HIGHLIGHTS OF CURRENT PRODUCTION PRACTICES IN ONTARIO – GREENHOUSE TOMATO

New England Vegetable & Berry Growers
and
Massachusetts Fruit Growers Association
14th Conference and Trade Show

December 13-15, 2005,
Expo Center of New Hampshire, Radisson Hotel, Manchester, New Hampshire, USA

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1. Present Status of the Greenhouse Vegetable Sector in Canada

The greenhouse vegetable industry is an important and growing segment of the Canadian agri-food industry (estimated value: $200 M in 1994; $1.0B in 2005). The latest official statistics (Statistics Canada Publ. 20-202 for 2004) estimated the Canadian greenhouse industry at $2.2 B and the greenhouse vegetable portion at $720 M (see detailed statistics in Table 1), but, industry analysts claim that the corresponding values in 2005 actually stood at $2.5 B and $1.0 B, respectively.

The main greenhouse vegetable crops in Canada are tomatoes [444 ha (1110 acres)], cucumbers [207 ha (517 acres)], sweet peppers [157 ha (392 acres)] and lettuce [15 ha (37 acres); see detailed statistics in Table 2].

Ontario, claiming more than half the greenhouse vegetables produced in Canada [487 ha (1215 acres)] compared to a national total of [823 ha (2057 acres)], is a net exporter of greenhouse tomatoes and cucumbers to the USA (the Ontario Greenhouse Vegetable Growers estimated that 70% of the Spring 2005 tomato crop was exported to the USA) while it is the main supplier of those two salad vegetables to Eastern Canada markets.

Although greenhouse vegetables are grown in all regions of Ontario, the major producing area is in the southern part of Essex County, in and around the Town of Leamington. With a 440 ha (1099 acres) greenhouse vegetable industry, Leamington boasts the largest concentration of greenhouse vegetables in North America. In fact, industry analysts estimated the Leamington and Ontario greenhouse vegetable industries at 501 ha (1253 acres) and 577 ha (1442 acres), for 2005, respectively (see article by S. Khosla, Greenhouse Vegetable Crop Advisor, Ontario Ministry of Agriculture and Food, in the September 2005 issue of the Greenhouse Canada magazine, pages 28-28),
Significant new greenhouse vegetable production technology that was transferred to commercial producers has been primarily responsible for dramatic yield increases over the last 8-10 years, estimated at 120-150% for tomatoes and 80-100% for cucumbers.

2. **Trends in the Greenhouse Vegetable Sector**

Product quality and safety are seen as key elements on which to build the strength of the greenhouse vegetable market. Despite the occasional problems of the greenhouse vegetable industry, the long-term prospect looks promising when one considers their market potential in North America. The optimism about the future is derived from a comparison of our levels of fruit and vegetable consumption with those of the Europeans. Statistics show, for example, that Europeans eat ten times the cucumbers Canadians eat and that the Americans eat ten times less than what the Canadians eat. The on-going change in consumer preferences towards fresh, natural, healthy foods can be expected to result in increased demand for greenhouse vegetables. Furthermore, it is believed that the future prosperity of the Canadian greenhouse vegetable industry lies largely in the US market because of the untapped consumer potential of big cities like New York, Boston, Detroit and Chicago. It is also widely believed within the industry that a lot of work can be done in N. America, to stimulate the consumption of greenhouse vegetables. The flourishing greenhouse ornamental industry in both Canada and USA, and its reliance on the benefits of promotion, advertising, information, research, and education is seen as an example to be followed. Given the market potential, a continuous research and technology transfer effort will be required to ensure high production efficiency and marketability of the final product.

3. **Greenhouse vegetable research at the GPCRC, and elsewhere in Canada.**

The Greenhouse Vegetable Research Team at the Greenhouse and Processing Crops Research Centre, with plant physiology, plant pathology, entomology, and greenhouse environment control inputs is the largest of its kind in North America. Specialized research facilities on-site and close proximity to the largest concentration of greenhouse vegetables in North America have offered, for several years, near ideal conditions for the conduct of truly mission-oriented research and have allowed Harrow to emerge as an internationally recognized centre for greenhouse vegetable research.

