

A NEW SERIES—The Biology of Invasive Alien Plants in Canada Instructions for Preparation of Accounts

S. I. Warwick¹, P. B. Cavers², and S. Darbyshire¹

¹*Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Central Experimental Farm, Ottawa, Ontario, Canada K1A 0C6; and* ²*Department of Biology, University of Western Ontario, London, Ontario, Canada N6A 5B7*

The term “invasive alien plants in Canada” as used in this series, refers to any vascular plant that has recently been introduced to Canada, has a history of invasiveness and/or weediness in other parts of its range, and/or has characteristics that indicate a potential to establish, proliferate, spread and cause broadly defined detrimental consequences in Canadian ecosystems (including agro-ecosystems). The series will form a companion to the Biology of Canadian Weeds (BCW) series initiated in 1972 (Cavers and Mulligan 1972; Cavers and Warwick 2000) and for which 127 accounts have been published to date (see Cavers et al. 2003). The new series is designed to draw attention to the issue of invasive plants and their impact in both natural ecosystems and agro-ecosystems.

Globalization of trade, with concomitant elaboration of transportation systems and increasing commodity diversity and volume, has increased the rate of introduction of invasive alien plants. Once established in Canada, they may cause export market loss and/or commodity devaluation, jeopardize native biodiversity and habitats through severe competition or displacement, and threaten environmental health through toxicity and/or increased herbicide use (White et al. 1993; Claudi et al. 2002). A conservative estimate of direct annual losses to major crop production alone was about a billion dollars in Canada in the early 1990s (Swanton et al. 1993). Pimentel et al. (2000) estimated the annual cost of invasive plants to the U.S. economy at about \$40 billion. Of this total, \$26.4 billion was attributed to cropland weeds, primarily through crop losses and damage. Darbyshire (2002) estimated that one to two new alien plant species are becoming established in Canada every year and that the rate will increase. Regulations, legislation, and enforcement concerning invasive alien plants occur at international, federal and provincial levels. There is a need for information to assist with early detection and accurate identification of new infestations as well as diagnosis of their potential for detrimental effects. The purpose of this new series will be to bring together published and unpublished information on the biology of these invasive alien plants, which will not only serve as an alert of emerging problems but can also be utilized as a basis for developing effective, economical and safe control methods. It is also intended that the series will engender research that will fill important gaps

in our knowledge of the biology of these species, including: effective eradication, quarantine and/or management strategies; detection of divergent genetic variation in species complexes; and, important life cycle information such as reproductive strategies, dispersal and population dynamics. The establishment of such a series was one of the key recommendations of a recent Committee on the Scientific Basis for Predicting the Invasive Potential of Nonindigenous Plants and Plant Pests in the United States [“Recommendation 5. A literature synthesis on the natural history of potential immigrant species, similar to the Biology of Canadian Weeds series published by the Canadian Journal of Plant Science, should be established, standardized and made accessible via the Internet”] (Anonymous 2002).

If you wish to write an account on an invasive alien plant species, you must first check that the species has not been assigned to someone else. This involves sending an “offer of contribution” to Dr. Warwick. After approval of your offer you may proceed with writing the paper. The completed paper is to be submitted directly to the Canadian Journal of Plant Science (see below).

Offers of contribution by individuals or groups should be made to Dr. Suzanne I. Warwick, Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Neatby Building, Central Experimental Farm, Ottawa, Ontario, Canada K1A 0C6, e-mail warwicks@agr.gc.ca. Suzanne Warwick and Stephen Darbyshire will serve as co-editors of the series. Contributions will be subject to approval by a committee set up by the Canadian Weed Science Society (CWSS). Potential authors should provide some evidence that the weed species is either established in Canada, or has been introduced and has the potential to establish in Canada. Approved submissions will be subject to re-approval after two years if the article has not been completed during that period. Any inquiries about the format to be used or advice on preliminary drafts should be directed to Dr. Warwick. She can also supply blank maps (or a pdf file) of Canada and will suggest specialists or institutions that will provide various types of services for authors. The Canadian Weed Science Society has a web site (<http://cwss-scm.ca/>) with on-line references to common English and French names of many weed species, links to provincial and federal legislation and

current lists of species published and in preparation for the Biology of Canadian Weeds series and this new series.

