Alberta survey of herbicide-resistant kochia (*Bassia scoparia*) in 2021

Charles M. Geddes[1]*, Mattea M. Pittman[1], Linda M. Hall[2], A. Keith Topinka[2], Julia Y. Leeson[3], Shaun M. Sharpe[3], and Hugh J. Beckie[3]

[1]Lethbridge Research and Development Centre (RDC), Agriculture and Agri-Food Canada (AAFC), Lethbridge, AB; *Correspondence: Charles.Geddes@agr.gc.ca
[2]Department of Agricultural, Food & Nutritional Science, University of Alberta, Edmonton, AB; [3]Saskatoon RDC, AAFC, Saskatoon, SK @charlesmgeddes

Introduction and Objectives

Kochia [*Bassia scoparia* (L.) A.J. Scott] is a problematic summer-annual tumbleweed capable of causing substantial crop yield losses in the Great Plains region of North America[1]. The impact of kochia on prairie farmlands continues to grow in the presence of unfettered selection for herbicide resistance[2-4] combined with efficient seed- and pollen-mediated gene flow[5]. All kochia in this region is considered acetolactate synthase (ALS) inhibitor-resistant[2,6]. A 2012 survey of Alberta reported glyphosate-resistant kochia at 4% of the sites sampled, while dicamba-resistant kochia was not found[6]. Glyphosate resistance had increased to 50% of the sites sampled by 2017, while 18% had dicamba resistance[2], 13% had fluroxypyr resistance, and 16% were resistant to all three herbicide sites of action (ALS inhibitors, glyphosate, and at least one synthetic auxin)[3]. Continued monitoring of herbicide resistance is important to understand the extent of the problem, and to inform integrated management strategies. The objectives of this research were to determine (***a***) the frequency and incidence of resistance to glyphosate, fluroxypyr, and dicamba among kochia populations in Alberta in 2021, and (***b***) how the extent of herbicide-resistant kochia in Alberta has changed since the previous surveys in 2012[6] and 2017[2,3].

Materials and Methods

- The 2021 survey took place in late-September/early-October and followed the methods of the previous two rounds of surveys in 2012[6] and 2017[2,3]
- Randomized-stratified survey based on cultivated area within each ecodistrict
- Kochia seed collected from 10–20 plants at each of **319 sites in Alberta** (314 sites with enough viable seeds for resistance diagnostics)
- Sampled sites included cropland, pastureland, and ruderal areas
- Seeds planted in 26 × 26 × 5 cm greenhouse flats with soilless potting mixture
- The greenhouse followed a 16-hr photoperiod, 20/18°C temperature regime, supplemented with 100 µmol m^{-2} s^{-1} light, and flats were watered daily.
- At least 40 individuals from each population were screened with each herbicide
- Seedlings treated at 3–7 cm height using a moving-nozzle cabinet sprayer (275 kPa; 200 L ha^{-1} solution; TeeJet® 8002VS nozzle; 2.4 km hr^{-1})
- Herbicides used:
  - **Glyphosate** at 900 g ae ha^{-1} (Roundup WeatherMAX®, Bayer CropScience)
  - **Fluroxypyr** at 140 g ae ha^{-1} (Prestige™ XCA, Corteva Agriscience)
  - **Dicamba** at 280 g ae ha^{-1} (Banvel® II, BASF Canada)
- Individual plants characterized as resistant (no injury or some injury with new growth) or susceptible (dead or nearly dead) at 3, 4 and 4 weeks after treatment with glyphosate, fluroxypyr, and dicamba, respectively.
- Populations categorized based on resistance incidence and frequency:
  - **Resistance incidence** = percentage of individuals within a sample that exhibited the resistance trait
  - **Resistance frequency** = percentage of samples containing the resistance trait within a given area or site classification

Data visualization

- Maps of resistance frequency within each county developed using QGIS 3.16[7]
- Distribution of resistance incidence for each herbicide tested in the current and historical surveys plotted using the 'ggplot2' package of R v. 4.2.1[8]

Results and Discussion

- **Glyphosate-resistant kochia was present at 78% of the sites sampled, while 44% had fluroxypyr-resistant and 28% had dicamba-resistant kochia** (**Figs. 1 & 2**). This represents an increase from 50%, 13% and 18% of sites with kochia exhibiting resistance to glyphosate, fluroxypyr, and dicamba, respectively, during the previous Alberta survey in 2017[2,3].
- Glyphosate-resistant kochia was widely distributed across southern Alberta, while the frequencies of resistance to **fluroxypyr and dicamba tended to cluster in distinct regions** (**Fig. 1**).
- **Triple-resistant kochia populations**, resistant to ALS inhibitors, glyphosate, and at least one synthetic auxin (fluroxypyr or dicamba), **increased from 16% of the sites in 2017[3] to 45% in 2021** (**Fig 2.**).
- Auxinic herbicide resistance overlapped only partly, where **more kochia samples exhibited resistance to either dicamba or fluroxypyr than to both** (**Fig. 2**).
- The incidence of kochia with resistance to glyphosate, fluroxypyr and dicamba among sampled sites continues to shift toward a **greater number of individuals within the samples tested exhibiting these resistance traits** (**Fig. 3**).

