efficacy at reasonable cost allowed some of the production systems to avoid anticipated yield losses due to weed competition (Table 7.3). In all cases, inputs for weed control (except for potato use, which is not for weed control) would increase. A concern was mentioned by two survey respondents that the increased herbicide cost could lead to application of lower rates than labels recommend, and this could lead to greater selection pressure for herbicide resistance in weeds.

Table 7.5. Estimated loss in production value and cost of weed control for selected crops and fallow in the United States with discontinuation of 2,4-D or all phenoxy herbicide labels.

	Loss of 2,4-D				Loss of MCPA and MCPB			
	Loss of production		Increased expense		Loss of production		Increased expense	
Crop	Yield[a]	Total value[b]	Weed control[a]	Total inputs[b]	Yield[a]	Total value[c]	Weed control[a]	Total inputs[c]
	%	$1000	$/A	$1000	%	$1000	$/A	$1000
Flax	--[d]	--	--	--	2	793	5.61	802
Millet	4[e]	1,600	2.25	909	4[e]	200	1.99	100
Rice	2	4,810	8.04	1,630	--	--	--	--
Rice, wild	10	270	4.87	14	--	--	--	--
Seed crops	0	0	3.76	620	0	0	2.76	425
Sugarcane	0	0	9.98	6,205	--	--	--	--
Pea, dry	--	--	--	--	0	0	4.62	214
Pea, green	--	--	--	--	0	0	19.36	1130
Potato	0	4,830[f]	(0.78)	(21)	--	--	--	--
Fallow	--	--	3.78	13	--	--	--	--
Total	--	11,510	--	9,370	--	993	--	2671

[a] Researcher survey estimated for acres previously treated with respective phenoxy herbicide as influenced by the alternative control program.

[b] Calculated from acres reported to have been treated with 2,4-D.

[c] Calculated from acres reported to have been treated with MCPA and MCPB.

[d] Not applicable.

[e] Loss of production included acres expected to be seeded with another crop.

[f] Loss of production value based on quality parameters not less yield.

The acceptability of alternative herbicide options also reduced the estimate of acres to be seeded to another crop or to include more tillage for weed control. Only millet would potentially lose acres of production if phenoxy herbicides were not available (Table 7.3). The benefits of reduced tillage or direct seeding systems extend beyond the initial moisture savings in dry regions to a multitude of soil health benefits. Therefore, many expect land managers to continue with current tillage practices. Tillage is performed for various reasons in many systems, but where tillage has been avoided, they would continue to run the system without tillage if possible.

Flax would suffer some yield loss without availability of MCPA (Table 7.3). Although a small amount of total crop value, a greater concern might be additional weed seed production, especially of wild mustard and redroot pigweed which would be poorly controlled. This could increase weed pressure in subsequent years, which would in turn cause input costs to prevent this to increase. A very small portion, about 6%, of North Dakota flax, was treated with soil-applied herbicides (Zollinger et al. 2014). Soil-applied herbicides such as sulfentrazone (9,400 lb) or mesotrione would help control many broadleaf weeds in the absence of MCPA; however, the combined cost of the chemical and its application would greatly restrict this practice. Increased use of bromoxynil (12,500 lb) or clopyralid (4,700 lb) would be likely choices, especially if a combination product were developed that had lower cost than the individual herbicides.

Millet acres could decline in some regions in favor of other crops with better weed control options (Table 7.3). Yield loss because of weed competition was not expected because of acceptable control with alternatives. Use of dicamba (42,000 lb) was suggested as a likely and common substitute within the same weed control practices, but fluroxypyr (10,500 lb) also was identified as a likely substitute. Cost of fluroxypyr would be much greater than dicamba, and would only be used for specific purposes such as kochia control. The added expense may lead some managers to reduce application rates, which could increase selection for resistance to these herbicides.

Rice yield was projected to decline by 2% without the use of 2,4-D based on a 2009 letter from the US Rice Federation to the Office of Pesticide Programs (Table 7.3). This translated to $4.8 million with current national production. Herbicide costs (81,000 lb of herbicides) to control weeds without 2,4-D increased by as much as $16/A in some states at that time. Total cost of production loss and increased expenses exceeded $6.4 million for rice.

Wild rice has two herbicides labeled for in-crop use. Labels for application of 2,4-D were only found for Minnesota. The only herbicide option to replace 2,4-D is carfentrazone. Minimum cost of chemical for this treatment is $50/A, so broad scale use is not expected as a general replacement for 2,4-D. In addition, the crop can experience severe damage if the leaves are too far out of the water. Weed control would continue to rely heavily on water management and crop competition. Under extreme weed pressure, estimated at 10% of acres treated with 2,4-D, carfentrazone would be used.

