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Potential yield loss in sugar beet due to weed interference in the United States and Canada

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Abstract

The objective of this WSSA Weed Loss Committee report is to provide quantitative data on the potential yield loss in sugar beet due to weed interference from the major sugar beet growing areas of the United States and Canada. Researchers and extension specialists who conducted research on weed control in sugar beet in the United States and Canada provided quantitative data on sugar beet yield loss due to weed interference in their regions. Specifically, data were requested from weed control studies in sugar beet from up to 10 individual studies per calendar year over a 15-yr period between 2002 and 2017. Data collected indicated that if weeds are left uncontrolled under optimal agronomic practices, growers in Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ontario, Oregon, and Wyoming would potentially lose an average of 79%, 61%, 66%, 68%, 63%, 75%, 83%, 78%, and 77% of the sugar beet yield. The corresponding monetary loss would be approximately US$234, US$122, US$369, US$43, US$40, US$211, US$12, US$14, and US$32 million, respectively. The average yield loss due to weed interference for the primary sugar beet growing areas of North America was estimated to be 70%. Thus, if weeds are not controlled, growers in the United States would lose approximately 22.4 million tonnes of sugar beet yield valued at approximately US$1.25 billion, and growers in Canada would lose approximately 0.5 million tonnes of sugar beet yield valued at approximately US$25 million. The high return on investment in weed management highlights the importance of continued weed science research for sustaining high crop yield and profitability of sugar beet production in North America.

Introduction

Sugar beet is a valuable cash crop grown mainly for sugar production in various regions of the United States and Canada. Sugar beet contains as much as 20% sugar by weight and is the source of 20% of the world's sugar supply, with the remaining 80% sourced from sugarcane (*Saccharum officinarum* L.) (Anonymous 2009). Currently most of the sugar beet grown in North America contains the transgene that confers resistance to glyphosate (ISAAA 2011). Glyphosate-resistant sugar beet was first introduced in the United States in 2008, and by 2011 nearly 95% of sugar beet grown in North America was seeded to glyphosate-resistant cultivars (ISAAA 2011).

Weeds are a major concern in sugar beet production due to limited weed control options and the ability of weeds to compete with the crop (Brimhall et al. 1965; Dawson 1965; Zimdahl and Fertig 1967). In general, producers are most concerned with weeds that emerge within the first 8 wk of planting (Wicks and Wilson 1983); of those, broadleaf weeds tend to be more competitive with sugar beet than grasses (Brimhall et al. 1965; Zimdahl and Fertig 1967). Major troublesome weeds in sugar beet production include common lambsquarters (*Chenopodium album* L.), hairy nightshade (*Solanum physalifolium* Rusby), horseweed

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Table 1. Potential annual average sugar beet area harvested, yields, total value, estimated yield loss (%), and losses in sugar beet production and in value from weed interference for each state or province that provided data for the period of 2002 to 2017.

State or province	Harvested area	Average yield	Total value	Potential yield loss	Potential loss in production	Potential loss in value (US$55.79 tonnes^{-1})
	ha	tonnes ha^{-1}	US$ × 1,000	%	tonnes ha^{-1}	US$ × 1,000
Idaho	67,831	78.0	295,208	79.3	61.9	234,100
Michigan	59,956	59.2	197,949	61.4	36.3	121,541
Minnesota	179,307	56.3	562,845	65.6	36.9	369,227
Montana	17,429	65.0	63,212	68.2	44.3	43,111
Nebraska	19,132	59.0	62,928	62.8	37.0	39,519
North Dakota	89,093	56.7	281,892	74.9	42.5	211,137
Ontario	3,866	68.7	14,807	82.6	56.7	12,231
Oregon	3,916	80.3	17,533	78.3	62.8	13,728
Wyoming	12,576	59.6	41,837	77.1	46.0	32,256

(*Erigeron canadensis* L.), redroot pigweed (*Amaranthus retroflexus* L.), velvetleaf (*Abutilon theophrasti* Medik.), waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer], kochia [*Bassia scoparia* (L.) A. J. Scott], and yellow nutsedge (*Cyperus esculentus* L.) (Schweizer and Dexter 1987). Velvetleaf at densities of 6 and 24 plants 30 m^{-1} of row decreased sugar beet yield 14% and 30%, respectively (Schweizer and Bridge 1982), while common lambsquarters at densities of 6 and 24 plants 30 m^{-1} of row reduced sugar beet yield by 13% and 48%, respectively (Schweizer 1983). Powell amaranth (*Amaranthus powellii* S. Watson) at densities of 6, 12, 18, and 24 plants 30 m^{-1} of row also decreased sugar beet yield 8%, 14%, 24%, and 25%, respectively (Schweizer and Lauridson 1985). The primary method of weed control in sugar beet within major sugar beet growing regions of the United States and Canada is the use of herbicides.

