The Critical Period for Weed 'Seed' Control: *The concept and its application*

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Introduction and Objectives

Increasing herbicide-resistant weed issues globally warrants reevaluation of fundamental weed control objectives. While the mitigation of crop yield loss remains critically important, reducing the proliferation of herbicide-resistant weeds warrants limiting their seed from returning to the soil seedbank[1]. The critical period for weed 'seed' control (CPWSC) builds upon the well-accepted concept of the critical period for weed control, or the period of crop growth and development during which the crop must remain weed-free to avoid unacceptable yield losses[2]. Instead, the CPWSC shifts the focus away from the crop and on to problematic weeds. The CPWSC is the period of the growing season during which weed management can mitigate unacceptable weed seed production and return to the soil seedbank[3]. The CPWSC provides a framework to target problematic weeds during phenological stages critical for seed development. Like the critical period for weed control, the CPWSC is derived from overlapping two component curves: (i) the critical period for weed emergence, and (ii) the critical period for seed production. The objective of this research was to expand on the concept introduced by Geddes and Davis (2021)[3] and demonstrate its utility by applying the methodology to seven problematic weed species in western Canada.

Materials and Methods

See Geddes and Davis (2021)[3] for the recommended methodology:

- **7 Weed species**:
  - Green foxtail — *Setaria viridis* (L.) P. Beauv.
  - Kochia — *Bassia scoparia* (L.) A.J. Scott
  - Lambsquarters — *Chenopodium album* L.
  - Redroot pigweed — *Amaranthus retroflexus* L.
  - Wild buckwheat — *Fallopia convolvulus* (L.) Á. Löve
  - Wild mustard — *Sinapis arvensis* L.
  - Wild oat — *Avena fatua* L.
- **1 Location**: near Lethbridge, AB (49.69°N, -112.76°W) in 2021
- **2 Randomized Complete Block Design** experiments for each species; 4 replicates:
  - Experiment 1: **Critical Period for Weed Emergence (CPWE)**
    - 10 treatments of different planting dates every 2 weeks starting April 14th
  - Experiment 2: **Critical Period for Seed Production (CPSP)**
    - 10 treatments of different harvest dates every 2 weeks starting June 16th
- Each species was planted at 200 viable seeds m^{-2} in separate 2 m × 2 m plots
- Plots were maintained free of other weed species by hand weeding
- **Main measurements**:
  - Emergence date (i.e., date of 50% emergence)
  - Weed seed retention (i.e., seeds retained on the aboveground plant tissue)
  - Weed seed shatter (i.e., cumulative seed shatter prior to each harvest date measured using seed catch trays)
  - **Total weed seed production** = weed seed retention + weed seed shatter
- **Data analysis**: Total weed seed production as a percent of the maximum was modelled as a function of cumulative growing degree days for each emergence date (experiment 1) and harvest date (experiment 2) using the 2-parameter log-logistic model in the 'drc' package of R v. 4.2.1[4]

$$y = \{100/1 + \exp[b(\log x - \log e)]\}$$

y = seed production (%)
x = cumulative GDD (T_{base} 0°C)
b = slope of the response curve at e
e = response curve inflection point

- The CPWE and CPSP models were overlaid to plot the CPWSC for each weed species using the 'ggplot2' package of R v. 4.2.1[4]

Results and Discussion

- Some weed species produced a substantial amount of seed from late emerging cohorts while others did not. For example, a 95% decline in seed production compared with early-emerging cohorts ranged among species from emergence dates as late as June 20 (1064 GDD , T_{base} = 0°C) for wild buckwheat to October 02 (3005 GDD) for green foxtail (**Table 1**).
- The beginning of seed production (5% threshold) ranged among species from June 27 (1216 GDD) for wild mustard to August 03 (2026 GDD) for green foxtail (**Table 2**).
- Seed production of green foxtail, kochia, lambsquarters, redroot pigweed, wild buckwheat, wild mustard, and wild oat could be reduced by a maximum of 85.2%, 90.6%, 88.2%, 81.9%, 99.9%, 86.4%, and 78.5%, respectively (**Fig. 1**; **Tables 3** & **4**).
- The CPWSC at a 20% seed threshold ranged from July 31 to August 12 (1961–2210 GDD) for green foxtail, July 12 to August 06 (1543–2089 GDD) for kochia, July 16 to August 05 (1632–2061 GDD) for lambsquarters, July 20 to July 24 (1712–1803 GDD) for redroot pigweed, June 15 to August 06 (985–2089 GDD) for wild buckwheat, June 27 to July 01 (1212–1306 GDD) for wild mustard, and was nonexistent for wild oat [minimum seed threshold of 21.5% by targeting July 03 (1357 GDD)] (**Fig. 1**; **Tables 3**, **4** & **5**).