Authors should consider carefully the status and history of the species in Canada in selecting the appropriate series. The Biology of Canadian Weeds series addresses undeniable problematic weeds in Canada, whereas the new Biology of Invasive Alien Plants series is designed to cover aliens in Canada that have demonstrable potential risk. As well as dealing with economic detriment, this series will also provide a strong emphasis on species causing problems to environmental health. The following are criteria for inclusion in the invasive alien series: “established aliens with potential for becoming invasive or weedy”, “aliens showing recent rapid expansion of geographic and/or habitat range in Canada”, and “established aliens showing invasive or weedy characteristics and/or patterns in other areas of the world with similar climatic conditions to Canada”. A number of species considered to be important invasives have already been dealt with under the Biology of Canadian Weeds series; potential authors should review the list of species covered under that series (Cavers et al. 2003). Most accounts will deal with a single species but some may logically describe two or more closely related species. All native species that are considered invasive will be covered under the Biology of Canadian Weeds series. In cases where the assignment to a particular series is not clear, the editors of both series may be called upon to make a judgement call. The new series will stress control-related aspects and requires more extensive coverage in some areas such as identification, occurrence, impact and prognosis and less extensive coverage in other areas of biology. In some cases, relatively little published information will be available for review, resulting in a short article. Nevertheless, such contributions are essential for early detection and management.

Finished manuscripts should be submitted to: Canadian Journal of Plant Science; Mr. T. Fenton, Head, Journals Section, Agricultural Institute of Canada, 141 Laurier Ave. W., Suite 1112, Ottawa, Ontario, Canada K1P 5J3. All contributions must comply with the format of this journal. Accounts, including all maps, drawings, diagrams and photographs, should not exceed 50 pages (12 point font, double-spaced with numbered lines). The authors are encouraged to provide the names and addresses (including phone numbers and e-mails if available) of three potential referees.

The following format is meant as a guide for the types of information to be included and arrangement of the accounts. Since many invasive alien plants have only recently been identified as problems, information in some fields may be sketchy or altogether lacking. Of the 14 topics listed in the outline below: 1 to 6 and 14 are essential and must be covered in substantial depth, and the rest may be covered in less detail. Inclusion of a dichotomous key for identification and a distribution map based entirely on examined herbarium specimens is strongly advised.

FORMAT

TITLE: Each account will be given a number when it is accepted for publication. The number will be part of the title and precede the species name, e.g., The Biology of

Invasive Alien Plants in Canada. 1. *Eriochloa villosa* (Thunb.) Kunth.

1. Species Name and Taxonomic Relationships

Give the scientific name (genus, species, and nomenclatural authority) currently accepted by plant taxonomists and synonyms that are or have been commonly used. Include English and French vernacular names (if available) of the species in *Common and botanical names of weeds in Canada* (Darbyshire et al. 2000) or other major references. Include a source citation for each name. Provide the Bayer code for the species if available (see web site <http://cipm.ncsu.edu/names/index.cfm>). Include also the Latin, English, and French names of the family to which the species belongs.

Provide information about the genus including: numbers of species world-wide, in North America and Canada; whether they are native or introduced to North America; and if any of the other introduced species are weeds. Any species or genus level taxonomic controversy should be outlined/discussed.

2. Description and Account of Variation

(a) *Species Description*—Present a short description of the invasive alien, similar to that given in *Weeds of Canada* (Frankton and Mulligan 1987) or the Biology of Canadian Weeds series. Use the metric system for measurements. Where possible, use simple descriptive terms rather than more technical taxonomic terms in describing features (or if no simple term exists explain the taxonomic term in brackets). Include the chromosome number(s) with provincial location of any Canadian material counted, and give the chromosome number range for the species as a whole.

(b) *Distinguishing Features*—Describe morphological characters that distinguish the invasive alien from all other Canadian plants with which it may be confused and include a diagnostic key (either in the text or as an Appendix).

(c) *Intraspecific Variation*—Describe any recognizable intraspecific variation in Canadian populations and populations elsewhere [taxonomic, cytological, ecological, genetic (allozyme, molecular data), chemical, etc.].

(d) *Illustrations*—Include a photograph or drawing, or both, of a mature plant, a seedling at approximately the two-leaf stage, and any other stage that persists for some time (for example, the rosette of a biennial). Each of these illustrations should portray clearly any diagnostic characters that would be useful for identification in the field. Important alterations in the appearance of any stage in the life history that results from grazing, mowing, herbicide applications, parasites, diseases, etc., would be useful. List any published illustrations or Internet sites with illustrations, such as the web site of the Weed Science Society of America (<http://www.wssa.net>).