There are only a few published surveys of yield loss due to weed interference in the last 100 yr. Cramer (1967) summarized the first estimates, which were published by the USDA in 1927. More recently, the WSSA Weed Loss Committee estimated sugar beet yield loss ranged from 2% to 70% in the United States (Chandler et al. 1984; Bridges 1992) and from 4% to 15% in Canada (Swanton et al. 1993). Previous reports provided snapshots of comparative yield loss due to weed interference across the United States and Canada, but they did not use background information on sugar beet hectares, tonnage, or price from each state or province. These earlier reports (Chandler et al. 1984; Bridges 1992; Swanton et al. 1993) relied on estimates from research and extension personnel, as well as comments from producers.

A robust estimate of potential sugar beet yield loss due to weed interference that incorporates production data would inform and guide research on integrated weed management strategies for sugar beet production across the United States and Canada. In the past 25 yr, research in breeding, cultural management, and adaptation of transgenic hybrids by growers have improved sugar beet productivity (Draycott 2008). A more current estimate of potential yield loss in sugar beet that accounts for these changes is needed, especially with the adoption of glyphosate-resistant sugar beet by growers in North America.

The objective of this study was to summarize the potential yield loss in sugar beet due to weed interference. The WSSA Weed Loss Committee integrated quantitative data from replicated, small-plot research and industry production statistics from each of the major sugar beet growing areas in the United States and Canada. The economic cost associated with weed interference in sugar beet will be presented from jurisdictions that provided data.

Materials and Methods

Researchers and extension specialists conducting research on weed control in sugar beet in the United States and Canada were contacted to provide estimates of sugar beet yield loss due to weed interference. Specifically, results were requested from weed control studies in sugar beet from up to 10 individual studies per calendar year over a 15-yr period between 2002 and 2017.

Each researcher/specialist was asked to provide the means for "weedy sugar beet yield" and the "weed-free sugar beet yield" from each trial he or she conducted in each year. Means were calculated from replicated studies. The "weedy yield" represented the mean sugar beet yield from weedy control plots, based on normal agronomic practices for optimal sugar beet yield with no in-crop weed control tactics applied. "Weed-free yield" was defined as the mean yield from plots with >95% weed control, again based on normal agronomic practices for optimal sugar beet yield.

Potential yield loss (YL%) for each region (state/province) was calculated as a percentage of yield lost for each individual study, which was averaged within each year, and then averaged across the 15-yr period as follows:

$$\text{Potential YL\%} = (\text{weed-free yield} - \text{weedy yield}) / \text{weed-free yield} \times 100 \quad [1]$$

Total area harvested (hectares), sugar beet yield (tonne ha^{-1}), total sugar production (tonne), and yearly average commodity price (US$ tonne^{-1}) for each state and province were obtained from USDA-NASS (2017) and the Canadian Sugar Institute (2015) reports. Yield and the monetary loss were weighted by the