Other human resource inputs into greenhouse vegetable research in Ontario are presently at the University of Guelph.

On a national basis, other significant research programs on greenhouse vegetables are supported by Agriculture and Agri-Food Canada at the Pacific Agricultural Research Centre (Agassiz, BC) and by Laval University and the MacDonald College in Quebec.

Further to publicly funded research programs on greenhouse crop production and protection significant research activity on these crops is also supported by private funds (major sources of funding are the Ontario and BC grower organizations but also individual growers and horticultural suppliers).
4. **Major ongoing research programs at GPCRC, Harrow, Ontario:**

  
  **Objective:** To optimize the heating pipe placement for greenhouse tomato on raised troughs.
  
  **Anticipated benefits:** improved microclimate, less disease incidence, higher early yield, and energy conservation.

- Year-round Cucumber Production with Supplemental Lighting and High-Wire System on Raised-Troughs (Dr. X. Hao et al)
  
  **Objectives:**
  1. To optimize the level of supplemental lighting,
  2. To develop a twin-head V high-wire cucumber production system for reducing the start-up costs of high-wire systems.

- Dynamic Optimization of CO₂ Enrichment in Greenhouse Vegetable Production (Dr. X. Hao et al)
  
  **Objective:** To dynamically optimize the CO₂ enrichment for greenhouse tomato under ventilated conditions.

- Biomass energy for greenhouses - CO₂ enrichment from flue gas of biomass (Dr. X. Hao et al)
  
  **Objective:** To assess the supply and conversion of biomass residues to provide energy for greenhouses in Canada.

- Supplementation of the hydroponic solution with sugar to improve productivity of greenhouse tomatoes under stress (Dr. A. P. Papadopoulos et al)
  
  **Objective:** To test the hypothesis that shifting growth into the day period using sugar supplementation could allow night time temperatures to be reduced, allowing a reduction in energy costs.

- Integrated systems for the production of organic greenhouse vegetables (Dr. A. P. Papadopoulos et al)
  
  **Objectives:**
  - To identify and evaluate organic media as substrates for the production of greenhouse vegetables and to develop appropriate nutrient feedings derived from organic substances.
  - To develop complete (integrated) methods for the organic production of vegetables in greenhouses and to provide appropriate detailed recommendations to the greenhouse industry.
  - To assess the commercial feasibility of organically grown greenhouse vegetables.

- Irrigation Strategies for Rockwool-Grown Tomatoes (Dr. A. P. Papadopoulos et al)
  
  **Objective:** To evaluate irrigation control strategies based on slab water content and slab EC and to integrate fully these two variables in irrigation control algorithms.  
  
  **Anticipated benefits:** Improved water use efficiency and crop productivity.

- Responses of Tomato, Cucumber, and Peppers to Kinetin Foliar Sprays (Dr. A. P. Papadopoulos et al)
  
  **Objective:** To quantify the biological activities of KIN-GroTM (a cytokinin preparation (0.5% kinetin) produced by Agrowchem Inc., Kingston, Ontario, Canada) foliar applications on tomato (cv. Rapsodie), cucumber (cv. Bodega), and pepper (cv. 4 Ever and 444).

- Using bee pollinators as a novel means of vectoring Beauveria bassiana to crops for pest control (Dr. L. S. Shipp et al).
Objectives: 1) To determine the effectiveness of bee pollinators as a means of vectoring B. bassiana to greenhouse peppers and tomatoes for pest control, and 2) to generate efficacy and non-target data for minor use registration for B. bassiana in Canada.

- Influence of light intensity and daylength on the effectiveness of biological control agents (Dr. L. S. Shipp et al).

Objectives: 1) To determine the influence of light intensity and daylength on the emergence and parasitism rates of Encarsia formosa and Eretmocerus eremicus against the greenhouse whitefly, and 2) To determine the influence of light intensity on the predation rate by Amblyseius cucumeris on western flower thrips.

- Feasibility study to evaluate nutrient solution disinfection using alternative methods in hydroponic greenhouse production (Dr. J. C. Tu et al).

