SUSTAINABLE CROP PROTECTION
Results from the Pesticide Risk Reduction Program

Banding herbicides in carrot production: Small Spray with Big Benefits

Carrot growers are continually striving to reduce pesticide use while improving the economic bottom line in their productions. The herbicide application technology known as banding is a potential option to achieve these goals. Herbicide banding consists of spraying the herbicide in a band directly over the crop row as opposed to making a broadcast application that blankets the entire carrot field with herbicide. The banded herbicide is applied pre-emergence (PRE) and/or post-emergence (POST) of the crop. Weeds in the space between the rows are removed by mechanical cultivation. This practice can decrease herbicide use by up to 66%.

Commercial sprayers can be easily converted to deliver banded herbicide applications. Boom nozzles are repositioned so they spray directly over the plant row, and excess nozzles can be blocked off. For banding, regular nozzle tips are replaced with flat fan even spray tips. To achieve a specific band width, various combinations of nozzle tip, spray angle and spray height can be used.

The Pesticide Risk Reduction Program of Agriculture and Agri-Food Canada's (AAFC) Pest Management Centre has supported research and development work to first determine the efficacy and then demonstrate the feasibility of commercial implementation of the banding technology in carrot production.

Phase 1: Experimental testing

Two experimental trials, at four testing sites, were conducted during 2007-2009 in carrot crops grown on mineral soils at the AAFC's Crops and Livestock Research Centre, Harrington Research Farm in Prince Edward Island (PEI). Both Trial 1 and Trial 2 compared the efficacy of the herbicide linuron on weed control and crop yield when applied as a broadcast or banded over the row. An untreated control was included in Trial 1 only. Carrots, cv. Neptune, were seeded on raised beds spaced at 90 cm between beds (Figure 1).

Figure 1. Carrot seeding on raised beds

For the banded application, the herbicide was sprayed on a 30 cm wide band over the carrot row using TeeJet® 8002EVS nozzle tips positioned at 18 cm height above the row (i.e. measured from the ground level at PRE, and from the top of carrot canopy at POST applications) (Figure 2).

Figure 2. Banding herbicide spray on carrots

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Figure 3. Side-knives for weed control on sides of raised beds

Figure 4. S-tines with shovels for weed control between the raised beds

Linuron was applied at the same label rates PRE (1.24 l ha^{-1}) and POST (2.47 l ha^{-1}) emergence on both broadcast and banded treatments. However, because banded sprays covered only one third of the surface area that broadcast sprays did, the actual amount of herbicide used per unit of area under the banded treatment was reduced by two thirds (i.e. 0.42 vs 1.24 l ha^{-1}, and 0.82 vs 2.47 l ha^{-1} in PRE and POST applications, respectively). The POST application of linuron was applied when carrots were about 12-20 cm tall.

Figure 5. Banded herbicide plot at mid-season

In the banded linuron plots, weeds on the sides of raised bed and between the rows (unsprayed areas) were controlled with a combination of side-knives (Figure 3) and S-tine cultivation (Figure 4). Typically, one pass with side-knives was applied at about 30 and again at 50 days after seeding (DAS). This was combined with one pass of S-tines with shovels at about 21 DAS and again at about 42 DAS with S-tines without shovels. This approach resulted in a total of 4 passes with cultivation equipment mounted individually on a cultivator for each pass. All cultivation treatments were timed to coincide with weeds being approximately 2-5 cm in height.

To assess weed pressure and herbicide efficacy within each treatment, weeds were sampled and dry weight of biomass per unit area was measured two weeks following the last cultivation. Carrots roots were harvested within a 3 m section from each plot to measure total and marketable yields for each treatment.

Weed control was greater than 99% with either broadcast or banded applications (Table 1). Herbicide banding combined with cultivation provided excellent weed control during the season compared to the broadcast application in all trials (Figure 5). Also, linuron applied in a band provided total and marketable carrot yields comparable to broadcast applications (Figure 6). Average marketable carrot yield with herbicide banding was 55.3 t ha^{-1} compared to 59.4 t ha^{-1} for the broadcast application.