Results

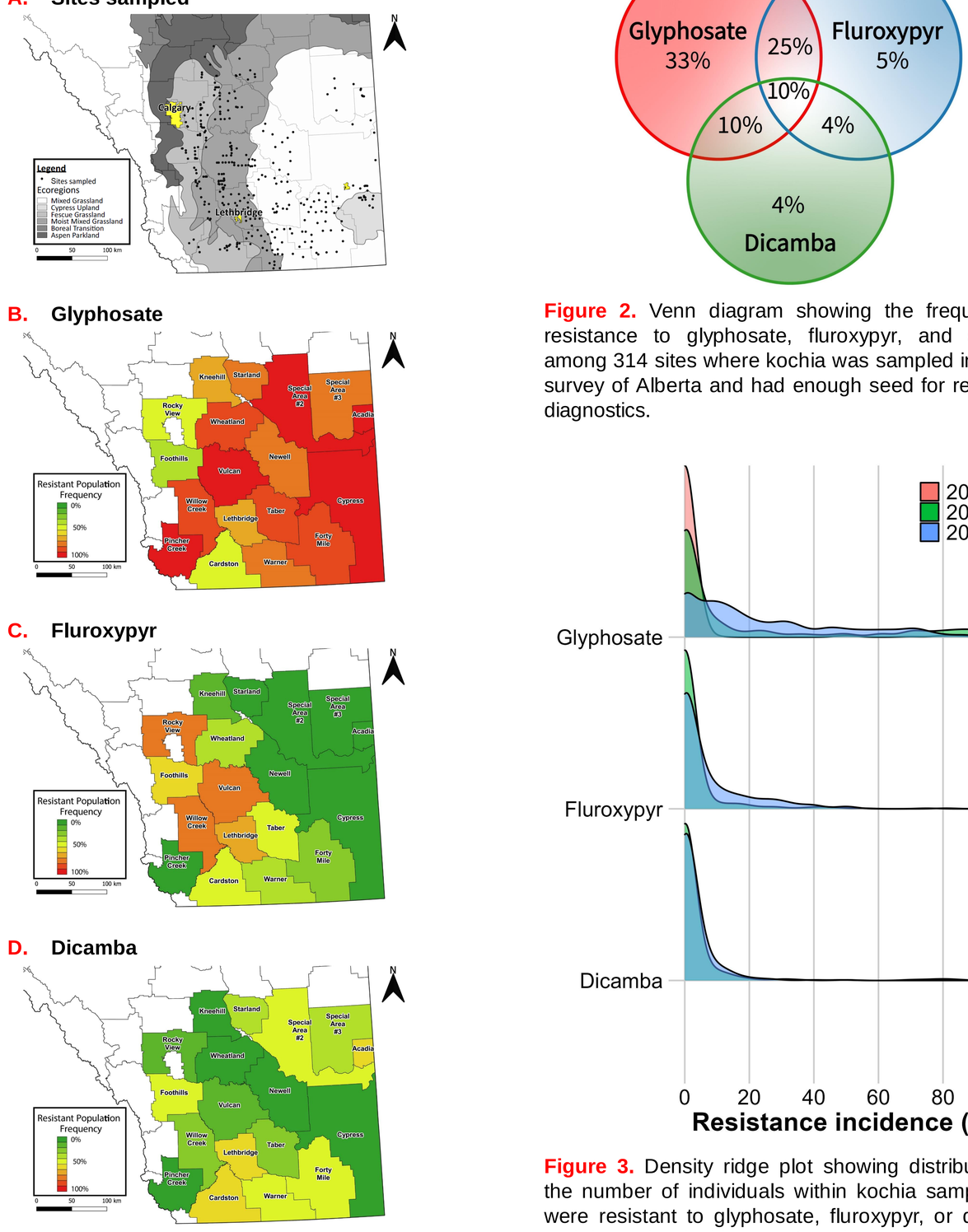

Figure 1. Locations of the 319 sites sampled (**A**), and frequency of sites with glyphosate- (**B**), fluroxypyr- (**C**), and dicamba-resistant (**D**) kochia confirmed within each county sampled during a 2021 survey of Alberta.

Figure 2. Venn diagram showing the frequency of resistance to glyphosate, fluroxypyr, and dicamba among 314 sites where kochia was sampled in a 2021 survey of Alberta and had enough seed for resistance diagnostics.

Figure 3. Density ridge plot showing distributions of the number of individuals within kochia samples that were resistant to glyphosate, fluroxypyr, or dicamba, and how the incidence of resistance has changed among surveys of Alberta in 2012 (n = 304)[6], 2017 (n = 309)[2,3], and 2021 (n = 314). Note: only glyphosate and dicamba were evaluated in 2012, and no dicamba-resistant kochia plants were found[6].

Conclusions

The current study documented the continued increase in kochia with resistance to glyphosate, fluroxypyr, and dicamba in Alberta, and suggests an immediate need to fortify integrated management programs with effective non-chemical strategies.

Further research is warranted to determine the mechanisms of auxinic herbicide resistance in kochia, and to elucidate integrated management tactics to help curb the rapid increase and manage the impact of herbicide-resistant kochia in Alberta.

References

[1] Geddes and Sharpe. 2022. *Crop Prot.* **157**:105981
[2] Beckie et al. 2019. *Can. J. Plant Sci.* **99**:281-285.
[3] Geddes et al. 2022. *Can. J. Plant Sci.* **102**:437-441.
[4] Geddes et al. 2022. *Weed Technol.* **36**:28-37.
[5] Beckie et al. 2016. *Weed Sci.* **64**:624-633.
[6] Hall et al. 2014. *Can. J. Plant Sci.* **94**:127-130.
[7] QGIS Development Team. 2020. www.qgis.org
[8] R Core Team. 2019. Vienna, AU.

Acknowledgments

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
WGRF
Saskatchewan Pulse Growers
Alberta Wheat Commission
Manitoba Crop Alliance
SaskCanola
Sask Wheat Development Commission
Manitoba Pulse Soybean Growers