Use of 2,4-D and Other Phenoxy Herbicides in Vegetable Crops in the United States

Steve Weller, Purdue University

- 2,4-D sees less use in vegetable production than other crops, but remains an important tool, largely for its ability to manage weeds that have become resistant to other herbicides.
- Loss of access to 2,4-D in asparagus crops would have a net loss of $6-8 million per year.
- Alternative herbicides remain significantly more expensive than 2,4-D.

Introduction

2,4-D is used in small quantities in two vegetable crops, asparagus and sweet corn. In a recent report, over 91% of asparagus and 90% of sweet corn acres in the US respectively received herbicide applications (Gianessi and Reigner 2007). 2,4-D provides excellent control of many dicot annual and perennial weeds in both crops. The elimination of troublesome broadleaf weeds allows for good crop growth, yield and economic return. No other vegetable crops have federal 2,4-D registration since most other vegetable crops are susceptible to injury by 2,4-D. The loss of a federal registration for 2,4-D would have a significant negative influence on acceptable weed control, especially of troublesome perennial weeds in asparagus. Asparagus production would decrease in some states from weed competition or damage from alternative mechanical or physical management methods, such as hand weeding where labor may be limited and expensive. Weed shifts could occur to more competitive weed species in some areas, especially since the main alternative to 2,4-D application after harvest is glyphosate and there are an increasing number of weeds now resistant to glyphosate that would become problematic. Loss of post-emergence applications of 2,4-D, and the recently lost clopyralid, in asparagus would decrease asparagus production an estimated 4.9% and increase production costs by a minimum of $8.77/A. The net annual societal loss of banning 2,4-D for asparagus would be $6 - 8.0 million. The situation in sweet corn is not as dire without 2,4-D. Use of 2,4-D has decreased recently, especially since 2005 with the registration of several new alternative herbicides. A second cause of reduced 2,4-D use is because many of the newer sweet corn varieties (su, sh2 and se) have increased susceptibility to 2,4-D injury. Economic losses and increased costs of weed management would be minimal without 2,4-D, however, with

Loss of post-emergence applications of 2,4-D, and the recently lost clopyralid, in asparagus would decrease asparagus production an estimated 4.9% and increase production costs by a minimum of $8.77/A. The net societal loss of banning 2,4-D for asparagus would be $6 - 8 million.

the increasing occurrence of weeds resistant to many of the commonly used herbicides in sweet corn, this situation could change. In this scenario, 2,4-D would become an excellent option for control of annual broadleaf weeds and also offer an effective option against perennial broadleaf weeds. Use of drop nozzles for 2,4-D application in corn would decrease variety injury by 2,4-D. The herbicide 2,4-D is a low-rate, high-efficacy herbicide that economically controls annual and perennial broadleaf weeds in these two vegetable crops. Continued registration is important for obtaining optimum yield, economic weed management options, and affordable food.

Losses from Broadleaf Weeds

Losses from weeds will vary depending on the specific weed and crop and the infestation level. Research information on losses from broadleaf weeds is limited for both asparagus and sweet corn.

Asparagus: Annual weeds are common in new plantings of asparagus and must be controlled to establish a vigorous stand. These weeds are generally managed throughout the United States (US) by the pre-emergence herbicides listed in Table 11.1 including diuron, metribuzin, trifluralin, metolachlor, sulfentrazone, linuron and halosulfuron. These herbicides provide good control of annual weeds, both broadleaves and grasses. Perennial weeds such as field bindweed, Canada thistle, and swamp smartweed can be major problems if they are not controlled, as they compete during the entire growing season. Since asparagus is a longer term perennial crop, on any site, the presence of perennial weeds will result in yield loss and quality reductions. The most recent estimates for crop losses due to loss of 2,4-D are from the previous 2,4-D assessment report (NAPIAP 1996) and were estimated at a 30% yield loss in WA, 10% loss in CA, and 5% in MI. These estimates would still be valid as the herbicide spectrum available for perennial weed control has not changed. In areas of heavy weed infestation no crop can be harvested. Perennial weeds also contribute to the decline of the asparagus stand. Even if the best management practices are used, the estimated crop loss from weeds is $10.2 million in asparagus, and the weeds remain best managed through the use of 2,4- D after harvest (Bridges and Anderson 1992).

