Weed Technology

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Potential potato yield loss from weed interference in the United States and Canada

Zahoor A Ganie[1], Nader Soltani[2], Andrew G McKenzie-Gopsill[3], Joel Felix[4], Pamela J. S. Hutchinson[5], J. Anita J. Dille[6] and Peter H. Sikkema[7]

[1]Senior Global R&D Scientist, Herbicide Discovery Biology, FMC Corporation, Newark, DE, USA; [2]Adjunct Professor, Department of Plant Agriculture, University of Guelph Ridgetown Campus, Ridgetown, ON, Canada; [3]Research Scientist, Agriculture and Agri-Food Canada, Charlottetown, PEI, Canada; [4]Associate Professor, College of Agricultural Science, Oregon State University, Ontario, OR, USA; [5]Associate Professor, Department of Plant Sciences, University of Idaho, Aberdeen, ID, USA; [6]Professor, Department of Agronomy, Kansas State University, Manhattan, KS, USA and [7]Professor, Department of Plant Agriculture, University of Guelph Ridgetown Campus, Ridgetown, ON, Canada

Abstract

Potato is the third most important staple food crop globally following rice and wheat. In the United States, potato is grown on approximately 410,000 ha with a farm-gate value of US$1,032 million. In Canada, potato is grown on approximately 134,000 ha with a farm-gate value of US$235 million. The objective of this manuscript, compiled by the Weed Science Society of America Weed Loss Committee, was to estimate potato yield loss caused by weed interference. Potato yield data from weedy and weed-free plots (or plots with >95% weed control) was obtained from researchers working on weed management in potato in the United States and Canada or from published manuscripts from 2000 to 2018. Potato yield loss from weed interference was 12% to 61% when no weed management tactics were implemented. The average yield loss for all states/provinces (where data was obtained) due to weed interference was 44%. Weed interference would cause a farm-gate loss of approximately US$465 million and US$61 in the United States and Canada, respectively, if weeds are not controlled. These results indicate that weed management is critical for successful potato production, and that an ongoing need for research exists on weed management in this crop.

Research Article

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Nomenclature:
Barnyardgrass; *Echinochloa crus-galli* (L.) Beauv.; common lambsquarters; *Chenopodium album* L.; green foxtail; *Setaria viridis* (L.) Beauv.; hairy nightshade; *Solanum physalifolium* Rusby; kochia; *Bassia scoparia* (L.) A.J. Scott; quackgrass; *Elytriga repens*L.; redroot pigweed; *Amaranthus retroflexus* L.; potato; *Solanum tuberosum* L.

Keywords:
Weed interference; potato yield; economic loss; herbicides; integrated weed management; potato

Author for correspondence:
Nader Soltani, Department of Plant Agriculture, University of Guelph Ridgetown Campus, 120 Main Street East, Ridgetown, ON, Canada N0P 2C0 Email: soltanin@uoguelph.ca

Introduction

Potato is grown on approximately 16.5 million ha worldwide, providing a staple food to more than 1.3 billion people (Devaux et al. 2021; FAOSTAT 2021). Major potato-producing regions in the world include Asia, Europe, and the Americas, accounting for 43%, 38%, and 13%, respectively, of global potato production; or 94% of global production when added together (FAOSTAT 2021). Recently there has been an increase in potato production in Africa (FAOSTAT 2021). The five highest potato-producing countries are China, India, Ukraine, Russia, and the United States. Canada ranks 13th in global potato production (FAOSTAT 2021). Potato is an economically important crop in North America and plays an important role in the food industry with >80% used for human consumption as fresh (baked, boiled, or mashed potatoes), frozen French fries, potato chips, and other products (dehydrated or canned potatoes, tater tots, wedges, spiral fries, etc.; Lin et al. 2001).

Potato is produced in various regions of the United States and Canada because it can be grown under a wide range of agroecosystems due to its adaptability, high productivity, relatively short production cycle, and compatibility with diverse cropping systems (Adams et al. 2022). Potato is anticipated to play an important role in feeding the increasing human population in the future due to its high yield potential, high harvest index (HI = 0.85, meaning that 85% of the potato plant biomass is edible human food) compared to other major food crops such as cereals (HI = 0.4 to 0.6; Jennings et al. 2020). In addition, potato crop produces more food in less time while consuming fewer resources and being associated with lower greenhouse gas emissions (Clune et al. 2017; Nemecek et al. 2012).

