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Plant Biotechnology: Current and Potential Impact For Improving Pest Management In U.S. Agriculture An Analysis of 40 Case Studies

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Herbicide Tolerant Sweet Corn

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14. SWEET CORN

Herbicide Tolerant

Production

Wisconsin is a major producer of sweet corn for processing and typically accounts for 20% of U.S. production [1]. In 2000, Wisconsin sweet corn growers produced 576000 tons (1.15 billion lbs.) of sweet corn on 95000 acres with a value of $38 million ($400/A). Wisconsin sweet corn acreage and volume of production has declined about 45% since 1990. (See Table 14.1.) One of the major reasons for this decline is the state's strict groundwater protection regulations that either prohibit or limit the use of the herbicide atrazine, depending on the location [4]. This prohibition makes weed control more expensive and sometimes impossible to attain. In addition, availability of sweet corn raw product becomes less dependable for processors. Thus, many food processing companies have closed or moved sweet corn acreage to other states where atrazine can still be used at effective rates [4].

Weeds and Herbicide Use

Wisconsin sweet corn acreage is infested with grass weed species (barnyardgrass, crabgrass, fall panicum, foxtail, wild proso millet and woolly cupgrass) and broadleaf weed species (ragweed, nightshade, lambsquarters, pigweeds and velvetleaf). Uncontrolled weeds compete with the sweet corn plants for light, nutrients, and moisture. As a result, uncontrolled weeds lower sweet corn yields significantly.

Sweet corn is a poor competitor with weeds due to a limited root system and poor late season canopy closure [7]. Sweet corn hybrids generally have less herbicide tolerance than most field corn hybrids, thus herbicides like bromoxynil, dicamba, and primisulfuron are registered for field corn but not for sweet corn [7].

Wild-proso millet was discovered in isolated areas of Wisconsin and Minnesota in the early 1970's, and by 1982, more than 400,000 hectares of cropland were infested [5].

Woolly cupgrass was first identified in Wisconsin in the 1960's and is now reported in over 35 counties and continues to spread to uninfested fields [9].

Row cultivators typically eliminate only about 60% of the annual weeds present in a sweet corn field, but escapes grow rapidly because of the failure of the crop to form a complete canopy and shade the soil fully at late season [4]. Cultivation alone is not a commercially effective treatment.

Ninety-seven percent of Wisconsin's sweet corn acreage is treated with herbicides to control weeds [2]. Table 14.2 lists the herbicides used for weed control in Wisconsin sweet corn and displays estimates of their usage in 1998. Typically, growers use a preemergence herbicide for broadleaf weed control, either atrazine or cyanazine. These two triazine herbicides provide good to excellent control of several broadleaf weed species, including ragweed and nightshade. The triazines also provide good to excellent control of lambsquarters and pigweeds, except on acreage where triazine resistant populations have developed. It has been estimated that approximately 25,000 of Wisconsin's sweet corn acres are infested with triazine resistant lambsquarters and/or pigweeds [4]. A small percentage of acreage (12%) is treated with bentazon postemergence for control of certain broadleaf species, including cocklebur, smartweed, and velvetleaf. However, bentazon does not control lambsquarters or pigweeds. 2,4-D is registered for use in sweet corn and provides good to excellent control of both lambsquarters and pigweeds. However, 2,4-D frequently injures many sweet corn hybrids, particularly when growing conditions are favorable for rapid sweet corn growth, or air temperatures are high. In a 1998 study, 2,4-D application to 20 commonly grown sweet corn hybrids resulted in greater than 5% plant height reduction in 19 hybrids and moderate to severe root damage to all 20 hybrids [11]. Such injury frequently results in broken or lodged plants, that cannot be harvested, malformed sweet corn ears that cannot be processed, and reduced crop yields.

The triazine-resistant lambsquarters and pigweeds are estimated to be causing a 20% yield loss on 25,000 sweet corn acres [4].

The primary herbicides used for grass weed control in Wisconsin sweet corn are alachlor, dimethenamid and metolachlor. These herbicides provide good to excellent control of barnyardgrass, crabgrass, fall panicum and foxtails. They do not control wild proso millet or woolly cupgrass. Pendimethalin suppresses these weeds but frequently causes excessive crop injury [4]. EPTC provides early season, but not late season control of these weeds if used no more frequently than once every three or four years. Used more frequently, enhanced soil microbial degradation reduces the effectiveness of EPTC against wild proso millet and woolly cupgrass [4]. Nicosulfuron is very effective in controlling wild proso millet and woolly cupgrass, and is applied to 24% of Wisconsin sweet corn acreage. Research has demonstrated that nicosulfuron provides 90% or greater wild-proso millet control and maintains sweet corn yields within 3-4% of maximum yields [5]. However, many sweet corn cultivars are extremely sensitive to damage from nicosulfuron applications, including Jubilee, the most widely grown hybrid. Of 85 sweet corn hybrids tested, nicosulfuron usage is permitted on only 37 [4] [21]. Thus, nicosulfuron cannot be used on all the acreage where wild proso millet and woolly cupgrass occur. Approximately 48,000 acres of Wisconsin sweet corn (50%) are infested with woolly cupgrass and wild proso millet [4]. Nicosulfuron is used to control the two species on one-half of this acreage. The remaining 50% are planted to the most popular hybrids, which cannot be treated with nicosulfuron. This suggests that about 25,000 acres of sweet corn are experiencing yield losses (estimated at 20%) due to these two annual grasses [4].