Objectives: To develop a practical, applicable, efficient and economical way to disinfect the run-off nutrient solution for recirculation and thus to reduce the environmental contamination due to nutrient discharge as well as to economize fertilizer use.

- Etiology, epidemiology and control of diseases of greenhouse tomato, cucumber and pepper (Dr. R. Cerkauskas).

- Control of powdery mildews of tomato, cucumber, and pepper incited by Oidium neolycopersici, Sphaerotheca fuliginea, and Leveillula taurica, respectively. (Dr. R. Cerkauskas).

- Etiology of bacterial stem and peduncle canker of pepper caused by Erwinia carotovora subsp. carotovora (E.c.c.) (Dr. R. Cerkauskas).

- Efficacy of disinfectants such as Virkon, Virucidal Extra and Chemprocide in the control of greenhouse pathogens (Dr. R. Cerkauskas).

- Control of Fusarium oxysporum f.sp. radicis-lycopersici in greenhouse cucumber (Dr. R. Cerkauskas).

- Development of integrated control measures for bacterial canker in tomato (Ms. G. Ferguson et al)

Objective: To understand the survival, epidemiology and transmission of the canker bacteria in the greenhouse environment and hence develop integrated control measures to reduce the impact of bacterial canker of tomato in the greenhouse.

- Influence of Shading on Light Transmission and Plant Temperature (Mr. S. Khosla et al)

Objective: To determine the light transmission and heat reduction characteristics of Reduheat.

- Influence of Stem Density and Stem Pruning on Eggplants (Mr. S. Khosla et al).

Objective: To determine ideal stem density and to evaluate the influence of stem pruning on fruit production and quality of eggplant.

- Evaluate micropore filtration at commercial site (Mr. S. Khosla et al)

Objective: To develop alternative systems for the disinfection of nutrient solutions and test their commercialization.

- Establish levels of nutrients in recirculation systems (Mr. S. Khosla et al)

Objective: To establish benchmarks for nutrient use in greenhouse vegetable production, to comply with NMA.

- Energy: Alternative energy sources e.g. wind/geothermal (Mr. S. Khosla et al)

Objective: To determine alternative sources of energy suitable to the greenhouse industry.

- Energy Audits (Mr. S. Khosla et al)

Objective: To establish a benchmark on energy consumption of various greenhouse operations.
Comparison of Milstop, Sporodex and the commercial standard for suppression of powdery mildew and yield differences in commercial cucumbers (Ms. G. Ferguson et al)
Objective: 1) To determine whether Sporodex confers a yield advantage over the commercial standard at one farm, and 2) To determine whether Milstop causes phytotoxic damage and effectively suppresses powdery mildew in two cucumber operations.

Pepino mosaic virus: studies on virus epidemiology, molecular and biological characterization leading to effective management strategies (Ms. G. Ferguson et al)
Objectives:
- Determine the genetic variability found among isolates of PepMV in Ontario and identify any unique molecular characteristics of Ontario isolates.
- Determine the rate of molecular evolution/adaptation of the virus in tomato.
- Assess the probability of ornamental species as potential alternate hosts for the virus.
- Assess the occurrence of virus on the seed coat of commercial seed and, if found, develop seed treatments to eliminate virus without compromising germination rates and seedling growth.
- Assess possible biological differences between virus isolates, including effects on fruit yield.
- Compare virus isolates in greenhouses with successive infections of PepMV to attempt to discriminate between ‘carry over’ of virus and a new introduction.

To determine the effectiveness of E2Y45 against cabbage looper in greenhouse tomato (Ms. G. Ferguson et al)
Objective: To generate efficacy data for registration of this product on greenhouse cucumbers initially, and then on other greenhouse vegetables subsequently.

Investigation of the effects of BTM on root growth of tomatoes in rockwool (Ms. G. Ferguson et al)
Objective: To determine whether BTM is associated with increased root vigour as a strategy for combating Pythium root rot.