Results

Table 1. The date of emergence of seven different weed species resulting in a reduction in seed production by 95% compared with the maximum potential seed production at Lethbridge, AB in 2021.

	Emergence date		
Weed species	Cumulative GDD, T_{base} 0°C	Calendar date	Julian date
Green foxtail	3005 ± 554	October 02	275
Kochia	2158 ± 359	August 09	221
Lambsquarters	2381 ± 564	August 21	233
Redroot pigweed	2670 ± 710	September 07	251
Wild buckwheat	1064 ± 106[a]	June 20	171
Wild mustard	1465 ± 173	July 08	189
Wild oat	1685 ± 432	July 18	199

Table 2. The date on which seed production reached 5% of the maximum potential seed production for each of seven different weed species at Lethbridge, AB in 2021.

	Harvest date		
Weed species	Cumulative GDD, T_{base} 0°C	Calendar date	Julian date
Green foxtail	2026 ± 154	August 03	215
Kochia	1714 ± 155	July 20	201
Lambsquarters	1677 ± 292	July 18	199
Redroot pigweed	1449 ± 214	July 07	188
Wild buckwheat	1807 ± 309	July 24	205
Wild mustard	1216 ± 112	June 27	178
Wild oat	1252 ± 68	June 29	180

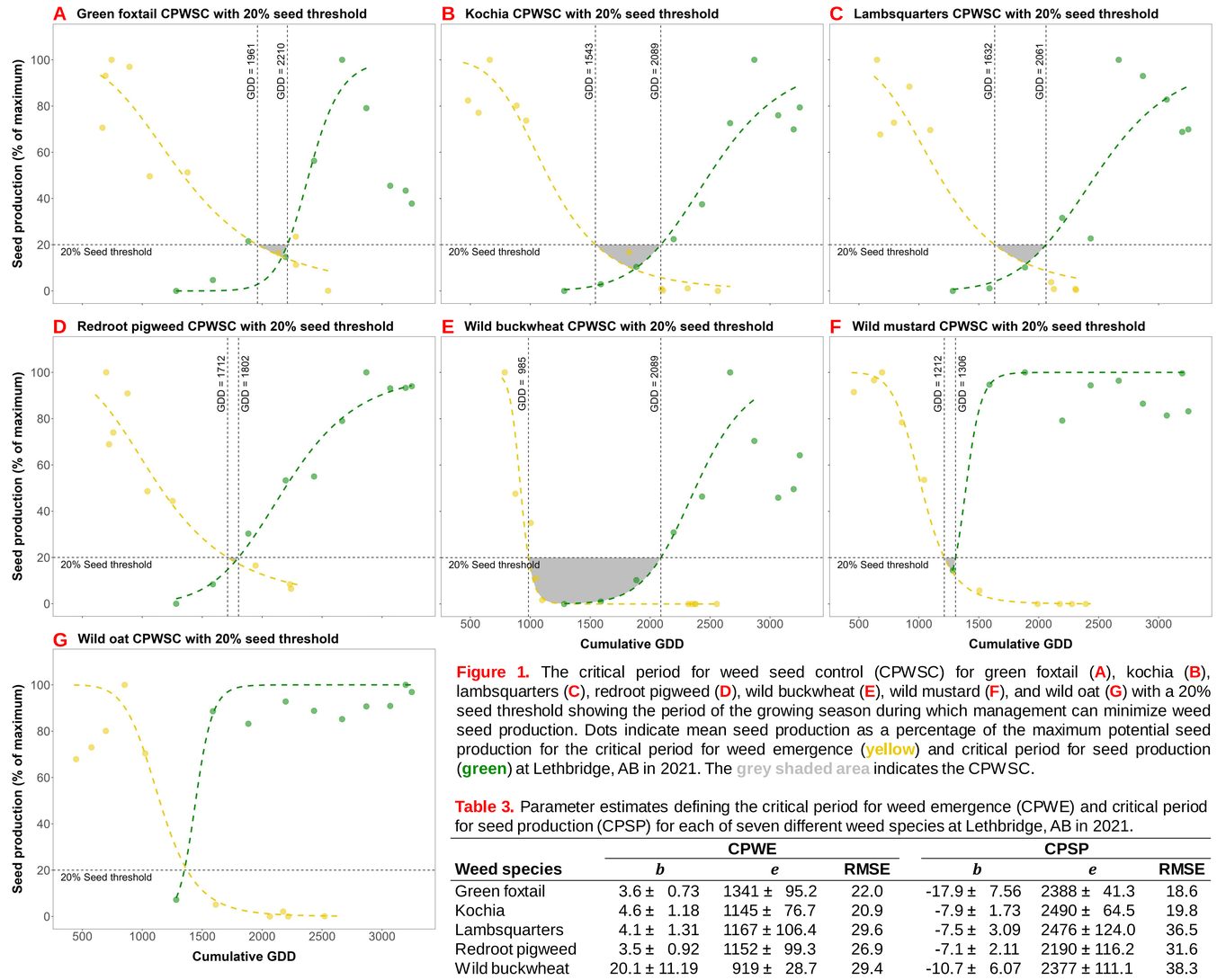

Figure 1. The critical period for weed seed control (CPWSC) for green foxtail (**A**), kochia (**B**), lambsquarters (**C**), redroot pigweed (**D**), wild buckwheat (**E**), wild mustard (**F**), and wild oat (**G**) with a 20% seed threshold showing the period of the growing season during which management can minimize weed seed production. Dots indicate mean seed production as a percentage of the maximum potential seed production for the critical period for weed emergence (yellow) and critical period for seed production (green) at Lethbridge, AB in 2021. The grey shaded area indicates the CPWSC.

Table 3. Parameter estimates defining the critical period for weed emergence (CPWE) and critical period for seed production (CPSP) for each of seven different weed species at Lethbridge, AB in 2021.

	CPWE			CPSP		
Weed species	*b*	*e*	RMSE	*b*	*e*	RMSE
Green foxtail	3.6 ± 0.73	1341 ± 95.2	22.0	-17.9 ± 7.56	2388 ± 41.3	18.6
Kochia	4.6 ± 1.18	1145 ± 76.7	20.9	-7.9 ± 1.73	2490 ± 64.5	19.8