<u>Herbicide Tolerant Sweet Corn</u>

Glufosinate (Liberty) is a nonselective herbicide effective against a wide range of weeds. Transgenic glufosinate-resistant sweet corn offers the possibility of a direct broadcast glufosinate application for grass and broadleaf weed control [6].

Resistance to glufosinate was obtained originally from a gene found in the bacteria species *Streptomyces hygroscopicus*. This gene encodes phosphinothricin acetyltransferase (PAT), an enzyme that catalyzes metabolic inactivation of glufosinate by acetylation [17]. This gene was incorporated successfully into embryonic maize suspension cells via microprojectile bombardment [18]. Stable transformed maize callus were obtained by selecting the bombarded suspension cultures on solid media containing glufosinate at a concentration lethal to non-transformed cells. Whole fertile plants demonstrating resistance to foliar applications of glufosinate were regenerated successfully [19].

Glufosinate-resistant field corn and sweet corn hybrids were developed via backcrossing with elite inbred lines [19].

Research with transformed sweet corn in Wisconsin demonstrated that two applications of glufosinate at 0.27 pound of active ingredient per acre produced greater than 90% control of wild proso millet, pigweeds, woolly cupgrass and common lambsquarters [11] [12] [13] [14] [6]. Glufosinate killed all woolly cupgrass and wild-proso millet plants that had emerged at the time of application [9]. PAT-transformed sweet corn is very resistant to glufosinate. No visible injury and little to no yield reduction occurs from glufosinate applications [6].

Estimated Impacts

In 1999, the State of Wisconsin applied for an emergency exemption for the use of glufosinate on sweet corn [4]. The request was granted; however, only about 1,000 acres were treated because of processors' concerns about the potential loss of sales in certain overseas markets due to concerns over genetically engineered sweet corn [10].

At that time, it was estimated that glufosinate would be used on 30,000 acres because only nine glufosinate-resistant hybrids were available (including Jubilee). The State's assessment was that glufosinate usage would prevent a 20% yield loss on those 30,000 acres [4]. The value of the additional yield is estimated at $2.4 million (See Table 14.3). The total increase in production would be 72 million pounds (See Table 14.3).

The 1999 price of glufosinate was $61 per pound of active ingredient [3]. Thus, growers would incur a cost of $33 per acre for applying 0.54 pound per acre of glufosinate. The cost of an herbicide application is estimated at $6.50 per acre for each application. Thus, two applications of glufosinate would cost $46 per acre. The total cost of the glufosinate applications on 30,000 acres would be $1.4 million. Thus, the net increase in income would be $1 million/yr. The total use of glufosinate would be 16,200 pounds of active ingredient.

All of the glufosinate-resistant sweet corn hybrids are transgenic and contain Bt genes because the glufosinate-resistant characteristic was used as a selectable marker for Bt. The Bt gene essentially eliminates the need to spray the sweet corn crop for corn borers or corn earworm. On the average, non-transgenic sweet corn grown in Wisconsin requires three applications of either a synthetic pyrethroid, carbamate or organophosphate insecticide to prevent worm contamination of the processed corn. This adds approximately $32 per acre to sweet corn production costs [4]. The resulting benefit on 30,000 acres would be $945,000 [4]. There is no added technology fee for use of glufosinate with glufosinate-resistant sweet corn. However, there is an added seed cost of $32 per acre for the Bt seed for processing sweet corn cultivars [20]. Thus, the insect control benefits balance out the increased cost of the transgenic seed.

Research demonstrated that damage from the European corn borer and corn earworm was reduced to zero in the transformed hybrids while untreated, non-transformed hybrids incurred 20% insect damage [8].

TABLE 14.1: Sweet Corn for Processing: Wisconsin

Year	Planted (000 Acres)	Production (000 Tons)	Value (Million $)
2000	95	576	38
1999	108	699	39
1998	112	657	40
1997	116	717	53
1996	120	701	55
1995	140	690	50
1994	161	1,002	63
1993	143	588	38
1992	162	795	48
1991	171	1,000	65
1990	161	809	53
1989	162	810	51
1988	151	609	35
1987	147	770	44
1986	133	656	38

Source: [1]

TABLE 14.2: Herbicide Use: Processing Sweet Corn: Wisconsin (1998)

Active Ingredient	% Acres Treated	Total Lbs AI/Yr (000)
Alachlor	31	68
Atrazine	50	42
Bentazon	12	13
Cyanazine	41	79
Dimethenamid	15	23
Glyphosate	12	10
Metolachlor	27	62
Nicosulfuron	24	1

Source: [2]

Table 14.3 Projected Impacts of Herbicide Tolerant Sweet Corn Wisconsin

Acreage:	30,000
Production Increase:	72 million lbs./yr.
Per Acre:	
Currently:	12000 lbs./A/yr.
Increase:	20%
Income Increase:	$2.4 million/yr.
Per Acre:	
Currently:	$400/A
Increase:	20%

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