Even if the best management practices are used, the estimated crop loss from weeds is $10.2 million in asparagus, and the weeds remain best managed through the use of 2,4-D after harvest.

Table 11.1. Percent of asparagus acres treated with herbicides in 2010 and change if 2,4-D were banned.

Herbicide	% Asparagus Acres Treated	Total lbs/applied	Projected % Increase w/o 2,4-D
		-(000)-	
Diuron	62	35.2	-
Glyphosate*	46	16.9	20
2,4-D*	29	13.2	-
Metribuzin	19	4	-
Halosulfuron**	9	0.1	1 -5
Linuron	5	1.5	-
Trifluralin**	23	8.3	1 - 5
Metolachlor**	22	8.2	1 - 5
Sulfentrazone**	9	0.5	1 - 5
Paraquat	8	2.4	-
Terbacil	2	0.5	-
Dicamba	-	-	5

*The only real substitute for post-emergent application of 2,4-D is glyphosate for broad spectrum weed control of troublesome perennial weeds such as Canada thistle, field bindweed and other broadleaf weeds. With greater numbers of glyphosate resistant weeds, the loss of 2,4-D would be a severe loss for asparagus growers. Replacement of 2,4-D with glyphosate would result in approximately a 13,000 lbs increase in glyphosate use.

**The use of these herbicides could increase by 1 to 5% depending on weeds present and herbicide effectiveness.

Sweet corn: Annual weeds in sweet corn tend to be the same species found in field corn wherever the crop is grown in the US. Annual weeds are well controlled by the pre-emergence herbicides listed in Table 11.2 with atrazine being the dominant pre-emergence herbicide used in both fresh market and processed sweet corn. Other pre-emergence herbicides, including dimethamid, metolachlor and acetochlor, are commonly added to atrazine in processing corn. Perennial weeds, if present in sweet corn, are competitive but much less common than annual weeds, as sweet corn is an annual short season crop. Recent estimates of crop loss to weeds even if the best management practices are used and major herbicides were restricted (especially atrazine and simazine) in sweet corn were 20% (Bridges 2011).

The difference in sweet corn weed management compared to asparagus and the use of 2,4-D is that in sweet corn several new herbicides have been introduced since the late 1990's that do an effective job of managing most annual broadleaf weeds and have become more commonly used in crop than 2,4-D for two main reasons (Table 11.2).

1. These herbicides (mesotrione, tembotrione, topramezone, fluroxypyr and carfentrazone) all provide excellent control of annual broadleaf weeds;
2. Most perennial weeds can be controlled with directed sprays of glyphosate or dicamba.

Table 11.2. Percentage of fresh market and processing sweet corn acres treated with herbicides in 2010 and subsequent change if 2,4-D were banned.

Herbicide	Fresh Market Acres Treated %-2010	Projected Use Increase w/o 2,4-D	Processing Acres Treated %	Projected Use Increase w/o 2,4-D
2,4-D	2	-	-	-
Acetochlor	1	-	13	-
Alachlor	5	-	-	-
Atrazine	57	-	66	-
Bentazon	4	-	3	-
Carfentrazon	1	-	4	+1%-
Dimethamid	5	-	30	-
Glyphosate	6	-	19	+1-2%
Mesotrione*	14	+1.2%	6	+1.2%
Metolachlor	4	-	30	-
Pendimethalin	11	-	6	-
Tembotrione*	3	+1-2%	34	+1.2%
Topramezone*	2	+1.2%	24	0.012

*These herbicide plus fluroxypyr have gained 2,4-D market share since their introduction and have greater safety than 2,4-D on many of the presently available Sh_1Sh_2 and Se sweet corn types. The loss for 2,4-D could be significant if the spread of herbicide resistant weeds to glyphosate, atrazine and HPPD inhibiting herbicides- mesotrione, tembotrione and topramezone occurs.