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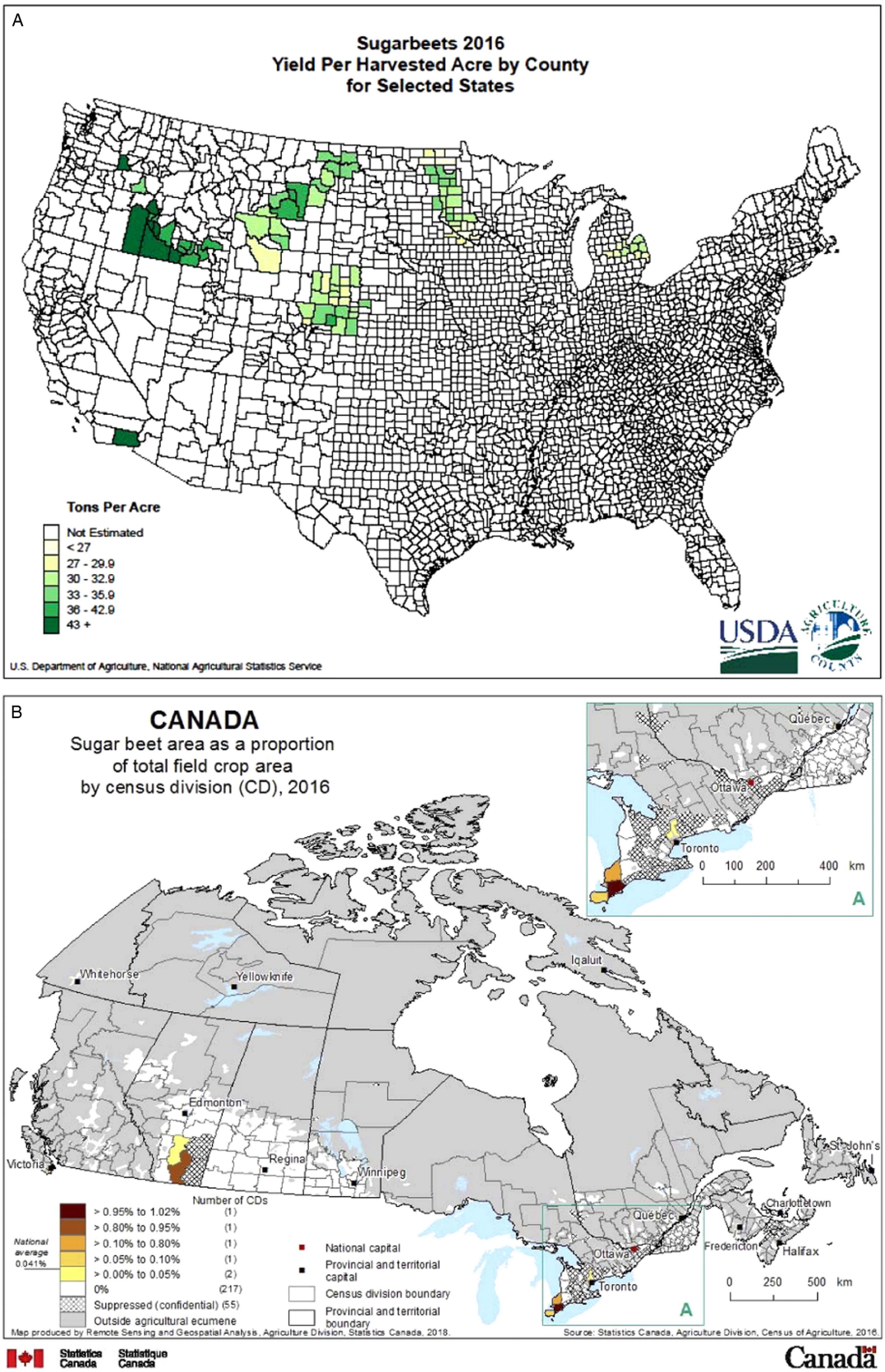

Figure 1. Sugar beet growing regions within the United States (A) and Canada (B). Images from (A) USDA-NASS: https://www.nass.usda.gov/Charts_and_Maps/graphics/SU-PR-RGBChor.pdf; (B) Statistics Canada: http://www.statcan.gc.ca/pub/95-634-x/2017001/article/54904/catm-ctra-129-eng.htm.

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quantity of sugar beet produced in each state or province. The estimated sugar beet yield loss due to weed interference was multiplied by mean sugar beet price for 2002 to 2017 to determine the potential monetary loss in each region. Average price of sugar beet between 2002 and 2017 was US$50.61 tonne^{-1}; this value was used to estimate potential monetary loss in the United States and Canada.

Results and Discussion

Data were obtained from 9 of 13 states or provinces that are major sugar beet growing areas in the United States and Canada; these included Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ontario, Oregon, and Wyoming, representing 93% of the sugar beet crop grown in North America (Table 1; Figure 1). The potential yield and monetary loss of sugar beet production due to weed interference based on normal agronomic practices for optimal sugar beet yield in different regions of North America for the period of 2002 to 2017 (averaged) are shown in Table 1.