In the United States, potato is grown on approximately 410,000 ha and resulted in 20,404 × 10^6 kg with a farm-gate value of approximately US$1.0 billion (USDA-NASS 2020). Most of the potatoes grown in the United States are produced in Idaho (31%), Washington (22%), Wisconsin (6%), Oregon (6%), and North Dakota (5%); other potato-producing states include Michigan, Colorado, Minnesota, California, Maine, Nebraska, Texas, and Florida (USDA-NASS 2020). In Canada, potato is grown on approximately 134,000 ha, and resulted in 4.647 × 10^9 kg with a farm-gate value of US$235 million (AAFC 2020; Anonymous 2021). The primary potato-producing provinces are Prince Edward Island (24%), Alberta (20%), Manitoba (19%), New Brunswick (15%), Quebec (12%), and Ontario (6%; AAFC 2020). In Canada, potato production

accounted for 27% of all vegetables, and 15% of all horticultural crops grown in 2020 (AAFC 2020).

Potato is highly vulnerable to pests including nematodes, diseases, insects, and weeds. Without any pest control (no use of nematicide, fungicide, insecticide, or herbicide) potato yield losses were as high as 64% on mineral soil (2.9% humus) and 85% on organic soil (63% humus) in Canada (Tolman et al. 1986). Furthermore, Tolman et al. (1986) reported that average potato yield losses were 47%, 18%, and 5% in the absence of insecticides, herbicides, and fungicides, respectively, on mineral soils. In the same study potato yield losses were 49% in the absence of insect control, 71% in the absence of weed control, and 52% in the absence of disease control on organic soils (Tolman et al. 1986). In contrast, Oerke (2006) estimated actual yield losses in potatoes worldwide due to pathogens, viruses, animal pests, and weeds were 14%, 7%, 11%, and 8%, respectively. Weeds not only cause yield losses in potato crops by competing for resources but are also associated with higher insect and disease infestations because common weed species such as nightshades provide an alternative host for potato pests (Alvarez and Hutchinson 2005; Boydston et al. 2008). The major economic impact of weeds is a decline in marketable potato yield due to a reduction in the number and size of tubers, a decrease in harvesting efficiency, and higher tuber injury that causes a reduction in shelf-life (Nelson and Thoreson 1981; Nowacki 1983).

Response of potato to weed infestation varies from field-to-field depending on environmental conditions, weed species composition, weed density, the relative time of weed and crop emergence, duration of weed-crop competition, potato cultivar, and other agronomic factors (Baziramakenga and Leroux 1994; Bellinder et al 2000). For example, the season-long presence of barnyardgrass or redroot pigweed in potato at one plant per square meter reduced marketable tuber yield by 19% and 33%, respectively (VanGessel and Renner 1990). Green foxtail at an average density of 439 plants m^{-2} allowed to compete for 2 wk after crop emergence reduced total and marketable potato yield tuber by 19% and 29%, respectively (Wall and Friesen 1990). Baziramakenga and Leroux (1994) reported that the critical period of quackgrass control in potato varies with the level of infestation and started at 15, 3, and 0 d after emergence under low (35 to 38 g m^{-2}), medium (87 to 95 g m^{-2}), and high (135 to 158 g m^{-2}) infestation levels, respectively, measured as rhizome dry biomass at 1 d after emergence. The critical period of weed control in potato crops varies with region, environmental conditions, soil type and nutrient status; and weed species composition, density, and time of emergence, but usually starts at planting and lasts until several weeks after flowering, which highlights the importance of both pre- and post-emergence weed control (Ciuberkis et al. 2007).

Labeled herbicide options for weed control are limited for use in potato, and research on weed management in potato is relatively scarce compared to other major crops. The literature contains limited research on weed management in potato compared to wheat, soybean, and corn. The number of research articles found with the use of crop names including corn, soybean, wheat, and potato as search terms in Weed Science Society of America journals (*Weed Technology* and *Weed Science*) published between the years 2000 and 2022 provides a comparative measure of weed management research in the aforementioned crops. There were 1,622, 1,600, 1,525, and 367 research articles published in *Weed Technology;* and 1,052, 1,174, 1,226, and 751 research articles published in *Weed Science* with wheat, soybean, corn, or potato used as the search term, respectively, between the years 2000 and 2022.