The potential problem of banning 2,4-D use in sweet corn would be if the spread of weeds resistant to glyphosate, atrazine and HPPD inhibiting herbicides-mesotrione, tembotrione and topramezone becomes widespread. If this occurs, no effective management tool would exist for these weeds. In addition, the combination of glyphosate and 2,4-D is an effective treatment for many difficult to control perennial weeds. Economic losses due to the banning of 2,4-D would be minimal at this point but it still provides an alternative tool to provide excellent broadleaf weed control and assist in resistance weed management by providing an alternative mechanism of action. At the present time, few weeds are resistant to 2,4-D.

The potential problem of banning 2,4-D use in sweet corn would be if the spread of weeds resistant to glyphosate, atrazine and HPPD inhibiting herbicides-mesotrione, tembotrione and topramezone becomes widespread. If this occurs, no effective management tool would exist for these weeds.

Current Control Methods

Asparagus: Most weeds are controlled in established beds of asparagus using pre-emergence herbicides and cultivation. Cultivation, depending on the region, can occur as many as 4+ times during the season. The herbicide(s) chosen for use depend(s) on the weed species present, and are usually applied pre-emergence to reduce competition during early season growth of the asparagus, as well as for residual weed control during the harvest season.

Herbicides used may include diuron, metribuzin, metolachlor, linuron, sulfentrazone, halosulfuron, and trifluralin (Table 11.3). Cultivation includes the rebuilding of the asparagus bed in late winter and possibly two or three other times during the year. Shallow cultivation of less than 3 inches will not damage asparagus crowns, but deep cultivation injures roots and crowns. Post-emergence herbicides can be used to control annual weeds before the spears emerge. Other post-emergence treatments may be used during the cutting season. Because asparagus beds may be in production for 10 to 12 years, perennial weeds often become the dominant problem and at present, there are only 3 herbicides registered for perennial weed control: 2,4-D, glyphosate, and dicamba.

Table 11.3. Yearly production, price and 2,4-D use in asparagus and sweet corn in the United States in 2014.

Crop	Acres in Production[a]	Production and Yield Units	Total Production	Acres Treated		2,4-D use[b] Pounds	Rate
	----------000----------		(000)	(000)	%	(000)	lb/A
Asparagus	23.8	743	73,441	6.9	29	13.2	1.57
Sweet Corn			Estimate*	10.5	2%	3.1	0.291
Fresh	215.15	25,346 cwt	25.6	4.3	2%	1.4	0.291
Processed	312.28	2,567.82 tons	96.2	-[c]	-	-	-
Total	527.43			10.5*		3.1*	-

[a]2014 USDA, NASSQuick Stat Data

[b]Based on 2010 USDA-NASS Quick Stats

[c]Data not available

*Total 2,4-D applied to sweet corn based on 2% of acres (527,000) treated with 0.291 lbs 2,4 -D/A/yr

Approximately 6,900 acres of asparagus were treated with 2,4-D (NASS Quick Stats 2014) which represents about 29% (23,800 acres) of the total asparagus harvested in the US (Table 11.1). The primary producing states are Washington, California, and Michigan, which grew the majority all of the harvested asparagus acreage in the US from 1990 to the present. Use of 2,4-D was most extensive in Washington and California, where ~ 30% of the acres of asparagus were treated, and in Michigan, where 2,4-D was used on 25% of the acres. About 13,200 pounds of 2,4- D were used in the US, averaging 1.6 lbs/A (Table 11.3) and the 2,4-D amine formulation is the only one used in the US for asparagus and sweet corn.

2,4-D is generally used for perennial weed control after harvest. Occasionally, it is used in the spring before spear emergence against annual broadleaf weeds and whatever perennials may be present. The first early spring application is broadcast over the bed, while the postharvest directed-sprays are applied with drop nozzles to avoid 2,4-D contact with the asparagus ferns, which can injure the crop.