In the United States, most of the sugar beet was grown in Minnesota followed by North Dakota, Idaho, and Michigan (Table 1). In Minnesota, sugar beet was produced on 179,307 ha, with a total annual yield of 10 million tonnes, with a monetary value of US$563 million. Minnesota accounted for more than a third of total sugar beet production in North America (Table 1). In Canada, Ontario growers produced sugar beet on 3,866 ha, with an annual production of 265,594 tonnes valued at US$15 million (Table 1).

Percent yield loss in sugar beet ranged from 61% to 83% if weeds were left uncontrolled while maintaining best agronomic management practices for optimum yield (Table 1). This would correspond to significant farm gate loss of income in each jurisdiction (Table 1): Idaho (US$234 million), Michigan (US$122 million), Minnesota (US$369 million), Montana (US$43 million), Nebraska (US$40 million), North Dakota (US$211 million), Ontario (US$12 million), Oregon (US$14 million), and Wyoming (US$32 million). The loss of gross revenue from weed interference in sugar beet across sampled regions would total approximately US$1.1 billion yr^{-1} (Table 1).

Previous estimates of yield loss in sugar beet were based on nonquantitative survey data and were substantially lower than the estimated yield loss in the current study. In a WSSA survey conducted between 1975 and 1979, sugar beet yield loss due to weeds was estimated to be only 2% to 10% and 6% to 12% in the United States and Canada, respectively (Chandler et al. 1984). Another similar WSSA survey conducted from 1989 to 1991 (Bridges 1992) reported that in the absence of weed control, sugar beet growers in California, Colorado, Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Oregon, and Wyoming estimated potential losses of 15% to 70%. In various provinces of Canada, only 4% to 15% yield loss from uncontrolled weeds in sugar beet was reported based on expert opinion surveys (Swanton et al. 1993). These values differ substantially from the overall average yield loss of 70% due to weed interference in sugar beet reported in the current study (Table 1). Data collected in this study are based on actual plots on research farms or field sites for weed management research, which can sometimes have higher weed populations. Also, some of the discrepancy between the current results and reports in previous surveys may be a result of inaccuracy associated with expert opinions (Herman and Reybould 2014). Expert opinions lack precise quantification of risk, suffer from observer-based error, and lack context of the full potential for harm (i.e., yield loss) to occur in the face of risk (i.e., competitive interactions) (Herman and Reybould 2014).

In 2017, sugar beet was grown on 450,861 ha and produced 32 million tonnes valued at approximately US$1.8 billion in the United States (Table 2). At an average yield loss of 70%, growers in the United States would annually lose nearly 22.4 million tonnes valued at approximately US$1.25 billion (Table 2). In Canada during 2015, sugar beet was grown on 9,050 ha and produced 638,000 tonnes root yield valued at approximately US $35.5 million. At an average yield loss of 70%, growers in Canada could annually lose 447,000 tonnes valued at approximately US $25 million (Table 2).

Based on these results, if weeds were left uncontrolled, sugar beet producers in North America could potentially lose 70% of their crop yield. Potential yield loss in sugar beet due to weed interference was shown to be 50%, 52%, and 71% yield loss in corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and dry bean (*Phaseolus vulgaris* L.), respectively, using a similar source of quantitative data (Soltani et al. 2016, 2017, 2018). Because initial sugar beet shoot growth is slow relative to annual weed species like common lambsquarters and redroot pigweed, sugar beet is predicted to suffer greater yield loss than other crop species when competing with weeds (Jursík et al. 2008). Based on this estimate, and the assumption that the cost of >95% in-crop herbicide weed control in sugar beet is US$120 ha^{-1} in North America (DER and PHS, personal observations), there would be a US$23 return for every US$1 invested in weed management in sugar beet production in North America. The high return on investment in weed management highlights the importance of continued weed science research for sustaining high crop yield and profitability of sugar beet production in North America.

Table 2. Annual total sugar beet production and value (US$) and annual potential loss in production and value (US$) from weed interference for the United States (USDA-NASS 2017) and Canada (Statista 2018).

Country	Harvested area	Total production	Value	Potential loss (based on 70% YL)	Net return for US$1 invested in weed management[a] at cost of US$120 ha^{-1}
	ha	tonnes	US$	US$	US$
United States	450,861	32,046,310	1,784,018,085	1,248,812,659	23
Canada	9,050	638,099	35,522,971	4,866,080	23
Total	**459,911**	**32,684,409**	**1,819,541,056**	**1,273,678,739**	

[a]Based on recommended herbicides currently used in sugar beet production (DER and PHS, personal observations).

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