The objective of this Weed Science Society of America Weed Loss Committee manuscript is to provide reliable estimates of potential yield losses in potato caused by weeds in the United States and Canada based on research trial data. Yield loss estimates will provide an understanding of the pernicious effect of weeds on potato yield and net returns to producers. Furthermore, the publication of this manuscript will, we hope, generate greater interest from herbicide manufacturers to register new or existing herbicides for weed management in potato and stimulate the development of long-term, sustainable integrated potato weed management programs by public weed scientists.

Materials and Methods

Weed science researchers and extension specialists who conducted research on weed management in potato in the United States and Canada were contacted to provide estimates of potato yield loss due to weed interference. Specifically, results were requested from weed control studies in potato from up to 10 individual studies per calendar year between 2000 and 2018. Data were also obtained from research reports published online or in peer-reviewed manuscripts from several states and provinces where we could not obtain any data on yield loss due to weed interference.

Researchers/specialists were asked to provide the means for "weedy potato yield" and the "weed-free potato yield" from each trial they conducted each year between 2000 to 2018. Means were calculated from replicated studies. The "weedy yield" represented the mean potato yield from weedy control plots, based on normal agronomic practices for optimal potato yield where no weed control tactics were applied. "Weed-free yield" was defined as the mean yield from plots with >95% weed control, again based on normal agronomic practices for optimal potato yield. The effect of herbicide programs on any possible crop injury that could cause yield penalty irrespective of >95% weed control was not considered because of the assumption that >95% weed control data could be from trials evaluating chemical, manual, mechanical, or any combination of management tools. Potential yield loss (YL%) for each state and province was calculated as a percentage of yield lost for each individual study, which was averaged within each year, and then averaged across the period for which data was available as follows:

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

Total area harvested (hectares), potato yield (kilograms per hectare), total potato production (kilograms), and average commodity price (US$ per kilogram) for each state and province were obtained from USDA-NASS (2020) and AAFC (2020) reports. Yield and monetary loss were weighted by the quantity of potato produced in each state or province. The estimated potato yield loss due to weed interference was multiplied by the mean potato price from 2000 to 2018 and was used to determine the potential monetary loss in each region. The average price of potato between 2000 and 2018 was US$0.0506 kg^{-1}; this value was used to estimate the potential monetary loss in the United States and Canada.

Results and Discussion

In the United States, data were received from key potato-producing states including Idaho, North Dakota, and Oregon, which represent approximately 43% of total potato acreage in the country.

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Table 1. Potential yield and monetary loss in potato for states and provinces that provided data.

	Area seeded	Yield	Total production	Price	Total value	Yield loss	Yield loss	Dollar loss	Number of trials	Trial year
	ha	kg × 1,000 ha^{-1}	kg × 1,000	\$ kg^{-1}	US\$	%	kg × 1,000	US\$		
United States										
Idaho	127,476	50.42	6,427,085	0.5061	325,274,770	43	2,763,647	139,868,151	35	2007 to 2018
New York	5,423	32.48	176,139	0.5061	8,914,397	12	21,137	1,069,728	1	2004
North Carolina	4,937	21.28	105,059	0.5061	5,317,054	21	22,062	1,116,581	1	1990
North Dakota	29,542	36.40	1,075,329	0.5061	54,422,391	20	215,066	10,884,478	10	2001, 2002
Oregon	18,211	67.20	1,223,779	0.5061	61,935,465	61	746,505	37,780,634	20	2007–2017
Texas	7,082	47.60	337,103	0.5061	17,060,793	23	77,534	3,923,982	1	2005
Washington	64,750	70.56	4,568,760	0.5061	231,224,944	55	2,512,818	127,173,719	6	1994, 1995, 2005, 2016, 2017
Wisconsin	27,114	43.36	1,175,663	0.5061	59,500,306	35	411,482	20,825,107	8	2006–2010
Canada										
Prince Edward Island	32,051	31.92	1,023,068	0.5061	51,777,467	26	265,998	13,462,142	21	2000–2006, 2018
Total North America	316,586				815,427,588			356,104,522		