Sweet corn: Weeds are controlled in sweet corn with a combination of pre-emergence and post-emergence herbicides (Table 11.2) and occasionally with cultivation. However, cultivation in herbicide treated fields is not a common practice. Several pre-emergence residual herbicides, such as metolachlor, acetochlor, alachlor, dimethamid, pendimethalin, and mesotrione, are available at planting for annual weed control. Atrazine is still the most common pre-emergence herbicide applied in sweet corn, with greater than 50% of the fresh and processed sweet corn acreage receiving it. Early post-emergence applications of atrazine mixed with a surfactant is still a commonly used treatment for control of annual grasses and broadleaf weeds. However, since the early to mid-2000's, mesotrione, tembotrione, topramezone and fluroxypyr have become commonly used for control of emerged broadleaf weeds, and have largely replaced much of the 2,4-D use as they are very effective on emerged broadleaf weeds, and have improved sweet corn variety tolerance over 2,4-D. Sweet corn may be cultivated two to three times depending upon the weed severity but this is becoming less common.

An estimated 2%, or 10,548 acres, of sweet corn in the US were treated with 2,4-D in 2014 (Table 11.1). Usage patterns of 2,4-D in sweet corn are similar to those for field corn. It is applied post-emergence for selective control of broadleaf annual weeds No more than two applications of 2,4-D are made per season, though normally only one application is made, and it is now most common to use a post-emergence treatment with drop-nozzles for emerged broadleaf weed control. This application timing would be most useful if any emerged perennial broadleaf weeds are present, since other post herbicide treatment products – except glyphosate – would not provide control of these perennial weeds. Another reason for 2,4-D use would be to control some broadleaf weed species that are not easily controlled with alternative herbicides, as well as weeds that have developed resistance to other herbicides, especially atrazine and glyphosate, and potentially to the HPPD inhibiting herbicides - mesotrione, tembotrione and topramezone. Therefore, even though 2,4-D use has declined recently, its continued availability would assist in herbicide-resistant weed management. Since it controls weeds that are larger than those that can be controlled with an alternative herbicide, such as bentazon, mesotrione, tembotrione, topramezone, and atrazine, 2,4-D is still a useful and needed product.

Even though 2,4-D use has declined recently, its availability assists in herbicide-resistant weed management, and since it controls weeds that are larger than those that can be controlled with an alternative herbicide such as bentazon, mesotrione, tembotrione and topramezone and atrazine, 2,4-D is still a useful and needed product.

Cost of Control Methods

In asparagus or sweet corn: 2,4-D is one of the least expensive treatments for the control of broadleaf weeds. In asparagus, the average cost of 2,4-D is $8.40/A, and in sweet corn it is approximately $1.53/A. Application costs would be added to the herbicide cost. Cultivation cost ranges from $3.60 to $4.60/A, and can vary by crop and location. Generally, with the use of herbicides, growers use one or no cultivations in sweet corn, but in asparagus as many as four or more cultivations are required. Hand weeding may also be required, and these costs can exceed $14/hr/person.

Impact of the Loss of 2,4-D

Asparagus: Alternative herbicides(primarily glyphosate and possibly some minor use of paraquat and/or dicamba) would be used on much of the acreage now treated with 2,4-D if it were lost. Actual pounds of herbicide used would remain similar to that applied presently, as the use rate in lbs/A for alternatives (mostly glyphosate) is similar to the present rate for 2,4-D of 1.57 lbs/A (Table 11.1). The cost of production would increase, as alternative herbicides are more expensive than 2,4-D. In addition, none of the alternative herbicides are as effective on Canada thistle as 2,4-D is. This is especially true since clopyralid, which is very effective on Canada thistle, was lost for use on asparagus crops. As a result, Canada thistle and other perennials would become more difficult to control and require costly mechanical cultivation and hand removal. A second consideration is the large increase in weeds resistant to glyphosate. Without 2,4-D, there is no viable alternative to address this problem. Growers do not generally use dicamba due to its potential for off-site movement to sensitive crops, and its spectrum of weed control does not include many weeds effectively controlled by 2,4-D such as Canada thistle.