Table 1. Effect of herbicide application methods on total weeds in carrots (2007-2009)

	Total weeds on the top of the carrot bed (g m^{-2} Dry Weight)	
Treatment (Actual amount of herbicide used)	Trial 1[z]	Trial 2[y]
Broadcast (3.71 l ha^{-1})	0.8	13.2
Banded (1. 24 l ha^{-1})	1.2	18.2
Untreated control (0 l ha^{-1})	289.0	---

[z] Mean of 2007 and 2008; [y] Mean of 2008 and 2009

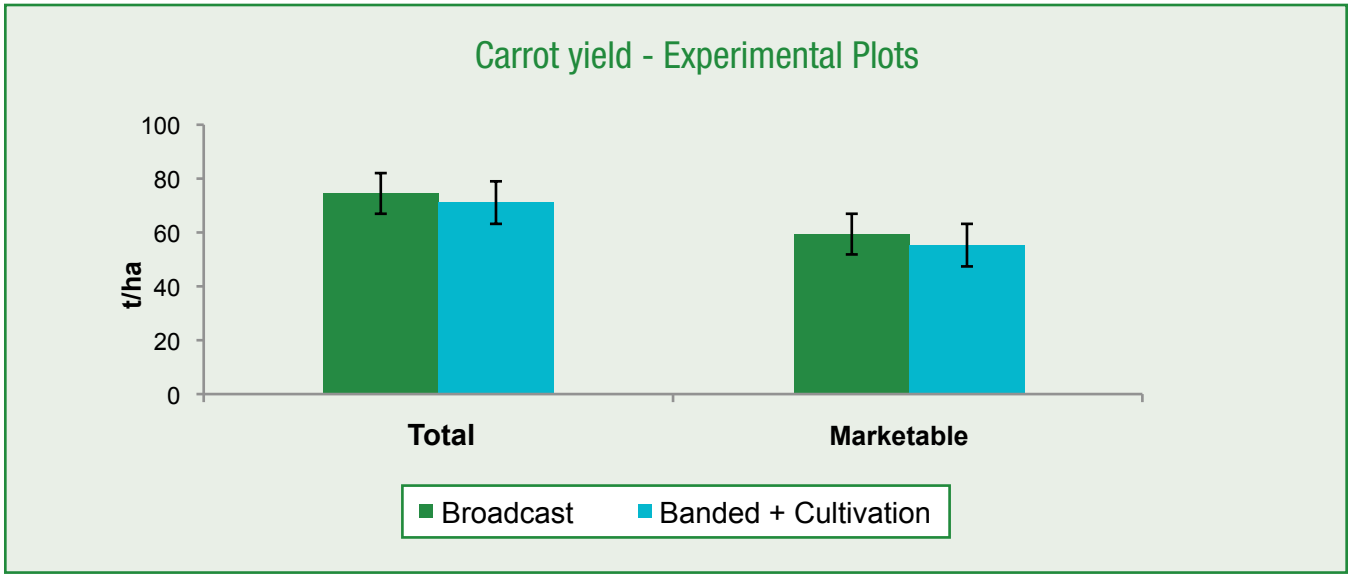

Figure 6. Effect of herbicide banding combined with in-furrow cultivation and broadcast herbicide applications on carrot yield in experimental plots (mean of 4 trials sites, 2007-2009)

Phase 2: Commercial field testing

Following encouraging results from the experimental testing, two demonstration trials were conducted to scale up performance testing of herbicide banding under commercial carrot production conditions.

The demonstration trials were established during 2010 and 2011 at two commercial farms producing carrots in PEI. Commercial spray equipment was retrofitted with new flat fan nozzles that were positioned to spray directly over each carrot row. The same treatment parameters, cultivation methods and measurements were used as in the experimental studies except for the carrot cultivars, with cv. Neptune and cv. Sugarsnax used in each trial site, over both seasons, respectively.

A total of four cultivation passes were used in 2010 (two with S-tines, two with side-knives) and only two passes were used in 2011 (one with S-tines, one with side-knives) depending on weed pressure within the trial plots (Figures 7, 8).

Results from the commercial demonstrations were consistent over the two years of the study and with those obtained from previous experimental work. Fields where banded herbicide was used were satisfactorily clean from weeds during the season (Figure 9). There were no significant differences in the total and marketable yields between the banding and broadcast herbicide treatments (Figure 10). There was actually an increased marketable weight and increased number of medium carrot roots produced using the banded technology compared to broadcast herbicide application. Average marketable carrot yield with herbicide banding was 52.9 t ha^{-1} compared to 50.4 t ha^{-1} for the broadcast application. Weed pressures were considered low in both years and did not seem to affect carrot root yield.