3. Economic Importance and Environmental Impact

(a) *Detrimental*—Specify the nature of loss or costs to native

biodiversity of natural ecosystems or to agricultural systems, industry and human health resulting from the growth of this species (e.g., eliminates native plant associations, reduces native genetic diversity through hybridization, competes with crop or pasture species, is toxic or irritant to farm animals or humans, chemically inhibits crop species, makes harvesting difficult, affects lawns or garden appearance, etc.). Is the invasive alien a close relative of species growing in Canada or elsewhere, with which it is capable of hybridization (See Section 9)? Does it have herbicide-resistant biotypes (See Section 11)? Does the invasive alien harbour insects or disease organisms that attack other plant species (See Section 13)? Give financial estimates of losses wherever possible. Does the invasive alien have, or is it expected to have, an environmental impact? Is the invasive alien able to establish populations in natural habitats and successfully compete with or exclude native species?

(b) *Beneficial*—Does the invasive alien have an important role as a part of various food chains? Does it bind together soils that are laid bare by fire, construction, farming, etc.? Is it an important genetic resource? Is it a source of honey? Does it have aesthetic value? Is the plant used as a crop plant, nursery plant, or ornamental in Canada or elsewhere? Does it or has it ever had any economic importance?

(c) *Legislation*—Is the invasive alien listed in any Canadian federal or provincial legislation or subject to quarantine regulations provincially, nationally or internationally (see web site of the Canadian Weed Science Society: <http://cwss-scm.ca>)?

4. Geographical Distribution

Give the distribution and abundance in Canada, North America and then its global distribution. Blank maps for plotting the Canadian distribution can be provided. If the weed is not yet widespread in Canada, it may be advisable to provide a map of the current U.S. distribution. Computer-based maps of acceptable standard can be used. Smaller scale maps may be used for species with a narrower distribution. Supplementary maps may be necessary if there are different biotypes or to show patterns of invasion over time. Maps should be based on examined and verified herbarium specimens to the extent possible; site records are also acceptable. See Holmgren et al. (1990) for herbarium abbreviations; on-line version available at <http://www.nybg.org/bsci/ih/ih.html>.

5. Habitat

(a) *Climatic Requirements*—Include the climatic (including microclimatic) limitations and preferences with regard to temperature, rainfall, atmospheric humidity, exposure to wind, etc. Where relevant, give the light intensity and its seasonal variation in relation to the life history and distribution of the species (where measurements are given, the methods used should be mentioned). Any restriction or expansion of distribution caused by low temperatures, flooding, drought or other extremes in climate should be considered.

(b) *Substratum*—Give the characteristics of the soils in various habitats and different parts of the range of the species.

If the species occurs in specific habitats or is geographically distributed in a way that suggests specific substrate requirements, identify the soil properties affecting this distribution (textural class, drainage class, soil reaction or profile types). Terminology should conform to that specified in *The Canadian System of Soil Classification* (3rd edition), NRC Research Press (Anonymous 1998).

(c) *Communities in which the species occurs*—Briefly describe the community (e.g., spring wheat fields, corn fields, lawns, waste places, forests [coniferous, deciduous or mixed, plantations), wetlands (bogs, fens, swamps, marshes, shallow open water), native prairie, etc.] and give the abundance and frequency of the species in each community. For each community where the species is an important component, list in tabular form the associated plants and give a history of the habitat (e.g., pasture for 50 years). State whether the invasive alien grows in the open or if it normally grows in the shade of other plants.

6. History

Provide evidence and dates for the first introduction of the species into North America and Canada. Also, give available information on date of subsequent introductions, persistence and rate of spread. Give any information on how the plant was originally introduced (e.g., as an impurity in crop seed, as a cultivated or ornamental plant, or in ballast).

7. Growth and Development

(a) *Morphology*—List any morphological characteristics that are of special importance in the colonization, invasiveness and survival of the species (e.g., underground stems, spines, unpalatable hairs, and hooked seeds) and discuss why these characteristics are of survival value. Indicate “new” attributes that make the species especially invasive in its new habitat (e.g., change in breeding system, dormancy or germination requirements, seed shattering, etc.)