In addition to a lack of alternative herbicide controls for perennials, many growers – especially in Washington and California – would have to expand the use of non-chemical weed measures. Such practices would include increased cultivation and hand removal.

An average yield loss of 30% in Washington, 10% in California and 5% in Michigan would occur if 2,4-D were no longer available to these major asparagus producing states. The total estimated increase in costs for use of both alternative herbicides and non-chemical weed control methods is estimated at $230/A. Gianessi and Reigner (2007) estimated hand weeding would require 4.85 hours/A and that tillage would also be necessary.

Sweet corn: If 2,4-D were banned in sweet corn, there would be a shift to other herbicides and non-chemical means of weed control. Approximately 2% of the sweet corn acres nationally are currently treated with 2,4-D compared to approximately 13.7% in 1992 (NAPIAP Report 1996). This has occurred because alternatives, especially the new HPPD inhibiting herbicides (e.g. mesotrione, tembtrione and topramezone), fluroxypyr and carfenrazone have all gained a greater market share. This pattern has occurred because the newer herbicides are effective

against most of the annual broadleaf weeds that 2,4-D controls, and they are less damaging to sweet corn cultivars, including the su, sh2 and se types. As stated earlier, in addition to annual weed control being sufficient with these alternative herbicides, perennial weeds, if present, could be controlled with directed sprays of glyphosate or dicamba. The problem with losing 2,4-D use in sweet corn would occur if weeds that are resistant to glyphosate, atrazine and HPPD inhibiting herbicides-mesotrione, tembotrione and topramezone - become widespread. If this occurs in sweet corn acreage, as has been seen in many agronomic fields of corn and soybean, then no effective management tool would exist for these weeds. Growers do not generally use dicamba in sweet corn as it has many of the same problems that 2,4-D has regarding variety susceptibility. In addition, applying a combination of glyphosate and 2,4-D results in effective control for many difficult to control perennial weeds, often greater than either herbicide applied alone. Economic losses due to the banning of 2,4-D would be minimal, at this point. However, 2,4-D still provides an effective tool to provide excellent broadleaf weed control, and assists in resistant weed management. In addition, 2,4-D has a different mechanism of action than the other herbicides mentioned (Table 11.2) and few weeds have developed resistance to 2,4-D.

The biggest fear would be its loss and lack of control options for herbicide resistant weeds.

There would be an increase in the use of mesotrione, tembotrione, topramezone, fluoroxypyr and glyphosate if 2,4-D were lost in sweet corn (Table 11.2). Since the use of 2,4-D has decreased to approximately 2% in most sweet corn production fields, the loss of 2,4-D would have minimal effect on yield and returns and/or costs to the consumer. Its loss and subsequent lack of alternative control options for herbicide resistant weeds would be highly problematic.

Weed Control Alternatives if 2,4-D Were Banned

Asparagus: In asparagus, a perennial vegetable, the primary troublesome broadleaf weeds, such as field bindweed and Canada thistle, are also perennials. However, there are also numerous summer-annual weed species to consider. Many of the weeds that are problematic emerge and grow after the beds are cultivated or hilled in the spring; during cutting; after cutting; and before fern growth. Applications of an herbicide can be made before cutting, during cutting (when no spears are present), or after cutting as a directed spray to the weeds between the ferning plants.

There are no alterative herbicides for use in asparagus that have all of 2,4-D's characteristics of safety to the crop, low cost, and ability to selectively control most broadleaf weeds. However, if 2,4-D were lost, other herbicides (especially glyphosate) would be used as the primary method to control weeds on acres currently treated with 2, 4-D. Glyphosate use would increase by approximately 20% as a result(Table 11.3). The use of 2, 4-D does provide farmers

with several weed management options and allows them to maintain asparagus in production without using cultivation. By controlling the principal weed, field bindweed, 2,4-D can reduce weed competition, reduce the buildup of destructive insects and increase harvest efficiency.