5. Major research achievements

Some of the most significant contributions by the GPCRC Greenhouse Vegetable Research Team are summarized as follows:
- A textbook: “Managing Diseases in Greenhouse Crops” (APS Press, St. Paul, MN) was published.
- The AAFC booklets "Diseases of Tomatoes" and "Diseases of Cucumbers" were revised and reprinted three times.
- Comprehensive crop production manuals: "Growing Greenhouse Tomatoes in Soil and Soilless Media" and "Growing Greenhouse Seedless Cucumbers in Soil and Soilless Media" were written and published by AAFC.
- Several chapters were written for the OMAF main publication on greenhouse vegetables: "Growing Greenhouse Vegetables in Ontario".
- An expert system was developed to assist the grower in decision-making for an integrated crop management approach. The “Harrow Greenhouse Manager” is now commercially available.
- Substantial savings in heating costs (up to 30%) and in capital investment (up to 50%) were demonstrated by growing tomatoes or cucumbers in double polyethylene houses, rather than in glass houses. Savings of more than $500 M are estimated with the exclusive use of double polyethylene greenhouses for the recent (1993-2003) expansion of the Leamington industry.

- Many studies in Plant Pathology and Entomology have resulted in pesticide reduction through improved timing of pesticide applications, development or optimization of biological control methods and development of new innovative control strategies. The result is a more competitive, market-oriented industry that has expanded both its domestic market in Ontario and its foreign markets into the northern United States.

- Development and commercial introduction of the Harrow Fertigation Manager® (HFM®), in cooperation with NRC and the private sector. The HFM is a patented, computer controlled, multi-fertilizer injector system for the precise application of fertilizers to any crop in accordance with pre-programmed seasonal fertigation programs (drip irrigation and fertigation of greenhouse vegetables, ornamentals, and field vegetables; computerization of hydroponics). More than 300 units are in commercial use in Canada, the USA, and Europe.

- Sporodex®, based on a newly-discovered fungus, Sporothrix flocculosa, was developed and registered as a biocontrol for powdery mildew of cucurbits, tomatoes and roses; the product is now commercially available.

- An energy use simulation program (ENERPASS) for greenhouses was developed in collaboration with Enermodal Engineering Ltd. This program can be used to design and evaluate energy-efficient greenhouses and to optimize energy efficiency in current greenhouse operations.

- Pythium and Fusarium spp., serious pathogens of vegetable crops, have been shown to be transmitted by fungus gnats and shore flies. Effective control strategies for these insects using biological control agents have been demonstrated to the growers.

- Development of a pest management program for western flower thrips, the most important overall pest of greenhouse vegetables; a mathematical model was developed that predicts the temperature and VPD conditions for the optimal rate of predation by Amblyseius cucumeris on western flower thrips.

- Characterization of the nutritional and environmental requirements, formulation of recommendations, and commercial introduction of sweet peppers as a greenhouse crop (Fertigation schedules, pruning, day and night temperatures, crop schedules, bumble bee pollination).

- System design, development of recommendations and introduction to commercial practice of various soilless methods of production. At present, 97% of sweet peppers, 97.77% of cucumbers and 99.3% of tomatoes in Ontario are cropped with soilless methods.

- Extensive research was carried out at several locations in Canada to quantify the effects of nutritional and environmental factors on tomato fruit quality and appropriate recommendations were offered to the growers.

- The use of the raised gutter was demonstrated and promoted; most of the tomato acreage in Leamington is now on raised gutters. Research continues on the use of supplemental lighting for the year-round production of tomatoes and (single stem) cucumbers on raised gutters.
6. New technologies implemented recently by the Industry:

- **Raised troughs**
The raised troughs (or gutters, as are better known in Europe) system, by its name is a system of growing plants on a series of raised platforms 30 to 100 cm above the floor of the greenhouse. The associated benefits are that an increased air movement around the plants is facilitated resulting in less disease, a more level growing surface is achieved resulting in more uniform crop growth, collection of excess nutrient solution and recycling is made much easier, work is at waist height and therefore workers do not have to work as hard, intercropping and the use of artificial lighting become more practical, and yield and fruit quality are expected to improve. According to Dave Orosz (an account manager with Farm Credit Canada, based in Essex, Ontario; see his article in the March 2005 issue of the Greenhouse Canada magazine, pages 22-24) a payback on investment in less than two years can be expected with tomatoes making this technology very attractive. All new greenhouses in the last few years have been ordered with raised troughs.