Seed crop management practices and production were expected to remain consistent without availability of 2,4-D or MCPA. Weed control would not suffer because alternatives provide good to excellent weed control. The alternative options that were identified included clopyralid (7,500 lb), fluroxypyr (15,000 lb), dicamba (20,000 lb), and bromoxynil (7,500 lb).

Sugarcane production was not expected to change because viable alternatives would be used. Cost to maintain production was estimated to increase by $9.98/A (Table 7.3). Cost of weed control included the addition of an adjuvant for a portion of acres that would not have already had an adjuvant included. Herbicides used to achieve weed control would be atrazine (373,000 lb) and mesotrione (30,000 lb).

Dry pea management does not include much use of phenoxy herbicides on a percentage of acres basis, so the weed control void left by MCPB discontinuation would not be significant.

The alternative herbicides bentazon (8,600 lb) and imazamox (1,100 lb) have greater cost than options mentioned in previous sections, but MCPB is relatively expensive as well. The cost of herbicide in either program would be fairly similar, but cost of adjuvants for the alternatives increased the expense of weed control to $4.62/A (Table 7.3).

Green Pea production included the use of MCPA and MCPB. The lower cost of MCPA, which was used on more acres than MCPB, resulted in a much higher cost per acre increase for green pea than field pea, even though similar alternatives were identified (Table 7.3). In addition to bentazon (11,000 lb) and imazamox (1,370 lb) with adjuvants, increased tillage was suggested and incorporated into the cost of weed control estimate. Total estimated additional expense of inputs to replace phenoxy herbicides was $1.13 million.

Potato was treated with 2,4-D for improved quality of red-skinned tubers, so yield loss was not expected in absence of 2,4-D (Table 7.3). This use has given weed control benefit according to growers, but the benefit has not been evaluated. The cost of herbicide shows as a gain in the system because the herbicide was not applied. However, the cost of application was not subtracted because the treatment was typically applied with fungicide, which was still needed. Loss in value of commodity was calculated with the adjustments that 15% of treated acres would have had quality issues related to color and the quality discount would have averaged 20% of value. Value was set at $14/cwt because value of fresh market red potato is much higher than the national average of all potato types and uses. Value of this treatment was $4.83 million, a 230- fold return on investment of $21,000 for 2,4-D.

Fallow does not produce a tangible commodity. Estimating the value of moisture storage depends greatly on the climate and weather as well as the subsequent crop grown. This value was allowed to remain in the production system of the subsequent crop. Cost of weed control was projected to increase $3.78/A (Table 7.3) with inclusion of dicamba (660,000 lb), fluroxypyr (92,000 lb), and bromoxynil (124,000 lb) as possible candidates to replace 2,4-D.

Reasons to Retain Phenoxy Herbicides

Flax

- Control of wild mustard and redroot pigweed would decline, which would allow more weed seed rain and lead to more intensive weed management in the future.
- MCPA is more effective against more annual broadleaf weeds than current alternatives.

Millet

- 2,4-D and MCPA were depended on quite heavily in some geographies for profitable millet production.
- Expense of alternatives could tempt growers to apply low rates, which may increase selection pressure for resistance to the alternative.

Rice

- Even with several alternatives to consider, the current level of weed control would not be maintained without the use of 2,4-D.

Wild rice

- Only one other herbicide is registered for postemergence control of broadleaf weeds.
- The only alternative costs $50/A at the minimum rate.

Sugarcane

- Importance and need for access to 2,4-D was highlighted by a near doubling of acres using the herbicide.
- One of the alternatives is increased use of atrazine, a restricted use pesticide.

Pea

- Tillage, which introduces negative aspects to soil health, may need to be increased without the use of MCPA and MCPB.

Potato

- Tuber quality benefits will be lost resulting in at least $4.8 million loss to the growers.

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Kirk's teaching responsibilities have included undergraduate and graduate instruction in Principles of Weed Science, Weed Identification, Advanced Weed Science, Herbicide Fate and Action, Professional Development, and Graduate Seminar. He is coordinator of the Crop and Weed Sciences academic program and advisor to the NDSU Agronomy Club. He received a B.S. in Agronomy from the University of Wisconsin at River Falls and completed M.S. and Ph.D. programs at Colorado State University, Fort Collins.