Field bindweed can be suppressed through the harvest season with an application of trifluralin at the time of hilling, when it can be incorporated into the soil in the bed, but the field bindweed will regrow after trifluralin dissipates. This treatment only results in partial control of annual smartweed and provides no control of swamp smartweed. Dicamba could be used as a selective treatment for field bindweed in place of 2,4-D, but it is registered only in the states of California, Oregon, and Washington. Glyphosate can be used for broadleaf and grass weed control during the harvest period after clean cutting the asparagus beds or before ferning. Glyphosate would be used on most of the acres currently treated with 2,4-D so its use would increase. Applications of other registered pre-emergence herbicides might increase from 1% to 5%, depending on weeds present, but the most common increases would occur for trifluralin, metolachlor, halosulfuron and sulfentrazone (Table 11.3). Dicamba would be applied post-emergence on ~5% of the acreage (Table 11.3).

Cultivation is used as a part of the management program for weeds in early spring when beds are formed. Only the surface soil of the beds is tilled, as deeper tillage injures the asparagus crowns. If weeds are severe throughout the year, the grower may cultivate during the harvest period. A cultivation at this time will often reduce asparagus yield by up to 10%, and could take the crop out of production for as much as 10 days. Though hand weeding is an alternative, it is expensive, slow, and generally impractical in large fields.

Sweet corn: If 2,4-D were banned for use on sweet corn, there would be a switch to other herbicides as shown in Table 11.2. The new HPPD inhibiting herbicides (mesotrione, tembtrione and topramezone) along with fluroxypyr and carfenrazone would be the major alternatives for in-season broadleaf weed control. Glyphosate use would increase slightly for any needed control of perennial weeds. In reality, little change would be seen in herbicide use patterns since 2,4-D use has decreased significantly over the last 10 years. The major concern would be resistant weed management if 2,4-D was banned. Cultivation is used as a method of weed control in sweet corn if herbicides are not effective or are not used. Since most growers do not routinely use cultivation in an herbicide treated field the pattern of cultivation would change little unless perennial weeds or escapes become prevalent in a field.

Compelling Reasons to Retain 2,4-D

There is no safe substitute for 2,4-D in asparagus production. Any substitute control method would increase damage to the plants, reduce yields, and increase costs to the grower and consumer.

In asparagus, 2,4-D allows the crop to be grown with reduced weed competition, and if lost, production would suffer. There is no safe substitute for 2,4-D in asparagus production. Any substitute control method (chemical or non-chemical) would increase damage to the plants, reduce yields, and increase costs to the grower and consumer. In sweet corn, 2,4-D is an economical, highly effective herbicide and a good tool for difficult perennial weeds. It is used in herbicide-resistant weed management in many agronomic crops, and this use will increase after introduction of 2,4-D to resistant corn, soybean and cotton crops. 2,4-D fits a niche as a selective post-emergence herbicide for broadleaf annual and perennial weeds, and is (if used with drop nozzles) generally safe to most sweet corn varieties.

Often 2,4-D is used instead of cultivation, which allows the soil to remain undisturbed, and thus soil erosion is reduced. Though not an essential herbicide for sweet corn in many areas, when used, 2,4-D reduces the use of some of the more persistent herbicides such as atrazine. In addition, cultivation and hand weeding can cause damage to young sweet corn through root cutting and plant removal.

Resistance Management

A banning of 2,4-D would limit farmers' options for effective perennial broadleaf weed management.

In asparagus there are no known instances where herbicide resistant weeds are currently a problem. However, a banning of 2,4-D would limit farmers' options for effective perennial broadleaf weed management. The other herbicides registered, with the general exception of glyphosate, are not effective on perennial broadleaf weeds. Only glyphosate would be registered to manage these weeds and field bindweed and Canada thistle populations would increase. Without 2,4-D and because of glyphosate limitations, weed resistance could proliferate.