(b) *Perennation*—Include the mode of perennation and give a general description of winter conditions.

(c) *Physiological data*—Include transpiration rates, osmotic values, etc., when relevant. Information on a broad range of physiological topics, including mineral nutrition, can also be placed here.

(d) *Phenology*—Give the times of maximal growth of roots and other underground organs; of appearance and growth of leafy shoots (especially for woody species); of flowering; of maturation and shedding of seeds; of germination of seeds or appearance (emergence) of seedlings.

(e) *Mycorrhiza*—State presence or absence of mycorrhiza and, if present, describe.

8. Reproduction

(a) *Floral biology*—Describe the mode of pollination of flowers. List the insect visitors to flowers and describe their behaviour. Are the flowers self-compatible? Are seeds usu-

ally produced by autogamy, allogamy, or agamospermy? Is there any evidence of outcrossing in species that can produce seeds autogamously? Does vivipary occur?

(b) *Seed production and dispersal*—What are the average numbers of seeds per fruit, per inflorescence, and per plant? What is the average weight per seed and/or per propagule? Give mode of seed dispersal and special features, if any (e.g., seeds attaching themselves to clothing and fur of animals).

(c) *Seed banks, seed viability and germination*—What is the longevity of seeds in the seed bank? Does the species have a persistent seed bank or only a transient one, and does this differ across the range of the species? Include information on the viability of seeds under different conditions (state how determined). Give geographical location for data on germination under natural conditions or seed source if under controlled conditions. List any special conditions affecting germination, e.g., sensitivity to light, necessity for preliminary freezing, etc., and conditions for successful establishment of seedlings.

(d) *Vegetative reproduction* – Describe the mode and rate of vegetative reproduction and spread. Describe any vegetatively produced propagules. Give the age of the plant when vegetative reproduction first occurs. State the relative importance of various means of reproduction. Is the reproductive strategy different in different habitats (e.g., more seeds in one habitat but more bulbils in a second habitat)?

9. Hybrids

Describe the existence and frequency of natural hybridization with other plants. Is there any evidence of interspecific hybridization between the species and cultivated plants? How can these hybrids be recognized? To what extent do the hybrids show a diminished fertility or increased vigour as compared with the parents? Are the hybrids of any biological or economic significance?

10. Population Dynamics

Give the rate of increase and decline of populations in various habitats (numbers of individual stalks should be given if possible). Include the mean length of life of individuals in various habitats. Do more plants appear or die in certain months or seasons or after certain changes in the habitat (e.g., drought, flooding) or manipulation (e.g., after clipping)? Describe the plant's competitive ability (intraspecific and interspecific) and its method of competing with other plants. Does the species usually occur as solitary plants, large patches, small patches, etc.? Give the number of generations per year, per decade, or perhaps per century.

Note: seed population dynamics should be discussed in Section 8c.

11. Response to Herbicides and Other Chemicals

Give the susceptibility of this species to the most widely used herbicides and herbicide combinations at various stages in its life history. If applicable, provide a brief list of

herbicides of potential use for control, including those that may not be registered in Canada. Are there any herbicide-resistant biotypes of the species in Canada and/or elsewhere? Has the composition of the associated flora changed in response to the repeated application of herbicides?

12. Response to Other Human Manipulations

Describe any response by the invasive alien to mowing, fertilizing chemicals and manure, ploughing, trampling, fallowing, crop rotation, harvesting, integrated pest management, etc.

13. Response to Herbivory, Disease and Higher Plant Parasites

Includes biological control and controlled grazing programs.

(a) *Herbivory*

- (i) Mammals, including both domestic and wild animals
- (ii) Birds and/or other vertebrates
- (iii) Insects
- (iv) Nematodes and/or other non-vertebrates

(b) *Diseases*

- (i) Fungi (e.g., Farr et al. 2002)
- (ii) Bacteria
- (iii) Viruses (e.g., Brunt et al. 1996)

(c) *Higher Plant Parasites*

In each instance for all subsections listed above, name the organism attacking the invasive alien (provide the Latin name and nomenclatural authority), indicate its host specificity, abundance and distribution. Describe the stage of the plant attacked, type of damage inflicted, response of the plant population, and value of the attacking species for control of the invasive alien.