Lambsquarters	4.1 ± 1.31	1167 ± 106.4	29.6	-7.5 ± 3.09	2476 ± 124.0	36.5
Redroot pigweed	3.5 ± 0.92	1152 ± 99.3	26.9	-7.1 ± 2.11	2190 ± 116.2	31.6
Wild buckwheat	20.1 ± 11.19	919 ± 28.7	29.4	-10.7 ± 6.07	2377 ± 111.1	38.3
Wild mustard	8.2 ± 2.44	1024 ± 34.4	17.1	-21.7 ± 19.41	1392 ± 110.1	34.3
Wild oat	7.6 ± 4.17	1144 ± 78.8	21.6	-20.5 ± 5.98	1446 ± 38.2	14.3

Table 4. Target dates for optimal management of weed seed production for each of seven different weed species at Lethbridge, AB in 2021.

Weed species	Seed production (% of maximum)	Target GDD (T_{base} 0°C)	Target calendar date	Target Julian date
Green foxtail	14.8%	2167	August 10	222
Kochia	9.4%	1867	July 28	209
Lambsquarters	11.8%	1898	July 29	210
Redroot pigweed	18.1%	1772	July 23	204
Wild buckwheat	0.1%	1282	June 30	181
Wild mustard	13.6%	1282	June 30	181
Wild oat	21.5%	1357	July 03	184

Table 5. The critical period for weed seed control (CPWSC) with a 20% seed threshold for each of seven different weed species at Lethbridge, AB in 2021.

Weed species	Cumulative GDD range (T_{base} 0°C)	Calendar date range	Julian date range
Green foxtail	1961 – 2210	July 31 – August 12	212 – 224
Kochia	1543 – 2089	July 12 – August 06	193 – 218
Lambsquarters	1632 – 2061	July 16 – August 05	197 – 217
Redroot pigweed	1712 – 1803	July 20 – July 24	201 – 205
Wild buckwheat	985 – 2089	June 15 – August 06	166 – 218
Wild mustard	1212 – 1306	June 27 – July 01	178 – 182
Wild oat	N/A	N/A	N/A

Conclusions

The current study showed that the CPWSC concept can be applied successfully to limit weed seed production and return to the soil seedbank for a range of summer-annual weed species in western Canada.

Further research aims to repeat this study at ten environments across western Canada to determine the CPWSC for these seven weed species and how it is affected by contrasting environmental conditions and production systems.

References

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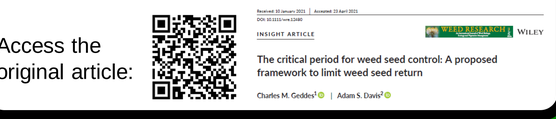

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