Many weeds found in field corn have developed resistance to the triazines (atrazine), glyphosate, the HPPD inhibitors (mesotrione, tembtrione and topramezone), and the PPO inhibitors (carfentrazone) .These weeds are often also found in sweet corn. If 2,4-D were banned, there would be a return to more atrazine use, even though there are atrazine-resistant weeds present in low numbers within wild populations. This would necessitate an increase in the use of a wider variety of tank mixtures of multiple herbicides, and most likely result in an increase in herbicide management costs to the farmer. Other concerns regarding

atrazine use include ground and surface water contamination. These uses would increase both costs and concerns related to resistance management and other possible environmental concerns. Banning 2,4-D would greatly reduce options for farmers of sweet corn for effective herbicide resistant weed management, and for keeping costs low.

Future Weed Management Options

In vegetable crops, as with many agronomic crops, there have been new herbicides introduced. However, no new mechanisms of action have been introduced since the HPPD inhibitors in the early 1990's. There have been reduced activities by the chemical industry in registering new herbicides for specialized, high value, low acreage market crops, especially vegetables. Some herbicides from the field corn market have become available for use in sweet corn on a limited basis. There have been a few new pre-emergence herbicides recently registered for use in asparagus, such as sulfentrazone and halosulfuron. In both crops, there has not been a substitute herbicide introduced that can completely replace 2,4-D. That is why it is important to maintain 2,4-D's registration in both sweet corn and asparagus. If for no other reason, the management of perennial weeds and the ever increasing numbers of weeds that are resistant to all the other marketed chemistries does require availability of 2,4-D. There is research being done on specialized in-row cultivators for sweet corn, and also an increasing interest in robotics as a potential weed removal technology. However, in both cases the technology is either expensive or still in prototype, and at this point neither option is as effective as herbicide use. These technologies are more problematic in a perennial crop such as asparagus, and generally are not as feasible as they might be in sweet corn. If weeds are not controlled with tillage or herbicides in either sweet corn or asparagus, there will be a greater need for hand weeding. Hand weeding is expensive, time consuming, and difficult work. It often does not provide sufficient benefits for workers. Few people are willing to do this work, so the available labor pool for such work is shrinking and expensive. This situation argues for the need to maintain effective herbicide tools such as 2,4-D. 2,4-D effectively manages many problematic weeds in sweet corn and asparagus production, and continues to offer a viable option for managing herbicide resistant weeds. In the future, with increasing labor pressures, the availability of tools such as 2,4-D which offer the effective weed control that keeps production costs low, yields high, and results in a high quality and affordable food supply.

LITERATURE CITED

Bridges, D.C. 2011. A biological analysis of the use and benefits of chloro-s-triazine herbicides in US corn and sorghum production. http://www.weeds.iastate.edu/mgmt/2011/atrazine/Bridges__9Nov2011.pdf

Bridges, D.C. and R.L. Anderson. 1992. Crop loss due to weeds in the United States by crop and region, p. 61-77 in D.C. Bridges, ed. Crop Losses Due to Weeds in Canada and the United States 1992. Weed Sci. Soc. Am., Champaign, IL.

Gianessi, L.P. and N.P. Reigner. 2007. The value of herbicides in US crop production. Weed Technol. 21:559-566.

NAPIAP Report. 1996. Biologic and Economic Assessment of Benefits from Use of Phenoxy Herbicides in the United States. NAPIAP Report, number 1-PA-96, November 1996.

NASS Data and Statistics Vegetables, chemical use data. http://www.nass.usda.gov/Data_and_Statistics/Pre-Defined_Queries/2010_Vegetables/index.asp 2010 Vegetable Chemical Use - Released July 27, 2011

NASS Quick Stats survey data on vegetables, asparagus and sweet corn. http://quickstats.nass.usda.gov/

Stephen C. Weller is a Professor of Weed Science in the Department of Horticulture and Landscape Architecture at Purdue University. His areas of specializations include research on and implementation of integrated weed management for vegetable crops, herbicide resistant mechanisms in weeds and he has over 25 years of experience in international agriculture development in Central America and Africa. He is a co-author on the textbook 'Weed Science Principles and Practices', 4th Edition.