Additional data were obtained from peer-reviewed manuscripts for other potato-producing states including Washington, Wisconsin, Texas, New York, and North Carolina. Overall data in the United States was based on 84 field trials conducted in various states that represented about 69% of total potato hectarage. Idaho and North Dakota provided consistent field data generated over years from 2007 to 2018, and 2007 to 2017, respectively (Table 1). The average potential yield losses due to uncontrolled weeds were as follows: Idaho, 43%; New York, 12%; North Carolina, 21%; North Dakota, 20%; Oregon, 61%; Texas, 23%; Washington, 55%; and Wisconsin, 35% (Table 1). Based on these estimates, if weeds are uncontrolled, potato growers may potentially lose money annually as follows (in millions of US\$): Idaho, \$140; New York, \$1; North Carolina, \$1; North Dakota, \$11; Oregon, \$38; Texas, \$4; Washington, \$127; and Wisconsin, \$21(Table 1). Nationally, in the United States, if no weed management tactics were implemented in potato there would be an estimated potato yield loss of 45%, an annual yield loss of 9.1 billion kg, and a farm-gate loss of US\$465 million (Table 2). Previously, Tonks et al. (2000) reported up to 63% yield reduction in potato infested with weed species, including common lambsquarters, redroot pigweed, and green foxtail. Similarly, season-long competition with hairy nightshade at 2 plants m^{-2} row resulted in a 77% reduction in total potato tuber yield (Hutchinson 2014). Another study reported a 43% reduction in total potato yield in plots infested with hairy nightshade, kochia, redroot pigweed, common lambsquarters, and green foxtail compared to a weed-free control (Hutchinson et al. 2003).

In Canada, potato yield loss data were received from Prince Edward Island, a major potato-producing province that accounts for 24% of total potato production in the country. Data were obtained from 21 field trials conducted over several years from 2000 to 2006, and in 2018 (Table 1). The potential potato yield loss from weed interference in Prince Edward Island was estimated to be 26%, which translates to a potential monetary loss of US\$13 million (Table 1). Nationally, in Canada, if no weed management tactics were implemented in potato there would be a yield loss of 1.2 billion kg, or US\$6 million (Table 2). Swanton et al. (1993) reported that yield losses due to weeds in potato were 5% in Alberta, Newfoundland, and Nova Scotia; 6% in Ontario; 8% in Manitoba and Quebec; 9% in British Columbia; and 10% in New Brunswick, Prince Edward Island, and Saskatchewan after weed management programs were implemented.

These survey data provide an estimate of the potential yield losses in potato in the United States and Canada in the absence of any weed control. The authors surmise that the yield loss may be lower on commercial farms because the weed pressure may not be as high and uniform as on research farms where many of the trials were conducted. Actual potato yield losses are lower as growers implement some form of weed management. For example, Oerke (2006) estimated worldwide potential potato yield loss from uncontrolled weeds was 30% contrary to the estimates of 8% actual yield loss with implementation of weed control programs.

The average yield loss in the United States and Canada, based on the data obtained, due to weed interference in potato, was 45% and 26%, respectively (Table 2). At this level of yield loss, potato growers will lose approximately US\$465 and US\$61 million in the United States and Canada, respectively, for a total estimated loss in North America of US\$526 million (Table 2). The potential potato yield loss from uncontrolled weeds reemphasizes the importance of investment in weed science research to develop

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Table 2. Annual total potato production and value (US $), and annual potential loss in production and value (US $) from weed interference for the United States and Canada.[a]

Country	Harvested area	Total production	Value[b]	Yield loss	Potential production loss	Potential value loss value
	ha	kg × 1,000	US$	%	kg × 1,000	US$
United States	410,931	20,403,907	1,032,641,733	45	9,181,758	464,688,780
Canada	133,749	4,646,918	235,180,520	26	1,208,199	61,146,935
Total	544,680		1,267,822,253		10,389,957	525,835,715

[a]Data were obtained from AAFC (2020) for Canada, and from USDA-NASS (2020) for the United States.
[b]Calculated at $US0.5061 kg^{-1} of potato.

long-term, sustainable, integrated weed management programs in potato.

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