14. Prognosis

Assess the degree to which the invasion of this species poses a threat to Canada. Indicate measures needed for curbing the invasion and/or eradicating the species. Where appropriate, describe the experience of other jurisdictions in dealing with invasion by the weed, and strategies employed elsewhere to attempt to halt its spread.

Note: In each section, place the Canadian (and/or North American) information first. Where possible in each section, indicate whether the study was done in the field or in a greenhouse/growth chamber. For field studies, provide the geographic location where the work was done (province/state, country) or the source of the wild population studied. For any plant species, provide the Latin name and nomenclatural authority when first mentioned in the text. In general, authors should cite printed materials and limit reference to illustrations/information from internet sites to those sites maintained by a major society or organization.

ACKNOWLEDGEMENTS

The authors thank Céline Boutin (Environment Canada, Ottawa), Paul Catling (Agriculture and Agri-Food Canada,

Ottawa), David Clements (Trinity Western University, BC), Erich Haber (National Botanical Services, Ottawa) and Claire Wilson (Canadian Food and Inspection Agency, Ottawa) for their suggestions and constructive criticisms of this article.

Anonymous. 1998. The Canadian System of Soil Classification 3rd ed. NRC Research Press, Ottawa, ON. 188 pp. [Online] Available: http://sis.agr.gc.ca/cansis/references/1998sc_a.html. [26 August 2003].

Anonymous. 2002. Predicting invasions of nonindigenous plants and plant pests. Committee on the Scientific Basis for Predicting the Invasive Potential of Nonindigenous Plants and Plant Pests in the United States. National Research Council, National Academy Press, Washington, DC. 194 pp.

Brunt, A. A., Crabtree, K., Dallwitz, M. J., Gibbs, A. J., Watson, L. and Zurcher, E. J. (Eds.) 1996 onwards. Plant viruses online: Descriptions and Lists from the VIDE Database. Version: 20th August 1996. [Online] Available: <http://image.fs.uidaho.edu/vide/refs.htm>. [26 August 2003].

Cavers, P. B. and Mulligan G. A. 1972. A new series—the biology of Canadian weeds. *Can. J. Plant Sci.* **52**: 651–654.

Cavers, P. B. and Warwick, S. 2000. The biology of Canadian weeds. Revised format and instructions for preparation of updated accounts. *Can. J. Plant Sci.* **80**: 237–240.

Cavers, P. B., Warwick, S. I. and Clements, D. R. 2003. The biology of Canadian weeds. Revised instructions and format. Updated lists of accounts published and in preparation. *Can. J. Plant Sci.* **83**: 661–665.

Claudi, R., Nantel, P. and Muckle-Jeffs, E. 2002. Alien invaders in Canada's waters wetlands, and forests. Natural Resources Canada, Canadian Forestry Service, Science Branch, Ottawa, ON. 320 pp.

Darbyshire, S. 2002. Pathways and transportation. Pages 21–42 in B. Tellman, ed. *Weeds across borders*. The Arizona-Sonora Desert Museum, Tucson, AZ.

Darbyshire, S., Favreau, M. and Murray, M. 2000. Common and scientific names of weeds in Canada. Publ. 1397/B. Agriculture and Agri-Food Canada, Research Branch, Ottawa, ON. 132 pp.

Farr, D. F., Rossman, A. Y., Palm, M. E. and McCray, E. B. 2002 onwards. Fungal Databases, Systematic Botany & Mycology Laboratory, ARS, USDA. [Online] Available: <http://NT.ars-grin.gov/fungaldatabases>. [26 August 2003]

Frankton, C. and Mulligan, G. A. 1987. Weeds of Canada (revised). Publication 948. Ministry of Supply and Services Canada. NC Press Limited, Toronto, ON. 217 pp.

Holmgren, P. K., Holmgren, N. H. and Barnett, L. C. (Eds.) 1990. Index Herbariorum, Part I: The Herbaria of the World, 8th ed. New York Botanical Garden, Bronx, NY. 693 pp.

Pimentel, D., Lach, L., Zuniga, R. and Morrison, D. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience* **50**: 53–65.

Swanton, C. J., Harker K. N. and Anderson, R.L. 1993. Crop losses due to weeds in Canada. *Weed Technol.* **7**: 537–542.

White, D. J., Haber, E. and Keddy, C. 1993. Invasive plants of natural habitats in Canada. Canadian Wildlife Service, Environment Canada/Canadian Museum of Nature, Ottawa, ON. 121 pp.