Figure 7. Cultivating with S-tines

Figure 8. Side-knives removing weeds

Figure 9. Herbicide banded carrot field near the end of the growing season

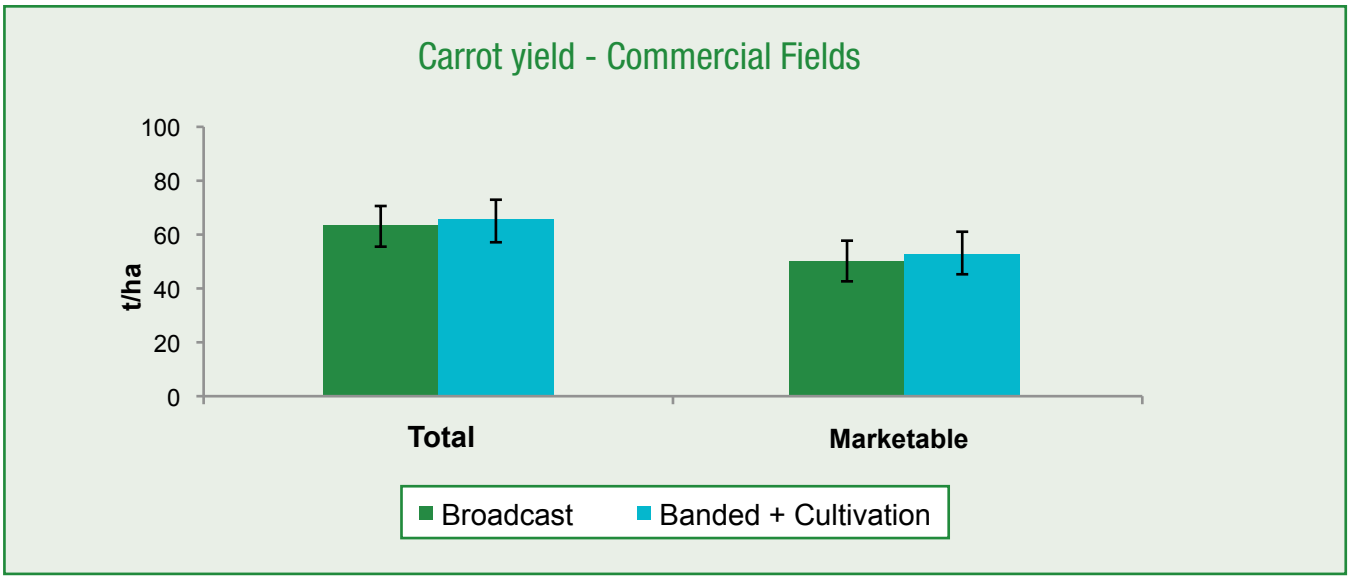

Figure 10. Effect of herbicide banding combined with in-furrow cultivation and broadcast herbicide applications on carrot yield under commercial field conditions (mean of 4 trials sites, 2010-2011)

Herbicide banding has many positive environmental and economic benefits

Conventional weed control in carrot production uses a broadcast herbicide application up to two times during the growing season. The banding approach reduces herbicide use by up to 66%, while maintaining comparable levels of weed control and yield. By lowering the load of pesticide use, this approach not only can reduce the risks to environment and human health, but also minimizes the risk of herbicide resistance development in weed populations.

Cost-benefit analyses demonstrated that herbicide banding can be economical. Banding offers a reduced production cost due to lower herbicide use. A producer can save up to \$9.00 ha^{-1} by using herbicide banding in combination with a single cultivation pass, where S-tines and side-knives are mounted together in tandem. Growers will need to install flat fan nozzles to facilitate banding. Potential savings may be reduced if additional cultivation is required to adequately control weeds in the non-banded area.

Overall, considering the increasing prevalence of environmental and herbicide resistance concerns, the banding method offers producers a beneficial and sustainable weed management approach. This technology could be easily adaptable to conventional carrot crops grown on raised beds or flat ground. Organic carrot operations may also use this banding technology as registered organic weed control products become available.

The results generated through these studies help to make banding technology readily adoptable for carrots grown in mineral soils. This work is part of the Pesticide Risk Reduction Program's action plan to implement a **reduced-risk strategy for integrated weed management in field vegetables**.

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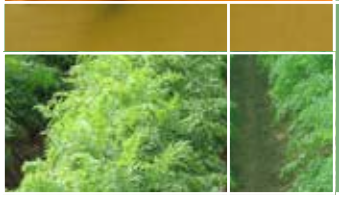

About the Pesticide Risk Reduction Program at Agriculture and Agri-Food Canada

The Pesticide Risk Reduction Program delivers viable solutions for Canadian growers to reduce pesticide risks in the agricultural and agri-food industry. In partnership with the Pest Management Regulatory Agency of Health Canada, the Program achieves this goal by coordinating and funding integrated pest management strategies developed through consultation with stakeholders and pest management experts.

The Pesticide Risk Reduction Program is actively pursuing the development and implementation of strategies which are key to reducing pesticide risks in the agricultural environment. To view the Program's current priorities and the issues being addressed, visit: www.agr.gc.ca/pmc. To consult other factsheets in this series, visit: www.agr.gc.ca/sustainable-crop-protection.

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