- **Recirculation**
This involves the collection of the excess nutrient solution, its treatment and reapplication; the treatment includes the adjustment of the nutrients and the purification of the nutrient solution. Preventing the excess nutrient solution from running away into the environment will soon become mandatory by law in Ontario (The Nutrient Management Act) but many growers have acted proactively and apply already the technology; certainly, all new greenhouses are built with a capacity to recirculate. Recirculation requires the installation of extra piping, large holding tanks, and a purification system for the spent nutrient solution. Based on the assumption that recirculation will achieve a 25-30 % reduction in water use and a 40-50 % savings in fertilizer costs, Dave Orosz has estimated a 1.5 – 4.0 year payback of investment in this technology.

- **Carbon dioxide recovery/Hot water storage**
This technology is based on running a boiler during the day time even when heating is not required to generate carbon dioxide for direct feeding to the crop; the hot water generated is stored in large insulated tanks and used in the night to heat the greenhouse. The cost of equipment required is fairly high but so is the benefit. Dave Orosz has reported that for a ten acre operation the payback of such an investment is 2-5 years, but for a 20 acre operation the estimate is reduced to 1-3 years. This is just another reason why it is generally recommended that new greenhouse operations should have a minimum size of 10 acres to be economically viable.

- **Grow pipe**
In the original version of the technology, as used in Europe, an extra heating pipe of a smaller diameter than usual is placed in close proximity to the growing tips of the plants; ideally the grow pipe is gradually raised automatically as the plants grow. The benefit is that heat is transferred by radiation to the growing tips of the plants (growth is directly proportional to temperature) allowing for a reduction in greenhouse air temperature and therefore in overall energy savings. In the most common form of the technology, as applied in Ontario, the grow pipe is stationary at some distance above the raised gutter. The anticipated benefits are a better (drier) microclimate around the lower part of the plants (less disease), faster fruit growth and ripening, and some energy savings. This is the last of four technologies investigated by Dave
Orosz, and he concluded that growers investing in this technology should expect a 3-5 year payback period.

- **Glass covered greenhouses**
  Following the widespread use of the inflated double polyethylene greenhouse in the last decade, a new trend surfaced a couple of years ago for the use of glass covered greenhouses; last year (2004) about 47% of the 155 acres of new greenhouses built in Ontario for the production of greenhouse vegetables were of the glass type. The increasing popularity of glass covered greenhouses has been brought about by an apparent bridging of the traditional gap in price between plastic and glass houses as well as by an ever increasing pressure on the industry to extend production into the winter months. The incorporation of an energy curtain in the new glasshouses is seen as an equally effective energy conservation technology as the high insulation offered by the double poly greenhouse. However, the recent sharp increases in energy prices are forcing many growers to abandon any hopes of growing a crop in the middle of the winter and the popularity of the glass covered greenhouse might prove short lived. Furthermore, innovative developments (e.g. high UV light transmittance for better bumble bee navigation, low Infra Red light transmittance for energy efficiency, and improved anti-condensate properties for less water dripping) in the area of greenhouse plastic covers are taking place at an accelerating rate making the plastic greenhouse once again a good choice.

- **Grafted plants**
  Grafting is now used extensively to achieve more vigorous plants; such plants are more likely to have healthier and stronger root systems, able to fight off root diseases that are a bigger threat in closed hydroponic systems. The most popular tomato rootstocks are ‘Big power’, ‘Maxifort’ and ‘Beaufort’. Specialized operations have being established for the raising of transplants that can also perform grafting in large scale.

- **New cultivars/new crop types/new crops**
  According to Mr. S. Khosla, Greenhouse Vegetable Crop Advisor with the Ontario Ministry of Agriculture and Food, located in Harrow, Ontario, (see his article in the September 2005 issue of the Greenhouse Canada magazine, pages 28-28), the most popular beefsteak-type greenhouse tomato cultivars in Ontario are: ‘Dundee’, ‘Macarena’, ‘Heritage’, ‘Big Dina’, and ‘Grow Dina’. These cultivars are replacing the traditional cv. ‘Rapsodie’ with a promise for high yield and improved product quality. Of the cluster-type (or tomatoes on the vine) the cvs. ‘Clarance’, ‘Trusco’, ‘Frisby’, ‘Tricia’ and ‘Randella’ make up 45% of the total greenhouse tomato production in Ontario. Other tomato types, such as cherry-type, cocktail-type, and roma-type are also grown in small scale. New crops that have been tried successfully are climbing beans and eggplant. Organic growing is extremely limited.

- **Alternative fuels (wood and waste products)**
  The present high energy costs and the prospect for even higher energy prices in the future are a major concern for growers and a strong incentive to search for alternatives. A small number of very large, and expensive, boilers have been installed for the heating of greenhouses with various forms of sawdust and/or wood chips.
7. Emerging Issues:
- How to assure food safety
- High energy costs
- Invasive species
- Non-tariff barriers
- Inadequate market intelligence
- Decreasing profitability
- The higher dollar exchange rate

8. Technology transfer
Education is a Provincial responsibility in Canada, and so is agricultural extension. In Ontario, we have a greenhouse vegetable specialist (Mr. Shalin Khosla) and a greenhouse crop IPM specialist (Ms. Gillian Ferguson) advising greenhouse vegetable growers on crop production and protection issues. They are conveniently located at the GPCRC (Harrow, ON) but serve the entire province of Ontario. Having the office of the Provincial greenhouse crop advisors at Harrow puts them under the same roof with the Federally employed scientists working on greenhouse crops and close to the Leamington based growers. Other Provinces with significant greenhouse vegetable industries (i.e. B.C., Quebec, Alberta, and N.S.) have their own greenhouse crop advisory services. The role of the Federally employed scientists in technology transfer is in supporting the Provincial extension personnel with up to date information, speaking at grower conventions, publishing articles in trade journals, speaking at grower seminars, and occasionally meeting and advising individual growers or groups of growers.

9. Acknowledgements
I thank my research colleagues for allowing me to include a list of their research projects in this summary.

<table>
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<th>Tomato</th>
<th>Cucumber</th>
<th>S. Pepper</th>
<th>Lettuce</th>
<th>Other</th>
<th>Total²</th>
<th></th>
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<td>92</td>
<td>56</td>
<td>x¹</td>
<td>x</td>
<td>358</td>
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<td>Quebec</td>
<td>34</td>
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<td>x</td>
<td>x</td>
<td>38</td>
<td>(5%)</td>
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<tr>
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<td>156</td>
<td>18</td>
<td>72</td>
<td>x</td>
<td>7</td>
<td>253</td>
<td>(35%)</td>
</tr>
<tr>
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<td>4</td>
<td>x</td>
<td>x</td>
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<tr>
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<td>x</td>
<td>x</td>
<td>x</td>
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<td>Canada Total³</td>
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<td>131</td>
<td>133</td>
<td>17</td>
<td>25</td>
<td>720</td>
<td>(100%)</td>
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¹ x = Confidential data (all Provinces)  ² Includes confidential data ³ Includes
Table 2. Area of Greenhouse Vegetables in Canada, in ha (acres).
Official estimates from Statistics Canada, Catalogue No. 22-202-XPB, 2004

<table>
<thead>
<tr>
<th>Province</th>
<th>Tomato</th>
<th>Cucumber</th>
<th>S. Pepper</th>
<th>Lettuce</th>
<th>Total</th>
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<td>Ontario</td>
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<td>140 (350)</td>
<td>73 (180)</td>
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<tr>
<td>Quebec</td>
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<td>17 (42)</td>
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<td>56 (140)</td>
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<td>25 (62)</td>
<td>84 (210)</td>
<td>x</td>
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<td>21 (52)</td>
<td>x</td>
<td>x</td>
<td>32 (80)</td>
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<tr>
<td>TOTAL³</td>
<td>444 (1110)</td>
<td>207 (517)</td>
<td>157 (392)</td>
<td>15 (37)</td>
<td>823 (2057)</td>
</tr>
</tbody>
</table>

¹ x = Confidential data
² Includes confidential data
³ Includes all Provinces